United States
Environmental Protection
Agency

PORTLAND HARBOR RI/FS

FEASIBILITY STUDY

June 2016

Prepared by:

U.S. Environmental Protection Agency

CDM Smith

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ACRONYMS

1,1-DCE	1,1-dichloroethene
1,1,1-TCA	1,1,1-trichloroethane
1,2,3,4,7,8-HxCDF	1,2,3,4,7,8-hexachlorodibenzofuran
1,2,3,7,8-PeCDD	1,2,3,7,8-pentachlorodibenzo-p-dioxin
2,3,4,7,8-PeCDF	2,3,4,7,8-pentachlorodibenzofuran
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
2,3,7,8-TCDF	2,3,7,8-tetrachlorodibenzofuran
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4,5-TP	2-(2,4,5-trichlorophenoxy)propionic acid
2,4-D	2,4-dichlorophenoxyacetic acid
2,4-DB	4(2,4-dichloropenoxy)butyric acid
2,4-DP	2-(2,4-dichlorophenoxy)propionic acid
ADAF	age-dependent adjustment factors
alpha-BHC	alpha-hexachlorocyclohexane
AOC	Administrative Order on Consent
ARAR	applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BCT	best conventional pollutant control technology
BEHP	bis(2-ethylhexyl) phthalate
BERA	baseline ecological risk assessment
BHHRA	baseline human health risk assessment
BIF	benthic invertebrate filter feeder
BMP	best management practice
BSAF	biota-sediment accumulation factor
BSAR	biota-sediment accumulation regression
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAD	confined aquatic disposal
CCC	Criterion Continuous Concentration
CDF	confined disposal facility

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
cis-1,2-DCE	cis-1,2-dichloroethene
cm2	square centimeters
cm3	cubic centimeters
CMC	Criterion Maximum Concentration
cm/yr	centimeters per year
COC	contaminant of concern
COPC	contaminant of potential concern
cPAH	cPAH carcinogenic PAH
CRD	Columbia River Datum
CSM	conceptual site model
CSO	combined sewer overflow
CT	central tendency
CWA	Clean Water Act
cy	cubic yards
DCA	1,1-dichloroethane
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DDx	sum of 2,4’- and 4,4’- DDD; 2,4’- and 4,4’- DDE; and 2,4’- and 4,4’- DDT
DEQ	Oregon Department of Environmental Quality
DMM	disposed material management
DNAPL	dense non-aqueous phase liquid
DOC	dissolved organic carbon
dw	dry weight
ECSI	Environmental Cleanup Site Information
EE/CA	engineering evaluation/cost analysis
EFH	essential fish habitat
EIC	epibenthic invertebrate consumer

ENR	enhanced natural recovery
E.O.	Executive Order
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESB	equilibrium sediment partitioning benchmark
FEMA	Federal Emergency Management Agency
FMD	future maintenance dredge
FPM	Floating Percentile Model
FR	Federal Register
FS	feasibility study
FWM	Food Web Model
g	gram
GCL	geosynthetic clay lner
GPS	global positioning system
GRA	general response action
HCH	hexachlorocyclohexane
HI	hazard index
HPAH	high molecular weight PAH
HQ	hazard quotient
HWIR	Hazardous Waste Identification Rule
HxCDF	hexachlorodibenzofuran
IC	institutional control
ISA	Initial Study Area
ITRC	Interstate Technology & Regulatory Council
kg	kilogram
Kennedy/Jenks	Kennedy/Jenks Consultants
L	liter
LDR	land disposal restriction
LNAPL	light non-aqueous phase liquid
LOAEL	lowest-observed-adverse-effect-level
LRM	Logistic Regression Model
LPAH	low molecular weight PAH

LWG	Lower Willamette Group
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
M3	cubic meter
MCPA	2-methyl-4-chlorophenoxyacetic
MCPB	4-(4-chloro-2-methylphenoxy)butanoic acid
MCPP	methylchlorophenoxypropionic acid
MDL	method detection limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MGP	manufactured gas production
MLLW	mean lower low water
MNR	monitored natural recovery
MOU	Memorandum of Understanding
NAPL	non-aqueous phase liquid
NAVD88	North American Vertical Datum of 1988
NC	not considered
NCP	National Contingency Plan
NLOC	non-lipid organic carbon
NLOM	non- lipid organic matter
NMFS	National Marine Fisheries Service
NPL	National Priorities List
NRC	National Research Council
NRWQC	National Recommended Water Quality Criteria
O&M	operation and maintenance
OAR	Oregon Administrative Rules
OC	organic carbon
OHA	Oregon Health Authority
ORS	Oregon Revised Statutes
PAC	powdered activated carbon
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether

PCB	polychlorinated biphenyl
PCDD/F	polychlorinated dibenzo-p-dioxin/furan
PCE	tetrachloroethene
PCP	pentachlorophenol
PeCDD	pentachlorodibenzo-p-dioxin
PeCDF	pentachlorodibenzofuran
POC	particulate organic carbon
POTW	publicly owned treatment works
PRG	preliminary remediation goal
PTW	principal threat waste
r2	coefficient of determination
RAIS	Risk Assessment Information System
RAL	remedial action level
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
RM	river mile
RME	reasonable maximum exposure
RNA	regulated navigation area
ROD	Record of Decision
RSL	regional screening level
SCRA	Site Characterization and Risk Assessment
SDU	sediment decision unit
SDWA	Safe Drinking Water Act
Site	Portland Harbor Superfund site
SMA	sediment management area
SMB	smallmouth bass
SOW	Statement of Work
SPAF	species predictive accuracy factor
SVOC	semi-volatile organic compound
SWAC	surface-area weighted concentration
TBC	to be considered

TCDD	tetrachlorodibenzo-p-dioxin
TCDD DE	D2,3,7,8-tetrachlorodibenzo-p-dioxin
TCDF	tetrachlorodibenzofurans
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
TEQ	toxic equivalency
THQ	target hazard quotient
TPH	total petroleum hydrocarbon
TRV	toxicity reference value
TSCA	Toxic Substances Control Act
TZW	transition zone water
UHC	underlying hazardous constituent
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USFWS	U.S. Fish and Wildlife Service
µg	microgram
µg/kg	microgram per kilogram
µg/L	micrograms per liter
UTC	universal treatment standard
VOC	volatile organic compounds
WQC	Water Quality Criterion
ww	wet weight
XAD	hydrophobic polyaromatic resin

Executive Summary

This FS focuses on approximately ten miles of the lower Willamette River from River Mile (RM) 1.9 (at the upriver end of the Port of Portland's Terminal 5) to RM 11.8 (near the Broadway Bridge). The terms Site, harbor-wide, and Site-wide used in this FS generally refer to the sediments, river banks, pore water, and surface water within this reach of the lower Willamette River, not to the upland portions of the Portland Harbor Superfund Site.

The U.S. Environmental Protection Agency (EPA) formally listed Portland Harbor as a Superfund Site in December 2000. EPA is the lead agency for the Site, with support from Oregon Department of Environmental Quality (DEQ). EPA has entered into a Memorandum of Understanding (MOU) with DEQ, six federally recognized tribes, two other federal agencies, and one other state agency, who have all participated in providing support in the development of this document

Many environmental investigations by private, state, and federal agencies have been conducted, both in the lower Willamette River and on adjacent upland properties, to characterize the nature and extent of contamination in the river, as well as to identify potential sources of contaminants that could continue to enter the river. Ultimately, the basis of this FS is the environmental data collected and compiled by the Lower Willamette Group (LWG) and other parties since the inception of the Portland Harbor Remedial Investigation and Feasibility Study (RI/FS) in 2001.

Site Background

The Site is located along the lower reach of the Willamette River in Portland, Oregon, and extends from approximately RM 1.9 to 11.8. While the Site is extensively industrialized, it is within a region characterized by commercial, residential, recreational, and agricultural uses. Land use along the lower Willamette River in the Site includes marine terminals, manufacturing, and other commercial operations, as well as public facilities, parks, and open spaces. The State of Oregon owns certain submerged and submersible lands underlying navigable and tidally influenced waters. The ownership of submerged and submersible lands is complicated and has changed over time.

Historically, this river was once a shallow, meandering portion of the Willamette River, but has been redirected and channelized via filling and dredging. A federally maintained navigation channel, extending nearly bank-to-bank in some areas, doubles the natural depth of the river and allows transit of large ships into the active harbor. Much of the river bank contains overwater piers and berths, port terminals and slips, and other engineered features. While the installation of a series of dams in the upper Willamette River watershed moderate fluctuations of flow in the lower portions of the river, flooding still occurs approximately every 20 years, with the last occurring in 1996.

Armoring to stabilize banks covers approximately half of the harbor shoreline, which is integral to the operation of activities that characterize Portland Harbor. Riprap is the most common bank-stabilization measure. However, upland bulkheads and rubble piles are also used to stabilize the banks. Seawalls are used to control periodic flooding as most of the original wetlands bordering the Willamette in the Portland Harbor area have been filled. Some river bank areas and adjacent parcels have been abandoned and allowed to revegetate, and beaches have formed along some modified shorelines due to relatively natural processes.

Development of the river has resulted in major modifications to the ecological function of the lower Willamette River. However, a number of species of invertebrates, fishes, birds, amphibians, and mammals, including some protected by the Endangered Species Act (ESA), use habitats that occur within and along the river. The river is also an important rearing site and pathway for migration of anadromous fishes, such as salmon and lamprey. Various recreational fisheries, including salmon, bass, sturgeon, crayfish, and others, are active within the lower Willamette River.

Nature and Extent of Contamination

Over 200 different contaminants have been detected at the Site in various media. To simplify describing the extent of contamination, 14 indicator contaminants were identified based on frequency of detection, ease of cross media comparisons, co-location with other contaminants, widespread sources, and similar chemical structures and properties. The highest concentrations of contaminants in sediments were typically found in nearshore and off-channel areas such as slips, embayments, and shallow areas, and near some known or suspected sources. Concentrations of organic contaminants (such as PCBs, PAHs, dioxins/furans, and DDx) are higher in subsurface sediment. While contamination originating from the watershed is widespread throughout the surface sediment at the Site, there are distinct areas of high contaminant concentrations scattered throughout the Site. These are generally are located near likely upland sources. Areas with higher contaminant concentrations are more prevalent in the lower (downstream) half of the Site, and multiple contaminants are co-located throughout the Site. Contaminant concentrations in other media are generally highest in the same areas where sediment concentrations are highest.

Summary of Baseline Human Health Risk and Ecological Risk Assessments

Baseline human health and ecological risk assessments were conducted for the Site to estimate the risks associated with exposure to contaminants based on current and likely future uses of the Site. Potential exposure to contaminants found in environmental media and biota was evaluated for various occupational and recreational uses of the river, as well as recreational, subsistence, and traditional and ceremonial tribal consumption of fish caught within the Site. Additionally, because of the persistent and bioaccumulative nature of many of the contaminants found in sediment, infant consumption of human breast milk was also quantitatively evaluated. The ecological risk assessment evaluated the potential for adverse effects to ecological receptors, including benthic invertebrates, fish birds and mammals, amphibians, and aquatic plants.

The baseline risk assessments concluded that cancer risks and other adverse human health effects resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment and surface water. Unacceptable risks to ecological receptors were identified in more than one media over large areas. There are multiple lines of evidence demonstrating unacceptable risks, and many of the contaminants exhibit the potential to biomagnify in the food web. Based on the results of the RI and the risk assessments, EPA has determined that an evaluation of remedial actions is necessary to protect public health or welfare and the environment from hazardous substances released at the Site.

Identification and Screening of Technologies

The foundation for developing a range of remedial action alternatives to address the risks at the site includes the identification of Applicable or Relevant and Appropriate Requirements (ARARs) develops Remedial Action Objectives (RAOs) that consider the contaminants and media of interest, exposure pathways and preliminary remediation goals identifies general response actions (GRAs) that focus on remediation of contaminated sediment and river banks, and a screening of remedial technologies and process options related to each GRA based on consideration of site-specific information.

ARARs

Section 121(d) of CERCLA requires remedial actions to comply with all applicable or relevant and appropriate federal environmental or promulgated state environmental or facility siting laws, unless such standards are waived. CERCLA provides that a remedy that does not attain an ARAR can be selected if the remedy assures protection of human health and the environment and meets one of six waiver criteria. Currently, EPA does not have a basis for waiving any ARARs, and any waivers would have to be conducted through the remedy selection process and documented in a ROD amendment.

In addition to ARARs, advisories, criteria, or guidance may be identified as “to be considered” (TBC) for a particular release. TBCs may be non-promulgated advisories or guidance that are not legally binding and do not have the status of potential ARARs.

Three categories of ARARs were identified for use in the FS: chemical-specific requirements, location-specific requirements, and performance, design, or other action-specific requirements.

Remedial Action Objectives (RAOs)

Remedial action objectives (RAOs) consist of media-specific goals for protecting human health and the environment that specify COCs for each media of interest; exposure pathways, including exposure routes and receptors; and an acceptable contaminant concentration or range of concentrations for each exposure route. Nine RAOs were developed for the Site.

Human Health

- RAO 1 – Sediments: Reduce cancer and noncancer risks to people from incidental ingestion of and dermal contact with COCs in sediments and beaches to exposure levels that are acceptable for fishing, occupational, recreational, and ceremonial uses.
- RAO 2 – Biota: Reduce cancer and noncancer risks to acceptable exposure levels (direct and indirect) for human consumption of COCs in fish and shellfish.
- RAO 3 – Surface Water: Reduce cancer and noncancer risks to people from direct contact (ingestion, inhalation, and dermal contact) with COCs in surface water to exposure levels that are acceptable for fishing, occupational, recreational, and potential drinking water supply.
- RAO 4 – Groundwater: Reduce migration of COCs in groundwater to sediment and surface water such that levels are acceptable in sediment and surface water for human exposure.

Ecological

- RAO 5 – Sediments: Reduce risk to ecological receptors from ingestion of and direct contact with COCs in sediment to acceptable exposure levels.
- RAO 6 – Biota (Predators): Reduce risks to ecological receptors that consume COCs in prey to acceptable exposure levels.
- RAO 7 – Surface Water: Reduce risks to ecological receptors from ingestion of and direct contact COCs in surface water to acceptable exposure levels.
- RAO 8 – Groundwater: Reduce migration of COCs in groundwater to sediment and surface water such that levels are acceptable in sediment and surface water for ecological exposure.
- RAO 9 – River Banks: Reduce migration of COCs in river banks to sediment and surface water such that levels are acceptable in sediment and surface water for human health and ecological exposures.

It is EPA's expectation that the State's actions to address upland sources will adequately address groundwater contamination. Should groundwater not be addressed adequately under those actions, EPA may at a future time determine if action is warranted under CERCLA to address groundwater and upland sources.

Contaminants of Concern (COCs)

Identification of COCs at the Site is based on whether the contaminant is a listed hazardous substance or poses unacceptable risks to human health, the significance of risks to ecological receptors, and chemical-specific ARARs or other statutory criteria. Risk-based human health COCs were identified in beach and in-water sediment, fish tissue and surface water for RAOs 1, 2, and 3. Risk-based ecological COCs were identified in sediment, surface water, porewater, and river bank soil for RAOs 5, 6, 7, and 9. Contaminants that were detected in upland media (storm water and groundwater) at concentrations that indicate the potential to migrate to the river at concentrations that exceed Maximum Contaminant Levels (MCLs) and National or State of Oregon water quality criteria were also designated COCs. There are 64 COCs at the Site, and include PCBs, PAHs, dioxins and furans, and pesticides.

Preliminary Remediation Goals (PRGs)

The preliminary remediation goals are developed using site-specific and default risk-related factors, chemical-specific ARARs, when available, and consideration of background concentrations. Human health risk-based PRGs for cancer effects were calculated based on an excess cancer risk of 1×10^{-6}. Risk-based PRGs for non-cancer effects were calculated as concentrations that would result in a specified hazard quotient of 1. Sediment concentrations needed to meet protective fish and shellfish tissue concentrations were estimated using a food-web model calibrated to predict COC concentrations in fish based on the concentration in sediment. The lower of the PRG based on either cancer or non-cancer effect was selected as the risk-based PRG for each COC.

Ecological risk-based PRGs were developed for sediment, surface water, and pore water to meet the objectives associated with RAOs 5 through 8, and were developed from medium- and contaminant-specific toxicity reference values (TRVs) protective of ecological receptors. PRGs based on consumption of prey (RAO 6) were calculated using the food-web model to predict acceptable COC concentrations in prey based on sediment concentrations. The lowest value for each COC was selected as the risk-based PRG for RAOs 5 and 6 to be protective of all species.

Background concentrations may be used to develop remedial goals when risk-based PRG concentrations are less than naturally occurring or anthropogenic background. In this context, the sediment background concentrations reflect substances or locations that are not influenced by the releases from the site and are either naturally occurring or due to other anthropogenic sources. If background concentrations are higher than the risk-based PRG, EPA defaults to background concentration, as a matter of policy.

General Response Actions, Remedial Technologies, and Process Options

GRAs identified for sediments and river banks are no action, institutional controls (ICs), monitored natural recovery (MNR), enhanced natural recovery (ENR), containment, in-situ treatment, sediment/soil removal, ex-situ treatment, beneficial use of dredged sediment, and disposal. Technologies and process options that could not be effectively implemented for the Site were screened out. Remedial technologies and process options eliminated based on technical implementability were limited to certain in-situ and ex-situ treatment technologies and certain disposal options. The remaining technologies and processes were then evaluated and screened for effectiveness, implementability, and cost – the same criteria that are used to screen alternatives prior to the detailed analysis. The No Action response was retained, as is required by CERCLA.

In addition to the no action response, the process options retained for further evaluation include:

- ICs, including, but not limited to, commercial fishing bans, fish and shellfish consumption advisories, waterway and land use restrictions through covenants or restricted navigation areas, or other dredging and structural maintenance restrictions in capping areas
- Monitored natural recovery, including, but not limited to, burial, sedimentation, bio-degradation, sorption, oxidation, and dispersion
- Enhanced natural recovery, including, but not limited to, thin layer placement
- In-situ treatment using physical immobilization, including, but not limited to, solidification/stabilization and sequestration
- Containment via engineered caps (including stone or clay aggregate material as armor), reactive caps, and geotextiles
- Sediment removal via excavation, mechanical and hydraulic dredging, and use of specialized and small scale dredge equipment. Disposal in an off-site landfill, RCRA disposal facility, or CDF
- Ex-situ treatment via particle separation, solidification/stabilization, and thermal desorption

Development and Screening of Alternatives

The remedial alternative strategy entails development of remedial alternatives such that they provide “a combination of methods, as appropriate, to achieve protection of human health and the environment,” consistent with the NCP. Additionally, EPA’s sediment remediation guidance recommends that a combination of remedial technologies and process options that are expected to effectively protect human health and the environment and achieve RAOs and PRGs for the Site within a reasonable timeframe be considered. Monitored natural recovery should be considered as a stand-alone remedy only when it would meet RAOs within a reasonable timeframe. This FS reflects the conclusion that there is no single remedy approach for sediment sites and that generally a combination of approaches (removal, containment, in-situ treatment, ENR and MNR) is the best approach to remediate large, complex contaminated sediment sites.

Remedial Alternative Development Strategy

The remedial alternative development strategy for the Site presents remedial alternatives evaluated within the FS that are expected to achieve protection of human health and the environment. The application of technologies considers Site characteristics so that remedial approaches most appropriate for site conditions (anthropogenic and environmental) are developed and applied in particular areas. There are four technologies available for sediment sites: dredging, containment, in-situ treatment, and ENR/MNR. Since it is already known that no one technology is appropriate for all areas of the Site due to the varied uses and hydrodynamics throughout the Site, this FS discusses the best technology to apply to various parts of the river.

Four distinct regions are addressed in each of the alternatives: navigation channel and future maintenance dredge (1,421 total acres), intermediate (572 total acres), shallow (174 total acres), and river banks (30,048 total lineal feet). Areas that have been subject to final EPA remedies (23 acres) will not be addressed in this FS. The navigation channel and the future maintenance dredge (FMD) region encompasses the federally authorized navigation channel and areas near and around docks based on information regarding vessel activity, dock configuration, and future site uses where maintenance dredging is likely to occur. FMD locations were developed from estimates of likely future navigation depth requirements and potential future maintenance dredging depths near and around docks. The intermediate region is defined as outside the horizontal limits of the navigation channel and FMD areas to the bathymetric elevation of 4 feet North American Vertical Datum of 1988 (NAVD88). The shallow region is defined as shoreward of the bathymetric elevation of 4 feet NAVD88. The river bank region refers to contaminated river banks.

Principal Threat Waste

The concept of principal threat was developed by EPA in the NCP to be applied on a site-specific basis when characterizing source material (USEPA 1991). Source material is defined as material that includes or contains hazardous substances, pollutants, or contaminants that acts as a reservoir for migration of contamination to groundwater, surface water, or air or that acts as a source for direct exposure. Further, principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.

PTW has been identified based on a 10^{-3} cancer risk (highly toxic) or NAPL within the sediment bed (source material) and on an evaluation of mobility of contaminants in the sediment. “Reliably contained” was not used in identifying PTW but rather was used to determine what concentrations of PTW could be reliably contained. COCs found at concentrations exceeding a 10^{-3} risk level are PCBs, cPAHs, DDx, 2,3,7,8-TCDD, 2,3,7,8-TCDF, 1,2,3,7,8-PeCDD, 2,3,4,7,8-PeCDF, and 1,2,3,4,6,7,8-HxCDF. Given the NCP’s expectation for treatment of PTW, in-situ and ex-situ treatment technologies are considered for the PTW areas. Containment technologies may be effective for addressing PTW when treatment technologies do not exist or are not practicable and it is reliably contained. Ex-situ treatment is used in conjunction with removal technologies. Sediment sites often have widespread contamination at low concentrations, which the NCP acknowledges is more difficult to treat. Therefore, the majority of the contamination removed from the Site is assumed to not require ex-situ treatment. However, some contaminated material removed from the Site may need to be treated as a requirement of the disposal facility or due to regulatory requirements.

Remedial Action Levels

Remedial action levels (RALs) are a range of contaminant concentrations that are less than the current Site-wide spatially-area weighted average concentrations (SWACs) for a particular contaminant, and are greater than the PRGs. They are commonly used at sediment sites to develop remedial alternatives and delineate areas exceeding a defined concentration threshold. The relative effect of remediating those areas can then be evaluated as part of the analysis of alternatives to determine whether RAOs can be met within a reasonable time frame. While specific RAL values are not cleanup levels, residual contaminant concentrations remaining after remediating the RAL footprint can be used to compare the relative effectiveness of the alternatives in reducing contaminant concentrations, which is directly related to risk reduction. In this FS, RALs are contaminant-specific sediment concentrations used to identify areas where capping and/or dredging will be assigned, and thus are the basis of the SMA footprints. The RAL concentrations were developed by plotting acres remediated against the post remediation SWAC. As each successive RAL represents a lower concentration, the associated area assigned capping/dredging increases with each RAL from B through H.

Sediment Management Areas

Sediment management areas (SMAs) are defined as the areas where primarily containment or removal technologies will be considered to immediately reduce risks upon implementation. They are defined by COC concentrations representing areas where MNR and ENR are not considered adequately to address RAOs in a reasonable time frame. Additionally, PTW NAPL/NRC and in-situ treatment areas for PTW are used to delineate SMAs. The COCs used to define the SMA boundaries encompass the majority of the spatial extent of contaminants posing the majority of the risks as identified in the baseline risk assessments. The focused COCs used for the development of SMAs are PCBs, total PAHs, 1,2,3,7,8-PeCDD, 2,3,4,7,8-PeCDF, 2,3,7,8-TCDD, and DDx.

Development of Alternatives

Nine alternatives were developed in this FS and are labeled A through I. Alternative A is a No Action Alternative, Alternatives B through I that apply the same suite of remedial technologies and process options to varying degrees based on Site-specific characteristics: containment, sediment/soil treatment (in-situ and ex-situ), sediment/soil removal, sediment/soil disposal, MNR/ENR, and institutional controls. Remedial actions will focus on reductions in concentrations of contaminants in sediment and river bank soils. These remedial actions, in conjunction with source control measures, are anticipated to reduce concentrations in other media as well, such as groundwater, surface water, upland soils, and air.

There are several elements common to Alternatives B through I:

- Navigation Channel: Contaminated sediment would be dredged to depth of the RAL concentrations.
- Future Maintenance Dredge Areas: Contaminated sediment would be dredged to depth of the RAL concentrations.
- Intermediate Areas: Contaminated sediment would be dredged to the lesser of the RAL concentrations or 15 feet.
- Shallow Areas: Contaminated sediment would be dredged to the lesser of the RAL concentrations or a maximum depth of 5 feet, and replaced with clean backfill with a beach mix cover to previous elevation. Where RAL concentrations exceed a depth of 5 feet, the contaminated sediment would be dredged to 3 feet and replaced with an engineered cap. NAPL or PTW that is not reliably contained within an SMA would be dredged to the lesser of the RAL concentrations or 15 feet.
- River Banks: If NAPL or PTW that is not reliably contained is present, a reactive armored cap is assumed.
- Remedy Implementation: For the purposes of the FS and developing remedial alternatives, the sequence of dredging is assumed to be from RM 11.8 to RM 1.9. Due to the uncertainty inherent at Superfund sites, there will be adjustments made throughout the design and construction process.
- Institutional Controls: Fish consumption advisories would be implemented after construction until PRGs are met. All caps will require waterway use or regulated navigation restrictions and land use or access restrictions, long-term monitoring, and O&M.

- Dredge Material: Removed material that is considered for low temperature thermal desorption treatment is assumed to be treated at the disposal facility. All other types of treatment are assumed to occur within barges prior to transport to the disposal facilities.

The dredged material removed from the Site would be managed in accordance with one of the two disposed material management (DMM) scenarios:

- DMM Scenario 1: Confined Disposal Facility and Off-Site Disposal. This scenario is only applied to Alternatives E through I because the estimated dredge volumes under these alternatives are adequate for placement in the CDF. Alternatives B through D did not meet the 670,000 cy of sediment threshold to justify construction of a CDF.
- DMM Scenario 2: Off-Site Disposal. This scenario is applied to all alternatives.

Technology Assignment Rules Within the Intermediate Region

Determining the appropriate dredging or capping technology to assign in an SMA is dependent on a number of Site-specific characteristics and environmental conditions. These factors include current and reasonably anticipated future land and waterway use, areas of erosion/deposition, sediment bed slope, infrastructure such as docks and piers, and physical sediment characteristics. A technology assignment process using a multi-criteria decision matrix was applied in the intermediate region. This matrix was developed as a method to guide the assignment of capping and dredging technologies, based on specific site characteristics within SMAs in the intermediate region. Each technology is scored based on multiple criteria related to hydrodynamics, sediment bed characteristics, and anthropogenic conditions.

Description of Alternatives

Alternative A, No Further Action: The No Further Action Alternative does not include any actions. The Oregon Health Authority would be expected to continue the fish consumption advisories already in place under state legal authorities, but the No Action Alternative does not include implementation of any new ICs or monitoring as a part of a CERCLA action for the Site. There are no costs associated with this alternative.

Alternative B: Alternative B has a total constructed area of 201 acres, and will allow 1,966 acres of sediment to naturally recover. It includes 99.8 acres of ENR and 6.7 acres of in-situ treatment, and is expected to take 4 years to construct. Additionally, 9,633 lineal feet of river bank are assumed to be laid back and covered with various caps using beach mix or vegetation. Alternative B involves dredging of 72.2 acres sediment to varying depths (494,000 to 659,000 cy) and excavating approximately 51,000 cy of river bank. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. Dredged and excavated material would be managed under DMM Scenario 2. The net present value cost is $451,460,000.

Alternative C: Alternative C has a total constructed area of 219 acres of sediment, and will allow 1,948 acres of sediment to naturally recover. It includes 116.8 acres of capping and dredging contaminated sediment, 97.4 acres of ENR, and 5 acres of in-situ treatment, and is estimated to take 5 years to construct. Additionally, 11,047 lineal feet of river bank are assumed to be laid back and covered with various caps. Alternative C involves dredging of 86.6 acres sediment to varying depths (592,000 to 790,000 cy) and excavating approximately 58,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy of sediment and 9,500 cy of soil. Dredged and excavated material would be managed under DMM Scenario 2.The net present value cost is $496,760,000.

Alternative D: Alternative D has a total constructed area of 267 acres, and will allow 1,900 acres of sediment to naturally recover. It alternative includes 176.9 acres of capping and dredging contaminated sediment, 87 acres of ENR, and 3 acres of in-situ treatment, and is estimated to take 6 years to construct. Additionally, 13,887 lineal feet of river bank are assumed to be laid back and covered with various caps. Alternative D involves dredging of 132.1 acres sediment to varying depths (950,000 to 1,266,000 cy) and excavating approximately 73,192 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. Dredged and excavated material would be managed under DMM Scenario 2. The net present value cost is $653,700,000.

Alternative E: Alternative E has a total constructed area of 329 acres sediment, will allow 1,838 acres of sediment to naturally recover. It includes 269.3 acres of capping and dredging contaminated sediment and 59.8 acres of ENR, and is estimated to take 7 years to construct. Additionally, 18,231 lineal feet of river bank are assumed to be laid back and covered with various caps. Alternative E involves dredging of 203.7 acres sediment to varying depths (1,653,000 to 2, 204,000 cy) and excavating approximately 96,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative E would be managed in one of two disposal scenarios: 670,000 cy would be disposed in the onsite CDF, and 983,000 to 1,534,000 cy would be disposed in off-site disposal facilities under DMM Scenario 1. Approximately 1,653,000 to 2,204,000 cy would be disposed in off-site disposal facilities Under DMM Scenario 2. The net present value cost for DMM Scenario 1 is $804,120,000, and is $869,530,000 for DMM Scenario 2.

Alternative F: Alternative F has a total constructed area of 533 acres, and will allow 1,634 acres of sediment to naturally recover. It includes 505.3 acres of capping and dredging contaminated sediment and 28.2 acres of ENR, and is estimated to take 13 years to construct. Additionally, 23,305 lineal feet of river bank are assumed to be laid back and covered with various caps. Alternative F involves dredging of 387.4 acres sediment to varying depths (3,825,000 to 5,100,000 cy) and excavating approximately 123,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative F would be managed in one of two disposal scenarios. The dredged material removed from the Site under Alternative E would be managed in one of two disposal scenarios: 670,000 cy would be disposed in the onsite CDF, 3,155,000 to 4,430,000 cy would be disposed in off-site disposal facilities under DMM Scenario 1. Approximately 3,825,000 to 5,100,000 cy would be disposed in off-site disposal facilities Under DMM Scenario 2. The net present value cost for DMM Scenario 1 is $1,316,560,000, and is $1,371,170,000 for DMM Scenario 2.

Alternative G: Alternative G has a total constructed area of 776 acres sediment, and will allow 1,391 acres of sediment to naturally recover. It includes 756.4 acres of capping and dredging contaminated sediment and 19.5 acres of ENR, and is estimated to take 19 years to construct. Additionally, 26,362 lineal feet of river bank are assumed to be laid back and covered with various caps. Alternative G involves dredging of 571.7 acres sediment to varying depths (6,221,000 to 8,294,000 cy) and excavating approximately 139,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative G would be managed in one of two disposal scenarios. Under DMM Scenario 1, 670,000 cy would be disposed in the onsite CDF, 5,551,000 to 7,624,000 cy would be disposed in off-site disposal facilities. Under DMM Scenario 2, 6,221,000 to 8,294,000 cy would be disposed in off-site disposal facilities. The net present value cost for DMM Scenario 1 is $1,731,110,000, and is $$1,777,320,000 for DMM Scenario 2.

Alternative H: Alternative H has a total constructed area of 2,167 acres sediment, MNR is not used in this alternative. It includes 2,167.2 acres of capping and dredging contaminated sediment, and is estimated to take 62 years to construct. Additionally, 30,048 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation. This alternative involves dredging of 1,631.9 acres sediment to varying depths (25,115,000 to 33,487,000 cy) and excavating approximately 158,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative H would be managed in one of two disposal scenarios; 670,000 cy would be disposed in the onsite CDF and 24,445,000 to 32,817,000 cy would be disposed in off-site disposal facilities under DMM Scenario 1. DMM Scenario 2 would result in disposal of 25,115,000 to 33,487,000 cy in off-site disposal facilities. The net present value cost for DMM Scenario 1 is $9,445,540,000, and is $9,524,940,000 for DMM Scenario 2.

Alternative I: Alternative I has a total constructed area of 291 acres sediment, and will allow 1,876 acres of sediment to naturally recover. It includes 231.2 acres of capping and dredging contaminated sediment and 59.8 acres of ENR, and is estimated to take 7 years to construct. Additionally, 19,000 lineal feet of river bank are assumed to be laid back and covered various caps. Alternative I involves dredging of 167.1 acres of sediment to varying depths (1,414,000 to 1,885,000 cy) and excavating approximately 103,0600 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative H would be managed in one of two disposal scenarios; 670,000 cy would be disposed in the onsite CDF and 744,000 to 1,215,000 cy would be disposed in off-site disposal facilities under DMM Scenario 1. DMM Scenario 2 would result in disposal of 1,414,000 to

1,885,000 cy in off-site disposal facilities. The net present value cost for DMM Scenario 1 is $745,890,000, and is $811,290,000 for DMM Scenario 2.

Detailed Analysis of Alternatives

A detailed analysis of individual alternatives against the evaluation criteria required by the NCP, and a comparative analysis that focuses upon the relative performance of each alternative against those criteria. The first two criteria are threshold criteria that must be met by each alternative to be eligible for selection as a remedy. The next five criteria are the primary balancing criteria upon which the analysis is based. The final two criteria are referred to as modifying criteria and evaluate state and community acceptance. The two modifying criteria will be evaluated following comments received during the public comment period and will be addressed in making the final remedy decision and discussed in the ROD.

The two **threshold criteria** are:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs

The five **balancing criteria** upon which the detailed analysis is based are:

- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility or Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

The two **modifying criteria** are:

- State Acceptance and Tribal Consultation and Coordination
- Community Acceptance

Spatial Scales for Alternatives Evaluation

The analysis of alternatives was conducted using several relevant exposure scales for receptors covered by each. Site-wide and smaller spatial scales were used to evaluate each alternative including attainment of the RAOs.

The Site was subdivided into four river segments:

- West shore to west navigation channel boundary
- Navigation channel

- East shore to east navigation channel boundary
- Swan Island Lagoon

Within each river segment, a scale of 0.5 RM was used for RAO 1 (sediment only) for direct contact exposure of people engaged in fishing activities, and a 1 RM was used for RAOs 2 and 6 for the dietary exposure of humans and ecological receptors that consume fish and shellfish. RAO 2 was also evaluated Site-wide.

Benthic risk was evaluated on a population level as the area exceeding RAO 5 PRGs.

Fourteen individual regions of the river within the Site were designated as sediment decision units (SDUs). The SDUs were identified as areas with the highest rolling 1 RM average concentrations of the focused COCs. Additional SDUs were defined to address areas where multiple contaminants at concentrations substantially greater than PRGs and/or unacceptable benthic risk were identified between RM 4 and 6.

Evaluation Process and Criteria

This evaluation focuses on sediment RAOs (1, 2, 5 and 6) although surface water RAOs (3 and 7), groundwater RAOs (4 and 8), and the river bank RAO (9) are also evaluated relative to actions being taken on the sediment.

- Effectiveness: Reductions in the Site-wide SWAC were estimated by assuming the constructed area achieves an ideal constructed surface concentration of zero. A post-construction weighed Site-wide SWAC was calculated and compared to the current weighted Site-wide SWAC. All the alternatives are effective in reducing risks from COCs at the Site. Alternative B relies on less construction and more MNR to reduce risks, and each alternative thereafter through H relies on more construction and less MNR.
- Implementability: All alternatives are implementable, with the amount of construction increasing from Alternative B through Alternative H. However, given the extensive degree of capping and dredging associated with Alternative H and the expected construction duration (62 years), Alternative H is considered less implementable than the other alternatives.
- Cost: Cost is generally proportional to the amount of construction and materials needed for each alternative. Thus, costs increase from Alternative B to Alternative H; Alternatives E and I are approximately the same. Present value costs for each alternative range between $451M (Alternative B) and $9.52B (Alternative H), with Alternative H being substantially more expensive than the other alternatives.

  Alternative C was screened out based on the small incremental increase in quantities of dredge and borrow materials between Alternatives B and C and the relatively small incremental decrease in focused COC concentrations when compared between Alternatives B and D or C and D. Alternative H was screened out primarily based on implementability and cost. The advantage of Alternative H is that it removes more contamination from the river and achieves the PRGs at the end of construction. However, it increases the amount of long-term O&M due to the increase in capped acres. Further, the time frame over which resuspension due to dredging activities would occur results in a greater time period for continued adverse effects to human health and the environment. Alternative H also has a cost approximately 5 times higher than the next closest alternative (Alternative G).

Summary of Comparative Analysis

All alternatives equally rely on the adequacy of DEQ’s source control to achieve PRGs and RAOs and to prevent recontamination of the Site. Addressing river banks will also help prevent recontamination of the Site. Alternatives E, F, G and I all meet the threshold criteria of Overall Protection of Human Health and the Environment and Compliance with ARARs. Alternative D may meet the threshold criteria, although there is more uncertainty with this alternative. Alternatives A and B do not meet the threshold criteria, therefore will not be further discussed.

Alternatives E, F, G, and I address all PTW at the Site and achieve the statutory preference for treatment, when applicable. Alternative D does not address all PTW at the Site. Alternatives E and I both provide approximately an order of magnitude risk reduction from the no action alternative at completion of construction. Both of these alternatives control the major sources of sediment contamination by sequestering higher contaminant concentrations under engineered caps or removing the material and containing it in a disposal facility, which are maintained in perpetuity. Post-construction risks for Alternative D are nearly twice those for the risk of Alternatives E and I. Alternatives F and G achieve the risks associated with the PRGs at completion of construction. However, Alternatives F and G have greater impacts to the environment than Alternatives E and I due to the increased construction footprints and time to construct (2-3 times longer to implement), which would increase impacts to the community and workers implementing the remedy.

Capped area is similar for Alternatives E (101 acres) and I (102 acres). Alternative D has less capped area (71 acres), but does not reliably contain all PTW remaining in the river. Compared to Alternatives E and I, Alternative F has almost twice the capped area (176 acres) and Alternative G has more than two and half times the capped area (260 acres). As the area to be capped increases, impacts to the benthic community increase and more long-term monitoring, maintenance, and river use restrictions would be required.

All the alternatives achieve reduction of toxicity, mobility, or volume through treatment by using in-situ and ex-situ treatment technologies that have been demonstrated to be effective at Superfund sites around the country. In all alternatives, 192,000 cy of removed sediment and soil is treated ex-situ at the off-site disposal facility using low temperature thermal desorption or cement solidification/stabilization. In-situ treatment is applied to areas where PTW is left in place or where residual groundwater plumes may be discharging to the river. Under Alternative I, in-situ treatment is applied to 113 acres of the Site through the addition of reactive components to caps and residual layers. This area is more than Alternatives D (108 acres) and E (109 acres). Alternative I would ensure that the preference for treatment is achieved for all PTW and increases protection from impacts from contaminated groundwater plumes discharging into the Site. While Alternatives F (145 acres) and G (238 acres) address an increased footprint of the contaminated groundwater plume area, these alternatives would also have greater impacts to the benthic community due to the larger construction footprints. There is uncertainty regarding the overall area of the Site impacted by contaminated groundwater, therefore, the need for in situ treatment to address contaminated groundwater will be refined during remedial design.

Alternatives E and I, with a construction duration of 4 months per year for 7 years, would reduce impacts from construction to the community, workers implementing the remedy, and the environment compared to 4 Alternative F (13 years) and Alternative G (19 years). Since Alternative I also involves less construction than Alternative E, Alternative I would have less short-term impact on the community, workers, and the environment. Impacts to the environment and community would continue until MNR achieves PRGs and RAOs. Alternative I achieves more interim targets than Alternative D and is therefore more reliable in achieving PRGs and RAOs in a reasonable time frame because it relies less on natural processes.

Since ICs are not applicable to ecological receptors, it is ideal to address all ecological risks at construction completion. While none of the alternatives address all ecological risks, Alternative G addresses the most ecological risks at the completion of construction although it impacts their habitat for the longest period of time during construction (19 years) and would take the longest time for benthic populations to recover due to the large area of habitat impacted (776 acres). Alternatives D, E, F and I address an area sufficient to ensure risks would not occur to the benthic population as a whole. While Alternative I does not achieve ecological PRGs for RAO 6 at construction, most of this remaining risk is in Swan Island Lagoon and will be addressed through ENR. Implementing Alternative I will eliminate the need to disrupt 485 acres of habitat for 12 additional years that implementation of Alternative G would require, which would delay the re-establishment of ecological communities.

The sources of contaminated groundwater plumes are expected to be controlled though cleanup actions and monitoring under DEQ oversight. It is EPA's expectation that the majority of the current identified groundwater plumes will be addressed by DEQ's actions and the alternatives will only need to address the portion of the plumes that extend into the river. Since the extent of these plumes impacting pore water is not currently known, these areas will need to be refined during remedial design and at that point it will be determined which residual groundwater plumes will need to be addressed in the river. Alternatives E and I both address 33 percent of the contaminated groundwater area as currently delineated. Alternative D addresses 23 percent of this area, Alternative F addresses 46 percent, and Alternative G addresses 62 percent.

Removing contaminated sediment and river bank soil out of the river has long term benefits for the Site, but there are also impacts to the environment and community associated with transporting the removed material to a disposal facility. Alternatives E and I have similar removed material volumes (approximately 2,024,000 cy and 1,752,000 cy, respectively) and achieve similar risk reductions and long term benefits post-construction compared to the other alternatives. While Alternatives F and G achieve higher risk reduction post-construction compared with current risks; however, removed material volumes are more than 3-4 times greater (approximately 4,585,000 cy and 7,397,000 cy, respectively) than Alternatives D, E and I. This means that implementing Alternatives F and G would impose significantly greater impacts to the environment and community and have much greater costs (1.5-2 times more than Alternatives E and I) that are not commensurate with the additional risk reduction relative to Alternatives E and I. Depending on which form of transportation is used for the removed material, these impacts include increased barge traffic on the river, which would impact commercial and recreational use of the river, increased traffic on the roads in the community if trucking is used, and increased traffic on the rail lines if rail is used. There are also increased environmental impacts, such as potential spills and sediment disturbance from wake waves and propwash, associated with transporting such large volumes of material.

Treatment and disposal of approximately 206,400 cy contaminated sediment and soil are assumed to be sent to a Subtitle C landfill for all alternatives and DMM scenarios. This material would be barged to an off-site transload facility and trucked to the landfill because it would not meet the criteria for disposal in a Subtitle D landfill or a CDF. Alternatives E, F, G and I include DMM Scenario1, which includes disposal of approximately 670,000 cy of removed material in the Terminal 4 CDF. The construction of a CDF would destroy approximately 14 acres of habitat within the Site and mitigation will be required for this lost acreage. Disposing approximately 670,000 cy of removed material in the onsite CDF reduces the number of barges needed and distance for the barges to transport the removed material to the appropriate transload facility. Reducing the transport distance for disposal also reduces the chance that accidents could occur as well as reducing the number of impacted communities. Removed material not disposed of in a Subtitle C landfill or a CDF is assumed to be disposed of in an off-site Subtitle D landfill. This material would be barged to an off-site transload facility and trucked to the landfill. If an on-site transload facility were constructed, the number of barges would be reduced, but the volume of truck and rail traffic through communities would be increased.

On a Site-wide scale, none of the alternatives achieve surface water PRGs for PCBs and 2,3,7,8-TCDD eq; however, surface water concentrations from contaminated sediment are within an order of magnitude of the PRGs for Alternatives D, E, F, G, and I. Alternatives F and G contaminant concentrations are within a factor of 5 of the PRGs. It is expected that MNR in conjunction with ICs and source control, including control of upriver sources, is necessary to achieve surface water RAOs.

Delivery of construction material to the Site is assumed to be conducted via barge, although other modes of transportation (truck and rail) may be used. Impacts from transporting construction materials to the site, such as truck or barge traffic, are directly related to the size and thickness of the caps, the construction of an on-site CDF and the volume of materials required. Alternatives E and I would require twice the materials needed than Alternative D and would require additional year of construction. Alternative F would require three times and Alternative G would require almost five times the volume of material as Alternatives E and I and construction durations are significantly longer (2-3 times as long).

MNR is expected to occur as cleaner upriver sediments deposit on surface sediment in the Site during low-flow periods and mix and disperse downstream during higher flow periods. This transitional process is expected to occur until static equilibrium is reached in the river system. In order to achieve PRGs in a reasonable time frame, the surface sediment concentrations need to be low enough that these processes will be able to reduce the exposure to contaminants in a reasonable time frame. Since much of the Site has lower concentrations of contamination, the greatest footprint is assigned this technology in all alternatives. However, as the footprint for MNR decreases, the area of disturbance of the aquatic environment due to construction increases, the longer these disturbances occur, and the more the alternative costs. Alternatives D, E and I have about the same MNR footprint (88, 85 and 87 percent of the Site, respectively) while Alternatives F and G have a 10 and 20 percent smaller MNR footprint, respectively. The Site-wide post-construction sediment PCB concentrations (contaminant that poses the greatest risk) are the same for Alternatives E and I (81 percent), which is 7 percent more than Alternative D. Further, the Site-wide post-construction sediment PCB concentrations would decrease by an additional 7 and 11 percent for Alternatives F and G, respectively, but will have 35-50 percent greater impact on the aquatic environment due to the increased constructed footprint than Alternatives E and I.

MNR is not considered to be effective within Swan Island Lagoon because water circulation is limited, and thus it does not receive sufficient cleaner sediment from upstream to allow natural recovery to occur in areas with lower contaminant concentrations. For this reason, ENR, which involves placing a sand layer on the contaminated sediment, will be used to further reduce contaminant concentrations in these areas. As the areas of construction for each alternative increase, the certainty that ENR will achieve PRGs also increases. Although decreasing the ENR footprint and increasing the area of construction provides for a more permanent and reliable remedial alternative, the added cost of dredging, capping, and long-term maintenance is not commensurate with the added protections gained from these technologies at lower sediment concentrations. Alternative D has the largest ENR footprint (74 percent of the area within Swan Island Lagoon), E and I have the same ENR footprint (51 percent) while Alternatives F and G have the smallest ENR footprints (24 and 16 percent, respectively). Post-construction risks for Alternative D are greater than interim targets. The ability of ENR in Swan Island Lagoon to achieve long-term effectiveness is uncertain since the volume of clean sand needed to dilute the remaining contaminated sediment is greater than Alternatives E, I, F and G, and several applications may be necessary. This would have greater disruption to the benthic population in Swan Island Lagoon for a longer period of time. Post-construction risks for Alternatives F and G are lower than the residual risk estimates, thus ENR would not be necessary. Post-construction risk estimates for Alternatives E and I are within a factor of 5 of the residual risk. Because the remaining concentrations in Swan Island Lagoon outside the SMA are sufficiently close to the PRGs, ENR would be sufficient to achieve and maintain protective levels in the long term and would reduce the costs from implementing Alternatives F and G.

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1. INTRODUCTION

This report presents the Feasibility Study (FS) for the Portland Harbor Superfund Site (Site) in Portland, Oregon (**Figure 1-1**). The Site was evaluated and proposed for inclusion on the National Priorities List (NPL) pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, or Superfund), 42 United States Code (U.S.C.) §9605, by the U.S. Environmental Protection Agency (EPA) and formally listed as a Superfund Site in December 2000. EPA is the lead agency for this Site, and Oregon Department of Environmental Quality (DEQ) is the support agency.

The supporting information used to develop this FS was collected and compiled by the Lower Willamette Group (LWG) and other parties since the inception of the Portland Harbor Remedial Investigation (RI)/FS) in 2001.[1] The LWG prepared a draft FS in 2012 for the Site pursuant to an EPA Administrative Order on Consent (AOC) for the Portland Harbor RI/FS (USEPA 2001, 2003, 2006). Oversight of LWG's FS was provided by EPA with support from DEQ. EPA modified the LWG's 2012 FS and finalized the document pursuant to a mutual agreement dated February 4, 2016. EPA has entered into a Memorandum of Understanding (MOU) with DEQ, six federally recognized tribes, two other federal agencies, and one other state agency[2] who have all participated in providing support in the development of this document.

The RI report[3] (USEPA 2016) has been completed and characterized the Site sufficiently to define the nature and extent of the source material and the Site-related contaminants. Baseline ecological and human health risk assessments (Windward Environmental, LLC [Windward] 2013; Kennedy/Jenks Consultants [Kennedy/Jenks] 2013) have also been completed. The site characterization and baseline risk assessments are sufficient to complete the FS for the Site.[4]

This FS focuses on approximately 10 miles of the lower Willamette River from River Mile (RM) 1.9 (at the upriver end of the Port of Portland's Terminal 5) to RM 11.8 (near the Broadway Bridge). The terms Site, harbor-wide, and Site-wide used in this FS generally refer to the sediments, river banks, pore water, and surface water within this reach of the lower Willamette River, not the upland portions of the Site.

[1] Some of the data used in the FS was collected prior to the listing of the Site.
[2] Government parties that signed the MOU include the Confederated Tribes and Bands of the Yakama Nation, the Confederated Tribes of the Grand Ronde Community of Oregon, the Confederated Tribes of Siletz Indians, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Nez Perce Tribe, the National Oceanic and Atmospheric Administration, the U.S. Department of the Interior, and the Oregon Department of Fish and Wildlife.
[3] This report was significantly revised by USEPA from the August 29, 2011 Draft Final RI Report submitted by the Respondents to the Administrative Order on Consent for Remedial Investigation and Feasibility Study U.S. EPA Docket Number CERCLA-10-2001-0240 dated and amended September 28, 2001, as amended on June 16, 2003 and April 27, 2006.
[4] Although this section identifies many specific sources of contamination, neither this section nor this report generally is intended as an exhaustive list of current or historical sources of contamination.

This FS is consistent with CERCLA, as amended (42 U.S.C. 9601 et seq.), and its regulations, the National Oil and Hazardous Substances Pollution Contingency Plan (40 Code of Federal Regulations [CFR] Part 300), commonly referred to as the National Contingency Plan (NCP) and was prepared in accordance with EPA guidance. Guidance documents used in preparing this FS include:

- *Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA 1988)*
- *Clarification of the Role of Applicable or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA (USEPA 1997a)*
- *Rules of Thumb for Superfund Remedy Selection (USEPA 1997b)*
- *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites (USEPA 2002)*
- *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA 2005)*
- *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study (USEPA 2000)*
- *Technical Resource Document on Monitored Natural Recovery (USEPA 2014)*

1.1 PURPOSE AND ORGANIZATION OF REPORT

The purpose of the FS is to identify, develop, screen, and evaluate a range of remedial alternatives to reduce risks from contaminated media to acceptable levels and to provide the regulatory agencies with sufficient information to select a remedy that meets the requirements established in the NCP. This FS report is comprised of four sections as described below.

- Section 1 – Introduction: Provides a summary of the Site RI, including Site description, Site history, nature and extent of contamination, contaminant fate and transport, and baseline human health and ecological risks.
- Section 2 – Identification and Screening of Technologies: Presents remedial action objectives (RAOs), preliminary remediation goals (PRGs) for addressing human health and ecological risks posed by contaminants in sediment and tissue, and general response actions (GRAs) for each medium of interest; identifies areas of media to which GRAs might be applied; identifies and screens remedial technologies and process options; and identifies and evaluates technology process options to select a representative process for each technology type retained for further consideration.

- Section 3 – Development and Screening of Alternatives: Presents a range of remedial alternatives developed by combining the feasible technologies and process options. The alternatives are then refined and screened to reduce the number of alternatives that will be analyzed in further detail. This screening aids in streamlining the FS process while ensuring that the most promising alternatives are being considered.

- Section 4 – Detailed Analysis of Alternatives: Provides the detailed analysis of each alternative with respect to the following seven NCP criteria: (1) overall protection of human health and the environment; (2) compliance with applicable or relevant and appropriate requirements (ARARs); (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, or volume through treatment; (5) short-term effectiveness; (6) implement ability; and (7) cost. In addition to the detailed analysis, a comparative analysis of remedial action alternatives is also presented in this section. EPA recognizes that this Site affects many stakeholders, including communities with environmental justice concerns, who live along the river or who live elsewhere but also use the river and considers impacts to these communities in the evaluation of remedial alternatives.

1.2 BACKGROUND INFORMATION

1.2.1 Site Description

The Willamette River originates within Oregon in the Cascade Mountain Range and flows approximately 187 miles north to its confluence with the Columbia River and is one of 14 American Heritage Rivers in the country. It is the 19th largest river in the United States by drainage and drains 11.7 percent of the State of Oregon. As Oregon's major port and population center, the lower Willamette River sees a great variety of uses, including shipping, industrial, fishing, recreational, natural resource, and other uses. The lower reach of the Willamette River from RM 0 to approximately RM 26.5 is a wide, shallow, slow moving segment that is tidally influenced, with tidal reversals occurring during low flow periods as far upstream as Ross Island at RM 15. The river segment between RM 3 and RM 10 is the primary depositional area of the lower Willamette River system. The lower reach has been extensively dredged to maintain a 40-foot deep navigation channel from RM 0 to RM 11.7.

The Site is located within the lower reach of the lower Willamette River in Portland, Oregon known as Portland Harbor (**Figure 1-1**). The Site extends approximately from RM 1.9 to 11.8. While the harbor area is extensively industrialized, it occurs within a region characterized by commercial, residential, recreational, and agricultural uses. Land use along the lower Willamette River in the harbor includes marine terminals, manufacturing, and other commercial operations as well as public facilities, parks, and open spaces. **Figures 1.2-1a** through **1.2-1d** illustrate land use zoning within the lower Willamette River as well as waterfront land ownership. The State of Oregon owns certain submerged and submersible lands underlying navigable and tidally influenced waters.

The ownership of submerged and submersible lands is complicated and has changed over time. **Figure 1.2-2** presents the current submerged land ownership.

Today the Willamette River is noticeably different from the river prior to industrial development that commenced in the mid to late 18^{th} century. Historically, the Willamette River was wider with more sand bars and shoals, and flow volumes were subject to greater seasonal fluctuation. The main river now has been redirected and channelized, several lakes and wetlands in the lower floodplain have been filled, and agricultural lands have been converted to urban or industrial areas. The end result is a river that is deeper and narrower than it was historically, with higher banks that prevent the river from expanding during high-flow events. The width of the Willamette River from the Broadway Bridge (RM 11.6) to the mouth (RM 0) currently varies from 600 to 1,900 feet. Further, the installation of a series of dams moderates fluctuations of flow in the lower Willamette River.

Little, if any, original shoreline or river bottom exists that has not been modified by or resulted from the above actions. Much of the shoreline has been raised, filled, stabilized, and/or engineered and contains overwater piers and berths, port terminals and slips, stormwater and industrial wastewater outfalls and combined sewer overflows (CSOs), and other engineered features. Constructed structures, such as wharfs, piers, floating docks, and pilings, are especially common in the Site where urbanization and industrialization are most prevalent. These structures are built largely to accommodate or support shipping traffic within the river and to stabilize the river banks for urban or commercial/industrial development. Constructed structures are clearly visible in the aerial photos provided in **Figures 1.2-3a** through **1.2-3n.**

Armoring to stabilize the river banks covers approximately half of the harbor shoreline and is integral to the operation of activities that characterize the Site. Riprap is the most common bank-stabilization measure. However, bulkheads and rubble piles are also used to stabilize the banks. Seawalls are used to stabilize banks and limit periodic flooding as most of the original wetlands bordering the Willamette in the Portland Harbor area have been filled. Some river bank areas and adjacent parcels have been abandoned and allowed to revegetate, and beaches have formed along some modified shorelines.

A federal navigation channel, maintained to a depth of -40 feet, with an authorized depth of -43 feet, extends from the confluence of the lower Willamette River with the Columbia River to RM 11.7. The lower Willamette River federal navigation project was first authorized in 1878 to deepen and maintain parts of the Columbia River and lower Willamette River with a 20-foot minimum depth. The depth of the navigation channel has been deepened at various intervals since that time; it was increased to 25 feet in 1899, 30 feet in 1912, 35 feet in 1930, and 40 feet in 1962. Container and other commercial vessels regularly transit the river. Certain parts of the river require periodic maintenance dredging to keep the navigation channel at its maintained depth. In addition, the Port of Portland and other private entities periodically perform maintenance dredging to support access to dock and wharf facilities. Except for the emergency dredging of some shoals, little navigational dredging has been performed since 1997 due to contamination of the river bottom. Dredging activity has greatly altered the physical and ecological environment of the river in the Site. The location of the federally authorized navigation channel and the future maintenance dredge areas are depicted on **Figures 1.2-4a** through **1.2-4e**.

Development of the river has resulted in major modifications to the ecological function of the lower Willamette River. However, a number of species of invertebrates, fishes, birds, amphibians, and mammals, including some protected by the Endangered Species Act (ESA), use habitats that exist within and along the river. The river is also an important rearing site and pathway for migration of anadromous fishes, such as salmon and lamprey. Various recreational fisheries, including salmon, bass, sturgeon, crayfish, and others, are active within the lower Willamette River. A detailed description of ecological communities in the Site is presented in the baseline ecological risk assessment (BERA) provided as Appendix G of the RI report.

1.2.2 Site History

Since the late 1800s, the Portland Harbor section of the lower Willamette River has been extensively modified to accommodate a vigorous shipping industry. Modifications include redirection and channelization of the main river, draining seasonal and permanent wetlands in the lower floodplain, and relatively frequent dredging to maintain the navigation channel. Historically, the Willamette was wider, had more sand bars and shoals, and fluctuated greatly in volume.

The lower Willamette River and its adjacent upland areas have been used for industrial, commercial, and shipping operations for over a century. Commercial and industrial development in the Site accelerated in the 1920s and again during World War II, which reinvigorated industry following the Great Depression. Before World War II, industrial development primarily included sawmills, manufactured gas production (MGP), bulk fuel terminals, and smaller industrial facilities. During World War II, a considerable number of ships were built at military shipyards located in the Site. Additional industrial operations located along the river in the post-World War II years included wood-treatment, agricultural chemical production, battery processing, ship loading and unloading, ship maintenance, repair and dismantling, chemical manufacturing and distribution, metal recycling, steel mills, smelters, foundries, electrical production, marine shipping and associated operations, rail yards, and rail car manufacturing. Many of these operations continue today. Contaminants associated with these operations were released from various sources and migrated to the lower Willamette River. The long history of industrial and shipping activities in the Site, as well as agricultural, industrial, and municipal activities upstream of the Site, has contributed to chemical contamination of surface water, sediment, and biota in the lower Willamette River.

The Portland Basin historically offered access to abundant natural resources in the rivers and on land, and many of these resources are still present, including fish, marine mammals, waterfowl, land mammals, and native plants. Native Americans have been using these resources for thousands of years. Fish are among the resources most frequently utilized by tribes in the Portland Basin and the Willamette Valley. Culturally significant species include salmonids, lamprey (eels), eulachon (smelt), and sturgeon. Native peoples also fished for a variety of other resident species, including mountain whitefish (*Prosopium williamsoni*), chiselmouth (*Acrocheilus alutaceus*), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth (*Mylocheilus caurinus*), and suckers (*Catostomus spp.*) (Butler 2004; Saleeby 1983). The harvest of the Pacific lamprey is of great importance to many tribes, and tribal members have noted a decrease in abundance and quality due to contamination. Of land mammals historically found in the Portland Basin, deer and elk were the most frequently utilized by Native people. Native plants were and continue to be gathered for food and medical purposes as well. Tribes through Tribal Treaties have reserved hunting, fishing (particularly targeting salmon and sturgeon species), and certain gathering rights. These subsistence activities provide food for tribal families and cultural heritage of knowledge and skills. Historic and contemporary uses of these resources overlap, and access to suitable patches of habitat continues to be both a challenge and an essential element of maintaining local tribal cultural knowledge, practices, and traditions.

1.2.2.1 Investigation History

Many environmental investigations by private, state, and federal agencies have been conducted, both in the lower Willamette River and on adjacent upland properties, to characterize the nature and extent of contamination in the river as well as to identify potential sources of contaminants that could continue to enter the river. Investigations have been conducted on the Site from the 1920s to the present, with most studies being performed from the late 1970s through the present. Nearly 700 documents and data sets were obtained that address conditions in the lower Willamette River. Specific historical and recent studies and data sets were selected for inclusion in the data set used to characterize and evaluate the Site in the RI and FS reports.

Site data were collected by the LWG during four major rounds of field investigations between 2001 and 2010 to complete the RI. The investigations were often timed around varying river height stages, river flows, and storm events. The field investigations first began in 2001 in the Initial Study Area (ISA) as defined by the AOC, Statement of Work (SOW), and Programmatic Work Plan as RM 3 to RM 9. As the studies commenced, the study area was expanded from RM 1.9 to RM 11.8 as well as a portion of the Multnomah Channel. Studies conducted by the LWG also included areas downriver of the Site to the confluence with the Columbia River at RM 0 and upriver to RM 28.4. Surface and subsurface sediment samples, sediment trap samples, river bank sediment and soil samples, surface water samples, stormwater and stormwater solids samples, groundwater samples, transition zone water (TZW) samples, and biota/tissue samples were collected and analyzed during the various investigations conducted.

1.2.2.2 Upland Source Control Measures

Identifying current sources of contamination to the Site and eliminating or minimizing these pathways, where possible, is critical for maximizing remedy effectiveness by minimizing the potential for recontamination of the sediment, surface water, and biota and overall long-term protectiveness after cleanup. In February 2001, DEQ, EPA, and other governmental parties signed an MOU agreeing that DEQ, using state cleanup authority, has lead technical and legal responsibility for identifying and controlling upland sources of contamination that may impact the river. Currently, DEQ is investigating or directing source control work at over 90 upland sites in the Site and evaluating investigation and remediation information at more than 80 other upland sites in the vicinity of the Site (DEQ 2014). Additionally, DEQ is working with the City of Portland under an Intergovernmental Agreement to identify and control upland sources draining to the Site through 39 city outfalls and with the Oregon Department of Transportation controlling highway and bridge runoff to the Site (City of Portland 2012).

The City prepared a CSO Management Plan (City of Portland 2005) with recommendations to address wet weather overflow discharges, including implementation of storage and treatment facilities along the Willamette River ("Big Pipe project") to control the CSO discharges. The primary means for increasing the storage capacity was through construction of the West Side Tunnel (completed in 2006) and the East Side Tunnel (completed in 2011).

The cleanup of known or potentially contaminated upland sites is tracked in DEQ's Environmental Cleanup Site Information (ECSI) database, which is available online at http://www.deq.state.or.us/lq/ECSI/ecsi.htm, and source control efforts are summarized in DEQ's Portland Harbor Upland Source Control Milestone and Summary Report (http://www.deq.state.or.us/lq/cu/nwr/PortlandHarbor/jointsource.htm).

Figures 1.2-5a through **1.2-5e** graphically display the status of DEQ's source control evaluations as of 2014 for various sites along the Site by potential release/migration pathways to the river. An important overall assumption of the FS is that upland sources in the Site will be sufficiently controlled to achieve RAOs using the DEQ process.

1.2.2.3 Early Action Sites

Within the Site, separate administrative orders have been executed by EPA with various parties for five specific sites. These sites are:

1. Terminal 4 – conducted by the Port of Portland
2. Gasco – conducted by NW Natural
3. Gasco and Siltronic – conducted by NW Natural and Siltronic
4. Arkema – conducted by Arkema
5. RM 11 E – conducted by Glacier Northwest, Inc., Cargill, Inc., PacifiCorp, CBS Corporation, DIL Trust, and City of Portland

These projects are currently in various stages of completion as described below.

- **Terminal 4 –** The Port of Portland has been implementing a removal action at Terminal 4. A Phase I Abatement Measure was completed in 2008. Remediation consisted of dredging 12,819 cubic yards of contaminated sediment and placing it in an off-site disposal facility, isolating contaminated sediment with an organoclay-sand mix cap in the back of Slip 3, and stabilizing the bank along Wheeler Bay.

- **Gasco –** A removal action was conducted at the Gasco site between August and October 2005. Approximately 15,300 cubic yards of a tar-like material and tar-like contaminated sediment were removed by dredging the river bank and nearshore area adjacent to the Gasco facility and disposed of off-site. After the removal action, an organoclay mat was placed along an upper-elevation band of the shoreline dredge cut. This mat was secured in place with a sand cap and quarry spalls (crushed rock). A 1 foot thick sand cap and 0.5 foot of erosion protection gravel were placed over the remainder of the removal area (0.4 acres). Approximately 0.5 foot of a “fringe cap” of sand material was placed over 2.3 acres of the area surrounding the removal area.

- **Gasco and Siltronic –** NW Natural and Siltronic are conducting site characterization and design evaluations for the area adjacent to their two facilities. Under the order, NW Natural and Siltronic have agreed to perform further characterization, studies, analysis, and preliminary design for the final remedy at the Gasco Sediment site. The studies and other work under the SOW will be incorporated into the Portland Harbor RI/FS for the remedy decision for the Portland Harbor Superfund Site. The design of the final remedy selected will be performed under the order. No cleanup actions have been taken to date.

- **Arkema –** Under an AOC with EPA, Arkema conducted additional site characterization and preliminary design evaluations for a planned Removal Action. No cleanup actions have been taken to date.

- **River Mile 11 East –** A group of Respondents, collectively known as the RM 11E Group (includes Glacier Northwest, Inc., Cargill, Inc., PacifiCorp, CBS Corporation, DIL Trust, and City of Portland) entered into an AOC with EPA to perform supplemental Portland Harbor RI/FS work in support of preliminary design activities. No cleanup actions have been taken to date.

In addition, a sediment removal action of the near-shore adjacent to the BP Arco Bulk Terminal in 2007-2008 under DEQ oversight resulted in the removal and off-site disposal of 12,300 cubic yards of petroleum-contaminated soil and sediment. Removed material was replaced with clean fill, and a new steel sheet-pile seawall was installed along the entire river bank of the BP Arco Bulk Terminal property.

1.2.3 Nature and Extent of Contamination

Due to the large number (over 200) of contaminants detected at the Site in various media, the nature and extent of contamination focuses on specific contaminants or groups of contaminants selected by evaluating several criteria discussed in Section 5.1 of the RI report.

As discussed in detail in Section 5 of the RI report, 14 contaminants were identified based on frequency of detection, ease of cross media comparisons, co-location with other contaminants, widespread sources, and similar chemical structures and properties. Information regarding an additional 18 contaminants is provided in Appendix D of the RI report. The concentrations of these contaminants in sediment and surface water are summarized in the following sections. As discussed in Section 5.1 of the RI report, additional contaminants beyond the indicator contaminants presented in the RI report (and summarized in this section) are present at the Site at concentrations that may pose unacceptable risk to human health and the environment. Section 2.2.1 of this FS identifies the contaminants of concern (COCs) selected for the Site and discusses the process for selecting the COCs. In addition, the data and information used to determine nature and extent of groundwater and river bank contamination was collected by individual parties under DEQ oversight but was not discussed in the RI report.

1.2.3.1 Sources

Historical and current locations of various industrial facilities identified along the lower Willamette River are provided by industrial sector in **Figures 1.2-5a** through **1.2-5j**. The approximate location of facilities is shown on the maps; however, the actual extent of historical and current facilities/operations is not shown. Detailed information regarding historic and current sources of contamination in the lower Willamette River is provided in Section 4 of the RI report.

Contaminants released during industrial operations and/or other activities to the air, soil, groundwater, surface water, and/or impervious surfaces can potentially migrate to the lower Willamette River via the following pathways: direct discharge, overland transport, groundwater, river bank erosion, atmospheric deposition, overwater activities, and upstream watershed.

One key migration pathway for contaminants from these various industries to the river was through direct discharge via numerous public and private outfalls, including storm drains and CSOs, which are located along both shores of the lower Willamette River in the metropolitan area. In the early 1900s, rivers in the United States were generally used as open sewers, which was also true for the Willamette (Carter 2006). The process water from a variety of industries, including slaughterhouses, chemical plants, electroplaters, paper mills, and food processors, was discharged directly into the river. In the 1950s, municipal conveyance systems included interceptors, and associated facilities were installed to reduce the volume of untreated sewage discharging to the Willamette from the City of Portland. Regulatory actions in the 1960s and 1970s, such as the Clean Water Act, gradually reduced the direct discharge of waste to the Willamette River.

Direct discharges and releases from upland or overwater activities at the Site likely contributed to the majority of the observed contaminant distribution in sediments. The majority of current contaminant pathways to the river (soil erosion, groundwater, and stormwater) from upland sources are a result of historical operational practices, spills, and other releases.

In addition, stormwater and nonpoint discharges within the Willamette River Basin are potential sources of contamination to the sediment, surface water, and biota at the Site. Contaminants in discharges and runoff from diverse land uses in the basin eventually enter the river upstream of the Site. Contaminant loading from sediment transport and water from upstream areas throughout the last century also contributed to the conditions currently observed at the Site.

1.2.3.2 Sediment

Sediment samples were collected from the Site and the lower Willamette River. Much of the sampling was conducted by the LWG under the terms of the AOC and consistent with EPA approved work plans. Sample locations were biased toward areas of known or suspected contamination. Additional sampling was conducted both upstream and downstream of the Site. Summary statistics of surface and subsurface sediment concentrations for the indicator contaminants are provided in **Table 1.2-1a-b**. Generally, concentrations of the contaminants were greater in subsurface sediment samples relative to concentrations in surface samples, confirming that historical inputs were greater than current inputs. However, there are noted areas at the Site where surface concentrations are greater than subsurface concentrations, likely reflecting more recent releases and/or disturbance of bedded sediments.

PCBs
With few exceptions, the highest polychlorinated biphenyl (PCB) concentrations in surface sediment are present in nearshore areas outside the navigation channel and proximal to known or suspected sources (**Figure 1.2-6a**). Similar spatial and concentration trends are observed for subsurface sediments (**Figure 1.2-6b**). Total PCB concentrations are typically greater in the subsurface than in surface sediments, indicating PCB sources are primarily historical. Overall, surface sediment PCB concentrations at the Site are greater than those in the upriver (upstream of Ross Island at RM 16) and downstream (main stem of the lower Willamette River downstream of RM 1.9 and Multnomah Channel) reaches.

Dioxins/Furans

Total polychlorinated dibenzo-p-dioxins/furans (PCDD/Fs) were detected at several locations along the eastern and western nearshore zones and in Swan Island Lagoon (**Figure 1.2-7a**). Limited surface PCDD/F data are available; thus, spatial resolution is somewhat limited, especially in the navigation channel. Total PCDD/F concentrations in the subsurface are generally greater than that observed in surface sediments (**Figure 1.2-7b**). The higher concentrations generally observed in subsurface sediment relative to concentrations in surface sediment are indicative primarily of historical input of these contaminants to the Site.

DDx

The highest reported DDx concentrations in surface sediments are present in localized areas in the western nearshore zones between RMs 6.3 and 7.5 (**Figure 1.2-8a**). DDx concentrations are typically greater in the subsurface than in the surface layer, indicating DDx sources are primarily historical (**Figure 1.2-8b**). The concentrations of DDx in surface sediments are greater at the Site than those in the upriver, downtown, Multnomah Channel, and downstream reaches.

Total PAHs

The highest reported concentrations of total polycyclic aromatic hydrocarbons (PAHs) in surface sediments generally occur in the western nearshore zone downstream of RM 6.8 and on the east side at approximately RM 4.5 (**Figure 1.2-9a**). Total PAH concentrations are generally higher in subsurface sediments at the Site as a whole, pointing to higher historical inputs to the Site (**Figure 1.2-9b**). At the Site, total PAHs in sediment are generally dominated by high molecular weight PAHs (HPAHs). Surface sediments from the western nearshore zone appeared to exhibit higher proportions of low molecular weight PAHs (LPAHs) than sediments from the eastern nearshore zone and the navigation channel but follow the general trend of HPAH dominance. Subsurface sediments generally exhibit similar PAH profiles to those in the surface sediments.

Bis(2-ethylhexyl) phthalate

The highest reported concentrations of bis(2-ethylhexyl)phthalate (BEHP) were observed in samples collected in surface and subsurface sediment from the eastern nearshore in Swan Island Lagoon, between RM 3.8 and 4.1 and in the International Terminals Slip (**Figures 1.2-10a** and **1.2-10b)**. BEHP concentrations are generally greater in surface than in subsurface sediments, indicating more recent inputs to the Site.

Total Chlordanes

The highest reported concentrations of total chlordanes were observed along the western nearshore zone between approximately RM 7 and 9 (**Figure 1.2-11a**). Total chlordane concentrations are generally higher in subsurface sediments at the Site, pointing to higher historical inputs to the Site (**Figure 1.2-11b**).

Aldrin and Dieldrin

Aldrin and dieldrin, have similar chemical structures and are discussed together here because aldrin readily undergoes biotic and abiotic transformation to dieldrin. The highest reported concentrations of aldrin were observed in the western nearshore zone from RM 6.8 to RM 7 and from RM 8.6 to RM 8.8 (**Figures 1.2-12a)**. The highest reported surface concentrations of dieldrin were observed in Swan Island Lagoon and in the western nearshore zone from RM 8 to 9 (**Figure 1.2-13a**). Aldrin and dieldrin concentrations are higher in subsurface sediments than surface sediments at the Site (**Figures 1.2-12b** and **1.2-13b**), indicating higher historical inputs of these pesticides to the Site.

Metals

The highest reported arsenic concentrations were reported in several locations in the eastern nearshore at RM 2.3, RM 5.6, RM 7.2, near the mouth of Swan Island Lagoon and in the western nearshore area at RM 6.8, RM 8.6, and RM 10.2 (**Figure 1.2-14a**). Arsenic concentrations are generally greater in the surface sediments than in subsurface sediments at the Site (**Figure 1.2-14b**). This indicates recent arsenic inputs to the Site.

The highest reported chromium concentrations were observed in the eastern nearshore zone at RM 2.1-2.4, RM 3.7-4.4, RM 5.6-5.9, and in Swan Island Lagoon and in the western nearshore zone at RM 6-6.1, RM 6.8-6.9, and RM 8.8-9.2 (**Figure 1.2-15a**). Chromium concentrations are generally greater in the surface sediments than in subsurface sediments at the Site (**Figure 1.2-15b**). This indicates recent chromium inputs to the Site.

The highest surface and subsurface copper concentrations were observed in the eastern nearshore zone at RM 2.1-2.4, RM 3.7-4, RM 5.5-6.1, RM 11.1-11.3, and Swan Island Lagoon and in the western nearshore zone from RM 4.3 through 10.4 (**Figure 1.2-16a**). Copper concentrations are generally similar in surface and subsurface sediments at the Site (**Figure 1.2-16b**).

The highest surface sediment zinc concentrations were found in the eastern nearshore zone at RM 4-4.6, RM 5.6, and RM 6.7 and the western nearshore zone between RM 8 and 9.2 (**Figure 1.2-17a**). The highest subsurface concentrations of zinc were found in the western nearshore zone at RM 9-9.2 and in Swan Island Lagoon (**Figure 1.2-17b**). Zinc concentrations are generally similar in the surface and subsurface sediments at the Site.

Tributyltin Ion

The highest concentrations of tributyltin were reported in surface sediment near the eastern nearshore zone at RM 3.7, RM 7.5, and in Swan Island Lagoon (**Figure 1.2-18a**). The highest subsurface concentrations of tributyltin are found in the eastern nearshore zone between RM 7 and RM 8 and in Swan Island Lagoon (**Figure 1.2-18b**). Concentrations are generally higher in subsurface than surface sediments at the Site, indicating primarily historical inputs to the Site.

1.2.3.3 Surface Water

Concentrations of contaminants in surface water samples varied both spatially and with river flow. Surface water sample locations with the highest reported contaminant concentrations are as follows:

River Mile	River Location	Sample ID	Contaminants
Multnomah Channel	Transect	W027	PCDD/Fs, aldrin, copper
2	East	W001	PCBs, DDx
	West	W002	chlordanes
	Transect	W025	PCBs, BEHP, aldrin
3	International Slip	W004	PCBs
	East	W028	PCBs
4	West	W029	BEHP, chlordanes
5	East	W030	PCBs, DDx, chlordanes
6	East	W013, W014, W032	PCBs, PCDD/Fs
	West	W015, W031	PCBS, PCDD/Fs, DDx, PAHs, chlordanes, aldrin, dieldrin, copper
	Transect	W011	PCDD/Fs, BEHP, aldrin
7	West	W016, W033	PCBs, PCDD/Fs, DDx
8	West	W019, W036	PCBs, PAHs, BEHP
9	West	W022, W037	DDx, zinc
11	Transect	W023	PCDD/Fs, chlordanes, copper
16	Transect	W024	BEHP, copper

RM 7E, RM 8E, RM 9E, and RM 10 were not sampled.

Concentrations of contaminants in surface water at the Site are generally higher than those entering the upstream limit of the Site (W024 at RM 16) under all flow conditions. The highest contaminant concentrations in surface water at the Site were found near known sources. Concentrations of total PCBs, dioxins/furans, DDx, BEHP, chlordanes, and aldrin in surface water are greater at the downstream end of the Site (RM 2 [W001, W002, W025] and in the Multnomah Channel [W027]) than concentrations entering the Site, which indicates that contamination from the Site is being transported downstream to the Columbia River.

1.2.3.4 Groundwater

Figure 1.2-19 and **Figure 1.2-20** show the nature and extent of known contaminated groundwater plumes currently or potentially discharging to the river. Cleanup of contaminated groundwater is being addressed and managed by DEQ under an MOU with EPA (see 1.2.2.2, above). However, in-water actions may need to be considered under this response to address residual impacts from these groundwater plumes. The following provides a discussion of the groundwater plumes presented in **Figures 1.2-19** and **1.2-20.** Additional information on these areas is available in DEQ's ECSI database.

East Side of Willamette River

RM 2
Evraz Oregon Steel Mill (ESCI Site ID 141) – Contaminants are manganese and arsenic.

RM 3.5
Time Oil (ECSI Site ID 170) – Contaminants are pentachlorophenol, arsenic, and gasoline- and diesel-range hydrocarbons.

Premier Edible Oil (ECSI Site ID 2013) – Contaminants are total petroleum hydrocarbon (TPH) (diesel-range hydrocarbons), manganese, and arsenic.

Schnitzer Steel Industries (ECSI Site ID 2355) – Contaminants include cis-1,2-dichloroethene (cis-1,2-DCE), tetrachloroethene (PCE), and trichloroethene (TCE).

NW Pipe (ECSI Site ID 138) – Contaminants include PCE, TCE, and vinyl chloride.

RM 4.5
Terminal 4 Slip 3 (ECSI Site ID 272) – Contaminants include TPH (diesel-range hydrocarbons).

RM 6
McCormick & Baxter Creosote Co. (ECSI Site ID 74) – Contaminants include pentachlorophenol, PAHs, arsenic, chromium, copper, and zinc.

Willamette Cove – Contaminants include PCBs (Rodenburg et al. 2015).

RM 11
Tarr Oil (ECSI Site ID 1139) – Contaminants include cis-1,2-DCE, PCE, TCE, and vinyl chloride.

West Side of Willamette River

RM 4
Kinder Morgan Linnton Bulk Terminal (ECSI Site ID 1096) – Contaminants include light non-aqueous phase liquids (LNAPL), diesel-range hydrocarbons, residual-range hydrocarbons, and gasoline-range hydrocarbons.

RM 5
BP Arco Bulk Terminal (ECSI Site ID 1528) – Contaminants include TPH (gasoline-range and diesel-range hydrocarbons), and the plume extends under the adjacent downstream property.

Exxon Mobil Bulk Terminal (ECSI Site ID 137) – Contaminants include gasoline- and diesel-range hydrocarbons.

RM 5.5
Foss Maritime/Brix Marine (ECSI Site ID 2364) – Contaminants include gasoline- and diesel-range hydrocarbons.

RM 6
NW Natural/Gasco (ECSI Site ID 84) – Contaminants detected in groundwater include PAHs, semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs) (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX]), cyanide, sulfide, sulfate and carbon disulfide, ammonia, and metals (aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, selenium, silver, thallium, vanadium, and zinc). Gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, and total petroleum hydrocarbon fractions are being added to the groundwater monitoring program.

RM 6 and RM 7
Siltronic (ECSI Site ID 183) – Contaminants include petroleum-related and chlorinated VOCs (benzene, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,1-dichloroethene, cis-1,2-DCE, trans-1,2-DCE, TCE, and vinyl chloride), PAHs, gasoline-range, diesel-range, and residual-range hydrocarbons, cyanide, metals (arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, thallium, vanadium, and zinc), 2,4,5-trichlorophenoxyacetic acid (2,4,5-TP), and 2-(2,4-dichlorophenoxy)propionic acid (2,4-DP).

RM 7
Rhone Poulenc (ECSI Site ID 155) – Known releases of organochlorine insecticides and herbicides, including pentachlorophenol (PCP), 2,4-DP, Bromoxynil, 4(2,4-dichloropenoxy)butyric acid (2,4-DB), 2-methyl-4-chlorophenoxyacetic (MCPA), methylchlorophenoxypropionic acid (MCPP), 4-(4-chloro-2-methylphenoxy)butanoic acid (MCPB), 2,4,5-trichlorophenoxyacetic acid [2,4,5-T], 2,4-dichlorophenoxyacetic acid (2,4-D), DDT, endrin, heptachlor, sodium chlorate, sodium arsenate, 2,4,5-TP, aldrin, dieldrin, chlordanes, and 2,4-DP have occurred at the site.

Contaminants migrating in groundwater include VOCs and herbicides. Contaminants infiltrating City Outfall 22B include: SVOCs (2,4,6-trichlorophenol, 2,4-dichlorophenol, 2-methylphenol, pentachlorophenol, and naphthalene), insecticides (aldrin, alpha-chlordane, dieldrin, gamma-chlordane, heptachlor epoxide, hexachlorobenzene, DDD, DDE, and DDT), dioxin/furans (2,3,7,8-tetrachlorodibenzo-p-dioxin [TCDD]), and metals (aluminum, boron, molybdenum, thallium, arsenic, barium, iron, manganese) (DEQ 2013).

Kinder Morgan Pump Station (ECSI Site ID 2104) – Contaminants include TPH.

Arkema (ECSI Site ID 398) – Contaminants detected in groundwater at the Site include, but are not limited to, DDT and its metabolites DDD and DDE (DDx) and VOCs (chlorobenzene, chloroform, PCE, TCE and benzene), perchlorate and hexavalent chromium. A chloride groundwater plume associated with the former salt piles is also present at the Site.

RM 8
Kinder Morgan Willbridge Bulk Terminal (ECSI Site ID 160) – Contaminants include gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, and arsenic.

Chevron and Unocal Willbridge Bulk Terminal (ECSI Site IDs 25 and 177) – Contaminants include gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, and metals (arsenic and manganese).

Chevron Asphalt Plant (ECSI Site ID 1281) – Contaminants include TPH (diesel-range and gasoline-range hydrocarbons), arsenic, BTEX and naphthalene.

RM 9
Gunderson (ECSI Site ID 1155) – Contaminants include 1,1-DCE, 1,1,1-trichloroethane [1,1,1-TCA], PCE, TCE, vinyl chloride, and PAHs.

Christensen Oil (ECSI Site ID 2426) – Contaminants include TPH (Stoddard solvent).

Univar (ECSI Site ID 330) – Contaminants include 1,1-dichloroethane (DCA), 1,1-DCE, cis-1,2-DCE, methylene chloride, PCE, toluene, 1,1,1-TCA, TCE, vinyl chloride, and xylenes.

Galvanizers Inc. (ECSI Site ID 1196) – Contaminants include zinc.

RM 10
Sulzer Pump (ECSI Site ID 1235) – Contaminants include TPH, PAH, and VOCs.

RM 11.5
Centennial Mills (ECSI Site ID 5136) – Contaminants include TPH (diesel-range hydrocarbons).

1.2.3.5 River Banks

River banks are a source of contamination to the Willamette River. This section provides a discussion of the known contaminated banks that are evaluated as part of this FS. These areas are contaminated by a variety of COCs that can enter the river through erosion or anthropogenic activities and will then reside in the sediment bed, water column, or enter into the aquatic food chain. Characterization and evaluation of contaminated banks is being managed by DEQ under an MOU with EPA. River bank remediation has already occurred at several locations in the Site, managed by DEQ under an MOU with EPA (see Section 1.2.2.2 above).

Since river bank contaminations is directly linked to the sediment bed and receptors through proximity and source and migration pathways, the known areas of contamination are included here and elsewhere in the FS. Including these areas supports the evaluation of and selection of alternatives in case it is determined that river bank contamination is best suited for remediation in conjunction with in-river activities. Other river banks may be included in the remedial action in the river if contamination is found during remediation of the river sediment. Information on these river banks is available in DEQ's ECSI database and in the FS river bank data compilation found in Appendix A.

East Side of Willamette River

RM 2
Evraz Oregon Steel Mill (ECSI Site ID 141) – Contaminants present in the river bank includes PCBs and metals (arsenic, cadmium, chromium, copper, lead, manganese, and zinc).

RM 3.5
Schnitzer Steel Industries (ECSI Site ID 2355) – Soils samples collected under the docks along the south shore of the International Slip have been found to be contaminated with PCBs and dioxins.

Premier Edible Oil (ECSI Site ID 2013) – Contaminants may include mercury, cobalt, antimony, barium, PAHs, zinc, copper, manganese, arsenic, carbazole, dibenzofuran, methylnaphthalene, petroleum hydrocarbons, BTEX, chlorinated solvents, and bis(2-ethylhexyl)phthalate.

RM 5.5
MarCom South (ECSI Site ID 2350) – Further investigation of the nature and extent of contamination in the river bank was conducted in 2012. Contaminants are PAHs and metals (arsenic, cadmium, chromium, copper, zinc).

RM 7
Willamette Cove (ECSI Site ID 2363) – River bank contaminants are PCBs, dioxins/furans, metals (lead, mercury, nickel, and copper), and PAHs.

RM 8.5
Swan Island Shipyard (ECSI Site ID 271) – Recent sampling results indicate that contaminants include metals (arsenic, cadmium, chromium, copper, lead, mercury, and zinc), PAHs, PCBs, and tributyltin.

West Side of Willamette River

RM 4
Kinder Morgan Linnton Bulk Terminal (ECSI Site ID 1096) – Contaminants are petroleum constituents (BTEXs and PAHs) and metals (arsenic and lead).

RM 6
NW Natural/Gasco (ECSI Site ID 84) – Contamination associated with historical MGP waste is known to be located in the river bank. Contaminants include PAHs, gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbons, cyanide, and metals (zinc).

RM 6 and RM 7
Siltronic (ECSI Site ID 183) – Contamination associated with historical MGP waste is known to be present in the northern portion of the Siltronic river bank. River bank contaminants include PAHs, gasoline-range hydrocarbons, diesel-range hydrocarbons, residual-range hydrocarbon, cyanide, and metals (zinc).

BNSF Railroad Bridge – Contamination associated with pesticide and herbicide releases from Rhone Poulenc and Arkema are known to be present in the river bank below and adjacent to the BNSF railroad bridge. River bank contaminants include dioxin/furans, metals (aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc), insecticides (DDD, DDE, DDT, aldrin, alpha-hexachlorocyclohexane [alpha-BHC], alpha-chlordane, beta-BHC, cis-nonachlor, delta-BHC, dieldrin, endosulfan I, endosulfan II, endosulfan sulfate, endrin, endrin aldehyde, endrin ketone, gamma-BHC, gamma-chlordane heptachlor, heptachlor epoxide, hexachlorobutadiene, methoxychlor, Mirex, oxychlordane, and trans-nonachlor), PCBs, SVOCs (acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, benzoic acid, benzyl alcohol, bis (2-ethylhexyl)phthalate, butylbenzylphthalate, chrysene, bibenzo(a,h)anthracene, dimethylphthalate, di-n-butylphthalate, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene. (AMEC 2011).

RM 7
Arkema (ECSI Site ID 398) – River bank contaminants include DDT, dioxin/furans, PCBs, and metals (chromium and lead).

GS Roofing (ECSI Site ID 117) – River bank contaminants include TPH and metals arsenic, chromium, lead, mercury, nickel, and selenium.

RM 8
Hampton Lumber and Glacier NW (ECSI Site ID 1239) – River bank contaminants include steel mill slag fill.

RM 9
Gunderson (ECSI Site ID 1155) – Contaminants include metals (lead, nickel, and zinc) and PCBs.

RM 10
Sulzer Bingham Pumps (ECSI Site ID 1235) – River bank contaminants include PCBs and metals arsenic, copper, lead, manganese, and zinc.

1.2.4 Contaminant Fate and Transport

Sediment contamination at the Site is associated with historical and recent sources and practices. Persistent contaminants (particularly PCBs and dioxin/furans) from sediments and surface water bioaccumulate in the food chain and usually result in the greatest risks to humans and wildlife that ingest fish and shellfish.

Internal contaminant fate and transport processes are those processes that affect the fate, transport and redistribution of contaminants at the Site as opposed to those processes that may affect the fate of contaminants in biota. The major internal fate and transport processes are:

- Erosion from the sediment bed
- Deposition to the sediment bed
- Dissolved flux from the sediment bed (pore water exchange)
- Groundwater advection
- Degradation (for some contaminants)
- Volatilization
- Downstream transport of either particulate-bound or dissolved phase contaminants

These processes interact to create complex patterns of sediment contamination that vary spatially, temporally, and by contaminant. Empirical estimates of contaminant loading associated with internal and external contaminant sources are provided in **Figures 1.2-21** through **1.2-25**. A discussion of the methodology used to derive the contaminant loading is provided in **Appendix K**. External sources include upstream loading; “lateral” external loading, such as stormwater runoff, permitted discharges, upland groundwater, atmospheric deposition, direct upland soil, and river bank erosion; uncontaminated groundwater advection through contaminated subsurface sediments; and overwater releases. Internal sources include surface sediment loading to the surface water via sediment and river bank erosion and sediment pore water exchange as well as deposition to surface sediment from surface water. **Figures 1.2-26** provides a visual summary of currently known or suspected contaminant source loads within and exiting from the Site for three representative contaminants: total PCBs, benzo(a)pyrene, and DDE.

Elevated contaminant concentrations at the Site are typically associated with areas near likely historical and/or existing sources. Although the highest sediment contaminant concentrations are generally found in nearshore areas, elevated-concentrations are also found in the higher-energy portion of the channel between RM 5 and 7. This may reflect past or current dispersal of material away from nearshore source areas. Throughout the Site, contaminant concentrations are generally higher in subsurface sediments than in surface sediments, indicating both higher historical contaminant inputs and improving sediment quality over time. Localized exceptions to the pattern of higher subsurface sediment concentrations exist in a few areas for some contaminants, likely reflecting more recent releases and/or disturbances of bedded sediments through natural or anthropogenic processes. Also, the depth of subsurface contamination is generally greater in nearshore areas as compared to the navigation channel.

Generally, areas of elevated contaminant concentrations in surface sediment correspond to areas of elevated concentrations in subsurface sediment, particularly in nearshore areas. Areas where only surface or subsurface sediments exhibited elevated contaminant concentrations point to spatially and temporally variable inputs and sources or to different influences from sediment transport mechanisms. Areas of higher contaminant concentrations are generally distinct from those in surrounding areas of lower concentrations. Within these areas, distinctly higher contaminant concentrations are also noted in sediment traps and in the particulate portion of the corresponding surface water samples. For example, these patterns are presented for PCBs, PAHs, dioxins/furans, and DDx in **Tables 1.2-5** through **1.2-8**.

Most areas of elevated contaminant concentration in sediment are located in nearshore areas. Downstream migration/dispersal of contaminants from these areas is apparent in sediment data patterns. The elevated levels in subsurface sediment indicate historical releases from upland and overwater sources while the lower surface sediment concentrations suggest the deposition and mixing of cleaner upriver sediments in contaminated areas.

Based on results of surface water data collected during the RI, resuspension and/or dissolved phase flux from the sediment bed and to some degree river banks are contributing to contaminant concentrations in surface water, particularly in quiescent areas where surface water mixing and dilution is minimal. Loading estimates presented on **Figures 1.2-21** through **1.2-25** are consistent with this concept, indicating the mass flux of contaminants exiting the downstream end of the Site in surface water, either directly to the Columbia River or via Multnomah Channel, is greater than the flux entering the Site.

Contaminant concentrations in stormwater entering the Site are generally greater than concentrations associated with upstream surface water. On a mass loading basis, lateral contaminant loads associated with upland sources are comparable to upstream loads for certain contaminants.

Groundwater plume discharges to surface water have been observed in several areas where groundwater plumes are suspected or known to exist. Dissolved phase flux from surface sediments to the water column have been inferred from RI data.

Finally, tissue contaminant data and food-web modeling indicate that persistent contaminants (particularly PCBs and dioxin/furans) in sediments and surface water bioaccumulate in aquatic species tissue.

The CSM integrates the information gathered to date and provides a coherent hypothesis of the contaminant fate and transport at the Site. **Figure 1.2-26** provides a simplified visual summary of this hypothesis, including the complete human and ecological exposure pathways.

1.2.5 Baseline Risk Assessment

This section presents a summary of the results of the baseline human health and ecological risk assessments (BHHRA and BERA). These assessments are presented in Appendix F and Appendix G of the RI report.

1.2.5.1 Baseline Human Health Risk Assessment

The overall process used for the BHHRA was based on the guidance provided in the *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A), Interim Final* (USEPA 1989b). The BHHRA presents an analysis of the potential for effects associated with both current and potential future human exposures to contaminants at the Site. Potential exposure to contaminants found in environmental media and biota were evaluated for various occupational and recreational uses of the river, as well as recreational, subsistence, and traditional and ceremonial tribal consumption of fish caught within the Site. Infant consumption of human breast milk was also quantitatively evaluated because of the persistent and bioaccumulative nature of many of the contaminants found in sediment.

Consistent with EPA policy, the BHHRA evaluated a reasonable maximum exposure (RME), which is defined as the maximum exposure that is reasonably expected to occur. In addition, estimates of central tendency (CT), which are intended to represent average exposures, were also evaluated. **Figure 1.2-27** presents the conceptual site model (CSM) for the BHHRA and **Table 1.2-2** provides a list of contaminants potentially posing unacceptable risks for human health.

The major findings of the BHHRA are:

- Estimated cancer risks resulting from the consumption of fish or shellfish are generally orders of magnitude higher than risk resulting from direct contact with sediment and surface water. Risks and noncancer hazards from fish and shellfish consumption exceed EPA's acceptable cancer risk of 1 x 10^{-4} and target hazard index (HI) of 1 when evaluated on a harbor-wide basis and when evaluated on the smaller spatial scale by river mile.

- Consumption of resident fish species consistently results in the greatest risk estimates. Evaluated harbor-wide, the estimated RME cancer risks are 4 x 10^{-3} and 1 x 10^{-2} for recreational and subsistence fishers, respectively.

- Noncancer hazard indices for consumption of resident fish species are greater than 1 at all river miles. Based on a harbor-wide evaluation of noncancer risk, the estimated RME HI is 300 and 1,000 for recreational and subsistence fishers, respectively. The highest hazard estimates for recreational fishers are at RM 4, RM 7, RM 11, and in Swan Island Lagoon.

- The highest noncancer hazards are associated with nursing infants of mothers, who consume resident fish from the Site. When fish consumption is evaluated on a harbor-wide basis, the estimated RME HI is 4,000 and 10,000 for breastfed infants of recreational and subsistence fishers, respectively. Evaluated on a harbor-wide scale, the estimated RME HI for tribal consumers of migratory and resident fish is 600, assuming fillet-only consumption, and 800, assuming whole-body consumption. The corresponding HI estimates for nursing infants of mothers who consume fish are 8,000 and 9,000, respectively, assuming maternal consumption of fillet or whole-body fish.

- PCBs are the primary contributor to risk from fish consumption. When evaluated on a river mile scale, dioxins/furans are a secondary contributor to the overall cancer risk and hazard indices. PCBs are the primary contributors to the noncancer hazard to nursing infants, primarily because of the bioaccumulative properties of PCBs and the susceptibility of infants to the developmental effects associated with exposure to PCBs.

- The greatest source of uncertainty in the risk and hazard estimates includes the lack of good site-specific information about consumption of resident fish from the Site. Because tribal fish consumption practices were evaluated assuming a combined diet consisting of both resident and migratory fish, it is not clear to what degree contamination in the Site contributes to those estimated risks. In addition, it is important to remember that the noncancer hazard estimates presented in the BHHRA are not predictions of specific adverse health effects, and the cancer estimates represent upper-bound values. EPA is reasonably confident that the actual cancer risks will not exceed the estimated risks presented in the BHHRA.

1.2.5.2 Baseline Ecological Risk Assessment

The BERA evaluated the potential for adverse effects on plants, invertebrates, amphibians, fish, and wildlife from exposure to contaminants at the Site.

The overall process used for the BERA was based on the guidance provided in the *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments – Interim Final* (USEPA 1997c).

The following receptor groups and exposure pathways were evaluated in the BERA:

- **Benthic invertebrates –** Direct contact with sediment and surface water, ingestion of biota and sediment, and direct contact with shallow TZW
- **Fish –** Direct contact with surface water, direct contact with sediment (for benthic fish receptors), ingestion of biota, incidental ingestion of sediment, and direct contact with shallow TZW (for benthic fish receptors)
- **Birds and mammals –** Ingestion of biota and incidental ingestion of sediment
- **Amphibians and aquatic plants –** Direct contact with surface water and shallow TZW

The assessment endpoints for all ecological receptors are based on the protection and maintenance of their populations and the communities in which they live. Special status species (species that are protected by federal and/or state regulations or otherwise deemed culturally significant) are assessed at the organism-level for survival, growth, and reproduction. Juvenile Chinook salmon and Pacific lamprey were identified as special status species in the Site. For practical reasons, the organism-level measurement endpoints (survival, growth, and reproduction) were used for all receptors, requiring extrapolation to assess risks to populations and communities.

Figure 1.2-28 presents the CSM for the BERA, and **Table 1.2-3a-b** provides a list of contaminants of potential concern (COPCs) posing potentially unacceptable ecological risks within the Site. A list of contaminants identified as contaminants of ecological significance is provided in **Table 1.2-4**.

The following presents the primary conclusions of the BERA.

- Sixty-six contaminants were determined to pose unacceptable risk to ecological receptors and are COCs. These 66 COCs included total PCBs, DDx, and total PAHs as individual COCs.
- Unacceptable risks to benthic invertebrates are clustered in 17 areas of concern.
- Contaminants in sediment and TZW that pose the highest risks tend to be clustered in areas that exhibit the greatest benthic invertebrate toxicity.

- PAH and DDx compounds are the COCs in sediment that are most commonly spatially associated with locations of unacceptable risk to the benthic community or populations.

- The combined toxicity of dioxins/furans and dioxin-like PCBs pose the greatest potential risk of reduced reproductive success in mink, river otter, spotted sandpiper, bald eagle, and osprey.

- Of the 66 contaminants and contaminant classes posing unacceptable risks, 20 were determined to pose risks ecologically high enough to consider in the development of remedial actions. The criteria for this determination are high unacceptable risks in more than one media; poses unacceptable risk over large areas; and the spatial extent of unacceptable risk encompasses other contaminants that only pose risk in isolated areas, pose risks to multiple receptors, multiple lines of evidence demonstrating unacceptable risks, and exhibit the potential to bioaccumulate in the food web.

1.3 FS DATABASE DESCRIPTION

This section describes the FS database that contains the sediment data used in the alternatives development and evaluations in this FS. The source of the sediment data within the FS database is the Site Characterization and Risk Assessment (SCRA) database used for evaluations in the RI report (USEPA 2016). However, the SCRA database did not use the same summing rules as were used in the baseline risk assessments. To allow for evaluations of risk reduction based on various alternatives presented in this report, it was necessary to ensure that the data were treated in a manner consistent with the baseline risk assessments. Data selection, evaluation, summation rules, and other rules and procedures for the FS database are described in Appendix A. The FS database only includes sediment data and does not contain pore water, surface water, TZW, or biota/tissue data; those data are retained in the SCRA database although they may be used for analysis in this FS.

For the RI and FS, a date collection of May 1, 1997 was used to define the initiation of the sediment dataset to follow the last major flood of the lower Willamette River in the winter of 1996. The SCRA database includes data collected through July 19, 2010. However, the following additional sediment data were added to the FS database:

- Additional updates to the SCRA database posted to the LWG’s portal through February 4, 2011.

- Gasco engineering evaluation/cost analysis (EE/CA) data as provided by Anchor QEA in 2013 that meet the FS sediment database protocols described in Appendix A.

- Arkema EE/CA data as provided by Integral in May 2014 that meet the FS sediment database protocols described in Appendix A.
- DEQ's ECSI data for contaminated river banks identified in Section 1.2.3.5.

As noted in Section 1.2.2.3, the RM11E Group entered into an AOC to collect additional data (to include sediment, river bank soil, pore water, and groundwater data) in support of preliminary remedial design activities. While the sediment data were not included within the FS database due to timing, all the data will be available in the Administrative Record for use during remedial design.

The SCRA database or the FS database may be used for some depictions or evaluations in this FS. Unless otherwise noted, the FS database was used for evaluations of sediment in this report.

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2. INTRODUCTION

This section lays the foundation for developing a range of remedial action alternatives to address the risks at the site. The information presented in this section identifies ARARs; develops RAOs that consider the contaminants and media of interest, exposure pathways and preliminary remediation goals; identifies GRAs that focus on remediation of contaminated sediment and river banks[1]; and screens remedial technologies and process options related to each GRA based on consideration of site-specific information.

The information presented in this section was developed consistent with EPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988), EPA *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005), and EPA *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (USEPA 2002).

2.1 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d) of CERCLA requires remedial actions to comply with all applicable or relevant and appropriate federal environmental or promulgated state environmental or facility siting laws, unless such standards are waived. CERCLA provides that a remedy that does not attain an ARAR can be selected if the remedy assures protection of human health and the environment and meets one of six waiver criteria described in Section 2.1.3.2.

"Applicable requirements" are defined in 40 CFR 300.5 as:

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

while "Relevant and appropriate requirements" are defined as:

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

[1] The response actions considered under this FS are for sediment and river bank soils, but the result will impact surface water. Groundwater is addressed only as it may impact sediment and surface water.

In addition to ARARs, advisories, criteria, or guidance may be identified as "to be considered" (TBC) for a particular release. As defined in 40 CFR 300.400(g)(3), the TBC category "consists of advisories, criteria, or guidance developed by the U.S. EPA, other federal agencies, or states that may be useful in developing CERCLA remedies." TBCs may be non-promulgated advisories or guidance that are not legally binding and do not have the status of potential ARARs.

Under CERCLA 121(e), federal, state, or local permits need not be obtained for remedial actions, which are conducted entirely on-site. "On-site" is defined as the "areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action" (40 CFR 300.5). Although a permit would not have to be obtained, the substantive (non-administrative) requirements of the regulation that would govern the permit were one warranted if not a CERCLA response action, must be met. Remedial activities performed off-site would require applicable permits.

2.1.1 Portland Harbor ARARs

Three categories of ARARs were identified for use in the FS:

- Chemical-specific requirements (**Table 2.1-1**)
- Location-specific requirements (**Table 2.1-2a-h**)
- Performance, design, or other action-specific requirements (**Table 2.1-3a-b**)

This section discusses the most significant ARARs and their general requirements and criteria. Other ARARs may be discussed throughout the FS as relevant to the evaluation being presented. The list of potential ARARs and TBCs will be refined throughout the FS process with ARARs finalized in the Record of Decision (ROD).

Chemical-Specific ARARs
Chemical-specific ARARs are usually health- or risk-based values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values that can be used as remediation goals or cleanup levels. If more than one such ARAR is available for a specific contaminant, alternatives should generally comply with the most stringent requirement. Sediment, river bank soil, surface water, and groundwater have been identified as media of concern at the Site. Although there are no promulgated federal or certain Oregon ARARs providing numerical standards for contaminants in sediment or soils, both federal and Oregon standards and criteria are available for surface water and groundwater. Oregon also has promulgated acceptable risk levels for human receptors.

In addition to Oregon Water Quality Standards (WQS), CERCLA requires a remedy attain the federal National Recommended Water Quality Criteria (NRWQC) that are protective of ecological receptors and human consumers of fish and shellfish if relevant and appropriate to the circumstances of the release of hazardous substances at the site

[42 U.S.C. 9621(d)(2)(A)]. Specific Oregon WQS and federal NRWQC and other chemical-specific ARAR numeric values are provided in **Table 2.1-4a-c**. In addition to numeric water quality criteria, Oregon narrative water quality criteria are potential ARARs that EPA will translate into numeric standards for each COC through the final remediation goals/cleanup levels.

Maximum contaminant levels (MCLs) and non-zero maximum contaminant level goals (MCLGs) established under authority of the Safe Drinking Water Act (SDWA) are considered relevant and appropriate to groundwater and surface water at the Site. Public drinking water systems in Oregon are subject to the Oregon Drinking Water Quality Act (Oregon Revised Statutes [ORS] 448 – Water Systems). While the State of Oregon has exercised primary responsibility for administering the federal SDWA, in practice, the Oregon drinking water standards match the national standards. EPA regional screening levels (RSLs) for tap water (USEPA 2015) have been identified as a TBC that constitute PRGs when MCLs and non-zero MCLGs or other chemical-specific ARARs are not available for a specific COC.

Oregon Hazardous Substance Remedial Action Rules set standards for the degree of cleanup required and establish acceptable residual risk levels for humans. It requires that hazardous substance remedial actions achieve one of three standards: “a) acceptable risk levels as defined in Oregon Administrative Rules (OAR) 340-122-0115 as demonstrated by a residual risk assessment, b) numeric cleanup standards developed as part of an approved generic remedy…, or c) for areas where hazardous substances occur naturally, the background level of the hazardous substances if higher than those levels specified in subsections [(a) and (b), above].” Subsection (b) is not an ARAR for this site because this cleanup is not a generic remedy as defined in Oregon’s rules. Therefore, OAR 340-122-0040(2)(a) and (c) and the relevant risk levels defined in OAR 340-122-0115 are ARARs. The following acceptable risk levels under OAR under part (a) above are considered applicable to the Site:

- A 1 in 1,000,000 (1×10^{-6}) lifetime excess cancer risk for individual carcinogens
- A 1 in 100,000 (1×10^{-5}) cumulative lifetime excess cancer risk for multiple carcinogens
- An HI[2] of 1 for non-carcinogens

Location-Specific ARARs
Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities in specific locations. Examples include floodplains, wetlands, archaeological or cultural resources, historic places, the presence of threatened or endangered species and sensitive ecosystems or habitats. Federal Emergency Management Agency (FEMA) regulations at 44 CFR 9 set forth the policy, procedure, and responsibilities of federal agencies to implement and enforce Executive

[2] An HI represents the sum of individual contaminant hazard quotients (HQs).

Orders (E.O.) 11988 (Management of Floodplain), as amended by E.O. 13690, and E. O. 11990 (Wetlands Protection) and the substantive portions of FEMA regulations. Although policies, including executive orders, are not ARARs, the FEMA regulations that require projects to not adversely impact existing flood storage capacity without appropriate mitigation are ARAR. Likewise, the FEMA regulation ARAR requires that any action (such as sediment cleanup) that encroaches on the floodways of United States waters cannot cause an increase in the water surface elevation of the river during a 500-year flood event.

Section 7 of the ESA, 16 U.S.C. 1536(a)(2), requires that actions authorized by federal agencies may not jeopardize the continued existence of endangered or threatened species or destroy or adversely modify critical habitat. It is EPA policy to consult with the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS) to ensure that actions are not likely to jeopardize the continued existence of any threatened or endangered species or result in adverse modification of species' critical habitat. If a jeopardy, or adverse modification opinion is issued by NMFS or USFWS, the opinion will include "reasonable and prudent alternatives" that are designed to allow the project to proceed in a manner that will not jeopardize the continued existence of the listed species or adversely modify designated critical habitat. Five species of listed salmonids are known to use the lower Willamette River as a rearing and migration corridor. Moreover, eight listed salmonid species, three additional listed fish species, and one listed mammal species are known to occur in the lower Columbia River near the confluence with the Willamette River. NMFS has designated critical habitat within the site. Additionally, the Magnuson-Stevens Fishery Conservation and Management Act requires federal agencies consult with NMFS on actions that may adversely affect essential fish habitat (EFH), which has also been identified within the Site. A preliminary biological assessment will be developed for the proposed remedy to ensure that the proposed cleanup action is not likely to jeopardize the continued existence of any threatened or endangered species present at the site or adversely affect EFH. Further consultation with NMFS and USFWS will be required prior to implementation of cleanup activities at the Site.

The lower Willamette River was used historically for tribal gatherings and ceremonies, and there may be a possibility of archeological and cultural artifacts buried within the Site. Various federal laws, such as the Native American Graves Protection and Reparation Act, 25 U.S.C. 3001-3013, Archaeological Objects and Sites National Historic Archaeological and Historic Preservation Act, 16 U.S.C. 469a-1, and National Preservation Act, 16 U.S.C. 470 et seq., provide requirements for preserving and collecting artifacts that may be found during performance of the remedy.

Action-Specific ARARs

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. These action-specific requirements do not in themselves determine the remedial alternative; they instead indicate how a selected alternative must be conducted. Some federal and state requirements may be both location-specific and action-specific ARARs because they are invoked due to an action occurring on critical habitat or other special location, and they place limits or requirements on how such action is conducted.

Section 404 of the Clean Water Act (CWA) regulates the discharge of dredged or fill material into navigable waters, with the exception of incidental fallback associated with dredged materials. This ARAR is applicable to cleanup actions in navigable waters of the Site that will discharge dredged material or capping material into the Willamette River or adjacent wetlands, including the specification of in-water disposal sites. The alternative evaluation process includes considerations of the CWA hierarchy to avoid or minimize loss of aquatic habitat or function, but if a loss was deemed unavoidable, mitigation will be included as part of the alternative. A 404(b)(1) analysis of the remedial alternatives is provided in Appendix J. The final assessment of loss and determination of mitigation will be made during remedial design. In addition to Section 404 of the CWA, ORS 196.825(5) and applicable substantive mitigation rules found at OAR 141-085-510, 141-085-680, 141-085 0685, 141-085-0690, 141-085-0710, and 141-085-715 provide requirements for mitigation for the reasonably expected adverse effects of removal or fill in a project development in waters of the state, including in designated Essential Indigenous Anadromous Salmonid Habitat.

Section 401 of the CWA along with the Oregon's water quality regulations also are significant action-specific ARARs that require reasonable assurances that the dredging, capping, and construction of the CDF will be done in a manner that will not violate applicable water quality standards. These laws require the imposition of any effluent limitations, other limitations, and monitoring requirements necessary to assure the discharge will comply with applicable provisions of the Clean Water Act. OAR 340-048-0015 provides that federally approved activities that may result in a discharge to waters of the state require evaluation as to whether an activity may proceed and meets water quality standards with conditions, which if met, will ensure that water quality standards are met.

Section 10 of the Rivers and Harbors Act prohibits the unauthorized obstruction or alteration of any navigable water, meaning cleanup activities need to be conducted in a way that does not obstruct navigation.

Also, federal and state solid and hazardous waste regulations may be ARARs for handling, characterizing, treating, and disposing of dredged sediment off-site and are described more fully in **Table 2.1-3a-b**.

2.1.2 ARAR Waivers

The NCP provides for waivers of ARARs under certain circumstances. According to 40 CFR 300.430(f)(1)(ii)(C):

> *"An alternative that does not meet an ARAR under federal environmental or state environmental or facility siting laws may be selected under the following circumstances:*
>
> 1. *The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;*
> 2. *Compliance with the requirement will result in greater risk to human health and the environment than other alternatives;*
> 3. *Compliance with the requirement is technically impracticable from an engineering perspective;*
> 4. *The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach;*
> 5. *With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state; or*
> 6. *For Fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment."*

The basis for ARAR waivers, including technical impracticability, is presented in USEPA 1989a. Currently, EPA does not have a basis for waiving any ARARs. Any ARAR waivers would have to be conducted through the remedy selection process and documented in a ROD amendment.

2.2 REMEDIAL ACTION OBJECTIVES

RAOs consist of media-specific goals for protecting human health and the environment. RAOs provide a general description of what the cleanup is expected to accomplish and help focus alternative development and evaluation.

RAOs specify:

- COCs for each media of interest
- Exposure pathways, including exposure routes and receptors
- An acceptable contaminant concentration or range of concentrations for each exposure pathway

The following general narrative RAOs have been developed for the Site. A brief summary of how each RAO will be addressed by the alternatives is also provided.

Human Health

- **RAO 1 – Sediment: Reduce cancer and noncancer risks to people from incidental ingestion of and dermal contact with COCs in sediment and beaches to exposure levels that are acceptable for fishing, occupational, recreational, and ceremonial uses.** Reducing concentrations, exposure to, and the bioavailability of the COCs in nearshore sediment and beaches will reduce risk at the Site. Ongoing source control efforts and the use of institutional controls (such as signs and fences) will provide additional risk reduction.

- **RAO 2 – Biota: Reduce cancer and noncancer risks to acceptable exposure levels (direct and indirect) for human consumption of COCs in fish and shellfish.** Reducing concentrations, exposure to, and the bioavailability of the COCs in sediment will subsequently reduce surface water concentrations and in fish and shellfish and will reduce risk at the Site. Ongoing source control efforts and the use of fish consumption advisories and education and outreach programs will provide additional risk reduction.

- **RAO 3 – Surface Water: Reduce cancer and noncancer risks to people from direct contact (ingestion, inhalation, and dermal contact) with COCs in surface water to exposure levels that are acceptable for fishing, occupational, recreational, and potential drinking water supply.** Reducing concentrations, exposure to, and the bioavailability of COCs in sediment will subsequently reduce surface water concentrations and will reduce risk at the Site. Ongoing source control efforts will provide additional risk reduction.

- **RAO 4 – Groundwater: Reduce migration of COCs in groundwater to sediment and surface water such that levels are acceptable in sediment and surface water for human exposure.** Reducing concentrations, exposure to, and the bioavailability of COCs in the pore water[3] and groundwater flux to surface water will reduce risk at the Site. Ongoing source control efforts will provide additional risk reduction.

[3] For the purposes of this FS, pore water is defined as interstitial water of bulk sediment within the biologically active zone.

Ecological

- **RAO 5 – Sediment: Reduce risk to benthic organisms from ingestion of and direct contact with COCs in sediment to acceptable exposure levels.** Reducing concentrations, exposure to, and the bioavailability of the COCs in sediment will reduce risk at the Site. Ongoing source control efforts will provide additional risk reduction.

- **RAO 6 – Biota (Predators): Reduce risks to ecological receptors that consume COCs in prey to acceptable exposure levels.** Reducing concentrations, exposure to, and the bioavailability of the COCs in sediment will subsequently reduce surface water concentrations and in fish and shellfish and will reduce risk at the Site. Ongoing source control efforts will provide additional risk reduction.

- **RAO 7 – Surface Water: Reduce risks to ecological receptors from ingestion of and direct contact with COCs in surface water to acceptable exposure levels.** Reducing concentrations, exposure to, and the bioavailability of COCs in sediment will subsequently reduce surface water concentrations and will reduce risk at the Site. Ongoing source control efforts will provide additional risk reduction.

- **RAO 8 – Groundwater: Reduce migration of COCs in groundwater to sediment and surface water such that levels are acceptable in sediment and surface water for ecological exposure.** Reducing concentrations, exposure to, and the bioavailability of COCs in the pore water and groundwater flux to surface water will reduce risk at the Site. Ongoing source control efforts will provide additional risk reduction.

- **RAO 9 – River Banks: Reduce migration of COCs in river banks to sediment and surface water such that levels are acceptable in sediment and surface water for human health and ecological exposures.** Reducing concentrations, exposure to, and the bioavailability of the COCs in river banks will reduce risk and recontamination at the Site. Ongoing source control efforts will provide additional risk and recontamination reduction.

Achieving the above RAOs relies on remedial alternatives' ability to meet final remediation goals/cleanup levels derived from PRGs. At this point, **Table 2.2-1a-d** provides PRGs that are based on such factors as risk, ARARs, and background. PRGs may be further modified through the evaluation of alternatives and the remedy selection process. Final cleanup levels will be selected in the Record of Decision.

It is EPA's expectations that the State's actions to address upland source control will adequately address contaminated soils, surface water, and groundwater contamination migrating to the river. Should sources not be addressed adequately under those actions, EPA may at a future time determine if additional action(s) is/are warranted under CERCLA. The RAOs above relate to the action being conducted under CERCLA, and meeting the above objectives is dependent on the source control actions being conducted by DEQ. In addition, an objective for addressing groundwater contamination, beyond its impact on sediment and surface water, is not included in this action as groundwater contamination is primarily due to the upland sources being addressed by the DEQ source control actions.

The primary objective of this action is to address the contaminated sediments in Portland Harbor, significantly reducing sediment concentrations and potential human health and ecological risks at the Site. Remediation of the sediment within the Site will have a substantial positive impact downstream, including the Columbia River. Although reducing loading to the Columbia River is not a direct objective of this action, it is an expected ancillary result of achieving the remedial action objectives presented above. The tribes and other stakeholders have identified impacts to the Columbia River as an issue that needs to be considered.

Throughout the RI and FS process, the Region has meaningfully engaged with the affected tribes and has encouraged and facilitated tribal involvement. The Region considered numerous factors, such as those mentioned above, to develop remedial alternatives for the Site. In addition, EPA also considered treaty-protected resources. The Region recognizes that the affected tribes have treaty-reserved or other fishing rights in areas impacted by the Site and that, once implemented, remedial alternatives will improve fish habitat and help further the tribes' rights to fish.

The following subsections discuss the development of PRGs for each RAO. The PRG identification process consists of the following steps:

1. Identification of the COCs (Section 2.2.1)
2. Development of PRGs for the applicable exposure routes and receptors (Section 2.2.2)
3. Identification and selection of potential target areas and volume estimate for remediation (Section 2.2.3)

2.2.1 Contaminants of Concern

EPA guidance defines COCs as a subset of the COPCs [4] that are identified in the RI/FS as needing to be addressed by the response action proposed in the ROD (USEPA 1999). Identification of COCs at the Site is based on whether the contaminant is a listed hazardous substance or poses unacceptable risks to human health, the significance of risks to ecological receptors, and chemical-specific ARARs or other statutory criteria specified in 40 CFR 300.430(e)(2)(i).

[4] COPCs are defined as those contaminants potentially site-related and whose data are of sufficient quality for use in the quantitative risk assessment (USEPA 1989b).

The BHHRA (Kennedy/Jenks 2013) and BERA (Windward 2013) evaluated contaminants in sediment, surface water, biota, and groundwater in the Willamette River and identified the pathways through which humans and ecological receptors could be exposed to those contaminants. Based on the risk assessment, a contaminant was identified as a COC if its exposure resulted in a cumulative lifetime cancer risk greater than 1 x 10^{-6} or a noncancer HQ greater than 1.0.

The COCs are presented in **Tables 2.2-2** and **2.2-3.** Antimony was eliminated as a COC for both ecological and human health because the unacceptable risk estimates were based on a single tissue sample in smallmouth bass. This sample result was considered to be unrepresentative of a true tissue concentration as it was likely the result of a sinker in the gut being incorporated into the chemical analysis. Likewise, lead was eliminated as a COC for human health and ecological dietary risks that were based on the same single smallmouth bass result. **Table 2.2-2a-e** presents the rational for selection of COCs for the FS, and **Table 2.2-3a-d** presents the COCs related to each RAO and media and identifies whether they are risk- or ARAR-based.

Risk-Based COCs
Risk-based COCs were identified as posing unacceptable risk to human health or the environment in a specific media based on the results of the baseline risk assessments. Risk-based human health COCs were identified in beach and in-water sediment (RAO 1), fish tissue (RAO 2), and surface water (RAO 3). Risk-based ecological COCs were identified in sediment (RAO 5 and RAO 6), surface water (RAO 6 and RAO 7), pore water (RAO 8), and river bank soil (RAO 9). Risk-based COCs are denoted with an “R” in **Table 2.2-3a-d**.

ARAR-Based COCs
Limited surface water and pore water sampling was conducted at the Site, and was not always conducted where there was a known surface water or groundwater contaminant source. Consequently, contaminants that were detected in upland media (storm water and groundwater) that may potentially migrate to the river at concentrations that would exceed the Safe Drinking Water Act MCLs and national or State of Oregon water quality criteria were also designated as ARAR-based COCs. These are denoted with an “A” in **Table 2.2-3a-d**. EPA expects that contaminated groundwater will be addressed through upland source control measures implemented under DEQ regulatory authority. However, since groundwater plumes may extend beyond the point of upland control and into the river, EPA considers these as COCs for those areas and in determining protective measures for the river environment.

2.2.2 Development of Preliminary Remediation Goals

The preliminary remediation goals are developed using site-specific and default risk-related factors, chemical-specific ARARs, when available, and consideration of background concentrations. Risk-based PRGs were developed to address unacceptable human health and ecological risks identified in the BHHRA and BERA, consistent with the NCP [300.430(e)(2)(i)]. These PRGs represent concentrations in environmental media that are protective of both human and ecological receptors for each RAO.

2.2.2.1 Human Health Risk-Based PRGs

The BHHRA evaluated exposures and associated risks and hazards based on a number of current and potential land and waterbody uses. Specific receptors evaluated were dockside workers; in-water workers; transients; recreational beach users; tribal, recreational, and subsistence fishers; divers; people using surface water for domestic household purposes; and infants consuming breast milk from mothers exposed to certain bioaccumulative contaminants. Risk-based PRGs were calculated using the reasonable maximum exposure assumptions for the most susceptible population evaluated in the BHHRA, consistent with the NCP. They were developed for COCs in sediment and biota tissue, assuming target cancer risk levels of 10^{-6} (point of departure) and 10^{-4} (for informational purposes) and a target noncancer hazard of 1, for each of the receptors evaluated in the BHHRA and using the methodology described in Section 3 of Appendix B.

Risk-based PRGs were calculated based on direct contact with beach and in-water sediment (RAO 1) and are to be protective of direct and indirect exposures through consumption of fish and shellfish (RAO 2). Risk-based sediment PRGs protective of fish/shellfish consumption were not developed for arsenic, hexachlorobenzene, mercury, BEHP, pentachlorophenol, and polybrominated diphenyl ethers (PBDEs) because a relationship between fish and shellfish tissue and sediment concentrations could not be determined. The risk-based PRGs for RAOs 1 and 2 represent the lowest value in each media (beach or in-water sediment, and fish/shellfish tissue) to be protective of all potential receptors. These risk-based values are presented in **Tables 2.2-4** and **2.2-5**.

MCLs and EPA RSLs for tap water were used to set PRGs for RAOs 3 and 4. These values are presented in **Tables 2.2-6** and **2.2-7**. RSLs are only used when MCLs or other ARARs are not available for a specific contaminant.

2.2.2.2 Ecological Risk-Based PRGs

Ecological risk-based PRGs were developed for sediment, surface water, and pore water to meet the objectives associated with RAOs 5 through 8. The ecological risk-based PRGs were developed from medium- and contaminant-specific toxicity reference values (TRVs) protective of ecological receptors and used in the BERA; the process is detailed in Section 4 of Appendix B.

Risk-based PRGs in sediment were selected from TRVs presented in the BERA that are protective of ingestion and direct contact with sediment (RAO 5) and calculated for upper trophic level receptors based on consumption of prey (RAO 6). The lowest value for each media was selected as the risk-based PRG for RAOs 5 and 6 to be protective of all potential receptors. Since water contributes to the exposure to PCBs and dioxins/furans for RAO 6, water TRVs in Attachment 10, **Table 2** of the BERA were used for RAO 6. Additionally, water TRVs from Attachment 10, **Table 2** in the BERA that are protective of ecological receptors were selected as risk-based PRGs for RAOs 7 and 8. The RAO 8 PRG for manganese was developed subsequent to the BERA, and the methodology is described in Windward 2014. The risk-based PRGs selected for RAOs 5 through 8 are presented in **Tables 2.2-8** through **2.2-11**.

2.2.2.3 PRGs Based on Chemical-Specific ARARs

Chemical-specific ARARs were discussed in Section 2.1.1. The PRGs for RAOs 3 and 4 are based on the lower of NRWQC (organism + water) and Oregon water quality criteria (WQCs) (organism + water), MCLs and non-zero MCLGs, as presented in **Table 2.1-4a-c**. EPA RSL values were only selected as PRGs when a value was not available based on NRWQCs, Oregon WQC or MCLs. These values are presented in **Tables 2.2-6** and **2.2-7**. The PRGs for RAO 7 are based on the lower of the NRWQC (chronic aquatic life) and Oregon WQC (chronic aquatic life) presented in **Table 2.1-4a-c** only when risk-based values are not available or are greater than ARAR. These values are presented in in **Table 2.2-10**.

2.2.2.4 PRGs Based on Background Concentrations

Background concentrations may be used to develop remedial goals when risk-based PRG concentrations are less than naturally occurring or anthropogenic background (USEPA 2002). In this context, the sediment background concentrations reflect substances or locations that are not influenced by the releases from the site and are either naturally occurring or anthropogenic. The derivation of background concentrations in sediment for the Site is described in Section 7 of the RI report. Background concentration for dioxin/furan congeners was not conducted in the RI report and is provided in Section 2 of Appendix B. There are insufficient data to compute defensible background concentrations for other media. Background sediment concentrations are presented in **Tables 2.2-4, 2.2-5, 2.2-8,** and **2.2-9**.

2.2.2.5 Selection of Preliminary Remediation Goals

PRGs for the Site are developed from site-specific risk-based PRGs, chemical-specific ARARs (when available), and consideration of background concentrations. The risk-based PRGs are compared to the chemical-specific ARARs, and the lower of the two values was then compared to background. Where both the risk-based PRGs and chemical-specific ARARs are less than the background concentration, the background concentration is selected as the final PRG. This process and the selected PRGs for each RAO are presented in **Tables 2.2-4** through **2.2-11**. PRGs for RAO 9 were selected as the lowest sediment PRG for each COC; the process and selected PRGs are presented in **Table 2.2-12**. **Table 2.2-1a-d** provides a summary of the selected PRGs for all RAOs, and the basis for each PRG is presented in **Table 2.2-3a-d**.

2.2.3 Identification and Selection of Potential Sediment Target Areas for Remediation

When developing remedial alternatives, it is necessary to identify the sediment that should be evaluated for remediation to meet the RAOs. Criteria for making this identification typically include identifying areas exceeding PRGs as well as geochemical and statistical interpretations of contaminant concentration data and sediment characteristics. These analyses are described in detail in Section 3 of the RI report and summarized below.

The river's cross-sectional area increases steadily from RM 12 to RM 9. In this area, a change in sediment texture is also observed (**Figure 2.2-1**). The river bed upstream of RM 11.8 is predominantly coarser sediment, with smaller areas of silt often located outside the navigation channel, while in the upper end of the Site (below RM 11.8), the sediment is predominately fine-grained material (silts) bank-to-bank, with pockets of coarser material (sand and gravel). At RM 8, the river narrows and the sediment again becomes coarser again until about RM 5 where the river cross-sectional area increases and sediment once more is predominately finer-grain material. Approximately 61 percent of the surface sediment within the Site and 69 percent of the volume is comprised of fine-grained materials (silts). The federally authorized navigation channel encompasses approximately 60 percent of the riverbed within the Site. Due to a combination of a wider cross-section and a deeper navigation channel (40 to 43 feet) below RM 11.8, thicker and wider beds of contaminated sediment accumulated in the Site.

Analysis of surface sediment contamination resulted in a series of observations that form the basis for much of the CSM. Most of the contaminants examined in studies conducted between 1995 and 2010 exhibited a broad range of concentrations (spanning an order of magnitude or more) within a given river mile interval within the Site. Obvious areas of elevated concentrations in nearshore areas were observed at the point of release, with decreasing concentrations moving downstream, across the river, and to a lesser extent upstream due to flow reversal. This same trend is also evident in the median concentrations by river miles (see **Tables 5.2-3, 5.2-5** and **5.2-7** in the RI report). Within the Site, the majority of the contamination is located in the nearshore areas. Some river miles are contaminated with only a few contaminants, whereas multiple contaminants are observed in other areas. Certain contaminants (PCBs, metals) are found site-wide, whereas others (PAHs, DDx, dioxins/furans) are found in only portions of the Site. In many cases, concentrations in subsurface sediment are higher than those measured in surface sediment. Since much of the site is erosional or transitional (deposition in some parts of the year and erosional in others) and contaminant mass exists in the river sediment, there is the potential for the contamination to be transported downstream.

The area where contamination in sediment exceeds the human health PRGs within the Site is approximately 2,190 acres (essentially the entire Site) and 30,048 lineal feet of river bank (**Figure 2.2-2**). However, the area of the sediment exceeding the ecological PRGs is 1,710 acres (78 percent of the Site) and 28,878 lineal feet of river bank. Concentrations of COCs within the Site sediments are summarized in **Table 1.2-1**. Based on this information, the entire river area from RM 1.9 to RM 11.8, including some riverbanks as identified in Section 1.2.3.5, are evaluated for actions under CERCLA authority because they contain COC concentrations that exceed the PRG for at least one contaminant or are a potential source of contamination to the river. However, the entire river area may not need physical construction activities (capping or dredging) for the remedy to achieve remedial action objectives and cleanup levels.

2.3 GENERAL RESPONSE ACTIONS

This section identifies the general response actions for the remedial alternatives evaluated in this FS. GRAs are major categories of media-specific cleanup activities such as source control, monitored natural recovery (MNR), enhanced natural recovery (ENR), institutional controls (ICs), containment, removal, or treatment that will satisfy the RAOs.

The focus of this FS is on remediation of contaminated sediment and river banks. Remedial actions will focus on reductions in concentrations of contaminants in sediment and river bank soils. These remedial actions, in conjunction with source control measures, are anticipated to reduce concentrations in other media such as ground water, surface water, upland soils, and air.

2.3.1 No Action

The NCP [40 CFR §300.430(e)(6)] provides that the no action alternative shall be considered at every site. The no action alternative reflects the site conditions described in the baseline risk assessments and remedial investigation report, and serves as a baseline against which the performance of other remedial alternatives may be compared. Under the no action alternative, contaminated river sediment would be left in place without treatment or containment. Oregon Health Authority (OHA) could continue to implement existing fish consumption advisories pursuant to state legal authorities, but no ICs or monitoring would be implemented as part of a CERCLA response action for the Site. According to USEPA, 1999, no action may be appropriate: (1) when the site or operable unit poses no current or potential threat to human health or the environment, (2) when CERCLA does not provide the authority to take remedial action, or (3) when a previous response has eliminated the need for further remedial response (often called a “no further action” alternative).

2.3.2 Institutional Controls

ICs generally refer to non-engineering measures intended to affect human activities in such a way as to prevent or reduce exposure to hazardous substances, often by limiting land or resource use. These controls have no ability to reduce ecological exposures. The NCP states that remedies should not rely solely on ICs and should be implemented in conjunction with other remedy components. EPA’s guidance *Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites* (USEPA 2012) will be used to develop appropriate ICs for this site. A site ICs program is intended to limit human exposure to contamination by instituting fish consumption advisories and enhanced community outreach program and limiting other activities during and after implementation of the remedy. The ICs program may include informational meetings, presentations, and workshops targeting affected community groups; development and distribution of informational materials, such as brochures or maps, and advisory notifications communicated through a variety of culturally appropriate outlets; design, installation, and maintenance of advisory signs at known fishing locations; and coordination with sport or recreational fishing clubs and licensing locations. ICs may also be used to protect in-situ caps by limiting waterway and land use activities that may reduce the cap’s ability to contain the contaminated sediment or groundwater such as boat anchoring and keel dragging, structure and utility maintenance and repair, and future maintenance dredging. Designated restricted navigation areas are one type of IC mechanism for effectuating waterway or land uses at this Site. Additional IC mechanisms may be developed during remedial design, as needed.

2.3.3 Monitored Natural Recovery (MNR)

Natural recovery typically relies on ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. These processes may include physical (burial and sedimentation or dispersion and mixing), biological (biodegradation), and chemical (sorption and oxidation) mechanisms that act together to reduce the risk posed by the contaminants. However, not all natural processes result in risk reduction; some may increase or shift risk to other locations or receptors. MNR includes monitoring to assess whether these natural processes continue to occur and at what rate they may be reducing contaminant concentrations in surface sediment but does not include active remedial measures. MNR should be considered as a stand-alone remedy only when it is anticipated to meet remedial action objectives within a time frame that is reasonable compared to active remedies (USEPA 2005). Factors that should be considered in determining whether the time frame for MNR is “reasonable” include the following:

- The extent and likelihood of human exposure to contaminants during the recovery period and, if addressed by ICs, the effectiveness of those controls

- The value of ecological resources that may continue to be impacted during the recovery period

- The time frame in which affected portions of the site may be needed for future uses, which will be available only after MNR has achieved cleanup levels

- The uncertainty associated with the time frame prediction

MNR may also be a component of a remedy, either in conjunction with active remediation or as a long-term measure to monitor the continued reduction of contaminant concentrations.

2.3.4 Enhanced Natural Recovery (ENR)

In areas where natural recovery is occurring, but not at a rate sufficient to reduce risks within an acceptable time frame, enhancement or acceleration of the recovery process by engineering means can be considered. Similar to MNR, ENR includes monitoring to assess whether natural processes continue to occur and at what rate they may be reducing contaminant concentrations in surface sediment.

An example of ENR is the addition of a thin layer of clean material (such as sand). This approach is sometimes referred to as “thin-layer placement” or “particle broadcasting.” A thin-layer cover normally accelerates natural recovery by adding a layer of clean material over contaminated sediment. The acceleration can occur through several processes, including dilution of contaminant concentrations in sediment and decreasing exposure of organisms to the contaminated sediment. A thin-layer cover is different than the isolation caps because it is not designed to provide long-term isolation of contaminants from benthic organisms and does not require that the layer be maintained.

A 3 to 6 inch layer of material is typically used in thin layer placement. The grain size and organic carbon content of the clean sediment to be used for a thin-layer cover needs to be carefully considered in consultation with aquatic biologists. In most cases, natural materials (as opposed to manufactured materials) approximating common substrates found in the area should be used. Clean sediment can be placed in a uniform thin layer over the contaminated area or it can be placed in berms or windrows, allowing natural sediment transport processes to distribute the clean sediment to the desired areas.

Another option that can be considered for ENR includes the addition of flow control structures to enhance deposition in certain areas of a site. Enhancement or inception of contaminant degradation through additives might also be considered to speed up natural recovery. However, when evaluating the feasibility of these approaches, state and federal water programs will be consulted regarding the introduction of clean sediment or additives to the water body.

2.3.5 Containment

Containment entails the physical isolation (sequestration) or immobilization of contaminated sediment by an engineered cap, thereby limiting potential exposure to, and mobility of, contaminants under the cap. Capping technologies require long-term monitoring and maintenance in perpetuity to ensure that containment measures are performing successfully because contaminated sediment is left in place.

Caps are generally constructed of granular material, such as suitable fine-grained sediment, sand, or gravel, but can have more complex designs. Caps are designed to reduce potentially unacceptable risk through: (1) physical isolation of the contaminated sediment or soil to reduce exposure due to direct contact and to reduce the ability of burrowing organisms to move contaminants to the surface, (2) stabilization and erosion protection to reduce re-suspension or erosion and transport to other sites, and/or (3) chemical isolation of contaminated media to reduce exposure from contaminants transported into the sediment pore water and water column. Caps may be designed with different layers (including “active” layers that provide treatment) to serve these primary functions, or in some cases, a single layer may serve multiple functions.

2.3.6 In-Situ Treatment

In-situ treatment of sediment refers to chemical, physical, or biological techniques for reducing contaminant concentrations, toxicity, bioavailability, or mobility while leaving the contaminated sediment in place. It may be beneficial to conduct a site-specific treatability study to determine the effectiveness of the treatment technology in the environment of the Site.

CERCLA requirements and considerations may influence the need for treatment (such as identification of principal threat waste (PTW) and/or the expectation of treatment as a principal element of the remedy to the extent practical) and determination that treatment should be considered for some portion of the material.

2.3.7 Sediment/Soil Removal

Removal of sediment can be accomplished either while submerged (dredging) or after water has been diverted or drained (excavation). This response results in the removal of contaminant mass from the river bed. Both methods typically necessitate transporting the sediment to a location for treatment and/or disposal. They also frequently include treatment of water from dewatered sediment prior to discharge to an appropriate receiving water body.

Dredging for environmental purposes should be distinguished from maintenance or navigation dredging. Environmental dredging is intended to remove sediment contaminated above certain action levels while minimizing the spread of contaminants to the water column and surrounding environment during dredging (National Research Council [NRC] 1997) while navigation dredging is intended to maintain waterways for recreational, national defense, and commercial purposes.

After removal, sediment often is transported to a staging or re-handling area for dewatering (if necessary) and further processing, treatment, or final disposal. Transport links all dredging or excavation components and may involve several different modes. The first element in the transport process is to move sediment from the removal area to the disposal, staging, or re-handling area. Sediment may then be transported for pretreatment, treatment, and/or ultimate disposal (USEPA 1994).

2.3.8 Ex-Situ Treatment

Ex-situ treatment involves the application of chemical, physical, or biological technologies to transform, destroy, or immobilize contaminants following removal of contaminated sediment. Depending on the contaminants, their concentrations, and the composition of the sediment, treatment of the sediment to reduce the toxicity, mobility, or volume of the contaminants before disposal may be warranted. Available disposal options and capacities may also affect the decision to treat some sediment. In general, treatment processes have the ability to reduce sediment contaminant concentrations, mobility, and/or toxicity by (1) contaminant destruction or detoxification, (2) extraction of contaminants from sediment, (3) reduction of sediment volume, or (4) sediment solidification/stabilization. Regulatory requirements may influence the need for treatment (such as Resource Conservation and Recovery Act [RCRA] Land Disposal Restrictions) and determination that some portion of the material constitutes PTW, and as such, treatment should be considered.

The treatment of contaminated sediment is not usually a single process but often involves a combination of processes or a treatment train to address various contaminant problems, including pretreatment, operational treatment, and/or effluent treatment/residual handling. Pretreatment modifies the dredged or excavated material in preparation for final treatment or disposal. When pretreatment is part of a treatment train, distinguishing between the two components may be difficult and is not always necessary. Pretreatment is generally performed to condition the material to meet the chemical and physical requirements for treatment or disposal and/or to reduce the volume and/or weight of sediment that requires transport, treatment, or restricted disposal. Pretreatment processes typically include dewatering and physical or size separation technologies.

2.3.9 Beneficial Use of Dredged Sediment

Following removal and, if necessary, ex-situ treatment, dredged material could potentially be used beneficially. Sediment that meets applicable criteria for contaminant concentrations and structural properties could serve a beneficial purpose such as structural fill, lower permeability cover soils, or capping for a brownfield or landfill without pre-treatment. In some instances, ex-situ treatment, such as ex-situ immobilization, is required prior to application of dredged sediment as fill or cover material. In addition, certain ex-situ treatment processes result in an end product that can be beneficially used (such as formation of glass following vitrification or cement aggregate following certain thermo-chemical processes). However, a review of existing literature and local knowledge did not identify any examples of treated sediment being used beneficially in the region surrounding the Site. Therefore, beneficial reuse will not be considered in this FS.

2.3.10 Disposal

Disposal refers to the placement of dredged or excavated material and process wastes into a temporary or permanent structure, site, or facility. The goal of disposal is generally to manage sediment and/or residual wastes to prevent contaminants associated with them from impacting human health and the environment.

Disposal of removed media can either be within an in-water disposal facility specifically engineered for the sediment remediation, (such as in a confined aquatic disposal [CAD] location or confined disposal facility [CDF]) or within an upland landfill disposal facility such as operating commercial landfills.

Contaminated sediment that has been removed from the environment is typically managed in upland sanitary landfills or hazardous or chemical waste landfills. It can also be managed within an in-water disposal facility specifically engineered for the sediment remediation.

Disposal typically requires dewatering and transport to the disposal site via land-based or water-based transportation. In some cases, sediments may be transported to the disposal location by hydraulically pumping the sediments as a slurry.

2.4 IDENTIFICATION AND SCREENING OF TECHNOLOGY TYPES AND PROCESS OPTIONS

This section identifies and screens remedial technology types, and process options that are potentially applicable to remediate contaminated sediment in the Site. The technology selection and screening processes are conducted in accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA 1988), the *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (USEPA 2002), and the *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005). Remedial technologies that are retained for further consideration based on site-specific data will be assembled into remedial action alternatives in Section 3.

The identified technology types are initially screened for technical implementability as described in Section 2.4.1 and then expanded into lists of potentially applicable process options as discussed in Section 2.4.2, and screened further for effectiveness, implementability, and relative cost. Ancillary technologies, such as sediment dispersion control options, sediment dewatering, wastewater treatment, and sediment transportation options are discussed in Section 2.4.3. Technologies and process options that were retained after the effectiveness, implementability, and cost screening are summarized in Section 2.4.4, and retained technologies and process options are presented in Section 2.4.5.

2.4.1 Identification and Initial Screening of Remedial Technology Types and Process Options

Following EPA's RI/FS guidance (1988), the universe of potentially applicable technology types and process options identified for this Site is reduced through an evaluation of technical implementability. Technology types refers to general categories of technologies, whereas process options refers to specific processes within each technology type. The screening of technologies is based on the current Site uses and conditions and/or reasonable likely future conditions and uses for the Site. Per the RI/FS guidance, this screening is also meant to address "incompatibilities" of the technology with respect to the medium or the contaminants (such as biological treatment for inorganics or persistent organics). During this screening step, process options and entire technology types can be eliminated from further consideration on the basis of technical implementability. Technology types presented in this section are grouped by the GRAs identified in Section 2.3.

The evaluation of technical implementability was based on a general understanding of the chemical and physical characteristics at the site. **Table 2.4-1a-c** presents remedial technologies and process options potentially applicable for each GRA at the Site. Shaded technologies and process options are not retained for further consideration based on implementability at this Site. Remedial technologies and process options eliminated based on technical implementability were limited to certain in-situ and ex-situ treatment technologies and certain disposal options. The technology types that are retained after this initial screening are discussed in Section 2.4.5.

2.4.2 Evaluation and Screening of Process Options

Process options presented in **Table 2.4-1a-c** that are determined to be technologically implementable are further evaluated in greater detail in this section in order to select one process to represent each technology type for further detailed evaluation in the FS. In some cases, more than one process option may be selected for a technology type when two or more processes are sufficiently different in their performance that one would not adequately represent the other. The selection of a representative process for each technology type is solely for the purpose of simplifying the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. The representative process provides a basis for developing performance specifications during preliminary design. However, the specific process actually used to implement the remedial action at a site may not be selected until the remedial design phase.

Process options are evaluated using the same criteria – effectiveness, implementability, and cost – that are used to screen alternatives prior to the detailed analysis. An important distinction to make is that at this time these criteria are applied only to technologies and the general response actions they are intended to satisfy and not to the site as a whole. Furthermore, the evaluation focuses on effectiveness factors at this stage, with less effort directed at the implementability and cost evaluation. The application of these criteria is discussed below:

- **Effectiveness:** Effectiveness is evaluated relative to other processes within the same technology type. This evaluation focuses on the ability to handle the estimated areas or volumes of contaminated sediment and meeting the PRGs, potential impacts to human health and the environment during the construction and implementation phase, and how proven and reliable the process is with respect to the contaminants and conditions at the Site.

- **Implementability:** Implementability evaluates each technology for technical and administrative feasibility of implementing a technology process. Since technical implementability is used as an initial screen of technology types and process options to eliminate those that are clearly ineffective or unworkable at this Site, this subsequent, more detailed evaluation of process options places greater emphasis on the technical aspects of implementability. Administrative feasibility refers to the ability to obtain permits for those components of an action that would occur off-Site (on-Site actions would be performed under CERCLA authorities); the availability of treatment, storage, and disposal services (including capacity); and the availability of specific equipment and technical specialists.

- **Relative Cost:** Cost plays a limited role in the screening of process options. Both capital and operation and maintenance (O&M) costs are considered. The cost analysis is based on engineering judgment, and each process is evaluated as to whether costs are low, moderate, or high relative to the other options within the same technology type.

Table 2.4-2a-g presents the effectiveness, implementability, and cost screening of technologies and process options. Technologies and process options that are retained after this screening are summarized in Section 2.4.5. The initial screening of technical implementability and subsequent evaluation of remedial technologies are presented on a technology-specific basis in the following sections.

2.4.3 Ancillary Technologies

Additional technologies and process options that are ancillary to the retained process options presented in Section 2.4.4 may be components of any remedial alternative implemented at the Site. These ancillary systems are described here in relation to their potential applicability to some of the primary technologies that are evaluated in **Table 2.4-2a-g**.

2.4.3.1 Sediment Dispersion Control

All dredges cause some re-suspension of sediment. The amount is generally less than 1 percent of the mass of sediment removed, and re-suspension can be controlled (Palermo 2005). Water-borne transport of re-suspended contaminated sediment released during dredging can often be reduced by using physical barriers around the dredging operation area, mechanical control techniques on the dredge equipment, and implementation of best management practices (BMPs).

Physical Barriers

Two of the more common approaches of physical barriers include silt curtains and sheet pile walls although several other designs are available that have been proven effective. Silt curtains are floating barriers designed to control the dispersion of sediment in a body of water. They are made of impervious flexible materials such as polyester-reinforced thermoplastic (vinyl) and coated nylon. The effectiveness of silt curtains is primarily determined by the hydrodynamic conditions in a specific location. Under ideal conditions, turbidity levels in the water column outside the curtain can be as much as 80 to 90 percent lower than the levels inside or upstream of the curtain (Francingues and Palermo 2005). Conditions that may reduce the effectiveness of these and other types of barriers include significant currents, high winds, changing water levels and current direction (i.e., tidal fluctuation), excessive wave height, and drifting ice and debris

(USEPA 2005). Silt curtains are generally more effective in relatively shallow (<10 feet), quiescent water; as water depth and turbulence due to currents and waves increase, it becomes more difficult to effectively isolate the dredging operation from the ambient water.

The use of silt curtains is not expected to be effective in the main channel of the river during dredging operations due to the presence of significant currents and tidal fluctuations. Consideration has been given to the use of silt curtains at off-channel areas (coves, embayments, slips, and lagoons) where the water velocities are much lower. In areas with working ship traffic, this approach would require developing a method for quickly removing and reinstalling the silt curtain during barge unloading operations. Silt curtains are retained for further consideration in the FS.

Sheet piling consists of a series of panels and piling with interlocking connections driven into the subsurface with impact or vibratory hammers to form an impermeable barrier. While the sheets can be made from a variety of materials, such as steel, vinyl, plastic, wood, recast concrete, and fiberglass, lightweight materials (plastic, fiberglass, vinyl) are typically surface mounted to the piling.

Sheet pile containment structures are more likely to provide reliable containment of re-suspended sediment than silt curtains although at significantly higher cost and with different technological limitations. Sheeting and/or piling must be imbedded sufficiently deep into the subsurface to ensure that the sheet pile structure will withstand hydraulic forces (such as waves and currents) and the weight of material (if any) piled behind the sheeting. Sheet pile containment may increase the potential for scour around the outside of the containment area, and sediment re-suspension may occur during placement and removal of the structures. The use of sheet piling may significantly change the carrying capacity of a stream or river and make it temporarily more susceptible to flooding (USEPA 2005). Sheet piling may be used in localized areas to prevent migration of highly contaminated sediment during dredging or during disposal operations. Sheet piling is retained for further consideration in the FS.

Mechanical Control Techniques

Mechanical control techniques are available for mechanical and hydraulic dredges as well as backhoes. Because conditions vary greatly throughout the Site, these equipment modifications are not considered standard practice and will be used where environmental conditions within the Site dictate the need for them.

Conventional mechanical dredging equipment, such as dredges that use a clamshell bucket, bucket ladder, or dipper and dragline, are ineffective for environmental dredging (Interstate Technology & Regulatory Council [ITRC] 2014). The closed or environmental bucket is a specially constructed dredging bucket designed to reduce or eliminate increased turbidity of suspended solids from entering a waterway. Clamshell dredge buckets can also be fitted with baffles and seals to slow the movement of contaminated water and sediment. The U.S. Army Corps of Engineers (USACE) used this type of seal, which is similar to a rubber gasket, at the Fox River and Green Bay sites to minimize leakage of PCB-contaminated water and sediment from the bucket.

Additional modifications to conventional mechanical dredging equipment based on site-specific conditions include (ITRC 2014):

- Fitting the crane with longer boom (arm) for additional reach during dredging
- Fitting an excavator with a longer arm for better access
- Using a fixed arm bucket instead of a cable suspended bucket to increase the accuracy and precision of cuts and provide greater bucket penetration in stiffer materials
- Equipping the bucket with hydraulically operated closure arms to reduce bucket leakage
- Installing a sediment dewatering and water collection and treatment facility on the barge or at a temporary staging site
- Installing global positioning system (GPS) and bucket monitoring equipment to the dredge to provide the equipment operator with precise coordinate control of the bucket during dredging operations.

Recent developments in hydraulic dredging equipment have typically included project or site-specific modifications in order to achieve the following objectives (ITRC 2014):

- Increase solids content in the dredged material and lower water content.
- Prevent debris from entering the auger or pump intake.
- Pump dredged material over greater heights or distances.
- Improve on shore dewatering of dredged material.
- Reduce potential for releasing dredged sediment into the water column.

Backhoes can be modified or equipped with covers for the bucket to improve retention of the sediment and minimize re-suspension.

Other control technologies include:

- **Pneuma pump**. The Pneuma pump is used primarily for removal of fine-grained sediment and offers high solids concentration (up to 90 percent) in the dredge slurry, with minimal turbidity.

- **Large capacity dredges**. Larger than normal dredges designed to carry larger loads. This allows less traffic and fewer dumps, thereby providing less disturbance at a disposal site.

- **Precision dredging**. Dredging utilizing special tools and techniques to restrict the material dredged to that specifically identified. This may mean thin layers, either surficial or imbedded, or specific boundaries.

Best Management Practices

Best management practices or operator-control techniques are important in preventing re-suspension of contaminated sediment. Different types of dredges require different operating practices to control sediment re-suspension. For any dredging operation, sediment re-suspension should be monitored and operations halted if needed to avoid excessive re-suspension of sediment. Examples of best management practices for different types of dredges include (ITRC 2014):

- Operators of bucket dredges can (1) slow the dredge cycle time, which reduces the velocity of the bucket hitting the river bottom; (2) eliminate multiple bites (the practice of "multiple bites" involves repetitive lowering, raising, and reopening the bucket to obtain a fuller sediment load); (3) avoid stockpiling of silty dredge material on the river bottom; (4) rinse the bucket at the barge to clean off excess sediment between loads; and (5) briefly stop the bucket at the waterline to allow excess water to drain before raising the bucket from the water.

- Operators of cutter head dredges can (1) reduce rotation speed of the cutter head, (2) reduce the cutter head swing speed so the dredge does not move through the cut faster than it can hydraulically pump the sediment, (3) increase pump rates to provide more suction, (4) operate just below the sediment surface to avoid exposed blades or too deep cutting, and (5) avoid bank undercutting by removing sediment in lifts that are less than or equal to 80 percent of cutter head diameter to reduce cave-ins and sloughing of sediment.

- Operators of hopper dredges can (1) reduce production rates to eliminate overflow of suspended sediment from the hoppers and (2) reduce the fill level of the hoppers to avoid accidental overflow in rough water.

The active removal (pumping) of water from sediment barges during dredging is another approach to lessen sediment re-suspension and contaminant releases. The approach eliminates overflow from the sediment barges and has been successfully incorporated as a best management practice at large-scale removals in Puget Sound (AMEC 2013).

The purpose of the BMP is to limit release of sediment and associated contaminants back into the waterway from the sediment barge. The findings from a case study of mechanical dredging document that barge overflow can represent a significant contribution to the formation of a residual layer of sediment (Dalton Olmsted & Fuglevand Inc. 2006) and can directly impact water quality and create a risk for offsite contamination.

As described in Fuglevand and Webb (2012), when dredging with an environmental mechanical dredge using an enclosed bucket, each bucket of material placed in the barge contains a portion of sediment and a portion of water because water is not allowed to drain from the bucket. During precision remediation dredging projects, a fill factor of 50 percent, meaning the dredging bucket is only half full of sediment on average over the course of the project, should be targeted due to relatively thin cuts intended to avoid removal of non-impacted sediment and to avoid over-penetration of the bucket. The volume of water placed in the barges for a remediation dredging project can therefore equal the volume of sediment dredged from the waterway. Thus, a 100,000 cubic meter (m^3) dredging project can result in that volume of sediment placed into barges plus another 100,000 m^3 of water. Failure to manage the water in the barge during dredging can result in the release of turbid water back into the dredged area with the potential for increased sediment re-suspension and release and additional generated residuals.

Implementation of this BMP can include activities, such as pumping of the excess water from the sediment barges during dredging, thereby limiting the amount of ponded water within the barge and preventing direct overflow from the barge back to the waterway. Removed water is pumped to a water management system designed to remove excess sediment and chemicals of concern prior to discharge of the water back to the waterway as dredging return water. With proper capture and management, the turbid water placed in a barge by the enclosed dredging bucket can be processed to remove suspended sediment and chemicals of concern that would otherwise be released back into the waterway, causing releases (Fuglevand and Webb 2012).

Dewatering Evaluation

After removal, dredged sediment typically requires dewatering to reduce the sediment water content. Dewatering is considered a form of ex-situ treatment because it reduces the volume and mobility of contaminants. Dewatering technologies are commonly used to reduce the amount of water in dredged sediment and prepare the sediment for transport and treatment or disposal. In many cases, the dewatering effluent will need to be treated before it can be disposed of properly or discharged back to receiving water. Dewatering is considered in greater detail here than in the physical ex-situ treatment section because of its common application in environmental dredging projects. Several factors must be considered when selecting an appropriate dewatering treatment technology, including physical characteristics of the sediment, selected dredging method, and the required moisture content of the material to allow for the next re-handling, treatment, transport, or disposal steps in the process.

Three categories of dewatering that are regularly implemented include passive dewatering, mechanical dewatering, and reagent enhanced dewatering/stabilizing methods. The following sections discuss the effectiveness and implementability of various dewatering process options applicable to the Site.

Passive Dewatering

Passive dewatering (also referred to as gravity dewatering) is facilitated through natural evaporation, consolidation, and drainage of sediment pore water to reduce the dredged sediment water content. Passive dewatering is usually applied to mechanical dredging process options when space permits. It is most often facilitated through the use of an onshore temporary holding facility such as a dewatering lagoon or temporary settling basin. In-barge settling and subsequent decanting can also be an effective passive dewatering method and can reduce the overall time needed for onshore passive dewatering operations. Passive dewatering techniques can also be applied to sediment that has been hydraulically dredged where the resulting slurry is pumped into a consolidation site and the sediment slurry is allowed to settle, clarify, and dewater by gravity after the site has reached capacity. Water generated during the dewatering process is typically discharged to receiving waters directly after some level of treatment or may be captured and transported to an off-site treatment and discharge location. Normal passive dewatering typically requires little or no treatability testing although characteristics of the sediment, such as grain size, plasticity, settling characteristics, and non-aqueous phase liquid (NAPL) content, are typically considered to determine specific dewatering methods, size the dewatering area, and estimate the time frame required for implementation.

Passive dewatering is generally effective and capable of handling variable process flow rates but can require significant amounts of space (depending on the volume of material processed and the settling characteristics of the sediment) and time for significant water content reduction. Passive dewatering is a widely implemented dewatering technology for mechanically dredged sediment. It is also amenable to hydraulic dredging with placement into a settling basin or with the use of very large geotextile tubes to confine slurry and sediment during passive dewatering. Hydraulic dredge sediment dewatering with geotextile tubes has been implemented at several sites but typically requires project-specific bench-scale evaluations during remedial design to confirm its compatibility with site sediment and properly select and size the geotextile tubes.

Depending on the desired moisture content of the sediment, the subsequent processing or handling steps, the volume of material to be dewatered, available space, and the ability to effectively manage the dewatering effluent, passive dewatering can be an implementable dewatering technology option. Passive dewatering has been retained as a process option for the Site, with in-barge passive dewatering selected as the representative process option for inclusion in the development of alternatives.

Mechanical Dewatering

Mechanical dewatering involves the use of equipment, such as centrifuges, hydrocyclones, belt presses, or plate-and-frame filter presses, to separate coarse materials or squeeze, press, or otherwise draw out water from sediment pore spaces. Mechanical dewatering is typically used in combination with hydraulic dredging to reduce the water content of the dredged slurry prior to ex-situ treatment (e.g., thermal) and/or disposal of the dewatered sediment. Mechanical dewatering may also be used in combination with mechanical dredging if the dredged material is hydraulically re-slurried from the barge. Sufficient onshore space is needed to accommodate the selected dewatering equipment, but this space is usually less than required for passive dewatering. A mechanical dewatering treatment train usually includes treating the dewater prior to discharge.

The mechanical dewatering treatment train typically includes screening to remove materials such as debris, rocks, and coarse gravel. If appropriate, polymers may be added for thickening prior to dewatering. These steps result in a dewatered cake that achieves project-specific volume and weight reduction goals of the dredged sediment. The mechanical dewatering process can be scaled to handle large volumes of sediment but requires operator attention, consistent flow rates, and consistent sediment feed quality.

Mechanical dewatering is generally an effective technology for both hydraulic and mechanical dredging and has been widely implemented for a range of sediment types and sediment end uses (such as upland disposal) and is likely the most effective method of achieving moisture content reduction over shorter time frames than passive dewatering. Bench-scale tests are often performed during remedial design to develop the specific process design, select equipment, and select polymer additives if appropriate. Mechanical dewatering has been retained as a process option for contaminated sediment at the Site and may be used where appropriate based on area specific design needs.

Reagent Dewatering

Reagent dewatering is an ex-situ treatment method in the category of stabilization/solidification methods, which are discussed along with other categories of ex-situ treatment. This technology removes water by adding a reagent to the bulk sediment that binds with the water within the sediment matrix to immobilize the leachable contaminants (typically metals) and/or enhance geotechnical properties. This process increases the mass of sediment due to the addition of the reagent mass. For situations where dewatering is the single goal, the most cost-effective, available, and effective reagent or absorptive additive is used, which depending on site conditions and economics could include quicklime, Portland cement, fly ash, diatomaceous earth, or sawdust, among others. Reagent mixtures can be optimized to provide enhanced strength or leachate retardation to meet specific project requirements.

Dewatering by the addition of reagents is effective and has similar or smaller space and operational requirements as mechanical dewatering. In some cases, reagent addition and mixing can be conducted as part of the dredged material transport and re-handling process, either on the barge or as dredged material is loaded into trucks or rail cars. In other cases, it can be added and mixed after offloading to the upland staging area. Also reagent addition may be used in combination with other forms of dewatering (e.g., filter press) and ex-situ treatment. Bench-scale testing is often necessary to determine the optimum reagent mixture prior to construction. However, case study information is available from other projects on the types of reagents used for sediment of various water contents, and this information is sufficient to determine the general effectiveness and implementability of this technology for this FS. For example, the Gasco Early Action used in-barge application and mixing of Portland cement as well as diatomaceous earth at the transload facility as a final dewatering "polishing" step. This approach required no extra upland treatment space or major changes to the transport and transload steps than would have been used otherwise.

A wide range of dewatering process options are likely feasible at the Site. As a result, reagent dewatering has been retained as a process option for contaminated sediment at the Site and may be used where appropriate based on area specific design needs.

2.4.3.2 Wastewater Treatment

Dewatering dredged material requires managing the wastewater generated during the dewatering process (dredged material typically has a water content ranging from 50 to 98 percent, depending on the dredging method) along with contact water (such as precipitation that has been in contact with contaminated material, decontamination water, and wheel wash water) from other facility operations. The purpose of wastewater treatment is to prevent adverse impacts on the receiving water body from the dewatering discharge to the lower Willamette River.

Wastewater will be generated by dewatering steps, and this water likely will either require treatment prior to discharge to the lower Willamette River or disposal at a publicly owned treatment works (POTW) facility. While the FS necessarily assumes a representative set of process options for the general screening and alternative development procedures, this does not imply that other process options are screened out from future consideration during remedial design. Unless specifically noted otherwise, all process options discussed in this section would be potential options during remedial design. For example, there may be opportunities for handling and discharging dewater, including addition of amendments to bind or absorb water, use of upland transfer or disposal holding areas to allow water to clarify before discharge, and discharge to publicly operated existing treatment facilities.

A wastewater treatment plant may be included as part of the on-site management of dredged material. An on-site wastewater treatment plant to manage wastewater for a facility handling sediment from the Site may include coagulation, clarification, multi-stage filtration, and granular activated carbon adsorption, with provision for metals removal, if necessary. The primary difference in the wastewater treatment plant for a hydraulic dredging operation as compared to a mechanical dredging operation would be the volume of wastewater to be treated; hydraulic dredging results in a larger volume of sediment-water slurry to be managed. The hydraulic dredging wastewater treatment plant would require a larger footprint. An on-site wastewater treatment system is retained for further consideration.

2.4.3.3 Transportation

Transportation would be a component for any remedial alternative that involves removal of contaminated sediment from the Site. The mode of transportation included in each remedial alternative would be based upon the compatibility of that mode of transportation or combination of modes to the other process options. The most likely modes of transportation are truck, rail, and barge. These are briefly discussed below.

Truck Transport

Truck transportation includes the transport of dewatered dredged material over public roadways using dump trucks, roll-off boxes, or trailers. This form of transportation is the most flexible but can be very costly over long haul distances. Truck transport also has the greatest potential to impact safety (in terms of traffic accidents), local streets, and traffic, depending on the location of the processing facility with respect to major highways. Further, diesel emissions from trucks can include significant amounts of particulate as well as sulfur and nitrous oxides, which have been shown to cause asthma.[5] In addition, greenhouse gases such as carbon dioxide contribute to global climate change. Therefore, diesel emissions from trucks would need to be evaluated in a green remediation workplan developed during the design phase of the project. A green remediation workplan should consider among all other environmental impacts of design to remediation of a project the transportation mode choices which minimize these emissions as well as greenhouse gases, e.g. rail or barge instead of using on road trucks for the majority of material hauling as transportation in these modes uses at most 10 percent of the fuel of moving the same amount of material in trucks. Whichever mode is chosen based on project specific details, emissions reductions should be pursued wherever possible which include, but are not limited to: idle reduction, avoiding haul routes near sensitive subpopulations (e.g. schools), tailpipe retrofits (e.g. diesel particulate filters), use of tier 4 engine technologies, and/or fuel modifications to lower both exposure and overall toxics and greenhouse gas emissions.[6] Transportation of dredged sediment via truck is retained for further consideration.

Rail Transport

Rail transportation includes the transport of dewatered dredged material via railroad tracks using gondolas or containers. Rail transport is desirable where sediment is shipped over long distances, for example, to out-of-state treatment or disposal facilities. Because rail transport requires coordination between multiple owners and many operators are unwilling to provide detailed information prior to entering actual negotiations, it is difficult to obtain accurate cost estimates. Rail transport may

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[5] www.epa.gov/greenercleanups/superfund-green-remediation-strategy-2010
[6] www.clu-in.org/greenremediation/docs/Clean_FuelEmis_GR_fact_sheet_8-31-10.pdf

require the construction of a rail spur from a sediment handling facility to a main rail line. Another impact can be timeliness of rail shipments with respect to regulatory schedules, such as RCRA hazardous waste 90-day holding times. Transportation of dredged sediment via rail is retained for further consideration.

Barge Transport

Barge transportation includes the transport of dredged solids directly to a processing (dewatering) or on-site disposal (CAD site or CDF) facility or the transport of dewatered dredged material to a trans-shipment or off-site disposal facility. Barge transport likely would be used for short distances such as from the dredging location to the dredged material handling facility. In addition, barge transport may be considered for longer distances if dredged material is hauled to out-of-state treatment or disposal locations that have the ability to accept barge-loaded dredged material. Transportation of dredged sediment via barge is retained for further consideration.

2.4.4 Summary of Retained Remedial Technologies and Process Options

In addition to the no action response, the following process options have been retained for further evaluation:

- ICs, including, but not limited to, commercial fishing bans, fish and shellfish consumption advisories, waterway and land use restrictions through covenants or restricted navigation areas, or other dredging and structural maintenance restrictions in capping areas
- Monitored natural recovery processes, including, but not limited to, burial, sedimentation, bio-degradation, sorption, oxidation, and dispersion
- Enhanced natural recovery, including, but not limited to, thin layer placement
- In-situ treatment using physical immobilization, including, but not limited to, solidification/stabilization and sequestration
- Containment via engineered caps (including stone or clay aggregate material as armor), reactive caps, and geotextiles
- Sediment removal via excavation, mechanical and hydraulic dredging, and use of specialized and small scale dredge equipment. Disposal in an off-site landfill, RCRA disposal facility, or CDF
- Ex-situ treatment via particle separation, solidification/stabilization, and thermal desorption

In addition, ancillary technologies for sediment dispersion control, dewatering, wastewater treatment, and transportation are retained for evaluation in the FS.

2.4.5 Selection of Representative Technologies and Process Options

To proceed further with the development of the remedial alternatives and to evaluate and develop costs in subsequent chapters for this FS, it is necessary to select representative technologies and process options.

No Action:

The no action response does not include any containment, removal, disposal, or treatment of contaminated sediment, no new ICs, and no new monitoring.

Institutional Controls:

Representative institutional controls retained for evaluation include fish consumption advisories, water way use restrictions and regulated navigation areas, and land use controls and access restrictions.

Existing OHA fish consumption advisories would continue under any of the remedial actions. Further, enhanced outreach to educate community members about the OHA consumption advisories and to emphasize that advisories would remain in place during and after remediation would be incorporated into the active remedial alternatives. Outreach activities would focus on communities (typically communities or groups with environmental justice concerns) known to engage in sustenance fishing, with a special emphasis on sensitive populations (children, pregnant women, nursing mothers, tribal members). These activities could also include posting multilingual signs in fishing areas, distributing illustrated, multilingual brochures, and holding educational community meetings and workshops.

Additional ICs, such as waterway and land use restrictions or special conditions (e.g., to protect the integrity of engineered caps), imposed on sediment disturbance activities could also be implemented as components of alternatives comprising active remedial measures.

Monitored Natural Recovery:

MNR may be included as a component of alternatives comprising active remedial measures. It includes monitoring of the water column, sediment, and biota tissue to determine the degree to which they are recovering to PRGs. Once active remediation is completed, the influx, mixing, and deposition of sediment originating from suspended sediment upriver and sediment transport from adjacent sediment will subsequently determine the extent to which the sediment surface within the Site is recovering.

Enhanced Natural Recovery:

The application of a thin layer of sand may be necessary in some areas of the Site to reduce the time for sediment concentration reductions over what is possible by relying solely on natural processes. Thus, areas that are stable (exhibit low shear stress) and are recovering naturally are candidates for ENR. ENR may be applied to broad areas of the Site with lower levels of contamination and net sedimentation and where significant erosion is not a concern.

Sediment Containment:

Several representative process options using a variety of materials for sediment containment are retained, including engineered caps (using stone or clay aggregate material as armor), reactive caps, and geotextiles. Due to the large area being considered for remediation and the limited precedent for using geotextiles, engineered sand caps with, and without, stone armor are selected as the representative process option for alternatives involving sediment containment. Reactive caps are retained to be considered in areas where there are groundwater plumes to eliminate the potential for the groundwater plume from entering the river environment. Reactive caps are also retained where there are COCs that have higher water solubility in areas with significant groundwater advection, and where thinner caps are needed in order to minimize any increase in flood potential.

Sediment Removal:

Two representative process options for sediment removal were retained, including excavation and mechanical dredging. The costs of remedial alternatives involving sediment removal are based on mechanical dredging as the representative process option because of the following:

- The additional challenges to implementability associated with the infrastructure needs for hydraulic dredging in the Portland Harbor area
- The availability of site-specific data regarding implementation

Although it would be possible to extend a hydraulic transport pipeline across the Willamette River by submerging it, due to the presence of berths and shipping lanes, it is preferable to locate a dewatering facility of sufficient size close to the river for the hydraulic dredging option.

Sediment Treatment:

Representative process options for sediment treatment retained include in-situ and ex-situ solidification/stabilization and sequestration and ex-situ thermal desorption. The effectiveness of solidification/stabilization treatment is highly dependent on the initial COC concentrations; therefore, it is more suitable for sediment with lower COC concentrations.

Sequestration by addition of an amendment, such as activated carbon, to the sediment modifies the sorption capacity of non-polar organics and certain metals such as mercury. The effectiveness of sequestration is highly dependent on the initial COC concentrations, the type and concentration of organic carbon in the sediment, and the mixture of COCs present. Multifunctional amendment blends may be used to address complex contaminant mixtures in sediment and subsequently may enhance overall sorption capacity. Usually, activated carbon serves as the backbone (for hydrophobic partitioning) and either is included as a layer of granular activated carbon mixed with sand and applied as a layer or blended in a briquette-like composite using an appropriate and non-toxic binder (e.g., clays or other binder materials; Ghosh et al. 2011). Amendments can be engineered to facilitate placement in aquatic environments, by using an aggregate core (such as gravel) that acts as a weighting component and resists re-suspension, so that the mixture is reliably delivered to the sediment bed where it breaks down slowly and mixes into sediment by bioturbation.

Thermal desorption is effective for SVOCs and PAHs and has been demonstrated at other sediment remediation sites. Fine-grained sediment and high moisture content will increase retention times. There is widely available commercial technology for both on-site and off-site applications. An acid scrubber will be added to treat off-gas.

<u>Disposal of Dredged Sediment</u>:

The three retained process options for disposal include an off-site commercial landfill, a RCRA disposal facility, and a CDF. RCRA regulations exclude dredged material that is subject to the requirements of CWA Section 404, which governs the disposal of the sediment in a disposal area within the navigable waters of the United States, from the definition of hazardous waste.

A CDF is more efficiently integrated with dredging; transporting and offloading dredged material to a CDF causes fewer short-term impacts to the community and would be more cost-effective than transporting and offloading to an off-site landfill. Therefore, a CDF site is also selected as the representative process option for disposal of dredged sediment.

However, to provide greater flexibility in managing large quantities of dredged material, disposal in an off-site commercial landfill has also been retained as an alternative representative process option. Many RCRA Subtitle C and D landfills are located in the United States. Non-hazardous dredged materials (as defined under RCRA) are eligible for direct landfill disposal at a RCRA Subtitle C or D facility if in compliance with the individual acceptance criteria of the receiving facility. An evaluation of handling and transport options for contaminated sediment and riverbank soils to be removed from the Site is presented in Appendix F. The evaluation describes handling and transport options for each of the retained commercial landfills identified in **Table 2.4-2a-g**. The Roosevelt Regional Landfill was selected as the representative commercial landfill (RCRA Subtitle D facility) because the landfill:

- Has demonstrated rail car to working face integration to handle sediment arriving in rail cars
- Can handle wet material that fails paint filter test (they need water to accomplish the sites waste to energy objectives (10 meg co-gen operation at the site using captured methane)
- Has large capacity to handle large waste volumes.

Hazardous dredged material that contain organic underlying hazardous constituents (UHCs) exceeding the universal treatment standards (UTS) but do not contain UHCs exceeding 10 times the UTS for soil or sediment are eligible for direct landfill disposal at a RCRA Subtitle C facility if the material is in compliance with the individual acceptance criteria of the receiving facility. There is only one RCRA Subtitle C facility in the vicinity of the Site, Chem Waste Landfill, and it was retained as the representative technology for hazardous waste.

3. DEVELOPMENT AND SCREENING OF ALTERNATIVES

This section presents the strategy used to develop, and screen remedial alternatives to address contaminated sediment at the Site. Alternatives were developed for the Site in accordance with CERCLA, the NCP (40 CFR §300.430), EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988), *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005), and *Guide to Principal and Low Level Threat Waste* (USEPA 1991).

3.1 REMEDIAL ALTERNATIVE DEVELOPMENT STRATEGY

The remedial alternative strategy for the Site entails development of remedial alternatives that are expected to achieve protection of human health and the environment. The NCP [40 CFR §300.430(a)(1)(iii)(C)] provides an expectation that the developed alternatives provide "a combination of methods, as appropriate, to achieve protection of human health and the environment." Additionally, consistent with EPA sediment remediation guidance, a combination of remedial technologies and process options that are expected to effectively protect human health and the environment and achieve RAOs and PRGs for the Site within a reasonable timeframe have been considered. Monitored natural recovery should be considered as a stand-alone remedy only when it would meet RAOs within a reasonable timeframe. (USEPA 2005). EPA Superfund sediment site remedies, including those in Region 10, also reflect the conclusion of the Superfund sediment remediation guidance that there is no single remedy approach for sediment sites and that generally a combination of approaches (dredging, capping, in-situ treatment and monitored natural recovery) is the best approach to remediate large, complex contaminated sediment sites. Therefore, this FS uses a combination of the remedial technologies identified in Section 2.4.

The application of technologies considers site characteristics so that remedial approaches most appropriate for site conditions (anthropogenic and environmental) are developed and applied in particular areas. EPA's 2005 Guidance (particularly the series of "highlights" of site characteristics conducive to particular remedial approaches; Highlight 4-2, 5-1, 6-2, and 7-2) and other resources describe site characteristics consistent with remedial approaches (USEPA 1991; USACE 2008; ITRC 2014). There are four technologies available for sediment sites: dredging, containment, in-situ treatment, and ENR/MNR. Since it is already known that no one technology is appropriate for all areas of the Site due to the varied uses and environmental conditions throughout the Site, this FS discusses remedial approaches best suited to conditions in various regions of the river.

Since the Site has multiple regions in various physical settings that are impacted with different COCs and contaminated to different degrees, it is challenging to develop a series of comprehensive alternatives for evaluation and comparison. Thus, several concepts and approaches were used to facilitate remedial alternative development. Therefore, four distinct regions have been identified that will be used to develop the alternatives: navigation channel and future maintenance dredge (1,421 total acres), intermediate (572 total acres), shallow (174 total acres), and river banks (30,048 total lineal feet). The regions were developed based on anthropogenic uses and/or site characteristics. Areas that have been subject to final EPA remedies (23 acres) are not addressed[1] in this FS. The navigation channel and the future maintenance dredge (FMD) region encompasses the federally authorized navigation channel and areas near and around docks based on information regarding vessel activity, dock configuration, and future site uses where maintenance dredging is likely to occur**.** FMD locations were developed from estimates of likely future navigation depth requirements and potential future maintenance dredging depths near and around docks. A description of how the FMD locations were determined is provided in Appendix C. The intermediate region is defined as outside the horizontal limits of the navigation channel and FMD region to the bathymetric elevation of 4 feet North American Vertical Datum of 1988 (NAVD88). The shallow region is defined as shoreward of the bathymetric elevation of 4 feet NAVD88. The river bank region refers to contaminated river banks identified in Section 1.2.3.5. These regions are presented on **Figure 3.1-1**.

Within each of these regions, there are several considerations that determine the appropriate technology assignments assumed for the FS. These include principal threat waste, contaminated groundwater, structures, contaminant concentrations (sediment management areas), ENR areas, and MNR areas, which are all discussed below.

3.2 PRINCIPAL THREAT WASTE

The concept of principal threat was developed by EPA in the NCP to be applied on a site-specific basis when characterizing source material (USEPA 1991). Source material is defined as material that includes or contains hazardous substances, pollutants, or contaminants that acts as a reservoir for migration of contamination to groundwater, surface water, or air or that acts as a source for direct exposure. Further, principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur.

The NCP [40 CFR §300.430(a)(1)(iii)(A) and (C)] establishes the following expectations regarding principal threats in developing appropriate remedial alternatives:

- EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.

[1] The McCormick and Baxter cap encompasses 23 acres of the Site that will not be addressed in the alternatives.

- EPA expects to use a combination of methods, as appropriate, to achieve protection of human health and the environment. In appropriate site situations, treatment of the principal threats posed by a site, with priority placed on treating waste that is liquid, highly toxic, or highly mobile, will be combined with engineering controls (such as containment) and ICs, as appropriate, for treatment residuals and untreated waste.

EPA has not prescribed a threshold level of toxicity to equate to a “principal threat;” however, EPA guidance (USEPA 1991) recommends that where toxicity and mobility of source material combine to pose a potential risk of 10^{-3} or greater, generally treatment options should be evaluated. In addition, waste contained in drums, lagoons or tanks, or free product (LNAPLs) or dense non-aqueous phase liquids (DNAPLs)] containing contaminants of concern are also generally considered PTW. CERCLA [42 U.S.C. §9621], the NCP, and EPA guidance state an expectation that treatment [be used] to address the principal threats posed by a site, wherever practicable. This section identifies the PTW areas and presents treatment methods that may be used to reduce their toxicity, mobility, or volume.

3.2.1 Identification of PTW Areas

Consistent with the NCP and EPA guidance and site-specific conditions, PTW has been identified based on a 10^{-3} cancer risk (highly toxic) or NAPL within the sediment bed (source material) and on an evaluation of mobility of contaminants in the sediment. “Reliably contained” was not used in identifying PTW but rather was used to determine what concentrations of PTW could be reliably contained.

The following criteria were utilized to identify PTW:

Source Material: NAPL has been identified in subsurface sediment offshore of the Arkema and Gasco sites (RM 6 through RM 7.5) as globules or blebs of product in surface and subsurface sediment (Anchor QEA 2012; CDM Smith 2013). However, areas of NAPL have not been fully delineated. NAPL observed in sediment cores offshore of Arkema contains chlorobenzene and DDT (dissolved). NAPL observed in sediment cores offshore of Gasco contains aromatic hydrocarbons and PAHs. There may be other locations within the Site where NAPL is located. **Figure 3.2-1** identifies the general locations where NAPL was observed in sediment offshore of Arkema, and **Figure 3.2-2** identifies the NAPL observed in sediment offshore of Gasco.

Highly Toxic: The following COCs were found at concentrations exceeding a 10^{-3} risk level at the Site using the assumptions and methodology presented in the BHHRA:

- PCBs
- cPAHs
- DDx

- 2,3,7,8-TCDD
- 2,3,7,8-TCDF
- 1,2,3,7,8-PeCDD
- 2,3,4,7,8-PeCDF
- 1,2,3,4,6,7,8-HxCDF

The highly toxic PTW concentrations for these COCs are presented in **Table 3.2-1**. Surface sediment areas exceeding one or more PTW highly toxic concentration levels are presented on **Figure 3.2-3**. The PTW evaluation includes only surface sediment, which poses the greatest risk of exposure given site-specific conditions.

3.2.2 Technologies Applied to PTW Areas

Given the NCP's expectation for treatment of PTW, in-situ and ex-situ treatment technologies are considered for the PTW areas as discussed below. Containment technologies may be effective for addressing PTW when treatment technologies do not exist or are not practicable and it is reliably contained. Containment of PTW will also incorporate reactive materials into the cap design, such as organophilic clay or activated carbon, therefore, meeting the preference for treatment.

3.2.2.1 In-Situ Treatment and Amendments

Activated carbon or organophilic clay may be utilized as potential treatment-based technologies for addressing PTW to reduce contaminant bioavailability (see **Table 2.4-2**). In-situ treatment may be utilized alone or in conjunction with other technologies. Stabilization or solidification may be used to address PTW underneath and around pilings, docks, berthing or mooring dolphins, and other structures servicing active wharfs or shore-based facilities that remain intact. In the federally authorized navigation channel and FMD region, in-situ treatment is not compatible with current or future uses due to episodic high flow events, which have the potential to erode sediment within large portions of the navigation channel, and the need for future maintenance dredging; thus, in-situ treatment is not considered to be effective over the long term or implementable in these areas. In intermediate, shallow, and river bank regions of the Site where principal threat waste is left in place, either in-situ treatment or amendments to caps will be implemented (cap areas are described in Section 3.4, below).

3.2.2.2 Containment

If sediment classified as containing PTW is located in an area designated for capping, then a reactive cap will be assumed for that area.

PTW that cannot be Reliably Contained: For the purposes of the FS, a simple capping model was utilized to identify PTW that cannot be reliably contained by a cap.

Representative Site conditions and capping options were modeled using this approach to determine the maximum concentrations of PTW material that would not result in exceedances of AWQC in the sediment cap pore water after a period of 100 years to be consistent with the long-term costing conducted in Appendix G. Contaminants modeled were chlorobenzene, dioxins/furans, DDx, naphthalene, PAHs, and PCBs. A description of this modeling effort is provided in Appendix D, and the results are summarized in **Table 3.2-2**. The areas where PTW would not be reliably contained are presented on **Figures 3.2-4** and **3.2-5.** This is an appropriate model to make FS-level decisions and is sufficiently rigorous to be used for decision-making at the FS phase. More rigorous modeling may be conducted as needed in remedial design.

Organoclay reactive layers in conjunction with low permeable materials are assumed at locations where NAPL or PTW that cannot be reliably contained is left in place either due to the depth of contamination or the presence of structures that preclude removal. Organoclay has recently been used as an amendment in the capping of NAPL at the McCormick and Baxter site in the Willamette River within the Site. The use of low permeability materials is expected to further retard contaminant migration. The following significantly augmented reactive cap design concept was assumed for both the shallow and intermediate regions with PTW that cannot be reliably contained:

- Chemical Isolation Layer: 1-inch organoclay mat
- Low Permeability Layer: 17-inch layer of fine-grained sand or other low permeability material
- Physical Isolation Layer: 12 inches of sand
- Stabilization Layer: 6 inches of armor stone

The organoclay mat is a reactive cap that treats the contaminant that may pass through the cap and, as such, constitutes treatment. The other types of caps do not constitute treatment.

3.2.2.3 Ex-Situ Treatment

Ex-situ treatment is used in conjunction with removal technologies (dredging and excavation). Sediment sites often have widespread contamination at low concentrations, which the NCP acknowledges is more difficult to treat. Therefore, it is assumed that the majority of the contamination removed from the Site will not require ex-situ treatment. However, some contaminated material removed from the Site may need to be treated as a requirement of the disposal facility or due to regulatory requirements. Four treatment technologies were retained for assignment and further evaluation: particle separation, cement solidification/stabilization, sorbent clay solidification/stabilization, and low temperature thermal desorption (see **Table 2.4-2**). These treatment technologies may be utilized as potential treatment based technologies for addressing PTW removed from the

Site. Section 3.4.9 discusses disposal management (including required treatment) for contaminated sediment and soil not classified as PTW.

As noted in the PTW guidance (USEPA1991), one of the examples cited that may limit the use of treatment includes: “The extraordinary volume of materials or complexity of the site make implementation of treatment impracticable.” At this Site, the total volume of sediment that exceeds the 10^{-3} excess risk value and NAPL is estimated at 637,008 cy. Of this volume, approximately 241,919 cy (Alternative B) to 637,008 cy (Alternative H) of PTW materials may potentially be excavated and sent off-site.

PCBs and dioxins/furans in sediment or river bank soils, exceeding the PTW concentration levels in **Table 3.2-1**, are examples of PTW expected to be removed during the remedy. Sediment and soil with concentrations of these contaminants that exceed the thresholds for PTW but do not exceed regulatory standards could potentially be disposed of off-site in a RCRA Subtitle D disposal facility. The volume of this material to be removed is estimated to be 357,749 cy (Alternative B) to 997,725 cy (Alternative H); treatment, although preferred, would not be practicable. Although not related to whether treatment is technically practicable, we think that this material can be reliably contained.

An additional evaluation will need to be conducted prior to disposal of dredged sediment containing any PTW related to NAPL, PAHs or DDx to determine the appropriate off-site disposal requirements. Thus, ex-situ treatment using solidification or low temperature thermal desorption is applied to some volume of dredged sediment and soil containing these contaminants. However, it is noted that for purposes of compliance with the RCRA Land Disposal Restrictions for organics, solidification is not commonly identified treatment methodology. Due to the lack of sufficient waste characterization of pesticide/chlorobenzene PTW wastes at RM 7W, the FS assumes cement solidification/stabilization, low temperature thermal desorption, and no treatment will be used in equal proportions to treat pesticide/chlorobenzene PTW. No ex-situ treatment was assumed for PCB and dioxin/furan PTW. Regulatory requirements for the “as generated” wastes and disposal facility requirements may affect the classification and disposal of wastes; thus, these treatment assumptions are subject to revision during remedial design of a selected remedy. These treatment assumptions are within the +50/-30 range for cost purposes in the FS.

3.3 CONTAMINATED GROUNDWATER DISCHARGE

Several contaminated groundwater plumes have been identified throughout the Site. The cleanup of contaminated groundwater from upland sources is being conducted under DEQ oversight through an MOU with EPA. Some of these groundwater plumes have migrated to the river and may have loaded upland contaminants to the local transition zone, including sediment and pore water. Even in instances where a groundwater plume has been controlled in the uplands, there may be a portion of the plume that has moved beyond the control point and continues to seep into the river.

3.3.1 Identification of Contaminated Groundwater Discharge Areas

While the full extent of groundwater contamination at the Site has not been delineated in the river, available information in the RI and the DEQ source control reports indicates that contaminants are being transported to the river via groundwater flow. Accordingly, all areas with known groundwater contamination are presented on **Figure 1.2-19.**

3.3.2 Technologies Applied to Groundwater Discharge Areas

Areas with groundwater contamination that exceed the PRGs or have the potential to exceed the PRGs for pore water are assumed to require an in-river reactive cap that relies on activated carbon to reduce the contaminant flux and limit potential exposures in conjunction with upland source control measures to address contaminated groundwater such as hydraulic containment. A reactive cap is also assumed to be required in areas where contaminated groundwater may seep through river banks.

3.4 SEDIMENT MANAGEMENT AREAS

Sediment management areas (SMAs) are areas where containment or removal technologies will be considered to immediately reduce risks upon implementation. They are defined by COC concentrations representing areas where MNR and ENR (which rely on natural recovery processes over time) are not considered adequately to address RAOs in a reasonable time frame.

3.4.1 Identification of SMAs

This FS focuses on applying dredging and capping in areas of higher contaminant concentrations because dredging and/or capping technologies are more effective and timelier than in-situ treatment and ENR in achieving risk reduction where contaminant concentrations are relatively high. These SMAs are determined by identifying areas with the most widespread contaminants that pose the highest risks (termed “focused contaminants”). A range of contaminant concentrations for these focused COCs is developed to delineate concentration contours or footprints for each alternative. Additionally, PTW NAPL/NRC is used to delineate SMAs.

3.4.1.1 Focused Contaminants of Concern

COCs were identified in Section 2.2.1. Focused COCs are those that the distribution encompasses the majority of the spatial extent of contaminants posing the majority of the risks as identified in the baseline risk assessments. The focused COCs are only used for the development of SMAs.

The focused COCs are:

- PCBs
- Total PAHs
- 1,2,3,7,8-PeCDD
- 2,3,4,7,8-PeCDF
- 2,3,7,8-TCDD
- DDx

3.4.1.2 Remedial Action Levels

Remedial action levels (RALs) are a range of contaminant concentrations that are less than the current site-wide spatially-area weighted average concentrations (SWACs) for a particular contaminant, and are greater than the PRGs. They are commonly used at sediment sites to develop remedial alternatives and delineate areas exceeding a defined concentration threshold. The relative effect of remediating those areas can then be evaluated as part of the analysis of alternatives to determine whether RAOs can be met within a reasonable time frame. While specific RAL values are not cleanup levels, residual contaminant concentrations remaining after remediating the RAL footprint can be used to compare the relative effectiveness of the alternatives in reducing contaminant concentrations, which is directly related to risk reduction. In this FS, RALs are contaminant-specific sediment concentrations used to identify areas where capping and/or dredging will be assigned, and thus are the basis of the SMA footprints. The evaluation and analysis used to develop the RALs is discussed in Appendix D. The concept of using RALs to identify areas to apply specific technologies has been used at other contaminated sediment sites throughout the nation. Examples include Lower Duwamish River (Region 10, Washington), Pearl Harbor (Region 9, Hawaii), Hudson River (Region 2, New York), Kalamazoo River (Region 5, Michigan), and Former Derecktor Shipyard (Region 1, Rhode Island).

The relationships between RAL concentrations and resulting site-wide SWACs (“RAL curves”) were developed by plotting acres remediated against the post remediation surface weighted average surface sediment concentration (SWAC). RAL curves for each focused COC are presented in **Figures 3.4-1** through **3.4-6**. Each point on the RAL curve corresponds to at specific RAL. A range of RALs consisting of seven different concentrations bracketing the distribution of contamination were selected for each focused COC. The selected RALs are a function of the distribution of surface sediment data at the Site and reflect uncertainties in the distribution of contamination and the interpolation method utilized. SMAs were then developed by aggregating the concentration contour footprints of the area where each COC exceeded the RAL and the PTW NAPL/NRC footprint and assigned capping and/or dredging technologies. As each successive RAL represents a lower concentration, the associated area assigned capping/dredging increases with each RAL from B through H.

PCBs

The selected PCB RALs and the resulting SWACs and acres are presented in **Table 3.4-1.** The PCB RAL contours are presented on **Figure 3.4-7**.

Total PAHs

The selected total PAH RALs and the resulting SWACs and acres are in **Table 3.4-2**. The total PAH RAL contours are presented on **Figure 3.4-8**.

Dioxins and Furans

Due to the focused nature of the sampling and the lack of data density for dioxins/furans, RAL curves and values were developed based on areas with greater data density. Therefore, RM 7W was used for 1,2,3,7,8-PeCDD, and 2,3,4,7,8-PeCDF and RM 9W was used for 2,3,7,8-TCDD. These RAL values were then applied to a RAL curve on a site-wide basis.

Several dioxin/furan PRGs are less than or within the range of method detection limits (MDLs). In addition, the low density of dioxin/furan samples requires interpolation across large areas where no data are available, which can lead to a conclusion that specific locations are identified as exceeding the RAL when they may not. Because some PRGs are below the MDLs, the interpolation process will “map” some samples designated as less than the MDL. These issues necessitated a modified approach in the development of the dioxin/furan RALs for the FS, which is described below:

2,3,7,8-TCDD: Only five samples were identified for RALs B, C, and D as initially defined. Thus, a single value (equivalent to the D RAL) will be used for all three alternatives. Due to the number of non-detect results that would be greater than any potential F or G RALs, the E RAL will be used for the E, F, and G Alternatives.

1,2,3,7,8-PeCDD: Due to the number of non-detect results that would be greater than any potential E, F, or G RALs, the D RAL will be used for E, F, and G alternatives.

2,3,4,7,8-PeCDF: Only a single sample was identified as representing possible B, C, D, and E RALs. Thus, the E RAL will be used for the B, C, and D alternatives, and the F RAL will be used for the E and F alternatives.

The selected dioxin/furan RALs and the resulting SWACs and acres are presented in **Table 3.4-3**. The dioxin/furan RAL contours B through G are presented on **Figures 3.4-9** through **3.4-11.**

DDx

The highest DDx concentrations are found primarily at RM 6.6-7.8W. Because of the localized nature of this contamination, DDx RALs were determined based on the distribution within that localized area. However, alternatives based on these RALs are evaluated on a site-wide basis. The RALs for DDx and the resulting SWACs and acres are presented in **Table 3.4-4**. The DDx RAL contours are presented on **Figure 3.4-12**.

Summary of RALs
A summary of RALs for the focused COCs used to develop Alternatives A through H are presented in **Table 3.4-5**. Alternative I SMAs are based on a combination of different RALs and PTW high concentration values applied in specific areas of the Site. The RALs for Alternative I are presented in **Table 3.4-6** and the location for where the RALs apply is presented in **Figure 3.4-13.** SMAs are the combination of PTW NAPL/NRC and the RALs presented in **Tables 3.3-5** and **3.3-6** and are presented on **Figure 3.4-14a-h**.

3.4.2 Navigation Channel and FMD Region

SMAs within the federally authorized navigation channel or designated as FMD are assigned dredging as a technology due to minimum water depth requirements, the placement of thin sand layers, in-situ treatment amendments, and conventional or reactive caps because stand-alone technologies above the established navigation dredge depth are considered incompatible with current and future waterway uses.

The current authorized elevation for the lower Willamette River is -43 feet Columbia River Datum (CRD) although the navigation channel is currently only maintained to -40 feet CRD. Future channel depths could be increased to -48 feet CRD (Anchor QEA 2012). Therefore, the 48-foot channel depth was assumed with an additional 3-foot advanced maintenance/overdredge allowance and a 2-foot thick operational buffer between the top of in-situ caps. Given these assumptions and restrictions and taking into consideration the thickness of any placed material, only dredging is considered a viable technology in this region (USACE 2010). The same logic was assumed for FMD locations as well. Even in the case of dredging, navigation and maintenance dredge depth requirements will need to be considered during the design and implementation of dredging activities and the placement of any thin layer covers for managing residuals.

3.4.3 Structures

All structures located within the Site (both those that are planned for removal and those that are not) are shown on **Figure 3.4-15**. Pilings, docks, berthing or mooring dolphins, and other structures servicing active wharfs or shore-based facilities will likely remain intact during remedial activities. Contaminated sediment and river bank materials underneath these structures are assumed to be capped to the extent practicable.

Other structures (such as dilapidated, obsolete, or temporary structures) with their foundations in contaminated sediment or river bank materials and not servicing active wharfs or shore-based facilities are described as obstructions and are assumed to be removed prior to capping activities. There also are moveable floating dock structures found within the Site that could be moved to allow for remediation. Removal of dilapidated, obsolete, or temporary structures will incorporate controls to prevent adverse water quality impacts and the transport of contaminated sediment. For cost estimating purposes, EPA assumed that between 391 (Alternative B) and 3,618 structures

(Alternative H) potentially causing an obstruction to dredging and capping would need to be removed at the Site. In addition, between 7 (Alternative B) and 10 (Alternative H) moveable floating dock structures were also identified that would be relocated during dredging and capping activities. Where structures are removed, the technology assignments default to those described for the shallow and intermediate regions.

3.4.4 Shallow Region

The shallow region is assigned dredging with backfilling or capping after dredging to remove or contain contamination while maintaining water depths. Maintaining the elevation of the nearshore sediment bed prevents the loss of shallow water habitat, an increase in the flood rise, and the conversion of submerged lands to upland following placement of material in the river. Avoiding or minimizing impacts to the aquatic environment and flood rise need to be considered and evaluated to meet Clean Water Act and federal floodway requirements as part of the feasibility evaluation of where remedial caps can be placed. The determination of 4 feet NAVD88 as the boundary for this region was based on an assumed cap thickness of 3 feet (if capping were to be applied) and a mean low water level (MLLW) elevation of 7 feet NAVD88. This will allow for maximum thickness of material placed in the river that remains submerged at MLLW. While there may be opportunities to place material above the 4 feet NAVD88 elevation, they would likely require special design considerations and are best addressed as part of remedial design rather than as part of the alternative development in the FS.

Evaluations of the impact of climate change on river flows within the Willamette watershed suggest an increase in winter flow and a decrease in summer flow, with an earlier peak flow due to lower snow packs within the watershed (Naik and Jay 2011). Because of a lower snow pack and more frequent fall and winter rain events, more high flow events are expected but of less magnitude than the large flood events observed in the 1900s (Jung, I. and Chang, H. 2011). As a result, it is reasonable to project that the placement of caps within the shallow region without prior dredging may result in more exposed sediment in the future during summer low flow conditions, thus, loss of aquatic habitat.

Placement of capping material in the shallow region would result in positive change in the bathymetry that may require mitigation under Section 404 of the Clean Water Act and would also affect the flood rise capacity of the river and result in greater tidal intrusion. To allow for a net zero bathymetry change, this FS assumed equivalent cap thickness is dredged prior to placement. This assumption limits the need for mitigation.

Water depth is less critical for implementation of dredging-based technologies due to the generally shallow water conditions associated with the SMAs. Access to nearshore areas is achieved by dredging from the shore or the use of shallow draft barges and long-reach excavators.

3.4.5 River Bank Region

Although data are available to determine whether some river banks are contaminated, the data density is insufficient to fully delineate the areas for capping/excavation. Therefore, the FS assumes that technology assignments for SMAs were extended to contaminated river banks. This application of the technologies is based on assumption that the nature and extent of contamination and site-specific characteristics are sufficiently similar. Where SMAs are projected onto the river bank, removal followed by capping is the assigned remedial technology.

The vertical slope of the river banks vary widely throughout the Site. Many of the contaminated river banks currently have slopes that exceed an optimum slope of less than 5H:1V.[2] Current industrial and commercial operations may have structures near the river bank that preclude obtaining this desired slope. Contamination in river banks may extend into the upland source areas of the Site, and the cleanup of those areas is beyond the scope of this FS. Therefore, for cost estimating purposes, bank volumes and areas are based on linear feet and the simplified assumptions described in Appendix D. Engineered caps with beach mix are assumed to be placed on river banks that are prone to erosive forces. Vegetation is assumed to be planted on caps that are not prone to erosion.

Land-based excavators are assumed to be used for removal of contaminated river bank materials or near-shore sediment in locations above water levels, where practical, to limit off-site transport of disturbed river bank materials by the river. The removal of river bank material is assumed to be conducted in the late summer and early fall when river stage is low.

3.4.6 Intermediate Region

Determining the appropriate dredging or capping technology to assign in an SMA is dependent on a number of site-specific characteristics and environmental conditions. These factors include current and reasonably anticipated future land and waterway use, areas of erosion/deposition, sediment bed slope, infrastructure such as docks and piers, and physical sediment characteristics.

A technology assignment process using a multi-criteria decision matrix was applied in the intermediate region. This matrix was developed as a method to guide the assignment of capping and dredging technologies, based on specific site characteristics within SMAs in the intermediate region. Each technology is scored based on multiple criteria related to hydrodynamics, sediment bed characteristics, and anthropogenic conditions. The outcome of the matrix is that a technology is assigned to each pixel of the subject area based on environmental conditions. The scoring approach and criteria are presented on **Figure 3.4-16**. Appendix C provides further detail on the development of the technology assignment process.

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[2] The optimal slope of less than 5H:1V is for habitat considerations based on input from the National Marine Fisheries Service (Personal Communication, Genevieve Angle, NMFS, June 10, 2014).

Capping and dredging technologies were assigned a score of +1, 0, -1, or NC (not considered) for each criteria described below. The score reflects whether, on an absolute or comparative basis, a given site characteristic favors application of a remedial technology (+1), is neutral to the application of a remedial technology (0), limits application of a remedial technology (-1), or is NC. Engineered caps and armored caps were scored equally and were not considered appropriate in wind- and vessel-induced wave zones, where river bed slopes are greater than 15 percent and in propwash zones because of the likelihood of these environments to adversely impact the technology, thus, be less reliable and protective. Each pixel was evaluated relative to the criterion and scored according to the matrix. The values assigned for each criterion were then summed for each technology, and the technology with the highest total score was assigned to the pixel. The criteria and associated scoring are described below.

3.4.6.1 Hydrodynamics

Criteria related to hydrodynamics include wind wave zones, sediment erosion potential, sediment deposition rate, and water depth.

Wind Wave Zones and Erosion Potential
Wind- and vessel wake-generated waves and shear-stress on bottom sediment during high flow events were evaluated as criteria to determine whether an area was erosive. These criteria consider the potential for bedded sediment in the river to be eroded and transported downstream.

Nearshore areas are more likely to be subject to wave action generated from wind or vessel traffic. The areas subject to wave action are dependent on river level fluctuations but have been defined in this FS as areas with surface sediment elevations ranging from 0 to13 feet NAVD88, based on an analysis presented in Appendix C. These areas are not conducive to depositional MNR, ENR, in-situ treatment, or unarmored sediment caps due to wave-induced erosion potential. Wind- and wake-generated wave zones are presented on **Figure 3.4-17**.

Bedded sediment is prone to erosion and transport when forces generated by water flow exceed the critical shear stress of the sediment bed. Evaluation of daily mean discharges for the lower Willamette River, as measured at the Morrison Bridge, show that the Willamette River in Portland regularly experiences large discharges sufficient to erode substantial portions of the sediment bed (see Section 3 of the RI report). The estimated bed shear associated with a 2-year return flood event of 156,000 cfs was used to estimate erosion potential. In this analysis, the maximum predicted bottom shear stress values during a 2-year flow event were determined and then compared to the critical shear stress values of the bedded sediment. Areas where the shear stress of the 2-year event exceeds the critical shear stress of the bedded sediment are considered erosive. The 2-year return interval delineates areas that are routinely impacted by a flow event rather than areas that rarely experience flows that exceed the shear stress of the bedded sediment such as the footprint impacted by the 100-year flow event. The sediment bed area impacted by a 2-year event is smaller than the area impacted by a 100-year event because the spatial area of the sediment bed considered erosive is positively correlated with the return interval. Estimates of shear stress throughout the Site are shown on **Figure 3.4-18a-c**.

Wind- and vessel-generated wave erosive areas are nearshore; high flow erosive areas are generally in the navigation channel. As shown in **Figure 3.4-16**, the presence of either of these lines of evidence triggered scoring an area on the basis of the erosive criteria (except that engineered [unarmored] caps were not considered [NC] in wind/wave areas). If an area is considered erosional, dredging is scored higher (more favorable) than capping because sediment caps are less reliable under erosive conditions and there is less confidence in their long-term effectiveness.

Deposition

This criterion evaluates the sediment deposition rate, which is indicative of a stable, non-erosive environment. The difference in elevations between bathymetric surveys and the ratio of the surface and subsurface sediment concentration were evaluated to determine if areas could be considered depositional.

Bathymetric survey results from January 2002, May 2003, January 2009, and November 2011 were used in this evaluation. The difference in sediment depth was evaluated for these bathymetric pairs and is presented on **Figure 3.4-19a-h**. The difference between the 2002 and 2009 surveys was evaluated to estimate the long-term changes in bathymetry. The difference between the 2003 and 2009 surveys was also evaluated to understand the uncertainty in long-term deposition rates. Considering the accuracy of the surveys (+/-0.5 feet)[3] and the time frame being considered (7 years or 5.67 years depending on whether 2002 or 2003 is selected as the initial survey date), the minimum detectable sediment deposition rate was estimated to range between 2.2 and 2.7 cm/yr. Based on this analysis, a sediment deposition rate of 2.5 cm/year was selected as the threshold for identifying the area as depositional. Areas of the Site with sediment deposition rates greater than 2.5 cm/year are shown on **Figure 3.4-20**.

Depositional processes over time are assumed to have led to sediment with lower level contaminant concentrations overlaying more sediment with higher level contaminant concentrations. The requirement for this evaluation was a subsurface to surface contamination concentration ratio of 2, where surface sediment is considered the upper 40 cm[4], for interpolating surface and subsurface concentrations for the focused COCs. Based on the uncertainty of analytical data, a subsurface sediment concentration twice the surface sediment concentration is considered the minimum criteria for concluding that cleaner material is being deposited on the sediment bed. These areas are presented on **Figure 3.4-21**.

[3] "The vertical accuracy of collected water depths was 0.5 ft, and the horizontal accuracy was 1 meter." (Cover letter to: Attachment A. Lower Willamette River Multibeam Bathymetric Survey Report Submitted to: Striplin Environmental Associates, Inc. Submitted by: David Evans Associates, Inc. April 26, 2002).

[4] The surface sediment data set includes all samples with intervals starting at 0 cm and extending to depths ranging to 40 cm bml.

If an area is considered depositional, capping is scored higher than dredging, indicating that depositional environments are conducive for containment technologies that rely on isolation.

Shallow
This criterion does not apply to the intermediate region of the Site and was not used to score technologies.

3.4.6.2 Sediment Bed Characteristics

Sediment bed characteristics considered in the evaluation include sediment bed slope and the presence of cobbles, armor rock, and bedrock.

Slope
Sediment slope and slope stability are considered relevant for all remedial technologies. Sediment slope must be considered during the placement of in-situ treatment amendments and capping materials. In addition, slopes must be considered for dredging to account for stability and sloughing of contaminated sediment. Although there is the potential that caps may be engineered for slopes up to 30 percent, special cap design and placement methods may be required when the slope is greater than 30 percent. Engineering and construction become more complex and less conducive compared to a flat surface. The FS assumes that capping on slopes less than 15 percent does not require special considerations. This is a liberal assumption since there are examples where capping proved difficult on slopes less than 15 percent (for example, cap materials were not retained on slopes of approximately 7 percent when placed by a bottom dump barge for the pilot cap at Palos Verde Shelf). At steeper slopes, the special considerations required for caps warrant a more engineered design. As a result, two separate slope criteria have been established: 15 to 30 percent and greater than 30 percent. These areas are presented on **Figure 3.4-22.**

At slopes between 15 and 30 percent, dredging and armored capping were scored equally, recognizing that both would encounter some but not a substantially different degree of challenges associated with implementation. At slopes greater than 30 percent, armored capping was scored less than dredging, recognizing the impact of slopes on cap stability and the increase in design considerations to offset the impact. Engineered caps were not considered on slopes greater than 15 percent because of the potential lack of stability and impact on performance.

Cobbles, Rocks, and Bedrock
The presence of cobbles, rocks, and bedrock do not typically limit capping or in-situ treatment because the cap material or in-situ treatment amendment is placed on the sediment surface and any necessary mixing occurs naturally (ITRC 2014). Cobbles, rocks, and bedrock may limit short-term effectiveness of dredging-based remedies by impeding hydraulic dredging equipment, interfering with bucket closure and resulting in increased contaminant release rates (USACE 2008), or limiting placement of sheet pile containment during dredging. Finally, the presence of bedrock can limit the full removal

of contaminated sediment due to cracks and crevices that trap contaminated sediment and increase the amount of generated residuals and contaminated sediment release rates. However, there are currently no identified areas in the Site where areas of cobble, rock, or bedrock are present, and therefore, scoring was not affected.

3.4.6.3 Anthropogenic Influences

Anthropogenic influences considered in the matrix include structures and pilings, heavy debris, and propeller-induced erosion (propwash).

Structures and Pilings
Structures and pilings are present throughout the Site. These structures pose operational and implementation constraints for all of the remedial technologies. In particular, dredging is affected because offsets needed to protect structural stability require special design considerations or could require removal of structures. In areas with structures and pilings, capping is scored higher than dredging. The location of structures and pilings is presented on **Figure 3.4-23**.

Propwash
Erosion due to propwash can limit the effectiveness of engineered caps and may also require special design considerations for capping. Propwash areas are evaluated only for large vessels and tugboats: propwash from recreational craft is considered to have minimal impacts. Based on results of modeling presented in Appendix C, propwash disturbance is generally limited to the upper 30 cm (approximately 1 foot) of sediment and is most prevalent in shallow portions of the navigation channel and in berthing areas. However, the modeling indicated a potential maximum disturbance depth of over 6 feet. Further, up to 3 feet of scour was estimated to occur at the U.S. Moorings location within the Site (URS 2003). Propwash areas based on the modeling effort are presented on **Figure 3.4-24**.

Propwash has the greatest impact on engineered caps because the erosive forces can erode and disperse the upper layer of the cap and make it less effective at containing the contaminated sediment. As a result, engineered caps are not considered viable in propwash zones. Armored caps can generally be designed to prevent propwash-induced erosion. Propwash is not a significant factor for dredging although propwash-induced erosion must be considered for any thin layer covers for residual management. In propwash areas, dredging is scored higher than armored caps, followed by engineered caps.

Debris
A high resolution sidescan sonar survey was conducted on the lower Willamette River in 2008 to determine the approximate distribution of debris in the river channel and along both banks of the river. The sidescan sonar survey area extended from RM 1 to RM 12.2 and extended 1/2 mile into Multnomah Channel. Debris was identified throughout the Site. A detailed presentation of sidescan sonar targets and their locations is provided in the *Lower Willamette River Sidescan Sonar Data Report* (Anchor QEA 2009). Because

the sidescan sonar survey identified pilings as well as debris, sidescan sonar targets identified as pilings were classified as structures for the purposes of this FS.

Heavy debris can lead to reduced dredging production rates and increased contaminant release rates (USACE 2008). Moderate to heavy debris areas are presented on **Figure 3.4-25**. In areas where moderate to heavy debris is present, dredging is scored low because of the need for a debris removal pass and because debris limits dredging effectiveness by increasing generated residuals and releases. While the presence of debris can affect cap placement and function, such issues can be addressed through greater cap thicknesses. Therefore, capping is scored higher than dredging.

3.4.6.4 Technology Assignment Results

The scores for each technology (engineered cap, armored cap, and dredging) are summed and result in three possible scoring outcomes: a technology receives the highest score, technologies are scored equally, or an area does not receive a score (an outcome when the area does not achieve the threshold for any of the criteria[5]). If a technology receives the highest score, then it becomes the representative technology. When dredging and capping score equally, capping is selected due to the lower initial capital cost. However, when engineered cap and armored cap score equally, the engineered cap is selected due to lesser habitat impacts.

3.4.7 Containment Technologies

Three containment technologies were retained for assignment and further evaluation: engineered caps, reactive caps, and armored caps (see **Table 2.4-2**). As described above, conventional or reactive caps are considered incompatible with current and future waterway uses in the navigation channel and FMD region; thus, containment-based technologies are limited to shallow and intermediate regions[6]. A review of a variety of FS and design-level cap configurations indicates that caps for sediment sites typically range between 2 and 3 feet in thickness, depending on site-specific conditions related to erosive forces, chemical isolation requirements, and habitat requirements. Cap thickness is dependent on site-specific considerations that will be refined in remedial design, including sediment strength, hydrodynamic conditions (scour), anticipated infrastructure needs, cap-disrupting human behavior (boat anchoring and spudding), groundwater flow rate, navigation and flood control, contaminant flux rate, and continuity of contamination. Sediment caps typically consist of a chemical isolation component, a physical isolation component, and a stabilization/erosion protection component (USEPA 2005). As a simplified cost assumption and to ensure sufficient thickness of each component, a 3-foot thick cap was assumed. The design concept information provided below is for comparison and costing purposes and is sufficient for an FS-level

[5] This occurrence never happened, but if it did, the default is to capping.
[6] The intermediate region is the area between the shallow region and the navigation and FMD region. This area can range in depth from -4 to -40 feet NAVD88.

approximation. The thickness, composition, and materials utilized in cap construction will be determined during remedial design.

3.4.7.1 Engineered Caps

Containment is the isolation in place of contamination in sediment that poses an unacceptable risk to human health and the environment. To prevent exposure, different materials are used to isolate or contain the contamination by creating a barrier. These barriers are engineered based on the site-specific considerations discussed above. This technique is used both on river banks and in the river. Several major considerations drive the conceptual design, cost estimates, and feasibility. A separate chemical isolation layer is not included for engineering caps. A physical isolation layer of 3 feet is assumed to be sufficient to limit contact with contaminated sediment by aquatic organisms and to isolate the COCs within the cap. In shallow areas, a stabilization layer of beach mix is added to accommodate the erosional forces associated with wind- and vessel-generated waves. This is a more habitat friendly armoring that mimics the existing beach composition that has proven effective in armoring the existing beaches at other sites (for example, Pacific Sound Resources, Thea Foss Waterway-Commencement Bay, Lower Duwamish Waterway Slip 4, and Sitcum-Commencement Bay). The following cap design concepts were assumed:

Shallow Region

- Physical Isolation Layer: 30 inches of sand
- Stabilization Layer: 6 inches of beach mix

Intermediate Region

- Physical Isolation Layer: 36 inches of sand

3.4.7.2 Armored Caps

Certain areas in the river will require armoring on caps to reduce erosion, particularly after large storm events. Re-deposition of fine-grained material in capped and armored areas is anticipated to occur over time, making the armored areas similar in surface grain size to non-armored areas. The following cap design concept was assumed for both shallow and intermediate regions:

- Physical Isolation Layer: 24 inches of sand
- Stabilization Layer: 12 inches of armor stone

3.4.7.3 Reactive Caps

Physical isolation of contaminated sediment may require an additional reactive layer when the vertical movement of dissolved contaminants by advection (flow of ground water or pore water) through the cap is possible and due to the nature of the contaminants (PTW). In these instances, the sorptive capacity of the cap material will determine the ability to retard contaminant flux through the cap. The reactive layer is assumed to consist of AquaGate+PAC with a powdered activated carbon (PAC) content of 10 percent mixed with sand to achieve an activated carbon content of 5 percent. In addition to the use of activated carbon as a reactive layer, the cap design concept includes using an impermeable layer (such as AquaBlok™) below structures in the absence of contaminated groundwater plumes. In the shallow region, the impermeable layer is overlain by 6 inches of beach mix as a stabilization layer. In the intermediate region, the impermeable layer is overlain by 6 inches of armor stone. The following cap design concepts were assumed:

Shallow Region

- Chemical Isolation Layer: 12-inch layer consisting of approximately 50 percent sand and 50 percent AquaGate+PAC
- Physical Isolation Layer: 18 inches of sand
- Stabilization Layer: 6 inches of beach mix

Intermediate Region

- Chemical Isolation Layer: 12-inch layer consisting of approximately 50 percent sand and 50 percent AquaGate+PAC
- Physical Isolation Layer: 24 inches of sand

3.4.7.4 Armored Reactive Cap

Within certain areas in the river where reactive caps are needed, armoring to reduce erosion, particularly during and after large storm events, may also be necessary. The following cap design concept was assumed for both the shallow and intermediate regions:

- Chemical Isolation Layer: 12-inch layer consisting of approximately 50 percent sand and 50 percent AquaGate+PAC
- Physical Isolation Layer: 12 inches of sand
- Stabilization Layer: 12 inches of armor stone

3.4.7.5 Additional Cap Considerations

The following considerations apply to the assumed cap design concepts throughout the site.

Cap Placement

Cap material is assumed to be placed on the river bed using either a hydraulic diffuser or clamshell bucket.

Bioturbation Potential
Bioturbation is the displacement and mixing of sediment by burrowing or boring organisms. The extent bioturbation would affect the integrity of caps will be considered during the design phase. To prevent benthic organisms from disturbing the chemical isolation component of a cap, a bioturbation component of cap design is needed. According to data collected from surveys of benthic invertebrates in the lower Willamette River in October 2002 and July 2005, dipteran and oligochaetes are the most diverse taxonomic groups while chironomids, oligochaetes, and bivalves are the most common groups. Burrowing depths of these organisms are approximately 4 to 10 cm (1.5 to 4 inches). The isolation layer provided in the cap design concept is sufficient to accommodate this level of bioturbation. This layer will reduce the potential for organisms to contact the underlying contaminated sediment or create preferential flow paths from the contaminated sediment, through the cap, to the surface water.

Aquatic Habitat Areas
Shallow water habitat provides critical functions to the river environment that must be retained to the maximum extent practicable. Shallow water habitat is defined as the area less than 20 feet of water depth as measured at the ordinary low water elevation. Adverse impacts on overall habitat existence and functions are important considerations during cap design and implementation. Because avoiding or minimizing impacts to the aquatic environment is a requirement under the Clean Water Act, it has been assumed that an engineered beach mix layer should be applied to the uppermost layer of all caps in nearshore areas. This beach mix layer will provide a substrate similar to the natural substrate existing in the river to minimize habitat impacts from the cleanup actions and help to stabilize the cap.

3.4.7.6 Monitoring

Monitoring is an integral component of capping and will be conducted to evaluate long-term effectiveness. The monitoring program will include sediment, river banks, surface water, pore water, and fish tissue samples collected at the following frequencies:

- Remedial Baseline Monitoring will be conducted prior to implementation of remedial activities to gage the performance of the remedy.

- Long-term Monitoring is assumed to commence the year following completion of remedy implementation and take place every 2 to 3 years for the first 10 years and once every 5 years thereafter until remedial goals are achieved.

It is expected that the state, the tribes and the Natural Resource Trustees will continue to have significant roles in developing and implementing monitoring activities for the site.

3.4.7.7 Institutional Controls

ICs will be used to prevent or limit exposure to contaminants and ensure integrity of caps on both a short- and long-term basis.

Waterway Use Restrictions or Regulated Navigation Areas (RNAs): Where caps will be utilized to contain contamination, waterway use restrictions or RNAs may be necessary to ensure the integrity of the cap is maintained by limiting activities that could affect the ability of the cap to contain contaminated sediment or groundwater from being released to the environment. This could include prohibiting anchoring of vessels or the use of spuds to stabilize vessels in areas containing caps. Notifications such as signs and buoys placed by the Oregon Marine Board may be used to warn vessels from the area. RNAs have been successfully used in the past to protect remedial actions at the Site. RNAs were required to protect the McCormick and Baxter cap and the Gasco interim action cap from vessel activities. Periodic inspections of RNA notifications will be needed to ensure they are functional and effective.

Land Use/Access Restrictions: Land use or access restrictions may be needed in nearshore areas and river banks owned by companies or individuals to maintain the integrity of caps by limiting activities that could affect the ability of the cap to contain contaminated sediment/soil or groundwater from being released to the environment and prevent exposure to human receptors. Easements and equitable servitudes may be effective land use restrictions to protect cleanups and could be used at the Site. Monitoring, including inspections, will be needed to ensure that restrictions are functioning as intended.

3.4.8 Removal Technologies

Two removal technologies were retained for assignment and further evaluation, dredging and excavation (see **Table 2.4-2**). Mechanical dredging using fixed arm or cable arm dredges or land based excavators were identified as the representative process option for removal of contaminated sediment and river bank soil. However, the most appropriate and effective equipment will be determined during the design phase and used during construction. Several major considerations drive the design concept, cost estimates, and feasibility evaluation for the dredging included in the remedial alternatives, such as the following:

3.4.8.1 Mechanical Removal Equipment

Environmental/closed buckets are assumed for mechanical dredging of sediment to lessen releases to the water column. Articulated fixed-arm dredges are the preferred dredging option due to the greater bucket control that can be achieved with this dredge type versus cable-operated dredges. This greater bucket control has proven to limit contaminant resuspension and release at other sediment sites (AMEC et al. 2012).

Articulated fixed-arm dredges are assumed to have a maximum arm reach of 50 feet and bucket sizes ranging from approximately 2 to 6 cy although bucket size decreases as arm length increases. A 4 cy bucket size is assumed for all operations where bucket size is not limited by existing structures. A 2 cy bucket is assumed for dredging around and beneath existing structures.

Cable-operated dredges are assumed for those Site conditions where fixed-arm dredges are not viable (such as water depths exceeding 40 feet) and will have no water depth limitations at the Site. Cable operated dredges are assumed to have a bucket size of 10 cy.

3.4.8.2 Productivity

The duration of the dredging season is assumed to be 122 days based on an in-water fish work window established for the Willamette River of July 1 through October 31. This in-water work window accounts for fish migration patterns and may be refined following discussions with the relevant technical experts at the appropriate natural resource agency.

Dredging and excavation operations are assumed to occur 24 hours/6 days per week (Schroeder and Gustavson 2013). The daily and weekly durations of removal operations may be refined if community "quality of life" concerns (such as nighttime noise or light pollution) are identified. The uncertainty in the costs due to these duration assumptions is discussed further in Appendix N.

3.4.8.3 Volume Estimates

Dredge prisms are defined as the continuous three-dimensional extent of sediment planned for removal. Limited data exist on the depth of contamination at the Site. Core profiles showing depth of contamination for the focused COCs are presented on **Figures 3.4-26a-v** through **3.4-31a-h**. Consequently, a Natural Neighbors geostatistical interpolation was conducted using the existing subsurface data and assigning each pixel a depth to threshold corresponding to the deepest sediment sample with concentrations exceeding PRGs. The depth profiles within the SMAs from this interpolation are presented on **Figure 3.4-32a-f**. The volume of contamination in each SMA was calculated by summing the volumes (area of each pixel multiplied by its interpolated or measured depth to threshold) of the pixels in each SMA. A multiplier (over-dredge factor) of 1.5 to 2.0 was applied to the dredge volume to account for the need to maintain gradual side slopes within the dredge prism to prevent slope failure and provide a range of expected dredge volumes.

Dredge depths are also based on the RALs to limit the requirement for a cap and ensure that future exposures will not recontaminate the Site above concentrations left at the surface. A maximum dredge depth of 15 to 19[7] feet is assumed since deeper dredge depths would require special design and side slope stabilization considerations. The shallow region encompass special habitat considerations; thus, leave surfaces (the surface elevation after construction) are assumed to be at the existing elevation. Any material removed would require backfill to the existing elevation. As dredge depths increase, volumes and costs for disposal of removed material increase as well as volumes and costs for fill material. A maximum dredge depth of 5 feet in nearshore areas is assumed

[7] Based on available information, 9 acres of the Site have contamination greater than PRGs at depths greater than 15 feet. These areas are located in the Navigation Channel, FMD, and Intermediate regions of the Site. Due to the very small volume that this creates and that an over-dredge of 3 to 5 feet would need to be made to place a cap in these areas due to current and future uses, these were included in the dredge volumes.

because contamination greater than RALs in this area of the Site is generally less than 5 feet. Removing contamination greater than the RAL precludes the need for restrictions and long-term management of caps in these areas by removing the contaminated material.

If contamination above the RALs extends below the maximum dredge depth, a cap is assumed to be placed over the residual contamination. Otherwise, a 1 foot thick sand layer will be placed over the dredged area to cover the exposed surface and isolate any dredge residuals and remaining contaminated sediment inventory.

Single pass production dredging (one dredge pass to the appropriate depth followed by confirmation sampling) is assumed for all dredging areas. A vertical accuracy of 1 foot was assumed for estimated depths; hence, a 1-foot over-dredging allowance was used for volume estimates.

3.4.8.4 Release

Release is the mechanism by which dredging operations result in the transfer of contaminants from sediment pore water and sediment particles into the water column or air (USACE 2008). BMPs, such as those described in Section 2.4.3.1, may be used to minimize releases to the water column. Monitoring of water quality parameters will be conducted to measure the effectiveness of these controls and determine whether additional control measures may be required.

3.4.8.5 Residuals

Residuals refer to contaminated sediment remaining in or adjacent to the footprint after dredging is completed (Palermo et al. 2008). Managing dredge residuals through the placement of clean material soon after dredging is an important BMP for lessening contaminant release and resuspension and transport of contaminated dredging residuals. This is best accomplished with a 6- to 12-inch layer of sand applied over the dredge area as soon as possible (the design dredge elevation has been met in greater than or equal to 95 percent of the dredging work area [adapted from The Louis Berger Group 2010[8]]). Sediment cores are assumed to be taken through the post-dredge thin sand layer to confirm that the required layer of sand has been applied to manage residuals. These cores will be taken once the thin sand layers have been applied.

Contaminant releases in the absence of a post-dredge thin sand layer and operational BMPs are typically on the order of 2 to 3 percent of the total contaminant mass removed (Bridges et. al., 2008). Placement of 12 inches of sand as a residual management layer is assumed for all dredge areas to minimize exposure to dredged residuals, taking into account mixing and bioturbation. The placement of 12 inches of sand eliminates the need for additional dredge passes and ensures that the leave surface is clean[9]. The residual

[8] Per Louis Berger (2010), "[a] dredging pass will be deemed to be successfully completed in a given sub-unit once 95% or more of the subunit is at or below the Depth of Contamination (DOC) elevation."

[9] A 6-inch residual cover would result in a post cover surface condition that is ½ the leave concentration. Fuglevand and Webb indicate that a nominal residual cover of 6-inches is used. Fuglevand, P.; Webb, R. 2012.

management layer will be placed daily once 95 percent of dredging is complete (to lessen the potential need for additional dredging passes to reach the desired dredge depth) in an area to control residuals and releases. In areas where PTW is present, the residual management layer is assumed to consist of AquaGate+PAC with a PAC content of 10 percent mixed with sand to achieve an activated carbon content of 5 percent.

During excavation, river bank material will be susceptible to erosion from wind and surface water runoff. Erosion control measures are assumed to either divert surface water flows/runoff around and away from excavations or limit off-site transport of eroded river bank materials. Sheet pile walls may need to be used to isolate ongoing excavations from erosive hydrodynamic forces if river stage increases during excavation. When sheet piles are not feasible (for example, where buried utilities are present), permeable berms (such as straw wattles) may be used.

3.4.8.6 Resuspension

Current velocities greater than 2.5 feet per second may limit the implementability and effectiveness of silt curtain controls, thereby increasing contaminant release rates/mass being transported away from the in-water work area during dredging activities (Palermo et al. 2008). However, dredging is assumed to occur from July 1 to October 31 when river currents are low. Silt curtains are assumed to be feasible in current velocities less than 2.5 feet per second. Silt curtains are assumed in water depths less than 50 feet and in areas where NAPL is not present. A combination of silt and bubble curtains was unable to prevent multiple water quality criteria exceedances downstream of the 2005 Gasco removal action involving NAPL (Parametrix 2006); thus, more rigorous controls will be necessary for removal of this material from the Site. Areas of potential NAPL presence and Site bathymetry identifying water levels at the 50 ft MLLW are presented on **Figure 3.4-33**.

Engineered rigid control measures (such as sheet piles) may minimize NAPL and sediment releases outside of the sheet pile enclosed work area. These measures should be incorporated into any remediation alternative involving the presence of NAPL.

As evidenced by recent environmental dredging projects in the Pacific Northwest (Boeing Plant 2), dredging BMPs can greatly lessen contaminated sediment releases, residuals, and resuspension. These dredging BMPs are assumed in this FS to be implemented at the Site.

3.4.8.7 Buried Debris and Pilings

Buried debris or denser sediment (hardpan) may impede removal of contaminated sediment and river bank materials at the Site and will be removed. A standard clamshell bucket, grapple, or equivalent will be used for removal of this material. Appropriate controls specifically designed for debris or structure removal (for example, 2007 Puget Sound piling removal BMPs) will be used to lessen releases and dredge residuals. Areas containing buried debris and pilings are presented on **Figure 3.4-34**. River bank debris removal as part of the CERCLA remedy will be addressed during the design.

3.4.8.8 Flood Rise Concerns

Balancing of dredge and fill volumes to the maximum extent practicable is assumed to limit flood rise concerns throughout the Site.

3.4.8.9 Material Handling

Mechanical dredging is assumed for all sediment assigned for dredging. Dredged material is assumed to be loaded directly into barges and transported for dewatering, treatment, or further transport. Sediment transport barges would be dewatered as necessary to prevent overflow and releases to the Willamette River. River bank materials excavated from above the water line are assumed to be loaded directly into containers or barges for transport and treatment as needed. An evaluation of handling and transport options for contaminated sediment and riverbank soils to be removed from the Site is presented in Appendix F.

3.4.8.10 Monitoring

Monitoring will be conducted to evaluate contaminant releases during dredging. The monitoring program will include surface water and air samples collected at the following frequencies:

- Remedial Baseline Monitoring will be conducted prior to implementation of remedial activities to gage the performance during dredging activities.
- Short-term Remedial Monitoring is assumed to be conducted daily during implementation.

It is expected that the state, the tribes and the Natural Resource Trustees will continue to have significant roles in developing and implementing monitoring activities for the site.

3.4.8.11 Institutional Controls

ICs will be used to prevent or limit exposure to contaminants during construction activities.

Fish Consumption Advisories: Fish consumption advisories would be required during dredging activities. The existing advisory would need to be revised by the State in conjunction with the final remedial action. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be evaluated to determine advisory effectiveness.

3.4.9 Disposal Material Management

The representative process options selected for each disposal technology for FS evaluation and cost purposes are:

- Off-site: Commercial Landfills: Roosevelt Regional Landfill (Subtitle D), and Chemical Waste Management of the Northwest (Chem Waste) Landfill (Subtitle C; accepts RCRA waste)

- On-site: CDF: Terminal 4 CDF

3.4.9.1 Material or Waste Regulatory Considerations

Several different types of contaminated material or waste could potentially be generated by dredging sediment from the Site. Media contaminated by spills, leaks, discharges from outfalls, and migration through groundwater or stormwater is not generally solid or hazardous waste as defined by RCRA until managed as waste and disposed on- or off-site.

The Off-Site Rule as set forth in the NCP (40 CFR §300.440) requires that CERCLA wastes transferred off of the cleanup site be placed in a facility operating in compliance with RCRA or other applicable federal or state requirements. EPA determines the acceptability of a disposal facility based on relevant violations or releases and compliance with specific acceptability criteria identified in 40 CFR §300.440. Each of the commercial landfills under consideration for disposal are assumed to be operating in compliance with their hazardous waste permits as required for CERCLA waste by the Off-Site Rule. Prior to disposal of CERCLA waste from the Site, the selected disposal facility’s compliance with the Off-Site Rule will need to be verified with the EPA regional Off-Site Rule compliance contact before any material is transported for off-site disposal. The proposed disposal facility would also need to accept the wastes to be transported prior to disposal.

Dredged material subject to requirements of a permit that has been issued under Section 404 of the CWA is excluded from the definition of hazardous waste (40 CFR 261.4(g)). This provision is discussed in the Hazardous Waste Identification Rule (HWIR) (63 Federal Register [FR] 65874, 65921; November 30, 1998). Oregon State adopted the HWIR rule in 2003. This rule means that RCRA regulatory requirements do not apply to sediment dredged at the Site and disposed of on-site, such as at the Terminal 4 CDF, if the material otherwise meets the CDF acceptance criteria. However, disposal of dredged sediment would need to comply with the substantive requirements of the 404(b)(1) guidelines under the Clean Water Act (40 CFR Part 230, particularly the substantive requirements contained in Subparts B through F and H).

If a listed or characteristic RCRA waste was generated and disposed of as part of historical operations at a site, then the contaminated media, such as sediment or soil, once managed as waste, may contain such regulatory waste, and all on-site actions would need to comply with relevant and appropriate RCRA storage, handling, and disposal requirements unless otherwise exempted under RCRA.

The expected regulatory waste types that may be generated include waste that contain RCRA characteristic hazardous wastes, RCRA- and State-listed hazardous wastes, and Toxic Substances Control Act (TSCA) waste. Additionally, material dredged and excavated from the Site may not be regulatory waste but has high concentrations, or other characteristics requiring special disposal considerations will include “Waste or Media containing Waste that May Warrant Additional Management.” Sediment dredged from the Site will require characterization to determine whether it should be classified as material containing hazardous waste under RCRA or otherwise meets disposal criteria for the CDF.

RCRA Characteristic Hazardous Wastes

Characteristic hazardous waste as defined in 40 CFR §261.24 is required to be treated under 40 CFR 268.9 so that it no longer exhibits the characteristic (dilution is not authorized as treatment) and meets the land disposal restrictions (LDRs) for all underlying hazardous constituents. Preliminary analysis indicates that characteristic RCRA waste may be present at the Site, although very little evaluation has been conducted to date. A total of 11 sediment cores were collected from the Site for toxicity characteristic leaching procedure (TCLP) analysis to determine if any sediment met the RCRA characteristic hazardous waste criteria for toxicity. Additional TCLP testing was conducted as part of the Arkema 2009 EE/CA investigation (Integral and ARCADIS 2011).

Results of four samples exceeded the TCLP criteria: benzene in one sample off-shore of the Gasco former MGP facility (see discussion of Waste or Media containing Waste that May Warrant Additional Management, below) and lead, benzene, and TCE in three samples at one location for each contaminant, respectively, off-shore of the Arkema facility. A review of chemical concentrations (particularly metals) across the Site indicates the potential for additional sediment to be classified as characteristic hazardous wastes based on the RCRA toxicity criteria. These areas are shown on **Figure 3.4-35**.

Characteristic hazardous waste is assumed to be taken off-site for disposal in the Chem Waste RCRA Subtitle C landfill unless contaminant concentrations exceed the land disposal restrictions specified in 40 CFR Part 268. In this case, treatment will be required as specified in 40 CFR §268.40 prior to disposal in the RCRA Subtitle C landfill. If sediment contaminant concentrations are less than acceptable LDR concentrations, then the material can be disposed of in the RCRA Subtitle C landfill without treatment. Once the RCRA characteristic has been removed and all underlying hazardous constituents have been treated to the RCRA LDR standards, it may be disposed of in a RCRA Subtitle D landfill.

Although there is the possibility that RCRA characteristic hazardous wastes may be present at the Site, the FS assumes that none of the sediment meet this criteria outside of NRC/NAPL PTW extents for the purposes of costing disposal options. This assumption is within the +50/-30 range for cost purposes in the FS.

RCRA- and State-Listed Hazardous Wastes

Two areas of sediment were identified as potentially containing RCRA-listed hazardous waste, and one area was identified as potentially containing Oregon State-listed hazardous waste. Certain sediment in the vicinity of the Siltronic outfall may contain RCRA F002-listed waste (non-industry specific spent solvent wastes) resulting from an accidental discharge of spent TCE to the Willamette River via an outfall. The other area where RCRA-listed waste may occur is near the groundwater discharge zone at RM 6.9 West. This area may contain F027-listed waste (non-industry specific discarded unused formulations containing tri-, tetra-, or pentachlorophenol that have contaminated sediment). In addition, sediment adjacent to and downriver from the Arkema site may contain DDT-manufacturing waste residues. This material may be classified as an Oregon State-listed hazardous waste based on the Oregon Pesticide Residue Rule (Oregon Administrative Rule 340-109), and if taken off-site will be managed in accordance with the Oregon State regulations. All detectable concentrations of pesticides removed from the Site would need to meet LDRs for that constituent, have the State make a contained-in determination, pass the DEQ 96-hour aquatic toxicity test, or have otherwise obtained DEQ approval to dispose in a RCRA Subtitle D disposal facility. Otherwise, waste containing pesticide residue would be required to go to a RCRA Subtitle C disposal facility without treatment. It was assumed that the State would make a contained-in determination for the majority of this waste would be disposed of in a RCRA Subtitle D disposal facility; only PTW would be required to go to the RCRA Subtitle C disposal facility. Appropriate testing will need to be conducted to determine if sediment removed from the approximate areas shown on **Figure 3.4-36** contains these listed RCRA- or State-listed wastes.

Material containing RCRA-listed hazardous wastes are to be taken off-site for disposal; they must be stored and handled appropriately and disposed of in a RCRA Subtitle C landfill. If a contained-in determination has been obtained from the State and the material meets the requirements, then the material can be disposed of in a RCRA Subtitle D landfill. Where RCRA F002-listed waste (spent halogenated solvents) from the Siltronic site is found to be co-mingled with the Gasco MGP waste, the material will be classified as a RCRA listed hazardous waste for management and disposal purposes.

If material classified as an Oregon State-listed hazardous waste based on the Oregon Pesticide Residue Rule is taken off-site for disposal, it may be managed in a RCRA Subtitle C hazardous waste facility, or it may be managed in a RCRA Subtitle D facility provided that the applicable land disposal concentration-based standards in 40 CFR §268.40 are met for waste pesticide containing any pesticide active ingredients listed in 40 CFR 261.33(e) and (f). For this, the State would need to make a contained-in determination.

Waste or Media Containing Waste that May Warrant Additional Management
MGP wastes are by definition not RCRA hazardous wastes per 40 CFR §261.24(a), which specifically excludes solid MGP waste. While MGP wastes are exempted as a RCRA hazardous waste, concerns about the toxicity and mobility of the material prompted EPA to classify these materials as a "Waste or Media containing Waste that May Warrant Additional Management" at the Site so the contaminated sediment could be appropriately handled and managed.

Waste with this designation may be specially managed as a non-hazardous waste at a Subtitle C facility based on the exceedance of TCLP criteria for MGP-related constituents and/or special considerations such as worker safety and equipment decontamination (USEPA 2004, 2005). However, if the material is treated and TCLP criteria are no longer exceeded after treatment, it may be disposed of in a RCRA Subtitle D facility. It was assumed for FS cost purposes that the MGP waste identified as PTW NAPL/NRC at the Gasco former MGP facility would exceed the TCLP criteria and would need cement-based solidification treatment prior to disposal in a Subtitle C disposal facility.

TSCA Waste
PCBs were not detected in sediment at concentrations exceeding 50 mg/kg during the RI. Should PCBs at concentrations exceeding 50 mg/kg be removed from the Site, the waste is assumed to be disposed at a TSCA disposal facility.

3.4.9.2 CDF Performance Standards

EPA established CDF performance standards for use in evaluating CDFs during the FS. These address short-term impacts during CDF construction and filling, medium-term impacts during dormant periods between CDF filling seasons and before final closure, and long-term impacts following final closure of the CDF. A summary of how these standards were addressed in the T4 60 Percent Design are shown in **Table 3.4-7a-c**. CDF acceptance criteria include the following:

- **No Hazardous Waste.** Sediment that would be designated as RCRA or State hazardous waste, whether listed waste or characteristic waste, are not eligible for placement in the CDF.

- **Waste or Contaminated Media Warranting Additional Management.** Sediment designated as a "Waste or Media containing Waste that May Warrant Additional Management" are not eligible for placement in the CDF due to concerns of contaminant mobility without adequate treatment. Such waste are not evaluated as eligible for placement in the CDF.

- **No PTW that is Highly Mobile.** Contaminated sediment identified as PTW that are highly mobile (cannot be reliably contained) are assumed to not be eligible for placement in the CDF without adequate treatment.

- **No Free Oil.** Sediment containing free oil or NAPL are PTW and not eligible for placement in the CDF.

- **Suitable Geotechnical Properties.** The geotechnical properties of the fill materials must be of an acceptable quality such that they do not affect the long-term performance of the CDF. Fill materials must be free of debris and significant organics, like wood chips, which could cause unacceptable obstructions, settlement, or gas generation.

- **Suitable Geochemical Properties.** The geochemical properties of the contaminated dredged sediment, primarily their leaching characteristics, must be shown to provide long-term protection of human health and the environment and the beneficial uses of the Willamette River.

- **Other Considerations.** Other factors may be considered in determining acceptability of contaminated dredged material such as the physical nature of the material, nature of the chemical contaminants, and quantity of material.

Maximum contaminant concentrations in sediment suitable for placement in the CDF were derived in the T4 60 Percent Design (Anchor QEA 2011) and are provided in Appendix E. Dredged sediment and excavated soil identified as PTW are assumed for purposes of FS cost estimates to not meet one or more of the identified acceptance criteria of the CDF and therefore need to be disposed of in a RCRA Subtitle D or C landfill.

3.4.9.3 Capacity of Disposal Facilities

An important factor in the development of remedial alternatives is the volumetric capacity of the disposal options as compared to the volumes of sediment that may be removed from the Site. The capacities of the various disposal options are summarized in the following sections.

Upland Commercial Landfills
The capacity of the Roosevelt Regional RCRA Subtitle D facility is essentially unlimited relative to the volume of sediment expected to be dredged from the Site. This facility accepts a wide range of wastes, is permitted to accept materials with free liquid, and can accept wastes transported by rail, barge, or trucking. Roosevelt has moderately high tipping fees when compared to a RCRA Subtitle C facility. Because it is located in Washington State, additional regulations concerning the transport and disposal of materials, including consideration of State of Washington Dangerous Waste regulations will need to be addressed.

Material that is not acceptable for disposal in a RCRA Subtitle D facility will be disposed of at a RCRA Subtitle C landfill. Only a small volume of dredged materials that do not meet RCRA Subtitle D acceptance criteria are expected to be generated. The capacity of the Chem Waste landfill example used in this FS is essentially unlimited with respect to the volume of hazardous wastes and other waste anticipated to be dredged from the Site for disposal in a RCRA Subtitle C facility. Wastes to be disposed of in this landfill must pass the paint-filter test. The Chem Waste Landfill can accept wastes transported by rail, barge, or trucking and has the highest disposal costs. Wastes that may warrant special management considerations due to the nature of the waste may be considered for RCRA Subtitle C management to ensure long-term protectiveness.

Terminal 4 CDF

Based on the current design, the capacity of the Terminal 4 CDF is 670,000 cubic yards of dredged contaminated sediment. This estimate does not include the volume that is expected to be gained due to consolidation settlement of the placed material and native sediment as the facility is filled. The current design analysis estimates that an additional 200,000 cy of contaminated sediment capacity may be gained by consolidation. The volumetric capacity of the CDF relative to the estimated volume of sediment to be dredged from the Site and acceptable for placement is a factor in determining the viability of constructing a CDF. Not all material removed from the Site is acceptable for disposal in the CDF; therefore, it was assumed that approximately 150 percent of the volume capacity of the CDF (670,000 cy), or approximately 1,005,000 cy, would be necessary to ensure sufficient quantity of material to justify the CDF's construction. By comparison, the capacity of the Roosevelt Regional Landfill and Chem Waste Landfill are approximately 90 million and 247 million cy, respectively. A conceptual plan of the proposed Terminal 4 CDF is shown on **Figure 3.4-37** and described in detail in 60 Percent Design (Anchor QEA 2011).

3.5 ENHANCED NATURAL RECOVERY AREAS

ENR may be used where natural recovery appears to be an appropriate remedy, yet the rate of sedimentation or other natural processes is insufficient to reduce risks within an acceptable time frame. Thin-layer placement normally accelerates natural recovery by adding a layer of clean sediment over contaminated sediment. The acceleration can occur through several processes, including increased dilution through bioturbation of clean sediment mixed with underlying contaminants. Thin-layer placement is different than the isolation caps and does not require long-term monitoring and ICs.

3.5.1 Identification of ENR Areas

Analysis of data collected during RI and information presented in the draft FS (Anchor QEA 2012) indicate that MNR is not occurring in Swan Island Lagoon at a rate sufficient to reduce risks within an acceptable time frame. There is limited water circulation within Swan Island Lagoon, further limiting the rate of sediment deposition and clean upriver sediment from entering this area of the Site. Since MNR is not considered a viable technology in this area, capping, dredging, and ENR are considered for meeting the PRGs in an acceptable time frame. An evaluation of using ENR in addition to capping and dredging to offset duration of construction and cost while still reducing risk in an acceptable time frame is provided in Appendix D. Therefore, ENR is being considered for the area in Swan Island Lagoon that is outside the SMAs to reduce risks. Where PTW is identified, treatment technologies will be also be assigned.

3.5.2 Technologies Applied

ENR is accomplished through the placement of a 12-inch layer of sand, which is expected to be sufficient to allow for mixing with the underlying sediment bed while also retaining clean sand above the mixed interval to minimize the potential for exposure to underlying material through bioturbation. In areas where PTW is present, 5 percent activated carbon is added to the sand layer. The thickness and composition of the ENR layer will be determined during remedial design.

3.6 MONITORED NATURAL RECOVERY AREAS

All other areas of the Site that exceed PRGs and have not been assigned a technology will be addressed using natural recovery processes. Natural recovery typically uses ongoing, naturally occurring processes to contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment. These processes may include physical (sedimentation or dispersion), biological (biodegradation), and chemical (sorption and oxidation) mechanisms that act together to reduce the risks posed by contaminants.

3.6.1 Evidence for MNR

Natural recovery processes (Magar et al 2009), including chemical transformation, reduction in contaminant mobility and bioavailability, physical isolation (or burial), and dispersion, are occurring to varying degrees throughout the lower Willamette River. MNR should be considered as a stand-alone remedy only when it would meet RAOs within a timeframe that is reasonable compared to remedies such as dredging and capping (USEPA 2005). Several of the factors affecting “reasonable” timeframes are present at the Site and include the following:

- The extent and likelihood of human exposure to contaminants during the recovery period could be significant given the large expanse of the Willamette River and the various recreational uses of the river. ICs may be implemented at the Site but have limitations as discussed in Section 3.6.3, below.

- Significant ecological resources, including threatened and endangered species, exist within the Willamette River.

- Multiple uses of the river are ongoing; some of these uses, such as navigation dredging, ship anchorage, fishing, and others, can affect contamination existing within surface and subsurface sediment.

- There is significant uncertainty with timeframe predictions for use of MNR as a stand-alone remedy.

For the purposes of the FS, it is expected physical isolation through natural deposition of cleaner material and dispersion and mixing are the primary mechanisms for natural recovery at the Site. Since the alternatives address varying volumes of the most contaminated sediment in the river, eliminating these source areas will promote and accelerate the natural recovery processes. MNR includes monitoring to assess the effectiveness that these natural processes are occurring but does not include physical remedial measures. Key aspects of the conditions present at the Site for MNR are presented below.

3.6.1.1 Incoming Sediment Particle Concentrations

Analysis of upstream sediment trap and suspended solids data indicate incoming sediment COC concentrations are lower than sediment concentrations in the Site. As one example, upstream surface water sampling events conducted over a range of flow conditions at RM 16 found incoming suspended sediment particle PCB concentrations varied between 1.5 and 23.6 µg/kg while the surface sediment concentrations at the Site ranged from <1 to 35,400 µg/kg. Therefore, MNR may be effective at some locations in the Site.

3.6.1.2 Sediment Deposition Rate

Burial is an important mechanism for natural recovery. Over time, cleaner sediment deposits on top of more contaminated sediment, decreasing contaminant exposure. Sediment deposition is well documented in areas of the Willamette. A clear example of the depositional nature of the river is in areas of the harbor where routine navigation dredging is needed and conducted. When an area of the river bed is excavated, the remaining cavity acts as a natural sediment trap.

Since the 40-foot channel improvement project in the 1960s, navigation maintenance dredging on the Willamette River federal navigation channel is typically required on a 3- to 5-year cycle, with amounts of dredged material varying between cycles and locations on the river. The total volume of maintenance dredging in the navigation channel between 1973 and 1995 was approximately 4.4 million cy, equating to an average of about 200,000 cy per year. Location-specific determinations of deposition can also be obtained from analyzing bathymetric surveys. A series of high resolution bathymetric surveys were conducted within the Portland Harbor Study Area at five different times between 2002 and 2009 (January 2002, July/September 2002, May 2003, February 2004, and January 2009). These can be used to estimate the depth of sediment deposition over the timeframes for the areas encompassed by the surveys.

One of the limitations associated with using bathymetric survey pairs to estimate sediment deposition is that the surveys are a “snapshot” in time and may not represent the dynamic nature of the sediment bed over time. As an example, **Figure 3.6-1** shows the bathymetric change in an SMA between RMs 5 and 6. The survey pairs range from generally erosional, to stable, to depositional between sequential survey pairs. This figure illustrates the dynamic nature of the sediment bed and the uncertainty associated with the conclusion that elevation changes between two surveys progressed evenly over time. This type of sediment bed behavior may also influence natural recovery: the process of burial would be interrupted during erosive periods, but dispersion would increase, if contaminated sediment was eroded.

The consistency of erosion or deposition processes between the different bathymetric surveys (the 5 different surveys have 10 different potential pairs for a bathymetric change analysis) were evaluated, and the results are presented on **Figure 3.6-2a-h**. Four types of results were generated:

- Consistently erosional: all 10 pairs were either neutral or >2.5 cm/year;
- Consistently depositional: all pairs were either neutral or <-2.5 cm/year;
- Consistently neutral: all pairs were between -2.5 and +2.5 cm/yr; and
- Dynamic equilibrium where there was a mix of results.

This analysis indicates that most of the Site is in dynamic equilibrium where both erosion and deposition occur. In many areas of the Site, the determination of deposition and the assertion that burial is a viable long-term recovery mechanism is largely dependent on which survey pair is selected.

Another challenge with using bathymetric surveys to indicate deposition rates is the incomplete coverage in the shallow region because it is difficult for survey boats to maneuver and obtain quality data. It is also the case that many of the areas of interest are also in the shallow region. The lack of information in these areas of interest lessens the ability to determine whether natural recovery is occurring.

The effectiveness of MNR will be dependent in large part on the rate of deposition. Two bathymetric surveys conducted in 2003 and 2009 were used in assessing whether areas at the Site were depositional. The typical bathymetric survey measurement error range is 0.5 feet, resulting in an uncertainty range of 1 foot for bed elevation changes between the two surveys. The uncertainty range in a single direction would be 6 inches, which equates to roughly 1 inch (2.5 cm) per year for the period between the May 2003 and January 2009 surveys. Therefore, a minimum deposition rate of 2.5 cm/year was assumed as the criteria for effective MNR.

3.6.1.3 Fish Tissue Contaminant Concentration Trends

Individual smallmouth bass were sampled in 2007, 2011, and 2012 and analyzed for PCBs. An evaluation of fish tissue concentrations over this time period was performed to evaluate the degree of natural recovery taking place at the Site. The most robust fish tissue data set exists for smallmouth bass and PCBs: smallmouth bass were the only fish collected during all fish tissue collection efforts, and PCBs were the only COCs analyzed in 2011 and 2012 fish tissue samples. Although there were some methodological inconsistencies between the surveys, the entire 2007-2012 data set (whole body fish analyzed for PCBs) was analyzed, grouped by side of river and river mile, ranging from

RM 2 through RM 11. An analysis of covariance model was fit to the data, including discrete terms representing river mile and east-west groupings and a continuous term representing year. In all but two instances (RMs 4E and 7E), concentration declines were not statistically distinguishable from zero. Possible explanations are the trend itself is close to zero, or the estimated coefficient could be very different from zero with a very wide confidence interval. The former would imply that the decay rate is small and that it is simply close to zero with strong level of confidence, whereas the latter indicates that the data are too sparse to precisely estimate the decay rate. Although the small sample size, limited number of time points, and inconsistency of in sampling methodology contribute to the uncertainty, the 2007 and 2012 fish tissue data will serve as a baseline for future evaluations of fish tissue PCB concentrations. However, baseline data for other bioaccumulative contaminants will need to be established in remedial design.

3.6.2 Monitoring

Monitoring is an integral component of MNR, and will be conducted to evaluate the long-term effectiveness. The monitoring program will include sediment, surface water, pore water, and fish tissue samples collected at the following frequencies:

- Remedial Baseline Monitoring will be conducted prior to implementation of remedial activities to gage the performance of the remedy.
- Short-term Remedial Monitoring is assumed to be conducted every 2 years during implementation of remedial measures.
- Long-term Monitoring is assumed to commence the year following completion of remedy implementation and take place every 2 to 3 years for the first 10 years and once every 5 years thereafter until remedial goals are achieved.

It is expected that the state, the tribes and the Natural Resource Trustees will continue to have significant roles in developing and implementing monitoring activities for the site.

3.6.3 Institutional Controls

ICs will be used to prevent or limit exposure to contaminants on both a short- and long-term basis.

Fish Consumption Advisories: Fish consumption advisories would be required until such time as RAO 2 is achieved as demonstrated through fish tissue monitoring. The existing advisory would need to be revised by the state in conjunction with the final remedial action. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be evaluated to determine advisory effectiveness.

3.7 COST

Cost estimates are developed according to *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (USEPA 2000). The levels of detail employed in making these estimates are conceptual but are considered appropriate for differentiating between alternatives. The cost estimates are based on the best available information regarding the anticipated scope of the respective remedial alternatives.

Cost estimates are developed for each remedial action alternative based on the RI data to define the scope of each alternative. Due to the uncertainty in RI data, the accuracy of cost estimates is less precise than estimates developed later in the design phase. The types of costs estimated include the following: (1) capital costs, including both direct and indirect costs; (2) annual O&M costs; and (3) net present value of capital and O&M costs (40 CFR 300.430 (e)(9)(iii)(G)). Remedial action alternative cost estimates for the detailed analysis are intended to provide a measure of total resource costs over time ("life cycle costs") associated with any given alternative. Cost estimates for detailed analysis of alternatives are developed with expected accuracy ranges of -30 to +50 percent of actual cost, as identified in the NCP.

Capital Costs: Capital costs are expenditures required to construct each alternative. They are exclusive of costs required to operate or maintain the remedial action throughout its lifetime. Capital costs, direct and indirect, consist primarily of expenditures initially incurred to build or install the alternative. Direct capital costs include all labor, equipment, and material costs associated with activities such as mobilization/demobilization; monitoring; site work; installation of dredging, containment, or treatment systems; and disposal. Indirect capital costs include contractor markups, such as overhead and profit, and expenditures for professional/technical services that are necessary to support construction and installation of the remedial action.

Annual Operation and Maintenance (O&M) Costs: These are post-construction costs necessary to ensure or verify the continued effectiveness of each remedial alternative. These costs are estimated on an annual basis and include all labor, equipment, and material costs and monitoring. Annual O&M costs also include expenditures for professional/technical services necessary to support O&M activities. Since the maintenance and monitoring activities identified for evaluation in the FS are assumed to occur on a recurring but periodic basis rather than annually, annual O&M costs are included as periodic costs.

Periodic Costs: These costs occur only once every few years (such as 5-year reviews and equipment replacement) or expenditures that occur only once or a few times during the entire O&M period or remedial time frame (such as at site closeout or remedy component repair/replacement). These costs may be either capital or O&M costs, but because of their periodic nature, typically it is more practical to consider them separately from other capital or O&M costs in the estimating process. Since the maintenance and monitoring activities identified for evaluation in the FS are assumed to occur on a recurring but periodic basis rather than annually, the alternatives include these activities as periodic costs.

Present Value Cost: The present value cost represents the amount of money that, if invested in the initial year of the remedial action at a given discount rate, would provide the funds required to make future payments to cover all costs associated with the remedial action over its planned life. Future O&M and periodic costs are included and discounted (reduced) by the appropriate present value discount rate over the period of analysis selected for each alternative. The present value was calculated based on a 7 percent real discount rate as recommended in *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (USEPA 2000). Also, per guidance, inflation and depreciation are not considered in preparing the present value costs.

The alternatives retained for detailed analysis all have containment components and thus have indefinite project durations and likely require perpetual maintenance. The assumed period of analysis used to develop estimates of present value costs for each alternative is 30 years although a 100-year period of analysis was also evaluated as part of sensitivity analysis presented in Appendix N since the costs of maintaining the caps will continue in perpetuity.

A “no-discounting” scenario is also included for the present value analysis of each alternative as recommended by the guidance for long-term projects (for example, project duration exceeding 30 years). A non-discounted constant dollar cash flow over time demonstrates the impact of a discount rate on the total present value cost and the relative amounts of future annual expenditures. Non-discounted constant dollar costs are presented for comparison purposes only and should not be used in place of present value costs in the Superfund remedy selection process.

The quantities used to develop costs are based on the assumptions presented earlier in this section and are presented in Appendix D. Detailed costs and supporting information associated with implementing the alternatives are presented in Appendix G. A summary of the costs for each Alternative is presented in **Table 3.7-1**.

3.8 DEVELOPMENT OF ALTERNATIVES

Remedial alternatives were assembled by combining the retained remedial technologies and process options identified in Section 2.4. Nine remedial alternatives were developed, including the no action alternative, based on the technology assignment assumptions presented earlier in this Section. Consistent with EPA guidance (USEPA 2005), a combination of remedial technologies and process options have been assembled into each alternative to account for variability in conditions throughout the Site. This combined approach is expected to effectively protect human health and the environment and achieve RAOs and PRGs for the Site within a reasonable timeframe.

Remedial alternatives developed for this FS include the no action alternative (designated as Alternative A), as required by the NCP, and eight remedial alternatives (designated as

Alternatives B through I) that apply the same suite of remedial technologies and process options to varying degrees based on site-specific characteristics. A summary of the Alternatives is presented in **Table 3.8-1**.

3.8.1 Common Elements

There are several elements common to Alternatives B through I. This section describes those common elements.

Technology Assignments
Flowcharts of the technology assignment process that apply to the navigation channel and FMD region, intermediate region, shallow region, and river banks are presented on **Figures 3.8-1a-d**. The primary differences between the alternatives is the size of the footprint of removal and containment based on the area of the SMAs defined for each alternative, as shown on **Figures 3.8-2a-f** through **3.8-9a-f**. The area of each assigned technology is presented in detail in **Table 3.8-2a-b** and summarized in **Table 3.8-3** Additional information on material volumes is provided in **Tables 3.8-4** and **3.8-5**

Navigation Channel and FMD Region
Contaminated sediment is assumed to be dredged to the depth of the RAL concentrations.[10] If NAPL or PTW that is not reliably contained has been identified in a dredge area, a reactive residual layer is assumed after dredging occurs. Otherwise, a residual layer is assumed after dredging occurs.

Intermediate Region
Contaminated sediment is assumed to be dredged to the lesser of the RAL concentrations or 15 feet (assumed maximum depth since special design and side slope stabilization considerations would need to be conducted on an area-specific basis). If NAPL or PTW that is not reliably contained has been identified in a dredge area, then either a significantly augmented reactive cap or a reactive residual layer is assumed after dredging occurs. Otherwise, a residual layer is assumed after dredging occurs.

Shallow Region
Contaminated sediment is assumed to be dredged to the lesser of the RAL concentrations or a maximum depth of 5 feet, and the dredged material will be replaced with clean backfill with a beach mix cover to previous elevation. If the RAL concentrations are not expected to be reached within 5 feet, the contaminated sediment will be dredged 3 feet and replaced with an engineered cap.

If NAPL or PTW that is not reliably contained is present within an SMA, the contaminated sediment is assumed to be dredged to the lesser of the RAL concentrations or 15 feet. The dredge prism is assumed to be replaced with a reactive residual layer, filled with sand to within 6 inches of the original elevation, and the last 6 inches will be beach mix. If NAPL or PTW that is not reliably contained extends to depths greater than 15 feet, a reactive cap is assumed to be placed at the bottom of the dredge prism, the

[10] That is dredging to the depth of where the concentration meets or is below the RAL.

remainder of the dredge prism is assumed to be replaced with sand to within 1 foot of the previous elevation, and the last 1 foot will be beach mix.

If PTW that can be reliably contained is present within an SMA, contaminated sediment is assumed to be dredged to the lesser of the RAL concentrations or a maximum depth of 5 feet, and the dredged material is assumed to be replaced with a reactive residual layer, backfilled with sand, and covered with 6 inches beach mix to the existing elevation. If the RAL concentrations are not expected to be reached within 5 feet, the contaminated sediment will be dredged 3 feet and replaced with an armored reactive cap.

River Banks
If NAPL or PTW that is not reliably contained is present, a reactive armored cap is assumed.

Remedy Implementation
For the purposes of the FS and developing remedial alternatives, the sequence of dredging is assumed to be from RM 11.8 to RM 1.9. However, during remedy design and construction, it may be more effective to deviate from this approach.

All the alternatives assume the remedy will be implemented as described. That is, there would be no changes identified during remedial design. Due to the uncertainty inherent at Superfund sites, there will be adjustments made throughout the design and construction process.

Dredged Material
Removed material that is considered for low temperature thermal desorption treatment is assumed to be treated at the disposal facility. All other types of treatment previously discussed in Section 3.2.2.3 are assumed to occur within barges prior to transport to the disposal facilities.

The dredged material removed from the Site would be managed in accordance with one of the two disposed material management (DMM) scenarios:

- DMM Scenario 1: Confined Disposal Facility and Off-site Disposal. This scenario is only applied to Alternatives E through I because the estimated dredge volumes under these alternatives are adequate for placement in the CDF. Alternatives B through D did not meet the 1,005,000 cy of sediment threshold to justify construction of a CDF.

- DMM Scenario 2: Off-Site Disposal. This scenario is applied to all alternatives.

All material to be disposed in an on-site disposal facility would be barged directly to the CDF. There is no existing transfer facility within the Site to facilitate off-site disposal. Unless an on-site transfer facility is constructed, the most likely mode of transportation will be to barge the dredged material to an off-site transloading facility on the Columbia River and then truck or rail it to the off-site disposal facility. Should an on-site transported facility be constructed, it is most likely that the material would be transloaded to an off-site disposal facility via rail. Little, if any, dredged material is expected to be trucked from an on-site transloading facility to the off-site disposal facility.

Institutional Controls

Fish consumption advisories would be implemented after construction until PRGs are met. All caps will require waterway use or regulated navigation restrictions and land use or access restrictions, long-term monitoring, and O&M.

3.8.2 Alternative A: No Action

The No Action Alternative does not include any actions beyond the early actions implemented at the Gasco and Terminal 4 sites in 2005 and 2008, respectively. The OHA would be expected to continue the fish consumption advisories already in place under State legal authorities but are not part of a CERCLA action, and the No Action Alternative does not include implementation of any new ICs or monitoring as a part of a CERCLA action for the Site. There are no costs associated with this alternative.

3.8.3 Alternative B

Alternative B has a total constructed area of 201 acres sediment and 9,633 lineal feet of river bank, will allow 1,966 acres of sediment to naturally recover, and will not address 20,416 lineal feet of known contaminated river bank.

The construction of this alternative includes 95.0 acres of capping and dredging contaminated sediment, 99.8 acres of ENR, and 6.7 acres of in-situ treatment. Additionally, 9,633 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation.

This alternative involves dredging of approximately 72.2 acres sediment to varying depths (494,000 to 659,000 cy) and excavating approximately 51,000 cy soil. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. Dredged and excavated material would be managed under DMM Scenario 2 for this alternative.

Estimated volumes of material[11] that would be needed for containment, residuals management, and in-situ treatment for sediment and riverbanks are:

- Sand – 387,000 cy
- Very fine, low-permeability sand – 8,400 cy
- Beach mix – 19,000 cy

[11] All material quantities are expressed as neat measurements and are summations of in-water quantities from Table 3.8-4 and riverbank quantities from Table 3.8-5. These summations may vary from the itemized quantities presented in Appendix D.2 due to rounding in Table 3.8-4.

- Armor – 30,000 cy
- Organoclay mats – 490 cy
- AquaBlok™ – 1,600 tons
- AquaGate+10%PAC – 50,000 tons

The design concept for Alternative B is shown on **Figure 3.8-2a-f**, and the proportion of the Site assigned each technology is presented on **Figure 3.8-10**. In-river construction duration for this alternative is estimated to be 4 years, with no additional time required to complete dredged material processing (i.e., dewatering and sampling for disposal parameters). The following alternative-specific schedule timeframes have been estimated:

- Year 0[12]: Establish initial conditions
- Year 0[13]: Construction of on-site material handling/treatment facility (if applicable)
- Year 0[14]: Start-up activities and mobilization, including pre-design investigations
- Years 1 and 2: Construct alternative
- Year 3: Demobilization and mitigation

3.8.3.1 Navigation Channel and FMD Region

Navigation Channel
The estimated area to be dredged is 34.2acres:

- 32.2 acres are dredged to 0 to 5 feet
- 1.8 acres are dredged to 5 to 10 feet
- 0.1 acre is dredged to 10 to 15 feet

Ex-situ treatment is assumed for 30,200 to 40,300 cy of the dredged material. In the areas dredged, 7.3 acres are covered with a reactive residual layer, and 26.9 acres are covered with a residual sand layer.

[12] Monitoring (sampling) of sediment, water, biota, and pore water will need to be the first phase, and it will encompass the entire Site to establish a baseline and delineate the SMAs for construction. It is expected that this phase will take 3 to 5 years.
[13] If a location for an on-site material handling/treatment facility is determined, construction of the facility would occur prior to construction activities.
[14] Year 0 is the first year of construction.

FMD
The estimated area to be dredged is 14.9 acres:

- 12.7 acres are dredged to 0 to 5 feet
- 2.1 acres are dredged to 5 to 10 feet
- 0.1 acre is dredged to 10-15 feet

Ex-situ treatment is assumed for 11,600 to 15,500 cy of the dredged material[15]. In the areas dredged, 14.6 acres are covered with a reactive residual layer, and 0.4 acre is covered with a residual sand layer. The estimated area of ENR is 87.8 acres.

3.8.3.2 Intermediate Region

The estimated area to be dredged is 9.0 acres:

- 4.7 acres are dredged to 0 to 5 feet
- 1.5 acres are dredged to 5 to 10 feet
- 2.3 acres are dredged to 10 to 15 feet
- 0.5 acre to be dredged to 15 to 17 feet

Ex-situ treatment is assumed for 85,800 to 114,400 cy of the dredged material. In the areas dredged, 0.4 acre is covered with significantly augmented reactive cap, 8.5 acres are covered with a reactive residual layer, and 0.2 acre is covered with a residual sand layer.

The area estimated to be capped is 22.0 acres: 3.1 acres of reactive cap, 2.8 acres of armored cap, 1.4 acre of AquaBlok™, 12.8 acres of reactive armored cap, 1.1 acre of significantly augmented reactive cap, and 0.8 acre of engineered cap. The estimated area of in-situ treatment is 6.7 acres, with 12.0 acres of ENR.

3.8.3.3 Shallow Region

The estimated area to be dredged is 14.1 acres:

- 12.7 acres are dredged to 5 feet
- 1.0 acre is dredged to 10 feet

[15] This volume includes the subset of the NRC/NAPL PTW volume from SDU 7W that is assumed to only receive pretreatment (dewatering using diatomaceous earth); however, pretreatment does not irreversibly treat the contaminants or reduce the mass of the contaminants through treatment. This note applies to other instances within Section 3 text of the total volume of sediments for ex situ treatment subdivided by region for all alternatives.

- 0.3 acre is dredged to 15 feet

Ex-situ treatment is assumed for 41,100 to 54,800 cy of the dredged material. Within the dredged areas, 2.8 acres are estimated to be covered with backfill, 5.0 acres with a reactive cap, 6.1 acres with a reactive residual layer, and 0.2 acres of significantly augmented reactive cap.

3.8.3.4 River Bank Region

An estimated 9,633 lineal feet of riverbank will be removed and ex-situ treatment is assumed for 9,500 cy of the excavated material. Within the excavated area, 8.5 acres are estimated to be covered with an engineered cap and 2.0 acres with a significantly augmented reactive cap.

3.8.3.5 Cost

Total capital costs estimated for this alternative are $352,097,000 over 4 years. Total periodic costs (including O&M) are $290,324,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $642,421,000, with a net present value cost of $451,460,000. Detailed costs associated with implementing Alternative B are presented in Appendix G and summarized in **Table 3.7-1**.

3.8.4 Alternative C

Alternative C has a total constructed area of 219 acres of sediment and 11,047 lineal feet of river bank, will allow 1,948 acres of sediment to naturally recover, and will not address 19,002 lineal feet of known contaminated river bank.

The construction of this alternative includes 116.8 acres of capping and dredging contaminated sediment, 97.4 acres of ENR, and 5.0 acres of in-situ treatment. Additionally, 11,047 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation.

This alternative involves dredging of approximately 86.6 acres sediment to varying depths (592,000 to 790,000 cy) and excavating approximately 58,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy of sediment and 9,500 cy of soil. Dredged and excavated material would be managed under DMM Scenario 2 for this alternative.

Estimated volumes of material that would be needed for containment, residuals management, and in-situ treatment for sediment and riverbanks are:

- Sand – 436,000 cy
- Very fine, low-permeability sand – 8,400 cy

- Beach mix – 23,000 cy
- Armor – 37,000 cy
- Organoclay mats – 490 cy
- AquaBlok™ – 2,200 tons
- AquaGate+10%PAC – 57,000 tons

The design concept for Alternative C is shown on **Figure 3.8-3a-f**, and the proportion of the Site assigned each technology is presented on **Figure 3.8-11**. In-river construction duration for this alternative is estimated to be 5 years, with no additional time required to complete dredged material processing (i.e., dewatering and sampling for disposal parameters). The following alternative-specific schedule timeframes have been estimated:

- Year 0: Establish initial conditions
- Year 0: Construction of on-site material handling/treatment facility (if applicable)
- Year 0: Start-up activities and mobilization including pre-design investigations
- Years 1 through 3: Construct alternative
- Year 4: Demobilization and mitigation

3.8.4.1 Navigation Channel and FMD Region

Navigation Channel
The estimated area to be dredged is approximately 40.8 acres:

- 38.4 acres are dredged to 0 to 5 feet
- 2.3 acre is dredged to 5 to 10 feet
- 0.1 acre is dredged to 10 to 15 feet

Ex-situ treatment is assumed for 30,200 to 40,300 cy of the dredged material. In the areas dredged, 8.1 acres are covered with a reactive residual layer, and 32.6 acres are covered with a residual sand layer.

FMD
The estimated area to be dredged is 18.9 acres:

- 16.4 acres are dredged to 0 to 5 feet
- 2.3 acres are dredged to 5 to 10 feet

- 0.1 acre is dredged to 10 to 15 feet

Ex-situ treatment is assumed for 11,600 to 15,500 cy of the dredged material. In the areas dredged, 17.7 acres are covered with a reactive residual layer, and 1.2 acre is covered with a residual sand layer. The estimated area of ENR is 85.5 acres.

3.8.4.2 Intermediate Region

The estimated area to be dredged is around 9.4 acres:

- 5.1 acres are dredged to 0 to 5 feet
- 2.2 acres are dredged to 5 to 10 feet
- 1.5 acres are dredged to 10 to 15 feet
- 0.7 acre to be dredged to 15 to 17 feet

Ex-situ treatment is assumed for 85,800 to 114,400 cy of the dredged material. In the areas dredged, 8.7 acres are covered with a reactive residual layer, 0.4 acre is covered with a residual sand layer, and 0.4 acre is covered with significantly augmented reactive cap.

The area estimated to be capped is 29.3 acres: 15.6 acres of armored reactive cap, 4.7 acres of reactive cap, 4.5 acres of armored cap, 1.6 acres of engineered cap, 1.9 acres AquaBlok™, and 1.1 acre significantly augmented reactive cap. The area of in-situ treatment is estimated to be 5.0 acres, with 11.9 acres of ENR.

3.8.4.3 Shallow Region

The estimated area to be dredged is 17.5 acres:

- 16.2 acres are dredged to 5 feet
- 1.0 acre is dredged to 10 feet
- 0.3 acre is dredged to 15 feet

Ex-situ treatment is assumed for 41,100 to 54,800 cy of the dredged material. It is also estimated that within the dredged areas, the following residual layers are used: 4.6 acres backfill, 0.2 acre significantly augmented reactive cap, 5.9 acres reactive cap, and 6.9 acres reactive residual layer.

3.8.4.4 River Bank Region

An estimated 11,047 lineal feet of riverbank will be removed and ex-situ treatment is assumed for 9,500 cy of the excavated material. Within the excavated area, 10.1 acres are estimated to be covered with an engineered cap and 2.0 acres with a significantly augmented reactive cap.

3.8.4.5 Cost

Total capital costs estimated for this alternative are $400,933,000 over 5 years. Total periodic costs (including O&M) are $317,464,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $718,397,000, with a net present value cost of $496,760,000. Detailed costs associated with implementing Alternative C are presented in Appendix G and summarized in **Table 3.7-1**.

3.8.5 Alternative D

Alternative D has a total constructed area of 267 acres sediment and 13,887 lineal feet of river bank, will allow 1,900 acres of sediment to naturally recover, and will not address 16,161 lineal feet of known contaminated river bank.

The construction of this alternative includes 176.9 acres of capping and dredging contaminated sediment, 87.0 acres of ENR, and 3.2 acres of in-situ treatment. Additionally, 13,887 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation.

This alternative involves dredging of approximately 132.1 acres sediment to varying depths (950,000 to 1,266,000 cy) and excavating approximately 73,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. Dredged and excavated material would be managed under DMM Scenario 2 for this alternative.

Estimated volumes of material that would be needed for containment, residuals management, and in-situ treatment for sediment and riverbanks are:

- Sand – 550,000 cy
- Very fine, low-permeability sand – 8,400 cy
- Beach mix – 32,000 cy
- Armor – 53,000 cy
- Organoclay mats – 490 cy
- AquaBlok™ – 3,700 tons
- AquaGate+10%PAC – 79,000 tons

The design concept for Alternative D is shown on **Figure 3.8-4a-f**, and the proportion of the Site assigned each technology is presented on **Figure 3.8-12**. In-river construction duration for this alternative is estimated to be 6 years, with no additional time required to complete dredged material processing (i.e., dewatering and sampling for disposal parameters). The following alternative-specific schedule timeframes have been estimated:

- Year 0: Establish initial conditions
- Year 0: Construction of on-site material handling/treatment facility (if applicable)
- Year 0: Start-up activities and mobilization, including pre-design activities
- Years 1 through 4: Construct alternative
- Year 5: Demobilization and mitigation

3.8.5.1 Navigation Channel and FMD Region

Navigation Channel
The estimated area to be dredged is 60.7 acres:

- 52.8 acres are dredged to 0 to 5 feet
- 7.8 acres are dredged to 5 to 10 feet
- 0.1 acre is dredged to 10 to 15 feet

Ex-situ treatment is assumed for 30,200 to 40,300 cy of the dredged material. In the areas dredged, 14.2 acres are covered with a reactive residual layer, and 46.4 acres are covered with a residual sand layer.

FMD
The estimated area to be dredged is 34.9 acres:

- 29.6 acres are dredged to 0 to 5 feet
- 4.7 acres are dredged to 5 to 10 feet
- 0.6 acre is dredged to 10 to 15 feet

Ex-situ treatment is assumed for 11,600 to 15,500 cy of the dredged material. In the areas dredged, 30.0 acres are covered with a reactive residual layer, and 4.9 acres are covered with a residual sand layer. The estimated area of ENR is 77.0 acres.

3.8.5.2 Intermediate Region

The estimated area to be dredged is 10.2 acres:

- 5.7 acres are dredged to 0 to 5 feet
- 2.1 acres are dredged to 5 to 10 feet
- 1.6 acres are dredged to 10 to 15 feet
- 0.8 acre is dredged to 15 to 17 feet

Ex-situ treatment is assumed for 85,800 to 114,400 cy of the dredged material. In the areas dredged, 9.1 acres are covered with a reactive residual layer, 0.7 acre is covered with a residual sand layer, and 0.4 acre is covered with significantly augmented reactive cap.

The estimated area to be capped is 43.5 acres: 20.4 acres of armored reactive cap, 6.1 acres reactive cap, 8.8 acres of armored cap, 3.3 acres of AquaBlok™, 1.1 acre of significantly augmented reactive cap, and 3.8 acres of engineered cap. The area of in-situ treatment is estimated at 3.2 acres, with 10.0 acres of ENR.

3.8.5.3 Shallow Region

The estimated area to be dredged is 26.3 acres:

- 25.0 acres are dredged to 5 feet
- 1.0 acre is dredged to 10 feet
- 0.3 acre is dredged to 15 feet

Ex-situ treatment is assumed for 41,100 to 54,800 cy of the dredged material. In the areas dredged, the following residual layers are used: 8.0 acres backfill, 1.3 acre engineered cap, 9.2 acres reactive cap, 7.7 acres reactive residual layer, and 0.2 acre significantly augmented reactive cap.

3.8.5.4 River Bank Region

An estimated 13,887 lineal feet of riverbank will be removed and ex-situ treatment is assumed for 9,500 cy of the excavated material. Within the excavated area, 13.2 acres are estimated to be covered with an engineered cap and 2.0 acres with a significantly augmented reactive cap.

3.8.5.5 Cost

Total capital costs estimated for this alternative are $556,004,000 over 6 years. Total periodic costs (including O&M) are $397,028,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $953,032,000, with a net present value cost of

$653,700,000. Detailed costs associated with implementing Alternative D are presented in Appendix G and summarized in **Table 3.7-1**.

3.8.6 Alternative E

Alternative E has a total constructed area of 329 acres sediment and 18,231 lineal feet of river bank, will allow 1,838 acres of sediment to naturally recover, and will not address 11,817 lineal feet of known contaminated river bank.

The construction of this alternative includes 269.3 acres of capping and dredging contaminated sediment and 59.8 acres of ENR. Additionally, 18,231 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation.

This alternative involves dredging of approximately 203.7 acres sediment to varying depths (1,653,000 to 2,204,000 cy) and excavating approximately 96,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative E would be managed in one of two disposal scenarios:

- DMM Scenario 1:
    - 670,000 cy to the onsite CDF
    - 983,000 to 1,534,000 cy to off-site disposal facilities
- DMM Scenario 2:
    - 1,653,000 to 2,204,000 cy to off-site disposal facilities

Estimated volumes of material that would be needed for containment, residuals management, and in-situ treatment for sediment and riverbanks are:

- Sand – 738,000 cy
- Very fine, low-permeability sand – 8,400 cy
- Beach mix – 48,000 cy
- Armor – 79,000 cy
- Organoclay mats – 490 cy
- AquaBlok™ – 5,700 tons
- AquaGate+10%PAC – 78,000 tons

The design concept for Alternative E is shown on **Figure 3.8-5a-f**, and the proportion of the Site assigned each technology is presented on **Figure 3.8-13**. In-river construction duration for this alternative is estimated to be 7 years, with no additional time required to complete dredged material processing (i.e., dewatering and sampling for disposal parameters). The following alternative-specific schedule timeframes have been estimated:

- Year 0: Establish initial conditions
- Year 0: Construction of on-site material handling/treatment facility (if applicable)
- Year 0: Start-up activities and mobilization, including pre-design investigation
- Years 2 through 5: Construct alternative
- Year 6: Demobilization and mitigation

3.8.6.1 Navigation Channel and FMD Region

Navigation Channel
The estimated area to be dredged is 79.3 acres:

- 69.2 acres are dredged to 0 to 5 feet
- 10.0 acres are dredged to 5 to 10 feet
- 0.1 acre is dredged to 10 to 15 feet

Ex-situ treatment is assumed for 30,200 to 40,300 cy of the dredged material. In the areas dredged, 15.8 acres are covered with a reactive residual layer, and 63.5 acres are covered with a residual sand layer.

FMD
The area estimated to be dredged is 71.4 acres:

- 51.2 acres are dredged to 0 to 5 feet
- 18.4 acres are dredged to 5 to 10 feet
- 1.4 acre is dredged to 10 to 15 feet
- 0.4 acre is dredged to 15 to 19 feet

Ex-situ treatment is assumed for 11,600 to 15,500 cy of the dredged material. In the areas dredged, 8.2 acres are covered with a reactive residual layer, and 63.2 acres are covered with a residual sand layer. The estimated area of ENR is 55.1 acres.

3.8.6.2 Intermediate Region

The area estimated to be dredged is 12.1 acres:

- 7.3 acres are dredged to 0 to 5 feet
- 2.0 acres are dredged to 5to 10 feet
- 1.5 acre is dredged to 10 to 15 feet
- 1.3 acre to be dredged to 15 to 17 feet

Ex-situ treatment is assumed for 85,800 to 114,400 cy of the dredged material. In the areas dredged, 8.6 acres are covered with a reactive residual layer, 3.1 acres are covered with a residual sand layer, and 0.4 acre is covered with significantly augmented reactive cap.

The area estimated to be capped is 63.9 acres: 30.6 acres of armored reactive cap, 9.4 acres of reactive cap, 13.5 acres of armored cap, 4.1 acres of engineered cap, 5.2 acres of AquaBlok™, and 1.1 acre of significantly augmented reactive cap. The area ENR is estimated at 8.7 acres.

3.8.6.3 Shallow Region

The area estimated to be dredged is 40.9 acres:

- 39.5 acres are dredged to 5 feet
- 1.0 acre is dredged to 10 feet
- 0.3 acre is dredged to 15 feet

Ex-situ treatment is assumed for 41,100 to 54,800 cy of the dredged material. It is also estimated that within the dredged areas the following residual layers are used: 13.5 acres backfill, 13.2 acres reactive cap, 1.6 acres engineered cap, 12.4 acres reactive residual layer, and 0.2 acre of significantly augmented reactive cap.

3.8.6.4 River Bank Region

An estimated 18,231 lineal feet of riverbank will be removed and ex-situ treatment is assumed for 9,500 cy of the excavated material. Within the excavated area, 17.9 acres are estimated to be covered with an engineered cap and 2.0 acres with a significantly augmented reactive cap.

3.8.6.5 Cost

DMM 1
Total capital costs estimated for this alternative are $748,071,000 over 7 years. Total periodic costs (including O&M) are $412,332,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $1,160,403,000, with a net present value cost of $804,120,000. Detailed costs associated with implementing Alternative E are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2
Total capital costs estimated for this alternative are $827,465,000 over 7 years. Total periodic costs (including O&M) are $412,332,000. The 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $1,239,797,000, with a net present value cost of $869,530,000. Detailed costs associated with implementing Alternative E are presented in Appendix G and summarized in **Table 3.7-1**.

3.8.7 Alternative F

Alternative F has a total constructed area of 533 acres sediment and 23,305 lineal feet of river bank, will allow 1,634 acres of sediment to naturally recover, and will not address 6,744 lineal feet of known contaminated river bank.

The construction of this alternative includes 505.3 acres of capping and dredging contaminated sediment and 28.2 acres of ENR. Additionally, 23,305 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation.

This alternative involves dredging of approximately 387.4 acres sediment to varying depths (3,825,000 to 5,100,000 cy) and excavating approximately 123,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative F would be managed in one of two disposal scenarios:

- DMM Scenario 1:
    - 670,000 cy to the onsite CDF
    - 3,155,000 to 4,430,000 cy to off-site disposal facilities
- DMM Scenario 2:
    - 3,825,000 to 5,100,000 cy to off-site disposal facilities

Estimated volumes of material that would be needed for containment, residuals management, and in-situ treatment for sediment and riverbanks are:

- Sand – 1,224,000 cy
- Very fine, low-permeability sand – 8,400 cy
- Beach mix – 70,000 cy
- Armor – 152,000 cy
- Organoclay mats – 490 cy
- AquaBlok™ – 5,700 tons
- AquaGate+10%PAC – 106,000 tons

The design concept for Alternative F is shown on **Figure 3.8-7a-f**, and the proportion of the Site assigned each technology is presented on **Figure 3.8-14**. In-river construction duration for this alternative is estimated to be 13 years, with no additional time required to complete dredged material processing (i.e., dewatering and sampling for disposal parameters). The following alternative-specific schedule timeframes have been estimated:

- Year 0: Establish initial conditions
- Year 0: Construction of on-site material handling/treatment facility (if applicable)
- Year 0: Start-up activities and mobilization, including pre-design investigations
- Years 1 through 11: Construct alternative
- Year 12: Demobilization and mitigation

3.8.7.1 Navigation Channel and FMD Region

Navigation Channel
The estimated area to be dredged is 178.0 acres:

- 135.4 acres are dredged to 0 to 5 feet
- 37.6 acres are dredged to 5 to 10 feet
- 4.9 acres are dredged to 10 to 15 feet
- 0.2 acre is dredged to 15 to 17 feet

Ex-situ treatment is assumed for 30,200 to 40,300 cy of the dredged material. In the areas dredged, 21.9 acres are covered with a reactive residual layer, and 156.1 acres are covered with a residual sand layer.

FMD
The estimated area to be dredged is 129.4 acres:

- 73.4 acres are dredged to 0 to 5 feet
- 51.6 acres are dredged to 5 to 10 feet
- 3.9 acres are dredged to 10 to 15 feet
- 0.5 acre is dredged to 15 to 19 feet

Ex-situ treatment is assumed for 11,600 to 15,500 cy of the dredged material. In the areas dredged, 15.3 acres are covered with a reactive residual layer, and 114.1 acres are covered with a residual sand layer. The estimated area of ENR is 22.3 acres.

3.8.7.2 Intermediate Region

The estimated area to be dredged is 18.2 acres:

- 11.8 acres are dredged to 0 to 5 feet
- 2.7 acres are dredged to 5 to 10 feet
- 1.8 acres are dredged to 10 to 15 feet
- 1.9 acres are dredged to 15 to 17 feet

Ex-situ treatment is assumed for 85,800 to 114,400 cy of the dredged material. In the areas dredged, 9.3 acres are covered with a reactive residual layer, 8.5 acres are covered with a residual sand layer, and 0.4 acre is covered with a significantly augmented reactive cap.

The estimated area to be capped is 115.1 acres: 44.0 acres of armored reactive cap, 11.1 acres of reactive cap, 44.2 acres of armored cap, 9.5 acres of engineered cap, 5.2 acres of AquaBlok™, and 1.1 acre of significantly augmented reactive cap. The area estimated to be ENR is 5.9 acres.

3.8.7.3 Shallow Region

The estimated area to be dredged is 61.8 acres:

- 60.4 acres are dredged to 5 feet
- 1.0 acre is dredged to 10 feet
- 0.3 acre is dredged to 15 feet

Ex-situ treatment is assumed for 41,100 to 54,800 cy of the dredged material. It is also estimated that within the dredged areas the following residual layers are used: 18.0 acres backfill, 21.0 acres reactive cap, 10.8 acres engineered cap, 11.7 acres reactive residual layer, and 0.2 acre of significantly augmented reactive cap.

3.8.7.4 River Bank Region

An estimated 23,305 lineal feet of riverbank will be removed and ex-situ treatment is assumed for 9,500 cy of the excavated material. Within the excavated area, 23.4 acres are estimated to be covered with an engineered cap and 2.0 acres with a significantly augmented reactive cap.

3.8.7.5 Cost

DMM 1
Total capital costs estimated for this alternative are $1,550,014,000 over 13 years. Total periodic costs (including O&M) are $549,512,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $2,099,526,000, with a net present value cost of $1,316,560,000. Detailed costs associated with implementing Alternative F are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2
Total capital costs estimated for this alternative are $1,629,407,000 over 13 years. Total periodic costs (including O&M) are $549,512,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $2,178,919,000, with a net present value cost of $1,371,170,000. Detailed costs associated with implementing Alternative F are presented in Appendix G and summarized in **Table 3.7-1**.

3.8.8 Alternative G

Alternative G has a total constructed area of 776 acres sediment and 26,362 lineal feet of river bank, will allow 1,391 acres of sediment to naturally recover, and will not address 3,686 lineal feet of known contaminated river bank.

The construction of this alternative includes 756.4 acres of capping and dredging contaminated sediment and 19.5 acres of ENR. Additionally, 26,362 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation.

This alternative involves dredging of approximately 571.7 acres sediment to varying depths (6,221,000 to 8,294,000 cy) and excavating approximately 139,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative G would be managed in one of two disposal scenarios:

- DMM Scenario 1:
    - 670,000 cy to the onsite CDF
    - 5,551,000 to 7,624,000 cy to off-site disposal facilities
- DMM Scenario 2:
    - 6,221,000 to 8,294,000 cy to off-site disposal facilities

Estimated volumes of material that would be needed for containment, residuals management, and in-situ treatment for sediment and riverbanks are:

- Sand – 1,770,000 cy
- Very fine, low-permeability sand – 8,400 cy
- Beach mix – 91,000 cy
- Armor – 246,000 cy
- Organoclay mats – 490 cy
- AquaBlok™ – 5,700 tons
- AquaGate+10%PAC – 137,000 tons

The design concept for Alternative G is shown on **Figure 3.8-7a-f**, and the proportion of the Site assigned each technology is presented on **Figure 3.8-15**. In-river construction duration for this alternative is estimated to be 19 years, with no additional time required to complete dredged material processing (i.e., dewatering and sampling for disposal parameters). The following alternative-specific schedule timeframes have been estimated:

- Year 0: Establish initial conditions
- Year 0: Construction of on-site material handling/treatment facility (if applicable)
- Year 0: Start-up activities and mobilization, including pre-design investigation
- Years 1 through 17: Construct alternative
- Year 18: Demobilization and mitigation

3.8.8.1 Navigation Channel and FMD Region

Navigation Channel
The estimated area to be dredged is 296.8 acres:

- 195.5 acres are dredged to 0 to 5 feet
- 93.2 acres are dredged to 5 to 10 feet
- 7.7 acres are dredged to 10 to 15 feet
- 0.5 acre is dredged to 15 to 17 feet

Ex-situ treatment is assumed for 30,200 to 40,300 cy of the dredged material. In the areas dredged, 35.0 acres are covered with a reactive residual layer, and 261.8 acres are covered with a residual sand layer.

FMD
The estimated area to be dredged is 163.0 acres:

- 78.0 acres are dredged to 0 to 5 feet
- 78.1 acres are dredged to 5 to 10 feet
- 6.2 acres are dredged to 10 to 15 feet
- 0.6 acre is dredged to 15 to 19 feet

Ex-situ treatment is assumed for 11,600 to 15,500 cy of the dredged material. In the areas dredged, 22.8 acres are covered with a reactive residual layer, and 140.2 acres are covered with a residual sand layer. The estimated area of ENR is 15.4 acres.

3.8.8.2 Intermediate Region

The estimated area to be dredged is 27.2 acres:

- 19.0 acres are dredged to 0 to 5 feet
- 4.4 acres are dredged to 5 to 10 feet
- 1.8 acres are dredged to 10 to 15 feet
- 2.0 acres are dredged to 15 to 17 feet

Ex-situ treatment is assumed for 85,800 to 114,400 cy of the dredged material. In the areas dredged, 9.7 acres are covered with a reactive residual layer, 17.2 acres are covered with a residual sand layer, and 0.4 acre is covered with a significantly augmented reactive cap.

The estimated area to be capped is 181.5 acres: 54.5 acres of armored reactive cap, 13.2 acres of reactive cap, 91.3 acres of armored cap, 16.3 acres of engineered cap, 5.2 acres of AquaBlok™, and 1.1 acre of significantly augmented reactive cap.

3.8.8.3 Shallow Region

The estimated area to be dredged is 84.6 acres:

- 83.3 acres are dredged to 5 feet
- 1.0 acre is dredged to 10 feet
- 0.3 acre is dredged to 15 feet

Ex-situ treatment is assumed for 41,100 to 54,800 cy of the dredged material. It is also estimated that within the dredged areas the following residual layers are used: 26.0 acres backfill, 25.9 acres reactive cap, 20.3 acres engineered cap, 12.4 acres reactive residual layer, and 0.2 acre significantly augmented reactive cap.

3.8.8.4 River Bank Region

An estimated 26,362 lineal feet of riverbank will be removed and ex-situ treatment is assumed for 9,500 cy of the excavated material. Within the excavated area, 26.8 acres are estimated to be covered with an engineered cap and 2.0 acres with a significantly augmented reactive cap.

3.8.8.5 Cost

DMM 1
Total capital costs estimated for this alternative are $2,421,152,000 over 19 years. Total periodic costs (including O&M) are $708,114,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $3,129,266,000, with a net present value cost of $1,731,110,000. Detailed costs associated with implementing Alternative G are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2
Total capital costs estimated for this alternative are $2,500,545,000 over 19 years. Total periodic costs (including O&M) are $708,114,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $3,208,659,000, with a net present value cost of $1,777,320,000. Detailed costs associated with implementing Alternative G are presented in Appendix G and summarized in **Table 3.7-1**.

3.8.9 Alternative H

Alternative H has a total constructed area of 2,167 acres sediment and 30,048 lineal feet of river bank. MNR is not used in this alternative, and all contaminated areas of the Site will be addressed through capping and dredging only.

The construction of this alternative includes 2,167.2 acres of capping and dredging contaminated sediment. Additionally, 30,048 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation.

This alternative involves dredging of approximately 1,631.9 acres sediment to varying depths (25,115,000 to 33,487,000 cy) and excavating approximately 158,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative H would be managed in one of two disposal scenarios:

- DMM Scenario 1:
    - 670,000 cy to the onsite CDF
    - 24,445,000 to 32,817,000 cy to off-site disposal facilities
- DMM Scenario 2:
    - 25,115,000 to 33,487,000 cy to off-site disposal facilities

Estimated volumes of material that would be needed for containment, residuals management, and in-situ treatment for sediment and riverbanks are:

- Sand – 4,846,000 cy
- Very fine, low-permeability sand – 8,400 cy
- Beach mix – 163,000 cy
- Armor – 760,000 cy
- Organoclay mats – 490 cy
- AquaBlok™ – 5,700 tons
- AquaGate+10%PAC – 201,000 tons

The design concept for Alternative H is shown on **Figure 3.8-8a-f**, and the proportion of the Site assigned each technology is presented on **Figure 3.8-16**. In-river construction duration for this alternative is estimated to be 62 years, with no additional time required to complete dredged material processing (i.e., dewatering and sampling for disposal parameters). The following alternative-specific schedule timeframes have been estimated:

- Year 0: Establish initial conditions
- Year 0: Construction of on-site material handling/treatment facility (if applicable)
- Year 0: Start-up activities and mobilization, including pre-design investigation

- Years 1 through 60: Construct alternative
- Year 61: Demobilization and mitigation

3.8.9.1 Navigation Channel and FMD Region

Navigation Channel
The estimated area to be dredged is 1,180.0 acres:

- 251.2 acres are dredged to 0 to 5 feet
- 840.6 acres are dredged to 5 to 10 feet
- 84.9 acre is dredged to 10 to 15 feet
- 3.3 acres is dredged to 15 to 17 feet

Ex-situ treatment is assumed for 30,200 to 40,300 cy of the dredged material. In the areas dredged, 74.3 acres are covered with a reactive residual layer, and 1,105.7 acres are covered with a residual sand layer.

FMD
The area estimated to be dredged is 240.7 acres:

- 33.3 acres are dredged to 0 to 5 feet
- 154.0 acres are dredged to 5 to 10 feet
- 50.8 acres are dredged to 10 to 15 feet
- 2.6 acres are dredged to 15 to 17 feet

Ex-situ treatment is assumed for 11,600 to 15,500 cy of the dredged material. In the areas dredged, 35.4 acres are covered with a reactive residual layer, and 205.3 acres are covered with a residual sand layer.

3.8.9.2 Intermediate Region

The area estimated to be dredged is 41.5 acres:

- 21.8 acres are dredged to 0 to 5 feet
- 14.9 acres are dredged to 5 to 10 feet
- 1.7 acres are dredged to 10 to 15 feet
- 3.1 acres are dredged to 15 to 17 feet

Ex-situ treatment is assumed for 85,800 to 114,400 cy of the dredged material. In the areas dredged, 10.0 acres are covered with a reactive residual layer, and 31.1 acres are covered with a residual sand layer, and 0.4 acre is covered with a significantly augmented reactive cap.

The area estimated to be capped is approximately 531.1 acres: 5.2 acres of AquaBlok™ cap, 392.8 acres of armored, 16.0 acres of reactive cap, 71.1 acres of reactive armored cap, 1.1 acre of significantly augmented reactive cap, and 44.9 acres of engineered cap.

3.8.9.3 Shallow Region

The area estimated to be dredged is 169.8 acres:

- 168.4 acres are dredged to 5 feet
- 1.0 acre is dredged to 10 feet
- 0.3 acre is dredged to 15 feet

Ex-situ treatment is assumed for 41,100 to 54,800 cy of the dredged material. It is also estimated that within the dredged areas the following residual layers are used: 52.1 acres backfill, 11.6 acres reactive residual layer, 69.2 acres engineered cap, 36.7 acres reactive cap and 0.2 acre significant augmented cap.

3.8.9.4 River Bank Region

An estimated 30,048 lineal feet of riverbank will be removed and ex-situ treatment is assumed for 9,500 cy of the excavated material. Within the excavated area, 30.8 acres are estimated to be covered with an engineered cap and 2.0 acres with a significantly augmented reactive cap.

3.8.9.5 Cost

DMM 1
Total capital costs estimated for this alternative are $8,869,180,000. Although the estimated construction period is 62 years, present value costs were estimated over the 30-year period of analysis used for all other alternatives in order to compare costs between alternatives. Total capital costs were undiscounted and applied in Year 0, using the simplifying assumption allowed in EPA FS cost estimating guidance. Total periodic costs (including O&M) are $1,284,174,000. Periodic 5-year review costs for the 62-year construction duration are estimated to be $1,848,000, the incremental increase for an additional 32 years is considered inconsequential on the overall cost for this alternative. The total undiscounted alternative cost is estimated to be $10,153,354,000, with a net present value cost of $9,445,540,000. Detailed costs associated with implementing Alternative H are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2
Total capital costs estimated for this alternative are $8,948,573,000. Although the estimated construction period is 62 years, present value costs were estimated over the 30-year period used for all other alternatives in order to compare costs between alternatives. Total capital costs were undiscounted and applied in Year 0, using the simplifying assumption allowed in EPA FS cost estimating guidance. Total periodic costs (including O&M) are $1,284,174,000. Periodic 5-year review costs for the 62-year construction duration are estimated to be $1,848,000, the incremental increase for an additional 32 years is considered inconsequential on the overall cost for this alternative. The total undiscounted alternative cost is estimated to be $10,232,747,000, with a net present value cost of $9,524,940,000. Detailed costs associated with implementing Alternative H are presented in Appendix G and summarized in **Table 3.7-1**.

3.8.10 Alternative I

Alternative I has a total constructed area of 291 acres sediment and 19,472 lineal feet of river bank, will allow 1,876 acres of sediment to naturally recover, and will not address 10,577 lineal feet of known contaminated river bank.

The construction of this alternative includes 231.2 acres of capping and dredging contaminated sediment and 59.8 acres of ENR. Additionally, 19,472 lineal feet of river bank are assumed to be laid back and covered with either a significantly augmented reactive cap or an engineered cap using beach mix or vegetation.

This alternative involves dredging of approximately 167.1 acres of sediment to varying depths (1,414,000 to 1,885,000 cy) and excavating approximately 103,000 cy. Ex-situ treatment is assumed for 156,000 to 208,000 cy sediment and 9,500 cy soil. The dredged material removed from the Site under Alternative I would be managed in one of two disposal scenarios:

- DMM Scenario 1:
    - 670,000 cy to the onsite CDF
    - 744,000 to 1,215,000 cy to off-site disposal facilities
- DMM Scenario 2:
    - 1,414,000 to 1,885,000 cy to off-site disposal facilities

Estimated volumes of material that would be needed for containment, residuals management, and in-situ treatment for sediment and riverbanks are:

- Sand – 676,000 cy
- Very fine, low-permeability sand – 8,400 cy

- Beach mix – 50,000 cy
- Armor – 80,000 cy
- Organoclay mats – 490 cy
- AquaBlok™ – 5,700 tons
- AquaGate+10%PAC – 81,000 tons

The design concept for Alternative I is shown on **Figure 3.8-9a-f**, and the proportion of the Site assigned each technology is presented on **Figure 3.8-19**. In-river construction duration for this alternative is estimated to be 7 years, with no additional time required to complete dredged material processing (i.e., dewatering and sampling for disposal parameters). The following alternative-specific schedule timeframes have been estimated:

- Year 0: Establish initial conditions
- Year 0: Construction of on-site material handling/treatment facility (if applicable)
- Year 0: Start-up activities and mobilization
- Years 1 through 5: Construct alternative
- Year 6: Demobilization and mitigation

3.8.10.1 Navigation Channel and FMD Region

Navigation Channel
The estimated area to be dredged is 39.5 acres:

- 33.5 acres are dredged to 0 to 5 feet
- 5.3 acres are dredged to 5 to 10 feet
- 0.1 acre is dredged to 10 to 15 feet

Ex-situ treatment is assumed for 30,200 to 40,300 cy of the dredged material. In the areas dredged, 10.9 acres are covered with a reactive residual layer, and 28.5 acres are covered with a residual sand layer

FMD
The area estimated to be dredged is 73.6 acres:

- 53.0 acres are dredged to 0 to 5 feet
- 19.6 acres are dredged to 5 to 10 feet

- 0.9 acre is dredged to 10 to 15 feet

Ex-situ treatment is assumed for 11,600 to 15,500 cy of the dredged material. In the areas dredged, 11.4 acres are covered with a reactive residual layer, and 62.2 acres are covered with a residual sand layer. The estimated area of ENR is 51.1 acres.

3.8.10.2 Intermediate Region

The area estimated to be dredged is 13.0 acres:

- 7.9 acres are dredged to 0 to 5 feet
- 2.2 acres are dredged to 5 to 10 feet
- 1.7 acre is dredged to 10 to 15 feet
- 1.1 acre is dredged to 15 to 17 feet

Ex-situ treatment is assumed for 85,800 to 114,400 cy of the dredged material. In the areas dredged, 9.5 acres are covered with a reactive residual layer, 3.1 acres are covered with a residual sand layer, and 0.4 acre is covered with a significantly augmented reactive cap.

The area estimated to be capped is 62.3 acres: 5.2 acres of AquaBlok™ cap, 10.7 acres of armored, 9.6 acres of reactive cap, 34.1 acres of reactive armored cap, 1.1 acre of significantly augmented reactive cap, and 1.7 acres of engineered cap. The area ENR is estimated at 8.7 acres.

3.8.10.3 Shallow Region

The area estimated to be dredged is 41.1 acres:

- 39.8 acres are dredged to 5 feet
- 1.0 acre is dredged to 10 feet
- 0.3 acre is dredged to 15 feet

Ex-situ treatment is assumed for 41,100 to 54,800 cy of the dredged material. It is also estimated that within the dredged areas the following residual layers are used: 10.9 acres backfill, 13.7 acres reactive residual layer, 3.0 acres engineered cap, 13.4 acres reactive cap, and 0.2 acre significant augmented cap.

3.8.10.4 River Bank Region

An estimated 19,472 lineal feet of riverbank will be removed and ex-situ treatment is assumed for 9,500 cy of the excavated material. Within the excavated area, 19.2 acres are estimated to be covered with an engineered cap and 2.0 acres with a significantly augmented reactive cap.

3.8.10.5 Cost

DMM 1
Total capital costs estimated for this alternative are $671,966,000 over 7 years. Total periodic costs (including O&M) are $421,940,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $1,093,906,000, with a net present value cost of $745,890,000. Detailed costs associated with implementing Alternative G are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2
Total capital costs estimated for this alternative are $751,359,000 over 7 years. Total periodic costs (including O&M) are $421,940,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $1,173,299,000, with a net present value cost of $811,290,000. Detailed costs associated with implementing Alternative I are presented in Appendix G and summarized in **Table 3.7-1**.

3.9 SCREENING EVALUATION OF ALTERNATIVES

The screening criteria conform to the remedial alternative evaluation requirements set forth in Section 121 of CERCLA, the NCP [40 CFR 300.430(e)(7)], and the RI/FS Guidance (USEPA 1988). Since it is required under the NCP that the no action alternative is used in the detailed evaluation and comparative analysis, Alternative A is not screened in this section. As stated above, Alternatives B through I all use the same combination of technologies to differing degrees. The three criteria used for the initial screening of alternatives are effectiveness, implementability, and cost.

Effectiveness
Reductions in the site-wide SWAC were estimated by assuming the alternatives achieve an ideal constructed surface concentration of zero. A post-construction site-wide SWAC was calculated and compared to the current site-wide SWAC. These results are presented in **Table 3.9-1**. All the alternatives are effective in reducing risks from COCs at the Site. Alternative B relies on less construction and more MNR to reduce risks, and each alternative thereafter through H relies on more construction and less MNR. The construction duration is presented on **Figure 3.9-1**.

Implementability
A comparison of the estimated acres assigned to each technology and cubic yards of dredging and borrow material for the alternatives is presented in **Table 3.9-2**. All alternatives are implementable, with the amount of construction increasing from Alternative B through Alternative H, as presented on **Figure 3.9-2**. However, given the extensive degree of capping and dredging associated with Alternative H and the expected

construction duration (62 years), Alternative H is considered less implementable than the other alternatives.

Cost

Cost is generally proportional to the amount of construction and materials needed for each alternative. Thus, costs increase from Alternative B to Alternative H. Present value costs for each alternative range between $451M (Alternative B) and $9.52B (Alternative H), with Alternative H being substantially more expensive than the other alternatives as presented on **Figure 3.9-3**.

EPA RI/FS guidance (USEPA 1988) notes that the entire range of alternatives originally developed do not need to be carried through the detailed analysis if all alternatives do not represent distinct viable options. Based on the information provided in the screening tables of the alternatives, Alternatives C and H were eliminated from further consideration and the detailed analysis in Section 4.

Alternative C was eliminated based on the small incremental increase in quantities of dredge and borrow materials[16] between Alternatives B and C and the relatively small incremental decrease in focused COC concentrations when compared between Alternatives B and D or C and D. The differences between Alternatives B and C include only a 0.1 percent increase in overall acres remediated with only a corresponding average 9 percent reduction of focused COC concentrations in surface sediment. Thus, it was concluded that Alternative C was not distinctly different from Alternative B.

Alternative H was eliminated primarily based on implementability and cost. Alternative H requires dredging and capping over the entire Site. Conducting dredging activities at 75 percent of the Site and capping the remainder is expected to result in substantial implementation challenges over a long period of time (an estimated duration of 62 years indicates a substantial amount of logistical coordination to shorten the implementation timeframe). The advantage of Alternative H is that it removes more contamination from the river and meets the PRGs at the end of construction. However, it increases the amount of long-term O&M due to the increase in capped acres. Further, the time frame over which resuspension due to dredging activities would occur results in a greater time period for continued adverse effects to human health and the environment. Alternative H also has a cost approximately 5 times higher than the next closest alternative (Alternative G). As a result, Alternative H was eliminated based on implementability and cost.

The remaining alternatives represent an appropriate range of remedial action alternatives. As a result, all other alternatives are carried forward for detailed analysis in Section 4.

[16] Material such as soil, sand, clay or gravel, that comes from either and upland or in-water borrow pit.

4.0 DETAILED ANALYSIS OF ALTERNATIVES

This section provides a detailed analysis of individual alternatives against the evaluation criteria required by the NCP and a comparative analysis that focuses upon the relative performance of each alternative against those criteria. The first two criteria are threshold criteria that must be met by each alternative to be eligible for selection as a remedy. The next five criteria are the primary balancing criteria upon which the analysis is based. The final two criteria are referred to as modifying criteria and evaluate state and community acceptance. The two modifying criteria will be evaluated following comments received during the public comment period and will be addressed in making the final remedy decision and discussed in the ROD.

The two **threshold criteria** are:

- Overall Protection of Human Health and the Environment
- Compliance with ARARs

The five **balancing criteria** upon which the detailed analysis is based are:

- Long-Term Effectiveness and Permanence
- Reduction of Toxicity, Mobility or Volume through Treatment
- Short-Term Effectiveness
- Implementability
- Cost

The two **modifying criteria** are:

- State Acceptance and Tribal Consultation and Coordination
- Community Acceptance

4.1 EVALUATION PROCESS AND CRITERIA

This section provides a brief description of the nine evaluation criteria and the evaluation process used in the detailed analysis. The focus of this evaluation will be on sediment RAOs (1, 2, 5 and 6) although surface water RAOs (3 and 7), groundwater RAOs (4 and 8), and the river bank RAO (9) are also evaluated relative to actions being taken on the sediment.

4.1.1 Spatial Scales

The analysis includes an evaluation using relevant exposure scales for receptors covered by each RAO consistent with the assumptions used in the baseline risk assessments. Site-wide and smaller spatial scales were used to evaluate each alternative including attainment of the RAOs. To conduct the smaller spatial scale evaluation, the Site was first subdivided into the following four river segments as presented on **Figure 3.1-1**:

- West shore to west navigation channel boundary
- Navigation channel
- East shore to east navigation channel boundary
- Swan Island Lagoon

This subdivision is preferred given the differing sediment dynamics and hydrodynamics of the shorelines and lagoon, current and future uses (such as the navigation channel), and the preference of many receptors for shoreline habitat. Subdivisions will allow for a more precise analysis of risk reduction for each alternative.

Several spatial scales were evaluated: 1) benthic risk was evaluated on a population level as the area exceeding RAO 5 PRGs (**Figure 4.1-1**), 2) 0.5 RM was used for RAO 1 (sediment only) for direct contact exposure of people engaged in fishing activities, consistent with the BHHRA, 3) 1 RM was used for RAOs 2 and 6 for the dietary exposure of humans and ecological receptors that consume fish and shellfish, and 4) Site-wide was used for RAO 2.

Contaminant concentrations were estimated on a rolling average developed from the surface sediment data in the FS database (Appendix A). Surface sediment results were averaged over a distance of 0.5 miles (RAO 1) or 1 mile (RAOs 2 and 6) in successive 0.1 mile increments in both the east and west nearshore segments, and the navigation channel.

Fourteen individual regions of the river within the Site were designated as sediment decision units (SDUs). The SDUs were identified as areas with the highest rolling 1 RM average concentrations of the focused COCs identified in Section 3. This corresponds approximately to the estimated 1-mile exposure area for which recreational fishing was evaluated in the BHHRA. This also corresponds with the home range of species such as smallmouth bass, hooded merganser, osprey, bald eagle and mink that were evaluated in the BERA. Additional SDUs were defined to address areas where multiple contaminants at concentrations substantially greater than PRGs and/or unacceptable benthic risk were identified between RM 4 and 6. A description of the development of the SDUs and an overlay of the SDUs on the rolling river mile average concentrations for each sediment COC is presented in Appendix D. Locations of the SDUs and their predominant contaminants are shown on **Figure 4.1-2**. A summary of information for each SDU, including location in the river, length, acres, basis for establishing the SDU and focused COCs within each SDU is provided in **Table 4.1-1**. The effectiveness of each remedial alternative is evaluated in part by comparing the alternative's post-construction SWAC in the SDUs to the PRGs for RAOs 2 and 6. This comparison provides an assessment of how the different alternatives reduce sediment contaminant concentrations, which can then be used to calculate reductions in contaminant concentrations in fish tissue. Risks to people and wildlife from consuming contaminated fish can then be evaluated for each alternative at the end of construction. Consumption of contaminated fish and shellfish is a significant exposure pathway for human health and the environment, thus it is important to understand the relative improvements that each alternative achieves at the end of construction.

4.1.2 Fate and Transport Modeling

EPA's *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (USEPA 2005) generally recommends mathematical modeling for large or complex sediment sites, especially where it is necessary to predict contaminant transport and fate over extended periods of time to evaluate relative differences among possible remedial approaches. These modeling efforts typically require large quantities of site-specific data. Where numerical models are used, verification, calibration, and validation typically should be performed to yield a scientifically defensible modeling study.

EPA's Contaminated Sediment Guidance also states that it is important that both calibration and validation be conducted at the space and time scales associated with the questions the model must answer. For example, if the model will be used to make decade-scale predictions, when possible, it should be compared to decade-scale trend data. Even when data exist for a much shorter time period than will be used for prediction, the long-term behavior of the model should be examined as a part of the calibration process. It is not unusual for a model to perform well for a short-term period, but produce unreasonable results when run for a much longer duration. The extent to which components of a modeling study are performed using verified models can determine to a large degree the defensibility of the modeling project. If a verified model has not been sufficiently calibrated or validated for a specific site, then the modeling study may lack defensibility and be of little value.

A hydrodynamic and sediment transport (HST) model developed by the LWG was presented in the Draft FS (LWG 2012). EPA commissioned external expert reviews of this model, which identified several shortcomings that limit its usefulness in predicting sediment transport within the Site. A more detailed discussion of the limitations associated with the Portland Harbor HST model is provided in Appendix H. The primary concerns identified by the expert review are:

- The HST model used models for channel flow (EFDC) and channel sediment transport (SEDZLJ). However, these modules were not coupled, such that changes in bed elevation due to deposition and erosion predicted by the SEDZLJ module are not coupled back into the EFDC module in each time step.

- The calibration of the HST model is limited.
    - The calibration of the model rests on attempts to reproduce observed difference between the 2003 and 2009 bathymetry, a time period without a major flood, water column data from 2004 to 2007, quarterly sediment trap data collected in 2007. The lack of temporal sediment quality data resulted in only a qualitative assessment of the model's ability to predict contaminant concentrations in sediment.
    - The HST model did not demonstrate that it was capable of correctly simulating tidal flows in the lower Willamette.
- The HST model does not accurately account for the complex circulation patterns of Multnomah Channel and Willamette River between Multnomah Channel and the confluence with the Columbia River.
- While the physical CSM emphasizes the importance of bedload transport indicating that about half the sediment load into the Site occurs from bedload transport, the HST model does not include this transport process.
- Sediment trend data do not exist for this Site; insufficient biota and water trend data exist to adequately validate the predictability of the model.

In the absence of trend data, EPA also compared the results of the HST model to the 2003-2009 bathymetry data to evaluate the ability of the model to predict the data set used in its calibration (the 2003 to 2009 bathymetric change data were used to calibrate the HST sediment transport model). A statistical analysis using simple regression was conducted to determine the predictability of the HST model; the methodology is presented in Appendix H. The results indicate that there is no correlation between the HST model predictions and actual bathymetric changes documented between 2003 and 2009 and that the model bias is always positive (more deposition is predicted than was actually measured). Overall, a comparison of the model output to its calibration data indicates the model does not accurately predict sediment deposition or erosion in the SDUs and limits the confidence in its ability to represent past, much less future, conditions.

EPA has concluded that the HST model predictions are inconsistent with the CSM for this Site, as it shows significant concentration reductions occurring within the first 10 years for the No-Action alternative. However, given that the majority of the contamination was released into the river 30-80 years ago and similar reductions have not been observed, the model results appear inconsistent with the empirical data collected during the RI.

For the reasons stated above and those presented in Appendix H, there is too much uncertainty in the current version of the HST model predictions to quantify reductions in sediment concentrations following the implementation of various remedial alternatives due to natural processes such as sediment deposition. Even though additional modeling efforts may be able to address some issues identified by EPA, additional sediment, biota and water trend data are needed to validate the model and make it scientifically defensible. Given the complexities of the Site, the uncertainty regarding future conditions, the compounded uncertainty of linked models that are based on assumptions and project decades into the future, and the influence of processes that are not modeled (wind/wave action, tidal influence, structures, prop scour, spudding, etc.), EPA has concerns whether any model would be able to adequately predict future conditions. Consistent with EPA's Contaminated Sediment Guidance (USEPA 2005), a predictive model is one of several lines of evidence that may be used in evaluating remedy performance, but should not the sole basis for remedy selection. Consistent with recommendations from the NRRB and CSTAG, EPA has enough information to move forward with a proposed remedy without a predictive model.

With the exception of Alternative H, all of the alternatives include natural recovery as a technology to achieve PRGs. Natural recovery of sediment contamination is likely occurring through burial, dilution, and dispersion mechanisms even though they cannot be reliably quantified using the HST model. These mechanisms are largely driven by continual import of relatively clean upriver sediment and after in-river source materials are removed or isolated and upland sources have been controlled are expected to further increase the effectiveness of natural recovery processes to reduce contaminant concentrations . However, natural recovery as evaluated in this FS does not explicitly document the contaminant declines in affected media because the RI sampling was not designed to assess trends, and thus does not support quantitative predictions of future contaminant concentrations derived from empirical observations or provide the basis of a mechanistic model intended to predict changes over time. As a result, EPA will rely on a robust post-construction monitoring program to track sediment and fish tissue contaminant concentrations and their progress toward remedial goals. This prospective, empirical approach will provide a clear basis for measuring progress toward achieving RAOs and over time, and the data collected will provide a firm basis for post-construction projections, if necessary. Through the five-year review process, these data will be used to determine any additional actions may be required to achieve RAOs.

EPA is using six lines of evidence to evaluate the effectiveness natural recovery in this FS: 1) difference in elevation between the 2003 and 2009 bathymetric pairs, 2) consistency between multiple bathymetric pairs, 3) sediment grain size (percent fines), 4) anthropogenic factors (propwash areas), 5) surface to subsurface concentration ratio, and 6) wind and wake wave areas. The evaluation of protection and risk reduction due to natural processes will be made based on the concentration reductions and residual risk at the completion of construction (at MNR Year 0) relative to interim risk-based targets and the six lines of evidence for MNR presented in Appendix D8.

4.1.3 Overall Protection of Human Health and the Environment

This evaluation criterion provides a final assessment as to whether each alternative provides adequate protection of human health and the environment. This criterion draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. It describes how risks associated with each exposure pathway would be eliminated, reduced, or controlled through treatment and/or engineering or institutional controls. Determining protectiveness for each of the alternatives includes an evaluation of the remaining sediment contaminant concentrations and associated risk at the completion of construction and the degree of confidence that natural recovery will be successful in reducing contaminant concentrations to the final remedial goals. These predictions inherently incorporate statistical uncertainties and are based on a mixture of sampling designs, and also are partially biased by analytical limitations and uncertainties. Spatial averages are based on weighted averages intended to counter the effects of spatially biased sampling designs. For these reasons, an uncertainty analysis of the Site-wide SWACs used to develop the RALs for each alternative was conducted to determine whether the alternative could reliably achieve protectiveness through meeting PRGs.

With the exception of Alternative H, all alternatives evaluated in this FS include MNR as a component of the remedy. As a long-term model is not available to predict the time to meet the PRGs, interim targets for risks and HIs were established to evaluate the potential for achievement of PRGs in a reasonable time frame, which was considered to be 30 years, commensurate with the site-specific contaminants and conditions. These interim targets are higher than residual risks once PRGs are achieved, and assume that further reductions with be achieved through MNR. Because the primary mechanism for MNR is through deposition, MNR is likely to be effective in the shortest amount of time in depositional environments after source control actions and active remediation of any sediment posing the highest risks have been completed (USEPA 2005). However, the majority of the Site is transitional; depositional during low flows and erosional in higher flows, which the exception of RM 11E and in the navigation channel at RM 6 that are erosional under all flow conditions. Further, the establishment of interim targets is consistent with EPA's Contaminated Sediment Guidance. Therefore, the protection of human health and the environment is assessed for each RAO by evaluating achievement of interim targets at the end of construction, as well as any additional benefit provided by measures that further reduce exposure risks such as ICs. The methodology and calculations for determining residual risk are presented in Appendix J and the methodology for determining reductions in surface water contaminant concentrations is presented in Appendix K.

<u>RAO 1</u>

Protection of human health from direct exposure to sediment contamination is evaluated as a comparison of the post-construction risk remaining for RAO 1 against an interim target of a 1×10^{-5} cumulative risk. This interim target limits the need for ICs because it is consistent with Oregon's risk standards. Post-construction risk was evaluated on a one-half river mile scale in river segments for RAO 1. A qualitative assessment of protectiveness for beaches is conducted for each alternative as there are no current means to quantitatively assess the effectiveness of the alternative in achieving PRGs in beaches. Contaminated beach areas under RAO 1 are assumed to only be addressed in areas adjacent to SMAs for each alternative.

<u>RAO 2</u>
Protection of human health for consumption of fish and shellfish is evaluated as a comparison of the post-construction risk remaining for RAO 2 against the following interim targets:

- A cancer risk of 1 x 10^{-4} was selected because residual risk exceeds 1 x 10^{-5} cumulative risk based on Oregon's risk standards but is the upper end of EPA's acceptable cancer risk range.

- A non-cancer hazard of 10 was selected because EPA defines the reference dose as "An estimate (with uncertainty spanning perhaps an order of magnitude) 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" (USEPA 2002). Therefore, a factor of 10 accounts for the order of magnitude uncertainty inherent in the definition of the reference doses used to calculate noncancer hazard estimates.

- Since the residual HI is greater than 10 for the infants, 10 times the residual HI was selected.

A fish consumption advisory is assumed to be necessary to provide protection in the short-term until PRGs are achieved. The post-construction risk was evaluated Site-wide, and on a river mile scale in river segments, and on an SDU scale for RAO 2.

<u>RAO 3</u>
Protection of human health for exposures to surface water is evaluated by comparing the expected post-construction reductions in surface water contaminant concentrations Site-wide to PRGs. There are insufficient data to evaluate surface water on a smaller spatial scales. This evaluation only considers surface water concentrations relative to contaminated sediment and does not evaluate contaminants from other sources (groundwater, storm water, upriver). There are insufficient data or detections to evaluate aldrin and BEHP; concentrations of chromium, hexachlorobenzene, MCPP and pentachlorophenol concentrations in surface water are not attributable to sediment contamination. An interim target is established at a factor of 10 (an order of magnitude) greater than the PRG for the contribution from contaminated sediment and does not include the contribution from upriver sources since the assumption is that upriver sources will be controlled.

<u>RAO 4</u>
Protection of human health from contaminated groundwater discharging to surface water is conducted qualitatively for each alternative as there are no current means to

quantitatively assess the effectiveness of the alternative in achieving PRGs in pore water. RAO 4 is evaluated as the percentage of the estimated area of sediment impacted by contaminated groundwater that is assumed to be addressed by each alternative. The qualitative assessment assumes that all groundwater contamination is adequately controlled prior to in-water construction such that they no longer continue to discharge and that any treatment of groundwater is to address portions of groundwater plumes that have migrated out into the river prior to these controls.

RAO 5

The protection of benthic species to contaminated sediment is evaluated using the benthic risk area defined by an order of magnitude greater than the RAO 5 PRGs. The post-construction interim target for RAO 5 was established at 50 percent reduction in the area posing unacceptable benthic risk. This is acceptable because protection of the benthic community is based on a population rather than individual effects, and is considered a target to which the benthic population as a whole can be stressed and still recover, in conjunction with the uncertainty associated with the predictive models used to develop these PRGs.

RAO 6

Protection of species that consume prey exposed to contaminated sediment is evaluated as a comparison of the post-construction HQ for RAO 6 against an interim target of 10, which is an order of magnitude greater than the residual HQ to be achieved by the PRGs (see rational under RAO 2, above). The post-construction HQ is evaluated on a river-mile scale in river segments and on an SDU scale for RAO 6.

RAO 7

Protection of ecological receptors for exposures to surface water is evaluated by comparing the expected post-construction reductions in surface water contaminant concentrations Site-wide to PRGs. There are insufficient data to evaluate surface water on a smaller spatial scales. This evaluation only considers surface water concentrations relative to contaminated sediment and does not evaluate contaminants from other sources (groundwater, storm water, upriver). There are insufficient data or detections to evaluate BEHP and PAHs; concentrations of ethylbenzene in surface water are not attributed to sediment contamination. An interim target is established at a factor of 10 (an order of magnitude) greater than the PRG for the contribution from contaminated sediment and does not include the contribution from upriver sources since the assumption is that upriver sources will be controlled.

RAO 8

Protection of ecological receptors from contaminated groundwater discharging to surface water is conducted qualitatively for each alternative as there are no current means to quantitatively assess the effectiveness of the alternative in achieving PRGs in pore water. RAO 8 is evaluated as the percentage of the estimated area of sediment impacted by contaminated groundwater that is assumed to be addressed by each alternative. The qualitative assessment assumes that all groundwater contamination is adequately controlled prior to in-water construction such that they no longer continue to discharge and that any treatment of groundwater is to address portions of groundwater plumes that have migrated out into the river prior to these controls.

RAO 9

A qualitative assessment of protectiveness for river banks is conducted for each alternative as there are no current means to quantitatively assess the effectiveness of the alternative in achieving PRGs in river banks due to uncertainty in contaminant concentrations and locations. Contaminated river banks under RAO 9 are assumed to only be addressed in areas adjacent to SMAs and are evaluated as the percentage of the estimated lineal feet of contaminated river bank addressed by each alternative.

Uncertainty Analysis

The alternatives presented in this FS cover a range of remedial footprints where capping and dredging/excavating technologies will be applied to address contaminated sediment and river bank soil. Since the RALs used to assign areas of capping and dredging were developed using Site-wide SWACs, an evaluation of the uncertainty in the pre- and post-remedy SWAC estimates was conducted as recommended by the NRRB and CSTAG, and a description of the methodology and results are presented in Appendix I. The uncertainty analysis was conducted for the focused COCs used to develop the RALs: PCBs, cPAHs, and DDx. Dioxin/furan congeners were not evaluated due to the low data density for these COCs. The analysis showed that for some alternatives, the uncertainty bounds of the post-remedial SWAC overlap the uncertainty bounds of the pre-remedial SWAC. This indicates that there is potentially no remedial benefit for those alternatives because the pre- and post-remedial SWACs are statistically indistinguishable when uncertainty in the SWAC estimates are taken into account. This analysis was used to compare the alternatives on their relative reduction in contaminant concentrations and therefore reliability in risk reduction as well as ability to achieve remedial goals through construction of capping and dredging. Conversely, supplemental measures such as ICs and natural recovery may result in further incremental risk reduction but cannot be identified quantitatively and thus also impart uncertainty with respect to alternatives.

4.1.4 Compliance with ARARs

Alternatives are assessed as to whether they meet applicable or relevant and appropriate federal and state requirements (ARARs) (see Section 2.1) unless such ARARs are waived under CERCLA Section 121(d)(4). Compliance with ARARs is determined by whether an alternative will meet all of the chemical-specific, action-specific, and location-specific ARARs and/or those that are to be considered (TBC) identified in **Tables 2.1-1** through **2.1-3**.

4.1.5 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to the expected residual risk and the ability of an alternative to maintain reliable protection of human health and the environment over time, once PRGs are achieved. This criterion includes the consideration of residual risk that will remain onsite following remediation and the adequacy and reliability of engineering (remedial technologies) and ICs to manage those risks posed by treatment residuals and/or untreated wastes.

4.1.5.1 Magnitude of Residual Risks

The magnitude of residual risks for each alternative includes both human health and ecological risks remaining from untreated waste or treatment residuals after PRGs are achieved. This evaluation determined the magnitude of the post-construction risk relative to the residual risk. The methodology for calculating post-construction risk is presented in Appendix J. Since ICs will be needed until PRGs are achieved, a comparison of the acceptable post-construction fish consumption rates to the acceptable fish consumption rates once PRGs are achieved is included. The post-construction loading of contaminated sediment from the Site to the Columbia will also be presented for each alternative. The methodology for calculating residual loading is presented in Appendix K.

The process of evaluating post-construction and residual risks uses the methodology and assumptions presented in the BHHRA and BERA. Exposure point concentrations (EPCs) for post-remedial exposures are based on modeled estimates of contaminant concentrations in sediment at the completion of construction. Carcinogenic risks and non-carcinogenic health hazards are estimated for the most protective RME scenarios only.

RAO 1

The magnitude of residual risk is evaluated on a one-half river mile scale. The magnitude of residual risk is presented as ratio of post-construction risk relative to the residual risk presented. Residual risk in beaches is not evaluated as there is not adequate data to conduct a quantitative evaluation; however, it is assumed that contaminated beaches contiguous with river bank or sediment contamination would be addressed.

RAO 2

The magnitude of residual risk is evaluated Site-wide (using a consumption rate of 142 g/day), and on a river mile and SDU scale (using a consumption rate of 49 g/day) for RAO 2. Arsenic, mercury, BEHP, hexachlorobenzene, PDBEs, and pentachlorophenol are not included in the evaluation of residual risks via consumption of fish because no relationship has been established between concentrations in sediment and concentrations in fish tissue. The magnitude of residual risk is presented as the ratio of the post-construction risk relative to the residual risk.

RAO 3
The magnitude of risk is evaluated Site-wide. There are insufficient data to evaluate surface water on smaller spatial scales. This evaluation only considers surface water concentrations relative to contaminated sediment and does not evaluate contaminants from other sources (groundwater, storm water, upriver). There are insufficient data or detections to evaluate BEHP and PAHs; concentrations of ethylbenzene in surface water are not attributed from sediment contamination. The magnitude of residual risk is presented as the ratio of the post-construction risk relative to the PRG

RAO 4
The magnitude of residual risk is evaluated Site-wide as the percentage of the estimated area of contaminated groundwater plumes addressed with each alternative.

RAO 5
The magnitude residual benthic risk is evaluated using the benthic risk area defined by an order of magnitude greater than the RAO 5 PRGs. The magnitude of residual risk is evaluated Site-wide as the percentage of the estimated benthic risk area addressed with each alternative.

RAO 6
The magnitude of residual risk is conducted on a river mile scale for RAO 6. Cadmium, copper, mercury and TBT are not included in the evaluation of residual risk via dietary exposure because no relationship has been established between concentrations in sediment and concentrations in prey species. The magnitude of residual risk is presented as the ration of the post-construction risk relative to the residual.

RAO 7
The magnitude of risk is evaluated Site-wide. There are insufficient data to evaluate surface water on a smaller spatial scales. This evaluation only considers surface water concentrations relative to contaminated sediment and does not evaluate contaminants from other sources (groundwater, storm water, upriver). There are insufficient data or detections to evaluate BEHP and PAHs; concentrations of ethylbenzene in surface water are not attributed from sediment contamination.

RAO 8
The magnitude of residual risk is evaluated Site-wide as the percentage of the estimated area of contaminated groundwater plumes addressed by each alternative.

RAO 9
The magnitude of residual risk is evaluated Site-wide as the percentage of the estimated extent of contaminated river banks addressed by each alternative.

4.1.5.2 Adequacy and Reliability of Engineering and Institutional Controls

This factor assesses the adequacy and suitability of engineering and institutional controls that are used to manage untreated wastes or treatment residuals remaining at the Site. Containment systems (caps and on-site CDF) and institutional controls will be assessed to determine that contaminant exposures, including residuals, to human and ecological receptors are within acceptable levels. This factor also addresses the long-term reliability of management controls for providing continued protection from residuals.

Institutional controls are a component of all remedial alternatives to manage human health risks from consumption of fish and shellfish in the short and long term. The primary control mechanisms are fish consumption advisories, in conjunction with public education and outreach programs to enhance awareness and effectiveness of the advisories as a means to reduce exposures to COCs. Fish consumption advisories are not enforceable and are generally understood to have limited effectiveness; one objective of the public education/outreach effort is to improve voluntary compliance with the advisories. These programs would likely be developed and administered by the responsible parties with EPA and OHA oversight and with participation from local governments, Tribes, and other community stakeholders. However, given that compliance is voluntary, institutional controls should therefore be relied upon to the minimum extent practicable. In addition, land use restriction mechanisms, such as RNAs and environmental covenants or equitable servitudes, will be used to protect capped areas where contamination is left in place at concentrations greater than PRGs needed to achieve RAOs. Both controls are difficult to monitor in a river environment. Land use restrictions in a river environment are also more difficult to enforce and have administrative costs in the long-term. Evaluation of institutional controls will include a discussion of the acceptable consumption rates at the completion of construction in relation to the acceptable consumption rate when RAOs are achieved. Areas where land use restrictions are needed will be discussed as acres of caps that will need to be managed for each alternative.

Repairs, maintenance, and other activities conducted in perpetuity will be necessary for various caps and the on-site CDF, if constructed. Monitoring, including measurement of COC concentrations in sediment, water column, pore water, groundwater and biota is another long-term component of the remedial alternatives. Monitoring of caps will be conducted to ensure and document the integrity and effectiveness of the cap in isolating contaminants. Cap repairs are assumed to be conducted as needed throughout O&M (for purposes of FS evaluations this is assumed to be no more than a hundred year period of analysis).

Upland source control measures designed to prevent the migration of contamination to the river will also need to be evaluated long-term; however, this FS assumes that all upland sources are adequately controlled and does not evaluate the effectiveness of the control measures. Upland source control measures will also need be to be evaluated for necessary repairs and maintenance performed under 5-year reviews of the CERCLA action.

4.1.6 Reduction of Toxicity, Mobility, and Volume through Treatment

CERCLA expresses a preference for remedial alternatives employing treatment technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances as their principal element. This evaluation will focus on ex-situ treatment of removed PTW prior to disposal, and reduction in mobility of other contaminants by in-situ treatment through containment under a reactive cap or through the use of reactive residual layers.

4.1.7 Short-Term Effectiveness

Short-term effectiveness addresses the time needed to implement the remedy and any adverse impacts that may be posed to the community, workers, and the environment during construction and operation of the remedy until PRGs and RAOs are achieved.

The evaluation of short-term effectiveness includes the risks to workers and the community from transport of wastes and capping and residual management materials, risks to workers on dredges or barges, measures to address those risks, numerical estimates to demonstrate that residuals can be successfully managed during dredging or capping activities, and BMPs to mitigate environmental impacts, such as emissions or noise.

Relevant experience at other sites is used to support implementation timeframes for in-river technology assignment components. Additionally, quantitative dredge production calculations are performed based on Schroeder and Gustavson (2013). Capping implementation timeframes are based on a review of similar types of capping projects and not specifically calculated for this project.

Time to achieve RAOs and PRGs will be quantitatively evaluated at the completion of construction and qualitatively evaluated post-construction (see discussion in Section 4.1.2 regarding limitations in the ability to evaluate this quantitatively). The qualitative evaluation will be conducted within the SDUs by comparing the likelihood of MNR achieving PRGs in a reasonable time frame based on the residual contaminant concentrations at the completion of construction.

4.1.8 Implementability

The technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation is evaluated under this criterion. Metrics used to gauge the relative magnitude of technical and administrative implementability of the alternatives include the surface areas actively managed for all active technologies and volumes. Areas and volumes managed are considered proportional to the degree of implementation difficulty. Acreage subject to MNR is also considered because it requires significant administrative effort over the long term to oversee and coordinate sampling and data evaluation as part of long term monitoring.

4.1.9 Cost

Cost estimates were presented in Section 3. The evaluation is not a cost-benefit exercise. The capital costs, O&M costs, and present value cost are presented for each alternative. Additionally, a discussion of factors that significantly change overall costs based on a cost sensitivity analysis (Appendix N) are presented for each alternative.

4.1.10 State Acceptance and Tribal Consultation and Coordination

4.1.10.1 State Acceptance

This criterion provides the government of the state where the project is located with the opportunity to assess technical or administrative issues and concerns regarding each of the alternatives. It also provides whether the State concurs with EPA's preferred alternative. State acceptance is not addressed in this FS but will be addressed in the ROD. Input and review of major RI/FS documents by the State of Oregon (as organized through DEQ) was sought and considered throughout the development of the FS.

4.1.10.2 Tribal Consultation and Coordination

Under current EPA policy and guidance,[1] EPA consults and coordinates with federally recognized tribes, when appropriate throughout the Superfund process. In this case, EPA consulted with tribal governments prior to listing the Site on the NPL. Since that time, EPA has been coordinating, throughout the RI/FS process, with the six federally recognized tribes.[2] In addition to the ongoing coordination, the tribes will be given the opportunity to raise technical and administrative issues and concerns regarding each of the alternatives during the public comment period on the Proposed Plan. EPA will also formally consult on the remedy decision, if formal consultation is requested by any of the tribes.

4.1.11 Community Acceptance

The alternatives evaluated in this FS and the preferred remedy that will be identified in the Proposed Plan will be presented to the public. Based on comments received during the public comment period, community acceptance will be considered and addressed in the ROD. Issues raised by the community will be discussed and addressed in the Responsiveness Summary Section of the ROD. Input from the public, potentially responsible parties and interested stakeholders was sought and considered throughout development of the FS. This occurred through monthly Community Advisory Group (CAG) meetings, meetings with the LWG, in ListServ notices, publication of

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[1] EPA Policy on Consultation and Coordination with Indian Tribes, May 4, 2011. Incorporates the Executive Order 13175 "Consultation and Coordination with Indian Tribal Governments", November 2000 and Presidential Memorandum, November 5, 2009. See also EPA Policy on Consultation and Coordination with Indian Tribes: Guidance for Discussing Tribal Treaty Rights, February 29, 2016

[2] Tribal governments that have met the requirements of the NCP (300.515(b)) and have signed an MOU with EPA.

information on the project website, and other activities consistent with the Community Involvement Plan (USEPA and ODEQ 2002, USEPA 2016).

4.2 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

4.2.1 Alternative A: No Action

4.2.1.1 Overall Protection of Human Health and the Environment

Alternative A would not be protective of human health and the environment. Under this alternative, the exposure and resuspension of contaminated sediment in the Site would continue to impact surface sediments, surface water, and biota and pose unacceptable risks to human health and the environment.

Because no action is taken, Alternative A would result in minimal reductions in COC concentration and related residual risks. Natural recovery process may reduce the COC concentrations over time, but are unlikely to achieve all PRGs for COCs or meet all RAOs in a reasonable time frame since releases occurred 30 to 80 years ago and unacceptable risks are present today. The RI indicates that natural recovery would not reduce unacceptable risks within a reasonable time frame. OHA would continue the fish consumption advisories already in place under State legal authorities. However, the existing advisories might not be sufficiently effective in protecting human health since the current recommended rate of one meal per month for the general population may not be sufficiently protective of consumers. In addition, consumption advisories do not address risk to ecological receptors.

4.2.1.2 Compliance with ARARs

Alternative A would not trigger ARARs since no action would be taken. Exceedances of chemical-specific ARARs for surface water and groundwater quality identified for the Site would continue for the unforeseeable future.

4.2.1.3 Long-Term Effectiveness and Permanence

Under this alternative no actions and no new controls would be put in place to address the contaminated media. Thus, contaminated media not already addressed as part of the previous actions would be left uncontrolled.

Magnitude of Residual Risk

Alternative A would not address the risks posed by the contamination at the Site. The presence of source material in the sediment would limit the ability for natural recovery processes to occur. Reductions in COC concentration and related risks are expected to occur over time, but the RAOs would not be achieved in a reasonable time frame. An evaluation of the contaminant loading from the Site to the Columbia River was conducted (Appendix K) and, for Alternative A, the contaminant load from the Site is estimated to be 1.7 kg PCBs/yr, 7.4 kg cPAHs/yr, 0.2 kg DDD/yr, 0.1 kg DDE/yr, 1.1 kg DDT/yr, and 0.0004 kg 2,3,7,8-TCDD eq/yr. This loading would continue for the foreseeable future.

The magnitude of residual risk for each RAO is as follows:

<u>RAO 1</u>
Direct contact carcinogenic risks are estimated to be 4 x 10^{-4} (**Figure 4.2-1a-c**). Unacceptable risk also would remain at the beaches.

<u>RAO 2</u>
Carcinogenic risks associated with consumption of contaminated fish and shellfish are 2 x 10^{-3} Site-wide (**Figure 4.2-2**), 4 x 10^{-2} on a river mile scale (**Figure 4.2-3a-d**), and 2 x 10^{-2} on an SDU scale (**Table 4.2-1**). The acceptable consumption rate is 1 eight-ounce fish meal every year (10 fish meal/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2** and **Table 4.2-2**).

The estimated non-cancer hazard (HI) is 138 Site-wide (**Figure 4.2-4**), 933 on a river mile scale (**Figure 4.2-5a-d**), and 479 on an SDU scale (**Table 4.2-3**). The acceptable consumption rate is 0.6 eight-ounce fish meals every year (6 fish meals/10 years) as presented in **Figure 4.2-4** and **Table 4.2-2**.

Non-cancer hazard (HI) to nursing infants is estimated at 3,333 Site-wide (**Figure 4.2-6**) 254,878 on a river mile scale (**Figure 4.2-7a-d**), and 22,589 on an SDU scale (**Table 4.2-4**). The acceptable consumption rate for women who may breastfeed is 0.1 fish meal every year (1 fish meal/10 years) as presented in **Figure 4.2-6** and **Table 4.2-2**.

<u>RAO 3</u>
Exceedances of surface water PRGs from contaminated sediment within the Site would continue for PCBs, cPAHs, DDD, DDE, DDT, and 2,3,7,8-TCDD eq (**Figures 4.2-8a-f**).

<u>RAO 4</u>
Approximately 243 acres of river bottom would continue to be impacted by residual contaminated groundwater plumes (**Figure 1.2-19**).

<u>RAO 5</u>
Unacceptable benthic risks would continue where it currently exists in approximately 1,289 acres throughout the Site (**Figure 4.1-1**).

<u>RAO 6</u>
The highest hazard quotient (HQ) is 138 on a river mile scale (**Figures 4.2-9a-e** through **4.2-17a-e**) and 70 on an SDU scale (**Table 4.2-5**).

RAO 7
Since no action is being taken, Alternative A would not reduce any loading from sediment to surface water given that conditions would remain as they are today (Appendix K) and the natural recovery that may be occurring has proven ineffective at reducing surface sediment concentrations to protective levels throughout the Site.

RAO 8
Approximately 243 acres of river bottom would continue to be impacted by residual contaminated groundwater plumes (**Figure 1.2-19**).

RAO 9
Approximately 30,049 lineal feet of river bank would remain contaminated and continue to erode and recontaminate the sediments (**Figure 2.2-2**).

Adequacy and Reliability of Institutional and Engineering Controls

There are no engineering or institutional controls under this alternative; however, fish consumption advisories currently issued by OHA would continue. Studies show that the existing advisories are not sufficiently effective in protecting human health since, despite their presence, some anglers still eat their catch and bring their catch home for their families to eat (May and Burger, 1996; Burger et al, 1999; Kirk-Pflugh et al, 1999 and 2011). In addition, consumption advisories are ineffective in reducing risk to ecological receptors.

4.2.1.4 Reduction in Toxicity, Mobility and Volume through Treatment

No treatment processes will be used with Alternative A. Therefore, no actions would be taken and there would be no reduction of toxicity, mobility or volume of contaminants through treatment. PTW would remain untreated within the Site. Reduction of COC concentrations in sediments would occur only through natural processes. Persistent organic pollutants, such as PCBs, dioxins/furans, pesticides, and some solvents, have half-lives on the order of months to years, and the presence of these contaminants decades after their release support this. In addition, this alternative does not include monitoring to confirm such reductions.

4.2.1.5 Short-Term Effectiveness

Alternative A assumes no construction activities. Therefore, there are no short-term risks to the community, workers, or the environment from implementation of this alternative. Risks to the community and environment would continue as a result of exposures to the contaminated media. Fish consumption advisories currently issued by OHA would continue under this alternative. The time until RAOs are attained through natural recovery processes is uncertain.

4.2.1.6 Implementability

There are no implementability issues associated with Alternative A since construction is not conducted. A future ROD amendment may be require if conditions warrant CERCLA actions.

4.2.1.7 Cost

There are no costs associated with this alternative.

4.2.2 Alternative B

Alternative B addresses the unacceptable risks to human health and the environment through capping, dredging, in-situ treatment and ENR of 201 acres of contaminated sediments and 9,633 lineal feet of river bank. The construction duration for this alternative is estimated to be 4 years, with no additional time required to complete dredged material processing. Resuspension/release during construction activities will be addressed through operational best management practices (BMPs) and engineered control measures. Institutional controls to restrict land uses, such as, Waterway Use Restrictions or Regulated Navigation Areas (RNAs) or environmental easements and equitable servitudes, are assumed be implemented to ensure residual risks are contained within the capped areas. Additionally, coordination with federal and state regulatory authorities on future permitting actions that may affect caps or other remediated areas would likely be needed. Alternative B relies on MNR to further reduce post-construction risks.

4.2.2.1 Overall Protection of Human Health and the Environment

Alternative B is unlikely to be protective of human health and the environment since the post-construction risks are greater than the interim targets thus MNR is unlikely to achieve PRGs within a reasonable time frame due to the uncertainty regarding the effectiveness of MNR with such high remaining contaminant concentration. A discussion of how Alternative B performs relative to the interim targets is presented below. The uncertainty analysis conducted in Appendix I for the RALs selected for this alternative further indicates that Alternative B is statistically indistinguishable from the No Action Alternative and may not perform any better. Protection of human health may be achieved through the use of fish consumption advisories and other ICs, although those may not provide sufficient protection in the short- and long-term.

<u>RAO 1</u>
The post-construction carcinogenic risks are estimated to be no higher than 5×10^{-5} (**Figure 4.2-1a-c**), which is within the acceptable risk range but greater than the interim target of 1×10^{-5}. Under Alternative B, only contaminated beaches located between SMAs and river banks would be addressed.

<u>RAO 2</u>

The post-construction carcinogenic risk is greater than the interim target of 1 x 10^{-4}. The estimated post-construction risk is 4 x 10^{-4} on a Site-wide scale (**Figure 4.2-2**). On a river mile scale, post-construction risks are no higher than 2 x 10^{-3} (**Figure 4.2-3a-d**). The highest post-construction risk on an SDU scale is 1 x 10^{-3}; with the exception of the NoSDU, 3.9W, 6NAV, and 6W, all post-construction risks on an SDU scale are greater than the interim target of 1 x 10^{-4} (**Table 4.2-1**); it is unlikely that ENR in Swan Island Lagoon would sufficiently reduce the risk in the long term due to the remaining concentrations outside the SMA.

The post-construction HI is 38 when evaluated Site-wide, which is greater than the interim target of 10 (**Figure 4.2-4**). On a river mile scale, the post-construction HI is no higher than 45 (**Figure 4.2-5a-d**), which is greater than the interim target of 10. The highest post-construction HI on an SDU scale is 34; the HI in SDUs 2E, 3.5E, 4.5E, 5.5E, 11E, 7W, 9W and Swan Island Lagoon are greater than the interim target of 10 (**Table 4.2-3**); it is unlikely that ENR in Swan Island Lagoon would sufficiently reduce the HI in the long term due to the remaining concentrations outside the SMA.

The post-construction HI for infants is 810 on a Site-wide scale (**Figure 4.2-6**), which achieves the Site-wide interim target of 1,320. On a river mile scale, the post-construction HI is no higher than 9,256 (**Figure 4.2-7a-d**), which is greater than the interim target of 450. The highest post-construction HI based on an SDU scale is 1,198; the HI in SDUs 11E, 7W, 9W and Swan Island Lagoon are greater than the interim target of 450 (**Table 4.2-4**); it is unlikely that ENR in Swan Island Lagoon would sufficiently reduce the HI in the long term due to the remaining concentrations outside the SMA.

Fish consumption advisories would be required until such time as RAO 2 is achieved. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

<u>RAO 3</u>
After construction of Alternative B, exceedances of surface water PRGs from contaminated sediment within the Site would continue for PCBs, cPAHs, and 2,3,7,8-TCDD eq at the completion of construction (**Figures 4.2-8a-f**). Only PCBs exceeds the interim target of 10 times the PRG.

<u>RAO 4</u>
Alternative B addresses 16 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-18** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 5

Alternative B addresses 48 percent of the area with unacceptable benthic risks (**Figure 4.2-19** and **Table 4.2-7**). This is does not achieve the interim target of 50 percent.

RAO 6

The post-construction ecological HQs are greater than the interim target of 10. The highest post-construction HQ is 34 on a river mile scale; only the post-construction HQ for BEHP is greater than 10 (**Figures 4.2-9a-e** through **4.2-17a-e**). On a SDU scale, only the post-construction HQ for BEHP in Swan Island Lagoon is greater than the interim target of 10 (**Table 4.2-5**) ; it is unlikely that ENR in Swan Island Lagoon would sufficiently reduce the HQs in the long term due to the remaining concentrations outside the SMA.

RAO 7

There is insufficient surface water data to evaluate the effectiveness of this alternative in meeting the PRGs for BEHP, PAHs and TBT. All other sediment-related PRGs for this RAO are achieved with this alternative. Ethylbenzene is expected to be addressed through RAO 8 and implementation of source control measures.

RAO 8

Alternative B addresses 16 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-18** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 9

Alternative B addresses 32 percent of the contaminated river bank through construction (**Table 4.2-8**); the remainder of the contaminated river bank would be left to no action.

4.2.2.2 Compliance with ARARs

Alternative B may not comply with all ARARs. Chemical-specific ARARs would be achieved over time through implementation of a combination of in-river remedial technologies, although this alternative relies heavily on MNR. It is unlikely that chemical-specific ARARs would be achieved in a reasonable time frame. Location-specific and action-specific ARARs would be achieved by meeting all of the substantive requirements during design, construction, implementation, and monitoring of the alternative.

Compliance with Chemical-Specific ARARs

Exceedances of water quality criteria for protection of human health from contaminated sediment within the Site would continue for PCBs, cPAHs, and 2,3,7,8-TCDD eq at the completion of construction. There is insufficient surface water data to evaluate the effectiveness of this alternative in meeting the aquatic life water quality criteria for BEHP, PAHs and TBT. All other chemical specific ARARs are achieved with this alternative. Ethylbenzene from contaminated groundwater is expected to be addressed to achieve RAO 8 through implementation of source control measures. However, Alternative B only addresses 16 percent of the sediments impacted by groundwater. Alternative B, in conjunction with adequate upland and upriver source control measures, would not achieve numeric human health and aquatic life water quality criteria and drinking water MCLGs and MCLs. Long-term monitoring and maintenance of engineering controls, pore water, and surface water assist in evaluating the ability of this alternative to achieve chemical specific ARARs.

Oregon's risk standards for degree of cleanup for hazardous substances [OAR 340-122-0115(2-4)] will not be achieved at the completion of construction, but may be achieved over time through MNR, ICs, and monitoring. However, with the concentrations of waste left in place, it is unlikely that chemical specific ARARs would be achieved within a reasonable time frame based on the slow or unreliable rate of MNR in many of the contaminated areas (Appendix D).

During implementation of this alternative potential short-term exceedances of some water quality criteria are possible. Under state law, OAR 340-041-004, short term degradation is allowable if the benefits of the lowered water quality outweigh the environmental costs of the reduced water quality as determined through an analysis of the specific water quality impacts and the development of a water quality monitoring plan during design. Through the analysis of the activity and in the water quality monitoring plan, EPA needs to determine that the activity will be conducted in a manner which will not violate applicable water quality standards beyond the specified short-term degradation period and contain the conditions determined to be necessary or desirable with respect to the discharge (also see Section 401 and implementing regulations of the Clean Water Act under Action-Specific ARARs). Compliance with water quality criteria will be met through application of the conditions placed on the discharge as specified in the water quality monitoring plan at a specified distance from the remedial operation. Examples of the types of conditions that will be required are: the use of BMPs, engineering controls and monitoring that will primarily seek to minimize sediment resuspension and dissolved chemical dispersion during dredging and capping activities.

Compliance with Location-Specific ARARs

Location-specific ARARs for Alternative B would be addressed during design and implementation of the selected remedy.

<u>ESA and EFH</u>

ESA requires that the remedial action may not jeopardize the continued existence of endangered or threatened species or result in the adverse modification of species' critical habitat. Agencies are to avoid jeopardy or take appropriate mitigation measures to avoid jeopardy. The Magnuson-Stevens Fishery Conservation and Management Act provides for the designation of Essential Fish Habitat (EFH) for waters and substrate necessary for commercially fished species to spawn, breed, feed, or grow to maturity. Actions that may adversely affect EFH need to be coordinated with NMFS. The substantive requirements of these ARARs would be met during design, construction and long-term monitoring of the alternative.

Compliance with ESA and EFH requirements would be met through preparation of a Site-wide Biological Assessment (BA) for the preferred alternative. The BA evaluates the effects to species listed as threatened or endangered under ESA found at the Site and those species' designated critical habitat and EFH from the proposed remedial activities and how such impacts will be mitigated and reduced. The BA determines whether the proposed combination of technologies and ancillary activities used to clean up the contaminated sediment and river banks may adversely affect listed species and propose BMPs and other mitigation measures to minimize the impacts to the species and critical habitat and EFH during construction of the remedy as well as mitigation that may be necessary to compensate for impacts to critical habitat. Long-term monitoring of the compensatory mitigation to assure it is functioning as designed will be required. The BA and a copy of the proposed plan will be provided to the Services (NMFS and USFWS) for their coordination and concurrence. As remedial design progresses there likely will be a need to supplement the Site-wide BA to address specific issues unique to remedy implementation at a particular area within the Site. If remedial activities may result in any take, a take permit will be requested from the Services.

<u>Federal Emergency Management Act</u>

These regulations at 44 CFR 9 sets forth the policy, procedure and responsibilities to implement and enforce Executive Orders 11988 (Management as Floodplain), as amended by 13690 and 11990 (Protection of Wetland). A simple analysis was conducted (Appendix P) to provide a cursory assessment of the potential for the remedy on a Site-wide and smaller SDU scale could affect flood rise. A HEC-RAS hydrodynamic model will be run to support the selected remedy in the ROD. The substantive requirements of this ARAR would be met during design and implementation of the alternative.

On a Site-wide scale, implementation of Alternative B would result in a net removal of 131,729 cy. However, on an SDU scale, net fill occurs in SDU 2E, SDU 5.5E, SDU 6.5E, NoSDU and in Swan Island Lagoon (Appendix P). A more detailed evaluation of flood rise will need to be conducted in these areas should this alternative be selected for the final remedy which would include consideration of the following:

- Minimize the use of remedial process options that result in a net increase of fill material placed within the river and adjoining flood plain
- Perform detailed modeling to demonstrate that the alternative does not result in unacceptable flood rise
- The use of natural features and nature-based approaches in the implementation of the alternative

- Placement of structures (such as an on-site transload facility) at a higher vertical elevation to address current and future flood risks
- The floodplain and corresponding elevations would be determined using these approaches:
  - Flood Rise: The evaluation of flood rise will need to consider 500-year flood elevation and freeboard and be based on the best-available, actionable hydrologic and hydraulic data and methods that integrate current and future changes in flooding based on climate science.
  - Channel Depth: The Willamette River currently has an authorized channel depth of -40 feet Columbia River Datum (CRD). Prior to listing of the Portland Harbor Superfund Site on the National Priorities List (NPL), the USACE proposed deepening the federally maintained navigation channel to -43 feet CRD. Deepening the navigation channel may mitigate the effects of cap and thick layer sand cover placement on flood rise associated with the sediment cleanup.
  - Climate Change: In general, climate change is expected to result in increased winter flow, decreased summer flow and lower snow packs. River flows within the Willamette River watershed are predicted to be higher in the winter, lower in the summer and with an earlier peak flow. In addition, because of a lower snow pack and more frequent fall and winter rain events, more high flow events are expected but of less magnitude than the large flood events observed in the 1900s. Uncertainties associated with potential climate change will be incorporated into the flood rise evaluation.

<u>Native American Protected Objects and Graves Protection Preparation</u>

During the RI, a cultural resource analysis was conducted and it concluded that there are possible archeological artifacts at the Site, but no gravesites were noted. EPA would meet the substantive requirements of this ARAR during implementation of the alternative in coordination and consultation with the relevant Tribes. If Native American cultural items or gravesites are present on a property, an inventory of such items would be compiled and items would be returned to the Tribes.

If removal of cairn, burial, human remains, funerary objects, or other sacred objects takes place, re-interment will occur under the supervision of the appropriate Indian tribe. Proposed excavation by a professional archaeologist of a Native American cairn or burial requires written notification to the State Historic Preservation Officer and consultation with the appropriate Indian tribe.

<u>National Historic Preservation Act (NHPA) and Archaeological Objects and Sites</u>

There are no areas within the area where action will be taken that have been registered under NHPA. The substantive requirements of this ARAR would be met during design and implementation of the alternative. If cultural resources on or eligible for the national register are present, it will be necessary to determine, in consultation with the appropriate State Historic Preservation Office, if there will be an adverse effect to the resource and, if so, how the effect may be minimized or mitigated. The unauthorized removal of archaeological resources from public or Indian lands is prohibited. A professional archaeologist must conduct any archaeological investigations at a Site.

Compliance with Action-Specific ARARs

Action-specific ARARs for Alternative B would be addressed during design and implementation.

CWA and Oregon WQS

The requirements of the CWA Section 404 and 404(b)(1) guidelines apply to selecting in-water disposal sites and evaluating impacts and compensatory mitigation for unavoidable impacts from placement of dredged and fill materials. The 404(b)(1) guidelines provide standards for the designation, construction and monitoring of in-water disposal sites and in-water filling activities in the Willamette River, and require that no such disposal shall jeopardize the existence of a listed species under the Endangered Species Act. At this Site, compliance with the CWA 404(b)(1) guidelines is documented in a 404(b)(1) evaluation that analyzed the potential impacts of the activities performed under the alternatives. Given the consideration of on-site mitigation and habitat built into this alternative and further analysis conducted under 404(b)(1) guidelines (Appendix L), it was determined that only armored caps within shallow water areas and on river banks results in unavoidable impacts that would require compensatory mitigation resulting from implementation of this alternative. An analysis of this ARAR is presented in Appendix L.

This alternative would meet all of the substantive requirements of this ARAR during design, construction, and long-term monitoring. Controls required for construction activities to minimize the impacts include, but are not limited to:

- water quality monitoring and substantive requirements of a contingency response plan to provide the necessary ARAR compliance documentation
- changes in production rates
- modification of work schedules
- perform work during low river flows
- use of surface booms or oil absorbent pads
- decontamination of construction equipment prior to in-water use
- prevent barge grounding
- prevent incidental release of dredged or capping and residual management material during transloading
- use of appropriate BMPs during transloading activities
- stormwater management at transloading facilities
- appropriate location of staging of demolition and construction materials

- meet substantive requirements of a Spill Prevention, Containment and Countermeasure (SPCC) Plan to provide the necessary ARAR compliance documentation
- fish capture and removal inside work isolation areas
- control and monitoring of dewatering activities and material
- residual layer placement as soon as possible
- use of physical barriers
- placement of material from lower to higher elevations
- monitoring for accurate placement of material
- use of clean capping and residual management material
- beach mix include materials less than 2.5 inches
- incorporation of vegetation on river bank caps, where possible

Even with implementation of avoidance and minimization efforts, it is anticipated that remediation of the Site will result in some unavoidable loss of some aquatic habitat. These losses will be offset by compensatory mitigation, which entails the restoration, establishment, enhancement, and/or preservation of wetlands, streams, or other aquatic resources conducted specifically for the purpose of offsetting authorized impacts to these resources. A compensatory mitigation framework will be developed which, in coordination with NMFS and USFWS, may use a Habitat Equivalency Analysis (HEA) method, Relative Habitat Value (RHV) scoring approach, or other approach for determining compensatory mitigation acreages. It was assumed that 15 acres would require mitigation under Alternative B.

The substantive requirements of the CWA Section 404(b)(1) trigger the need to consider the substantive requirements of the CWA Section 401 and Oregon’s Water Quality law. Pertinent water quality-specific information would be considered during design and a water quality monitoring plan will be developed to provide the necessary ARAR compliance documentation and include conditions on the activities to be met such as, but not limited to, dredging speeds and techniques, establishing a point of compliance for water quality criteria, type and frequency of monitoring samples, storm water management and treatment, erosion control measures, seasonal constraint, and restoration/mitigation measures.

Both CWA Section 401 and Oregon’s Water Quality Law require that any activity during the implementation of the remedial action that may result in a discharge to waters of the State requires reasonable assurance that water quality standards will be complied with and requires conditions and other requirements deemed necessary to be placed on the discharge. During dredging and placement of dredged or capping and residual management material, potential short-term exceedances of some water quality criteria are likely. However, through the application of BMPs and engineering control measures water quality criteria are expected to be met in accordance with Section 401 and Oregon’s Water Quality Law.

Rivers and Harbors Act

The Rivers and Harbors Act is an applicable requirement regarding remedial actions taken or constructed in the navigation channel and prohibits actions that would interfere with navigation. Contaminated sediments located in the navigation channel are assumed to be dredged and then a residuals management layer would be placed in the dredged area. Caps were not evaluated in this region of the Site due to incompatibility with navigational uses and the known depth of contamination, based on existing data. However, contamination at depths greater than the authorized depth of the navigation channel may be capped as long as the cap integrity is not impaired by future maintenance dredging. Disposal of dredged material was not evaluated in this region of Site due to incompatibility with its current use for navigation.

RCRA

The substantive requirements of the RCRA ARAR would be met during design and implementation of the alternative. Analytical testing results of dredged sediment will be used for waste characterization and determinations of appropriate disposal. Data collected during remedial design will initially be used to inform the appropriate disposal site. A Materials Management Plan would provide the necessary ARAR compliance documentation. The Materials Management Plan will define record keeping requirements, container requirements, storage requirements consistent with RCRA to be implemented during construction and operation of the transload facilities.

All dredged materials and contaminated river bank materials removed from the Site under this alternative would be managed under Disposal Management Method (DMM) Scenario 2 (off-site disposal facilities). Under Alternative B, approximately 14,700 cy of dredged sediment and excavated soils are treated using low temperature thermal desorption and 177,000 cy are treated using solidification/stabilization prior to disposal in a Subtitle C landfill. An additional 14,700 cy of dredged sediment and excavated soil are not treated prior to disposal in a Subtitle C landfill. Approximately 426,000 cy of dredge sediment and excavated soils are disposed in a Subtitle D landfill without treatment.

Oregon Hazardous Waste and Hazardous Materials

The substantive requirements of this ARAR would be met during design and implementation of the alternative. State-listed hazardous waste has been identified offshore within SDU 7W. Hazardous waste generated during remedial actions may be treated and temporarily stored at transload facilities pending final transport and disposition. A Materials Management Plan developed as part of the design addressing how State treatment and storage regulations will be complied with during the construction and operation of the transload facilities. Under Alternative B, the FS assumed that 44,100 cy of dredged sediment and excavated soils for disposal in a Subtitle C landfill may be managed as State-listed waste; of this total amount, 14,700 cy would not be treated, 14,700 cy would be thermally treated, and 14,700 cy would be treated using solidification/stabilization. Additionally, the FS assumed that up to

157,000 cy of dredged sediment (excluding sediment dredged from SDU 6W) may be managed as State-listed waste for disposal in a Subtitle D landfill without treatment.

Toxic Substances Control Act (TSCA)

The substantive requirements of this ARAR would be met during design and implementation of the alternative. There are currently no sediment sample results that exceeded the TSCA threshold, so it is anticipated that very little, if any, waste would be generated that would require compliance with this ARAR. Any TSCA waste containing greater than 50 mg/kg of PCBs generated as a result of remedial actions in the Site would meet requirements during transport and off-site disposal. The Chemical Waste Management Facility in Arlington, Oregon, is permitted to accept TSCA waste (RCRA and TSCA EPA ID Permit ORD089452353). The preparation of a Materials Management Plan during design and utilized during implementation will address proper handling and disposition of any TSCA waste generated during remedial actions.

General Emissions Standards and Fugitive Emission Requirements

The substantive requirements of these ARARs would be met during design and implementation of the alternative. Reasonable precaution to control fugitive emission of air contaminants will be taken in accordance with OAR 340-226. Emission of airborne particulate matter would be controlled to address OAR 340-208. Dust suppression will be maintained to eliminate air contaminant migration during remedial action in compliance with these ARARs. Air monitoring would be required to ensure that contaminants that volatilize would not exceed acceptable health based concentrations and adversely affect local communities and workers.

Marine Mammal Protection Act

The substantive requirements of this ARAR would be met during design and implementation of the alternative. The selected remedial actions will be carried out in a manner to avoid adversely affecting marine mammals (such as the Steller sea lion).

Migratory Bird Treaty Act (MBTA)

The substantive requirements of this ARAR would be met during design and implementation of the alternative. The selected remedial actions will be carried out in a manner to avoid adversely affecting migratory bird species, including individual birds or their nests (such as the Bald Eagle).

Fish and Wildlife Coordination Act

The substantive requirements of this ARAR would be met during design and implementation of the alternative. This statute and implementing regulations require coordination with federal and state agencies to ensure that any modification of any stream or other water body affected by any action authorized or funded by the federal agency provides for adequate protection of fish and wildlife resources.

4.2.2.3 Long-Term Effectiveness and Permanence

Alternative B permanently removes approximately 628,000 cy of contaminated sediment and river bank soil covering approximately 72 acres of river bottom and 9,633 lineal feet of river bank by dredging or excavating to targeted removal depths. Various caps would be placed over 28 acres of the Site. Residuals from dredging and contaminated areas subject to ENR (approximately 170 acres) would be managed with a thin layer sand cover. After construction is completed, the remediated areas would no longer pose unacceptable risks to humans and the environment. However, 91 percent of the area of contaminated sediment would rely on MNR to achieve PRGs and no action would be taken on 68 percent of contaminated river bank.

Magnitude of Residual Risk

Alternative B addresses the highest contaminant concentrations and would result in reducing the risks posed by the Site as well as the potential for contamination in the Site sediments to be dispersed to less contaminated areas and downstream to the Columbia River. Reductions in COC concentration and related risks are expected to occur over time, but the RAOs may not be achieved in a reasonable time frame. An evaluation of the contaminant loading from the Site to the Columbia River was conducted (Appendix K) and, for Alternative B, the only contaminant load from the Site after construction of Alternative B is 0.6 kg cPAHs/yr; all other contaminants would no longer contribute to the contaminant load, although the contaminant loads from upriver and the downtown reach are still appreciable. Contaminant loading from the Site sediments would continue until sediment PRGs are attained.

The magnitude of residual risks for each RAO are as follows:

<u>RAO 1</u>

The residual risk from exposure to nearshore sediment once PRGs are achieved is 6×10^{-6}. The post-construction risk is within EPA's acceptable risk range but is a factor of 8 greater than the residual risk estimate. In beach areas, the residual risk once PRGs are achieved is 9×10^{-6}; however, only contaminated beaches located between SMAs and contaminated river banks would be addressed and the magnitude of residual risk is uncertain because there may be areas of contaminated beach that will not be addressed through this alternative.

<u>RAO 2</u>

The Site-wide residual risk once PRGs are achieved is 8×10^{-5}. The post-construction risk is a factor of 5 greater than the residual risk estimate. On both a river mile and SDU scale, the residual risk once PRGs are achieved is 3×10^{-5}. The post-construction risk is a factor of 53 greater than the residual risk estimate on a river mile scale. All post-construction risks on an SDU scale exceed the residual risk estimate (**Table 4.2-1**); the risk ranges from a factor of 3 to 35 greater than the residual risk estimate. In Swan Island Lagoon, it is unlikely that ENR would sufficiently reduce the risk to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

The Site-wide residual HI once PRGs are achieved is 6. The post-construction HI is a factor of 6 greater than the residual HI estimate. On both river mile and SDU scale, the HI once PRGs are achieved is 2. The post-construction HI is a factor of 22 greater than residual HI estimate on a river mile scale. All post-construction risks on an SDU scale exceed the residual HI estimate (**Table 4.2-3**); the HI ranges from a factor of 2 to 17 greater than the residual HI estimate. In Swan Island Lagoon, it is unlikely that ENR would sufficiently reduce the HI to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

The Site-wide residual HI for the infant once PRGs are achieved is 132. The post-construction HI is a factor of 6 greater than the residual HI. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 45. The post-construction HI is a factor of 206 greater than the residual HI on a river mile scale. All post-construction risks on an SDU scale exceed the residual HI estimate (**Table 4.2-4**); the HI ranges from a factor of 2 to 27 greater than the residual HI estimate. In Swan Island Lagoon, it is unlikely that ENR would sufficiently reduce the HI to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

Further reductions in risk are expected through MNR and implementation of institutional controls, although the timeframe for achieving RAOs is uncertain. Fish consumption advisories would be required until such time as RAO 2 is achieved. The acceptable consumption rates once the PRGs are attained is 30 eight-ounce fish meals every year based on 1 x 10^{-5} risk, 16 eight-ounce fish meals every year based on non-cancer hazard, and 2 eight-ounce fish meals every year for women who may breastfeed (**Table 4.2-2**). After construction of Alternative B, the acceptable consumption rate is 5 eight-ounce fish meal every year (50 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 2.4 eight-ounce fish meal every year (24 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.3 fish meal every year (3 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

<u>RAO 3</u>
The Site-wide surface water contaminant concentrations from contaminated sediment in the Site is a factor of 13 greater than the PRG for PCBs, a factor of 6 greater than the PRG for 2,3,7,8-TCDD eq, and a factor of 1.2 greater than the PRG for cPAHs (**Figures 4.2-8a-f**).

<u>RAO 4</u>
Approximately 84 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative B (**Figure 4.2-18** and **Table 4.2-6**). Placement of reactive caps in locations of contaminated groundwater flux would reduce the exposure to those contaminants and assist in attainment of RAO 4. Residual risks will remain in areas of contaminated groundwater plumes that are not otherwise addressed by capping, dredging, in-situ treatment and ENR; however, the magnitude

residual risk is uncertain because it is likely that not all contaminated pore water will be addressed with this alternative.

RAO 5

Approximately 52 percent of the area with unacceptable benthic risks would not be addressed by Alternative B (**Table 4.2-7** and **Figure 4.2-19**). Further risk reductions are likely to occur over time due to natural recovery processes, but the degree in which these benthic risk areas might recover is uncertain because it is likely that an insufficient amount of the benthic risk areas will be addressed with this alternative.

RAO 6

The residual HQ once PRGs are achieved is 1 for each COC. The post-construction HQ on a river mile scale is a factor of 34 greater than the residual HQ estimate for BEHP, a factor of 6 greater than the residual HQ estimate for PCBs and TCDF, a factor of 4 greater than the residual HQ estimate for PeCDF, and a factor of 3 greater than the residual HQ estimate for HxCDF (**Figures 4.2-9a-e** through **4.2-17a-e**). On an SDU scale, the post-construction HQ varies but the maximum is a factor of 11 greater than the residual HQ estimate for BEHP, a factor of 5 greater than the residual HQ estimate for PCBs, a factor of 3 greater than the residual HQ estimate for TCDF, and a factor of 2 greater than the residual HQ estimate for HxCDF and PeCDF (**Table 4.2-5**). In Swan Island Lagoon, it is unlikely that ENR would sufficiently reduce the HQs to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

RAO 7

There is insufficient surface water data to evaluate the magnitude of residual risk. Since Alternative B focuses on containing or removing the highest contaminant concentrations at the Site through capping, dredging, in-situ treatment and ENR it is expected that this will result reductions in contaminant flux from the surface sediment to the surface water and subsequently surface water and fish tissue concentrations. Residual risks in surface water will remain in areas of contaminated sediment that are not otherwise addressed by capping, dredging, in-situ treatment and ENR; however, the magnitude of residual risk is uncertain because it is likely that contaminated sediments remaining will continue to impact the water column with this alternative.

RAO 8

Approximately 84 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative B (**Figure 4.2-18** and **Table 4.2-6**). Placement of reactive caps in locations of contaminated groundwater flux would reduce the exposure to those contaminants and assist in attainment of RAO 8. Residual risks will remain in areas of contaminated groundwater plumes that are not otherwise addressed by capping, dredging, in-situ treatment and ENR; however, the magnitude of residual risk is uncertain because it is likely that not all pore water will be addressed with this alternative.

RAO 9

Approximately 68 percent of contaminated river bank soils would not be addressed by Alternative B (**Table 4.2-8**). Removal of contaminated river bank materials and placement of either an armored or engineered cap using beach mix or vegetation would reduce exposure and erosion potential; however, the magnitude of residual risk is uncertain because it is likely that not all contaminated river banks will be addressed with this alternative.

Adequacy and Reliability of Engineering and Institutional Controls

Sediment removal, capping, and thin layer covers are reliable and proven technologies as long as they are designed for the appropriate environmental and anthropogenic conditions. Off-site thermal desorption, solidification/stabilization, and land-based disposal facilities are in operation and have proven to be reliable technologies.

Alternative B would be effective in limiting exposure to risks posed by COCs in the sediments and river bank soils provided the integrity of the caps is maintained. Therefore, the caps would need to be monitored and maintained in perpetuity. Reviews at least every five years, as required, would be necessary to evaluate the effectiveness of any of these alternatives because hazardous substances would remain onsite in concentrations greater than would allow for unrestricted use and unlimited exposure.

Operation and maintenance activities, ICs and long-term monitoring will be implemented to assure protectiveness and reliability of caps and thin layer covers. The following paragraphs further describe how these activities maintain the protectiveness and reliability of these controls:

- O&M will be required for material left in place and may include bathymetric surveys and diver performed monitoring at regular intervals to confirm the thickness of capping materials. In addition to regular surveys, supplemental surveys will be performed following episodic natural) and anthropogenic events that have the potential to disturb caps and sand covers.

- ICs include governmental controls, proprietary controls and informational devices. The reliability of ICs can be enhanced through activities such as regular inspection of buoys and other devices to delineate regulated navigation areas, administrative procedures and inspections to ensure the maintenance of co-located structures and ongoing public outreach efforts to enhance the effectiveness of informational devices. Coordination will need to occur with federal and state regulatory authorities during future permitting activities that may disturb subsurface contaminated sediment or capped areas. Additional institutional controls (see **Table 2.4-2**) would be necessary to maintain cap integrity in perpetuity. Fish consumption advisories, which rely on voluntary compliance, would be enhanced by additional outreach to improve their effectiveness in reducing risk to human health by limiting exposure to COCs.

- Monitoring of the effectiveness of the remedial alternative would include sampling of the water column, sediment, pore water, and biota tissue before, during and after construction to verify that risks to the ecosystem continue to decrease. The planned post-construction monitoring program would result in collection of the data necessary to determine whether the fish consumption advisory or other restrictions imposed as part of the remedial action could be relaxed. Tissue PRGs will be used during the post-construction monitoring period to evaluate if contaminant concentrations are decreasing toward PRGs as expected.

4.2.2.4 Reduction in Toxicity, Mobility and Volume through Treatment

Implementation of Alternative B reduces toxicity, mobility and volume through treating sediments and river banks where PTW is present or where groundwater plumes are discharging or have the potential to discharge into the sediment and surface water. PTW will be treated in-situ or ex-situ, depending on the technology assignment, while in-situ treatment will be used in areas where groundwater plumes are located.

Treatment Processes Used

Activated carbon or organophilic clay are the representative in-situ treatment technologies that reduce the bioavailable fractions and thus toxicity and mobility of contaminants as measured through pore water concentrations. The delivery mechanisms for activated carbon or organophilic clay include:

- Broadcast Activated Carbon: Direct broadcasting of 12-inches sand mixed with 5 percent activated carbon (0.12 pounds per square foot per centimeter [lbs/ft^2/cm])

- Reactive Caps: Includes a 12-inch chemical isolation layer comprised of sand mixed with 5 percent activated carbon (0.12 lbs/ft^2/cm)

- Reactive Residual Layer: 12 inches of sand mixed with 5 percent activated carbon (0.12 lbs/ft^2/cm)

- Significantly Augmented Reactive Cap: Includes a 1-inch organoclay mat

PTW that is highly mobile and not reliably contained (NRC) is identified to be treated ex-situ prior to disposal; however, ex-situ treatment of PTW is assumed only to the extent that it is required by the disposal facility. All PTW treated ex-situ under Alternative B is assumed to be disposed at a RCRA Subtitle C facility. In addition, the Subtitle C disposal facility selected as a representative process option (Chem Waste) uses treatment processes such as cement stabilization or thermal desorption, as needed, to meet LDRs for hazardous waste.

Amount of Material Destroyed or Treated

Under Alternative B, 70 acres of material are assumed to be treated in-situ (includes broadcast activated carbon, reactive caps, reactive residual layers and significantly augmented reactive caps) and 192,000 cy of material would be treated ex-situ.

Reduction of Toxicity, Mobility or Volume

Reduction of toxicity, mobility and volume would be achieved through:

- <u>Broadcast Activated Carbon</u>: 6.7 acres
- <u>Reactive Caps</u>: 23.0 acres
- <u>Reactive Residual Layer</u>: 36.5 acres
- <u>Significantly Augmented Reactive Cap</u>: 3.8 acres

In addition, based on the technology assignments for Alternative B, the quantity of dredged PTW (source material and not reliably contained) requiring ex-situ treatment is estimated at 192,000 cy. The actual amount of material subject to ex-situ treatment would depend on the results of the waste characterization testing during the remedial design. Thermal desorption reduces the mobility of approximately 39 percent of the dredged material that is PTW NRC/NAPL where stabilization/solidification would reduce the mobility most of this material. In addition, the mobility of contaminants would be further reduced through sequestration by placing it in a permitted landfill, not due to permanent and irreversible treatment.

For dredged material not subject to ex-situ treatment, mobility would be reduced by placing it into a permitted landfill (through sequestration, not treatment); there would be no reduction in toxicity or volume.

Irreversible Treatment

Activated carbon is not readily broken down in the environment and thermodynamic principles indicate that the bonding of COCs to activated carbon will remain strong over time. COCs are expected to remain bound whether the sorbent and bound chemicals remain in the sediment bed or are re-suspended and transported away from the area (ITRC 2014). As a result, use of activated carbon for in-situ treatment is considered permanent and irreversible as long as there is sufficient quantity of activated carbon to address the amount of contamination present.

Low-Temperature Thermal Desorption is an ex-situ remedial technology that uses heat to physically separate organic contaminants from excavated soils and sediments. Thermal desorbers are designed to heat contaminated sediments to temperatures sufficient to cause contaminants to volatilize and desorb (physically separate) from the sediment. Although they are not designed to decompose organic constituents, thermal desorbers can, depending upon the specific organics present and the temperature of the desorber system, cause some of the contaminants to completely or partially decompose. The vaporized hydrocarbons are generally treated in a secondary treatment unit (such as an afterburner, catalytic oxidation chamber, condenser, or carbon adsorption unit) prior to discharge to the atmosphere. Afterburners and oxidizers destroy the organic constituents. Condensers and carbon adsorption units trap organic compounds for subsequent treatment or disposal.

Solidification/Stabilization adds chemically reactive compounds to dredge materials that form stable solids that are non-hazardous or less-hazardous than the original materials. Solidification refers to the physical changes in the contaminated material when a certain binding agent is added. These changes include an increase in compressive strength, a decrease in permeability, and condensing of hazardous materials. Stabilization refers to the chemical changes between the stabilizing agent (binding agent) and the hazardous constituent. These changes result in a less soluble, less toxic material with reduced mobility. Common bonding agents include, but are not limited to, Portland cement, lime, limestone, fly ash, slag, clay, and gypsum. Because of the vast types of hazardous materials, each agent may be tested/piloted at the Site before a full-scale project is undertaken. Most binding agents used are a blend of various single binding agents, depending on the hazardous material. Portland cement has been used to treat more contaminated material than any other solidification/stabilization binding agent because of its ability to bind free liquids, reduce permeability, encapsulate hazardous materials, and reduce the toxicity of certain contaminants. Lime can be used to adjust the pH of the substance of drive off water by the exo-thermic reaction. Limestone can also be used to adjust pH levels.

Type and Quantity of Residuals Remaining After Treatment

Implementation of Alternative B address 37 percent of the PTW at the Site (**Table 4.2-9**). Therefore, this alternative does not meet the statutory preference for addressing all principal threat wastes to the maximum extent practicable. There would also be residual PTW that will remain under caps, although the treatment barriers in the caps would be designed to prevent exposure. While 15 acres of reactive caps are included in this alternative to deal with exposures from contaminated groundwater plumes, the full extent of exposure from these plumes is uncertain and has not been quantified. Based on the upland evaluations on the nature and extent of these groundwater plumes, this alternative would treat approximately 6 percent of contaminated groundwater discharging to the sediment bed within the Site. Additional characterization during remedial design would be required to ensure that the full extent of the exposure is addressed in remedy implementation.

4.2.2.5 Short-Term Effectiveness

Implementation of Alternative B would have some impact to the community, workers, and the environment during construction. The period of construction is estimated as 4 months per year for 4 years. During the construction period, approximately 628,000 cy dredged sediment and excavated soil would be transported off the Site and 496,000 cy capping and residual management materials would be transported into the Site. Dredged materials and capping and residual management materials will need to be handled by workers. Impacts to the environment would occur during construction and continue until RAOs are achieved. These impacts would include unacceptable human and ecological exposure as well as reducing the ability for humans to safely consume fish and the ability of the tribes to fully engage in their ceremonial practices. Impacts to the aquatic environment for are also described further in Appendix L.

Community Protection

There are some short-term risks to the community from exposure to contaminated sediments and river bank soils during the construction period. This alternative involves dredging of 72 acres and excavation of 9,633 lineal feet of river bank, with import of approximately 496,000 cy of capping and residual management material. Construction is assumed to proceed continuously for 24 hours per day, six days per week, 122 days per year, and for 4 years. Construction and operation of a treatment and transport facility may be necessary. Construction and operation activities may result in temporary noise, light, odors, potential air quality impacts and disruptions to commercial and recreational river users on both sides of the river. However, the actual duration at any specific location would be less than the overall construction period.

Material transported off-site for disposal is assumed to be conducted via barge to an off-site transloading facility and then trucked or railed to the disposal facility. Increased barge traffic transporting dredged material may interfere with commercial navigation, with increased potential for waterborne accidents and on-shore impacts from exhaust. If an on-site transloading facility were constructed, off-site disposal may result in upland impacts to the community through increased vehicular traffic (direct transport to off-site disposal or rail transfer facilities) with potential increases in accidents and air-quality issues associated with dust, odor, and vehicular exhaust. Under Alternative B, the capping and residual management materials for construction would require handling and transport through the community and would have impacts similar to those described for off-site disposal.

Measures to minimize short-term risks to the community will be addressed through implementation of health and safety plans and the use of BMPs, including but not limited to, the following:

- Limiting access to sediment processing at upland treatment and transfer facility areas to authorized and trained personnel.
- Pollution controls to minimize emissions and odors from construction activities.
- Engineering and navigation controls (established by the dredging and/or materials management contractor working in coordination with the U.S. Coast Guard and other entities) to mitigate increased river traffic.

- Isolating work areas with an adequate buffer zone so that pleasure craft and commercial shipping can safely avoid construction areas.

- Fish consumption advisories would continue under this alternative until such time as Remedial Action Objectives (RAOs) are achieved. COC concentrations in fish tissue are expected to increase during the course of the multi-year construction period; however, this will mainly occur during the in-water work window of July 1 through October 31. Based on experience at other sites [Hudson River (NY), Grasse River (NY)], recovery following construction is relatively rapid, on the order of a few years, and is expected to continue to decrease as contaminant concentrations in sediment decrease.

Worker Protection

Alternative B would pose potential risks to Site workers through:

- Direct contact with COCs in dredged sediment

- Demolition, removal, and/or replacement of structures

- Activities in a river environment such as working on a vessel, near heavy and mobile equipment in and around working docks

- Working around marine operations with frequent vessel traffic

- Transport of borrow materials and carbon amendment for cover construction

- Placing amendments in in-situ treatment areas

- Transport of contaminated sediment and river bank soils

Safety measures and BMPs would be used to minimize the impacts referenced above. Measures such as:

- Use personal protective equipment (PPE)

- Establish work zones

- Dust suppression during material handling and river bank actions

- Worker Health and Safety Plans

- Following Occupational Safety and Health Administration (OSHA) approved health and safety procedures

Environmental Impacts

Sediment removal and capping may result in short-term adverse impacts to the river, including:

- Exposure of fish and other biota to suspended and dissolved contaminants or material in the water column
- Temporary loss of benthos and habitat for the ecological community in dredged areas
- Increased emissions from construction and transportation equipment

Measures and BMPs would be used to minimize the above referenced impacts, including:

- Engineering controls to minimize resuspension/release during cap placement
- Sequencing of dredging and placement activities to minimize recontamination potential
- Conduct work within the in-water work window (July 1st through October 31st) to minimize impacts to migratory fish
- Silt curtains, sheet pile walls, or other physical barriers will be used as appropriate to minimize releases
- Actions will be taken to remove fish from within barrier enclosures prior to commencing construction activities

Precautions and controls will be taken to prevent incidental and accidental discharges of toxic materials from entering the water column from in-water work. These include:

- Use spill plates and aprons to prevent dropping dredge material into the water
- Reduction of cycle times
- Restrict lateral movement of the dredge bucket while under water
- Use closed dredge buckets whenever Site conditions allow
- Reduce or stop dredging during periods of peak current

Application of BMPs for emissions reduction would reduce short-term impacts posed to the environment and would consistent with the EPA Region 10 Clean and Green Policy. A Green Remediation Plan will be required during remedial design consistent with the outline provided in Appendix M. Emission reduction could be controlled through BMPs such as:

- Use of reusable energy sources.
- Limit idling of trucks and equipment.
- Rely on local sources of materials.
- Ensuring that trucks, barges and railcars are full prior to transport
- Implement onsite dust and noise control to reduce air pollutant and greenhouse gas emissions.
- Require clean fuel incentives in construction contracts.

Environmental impacts would continue until RAOs are achieved. Environmental impacts to human health via consumption would be controlled through fish consumption advisories.

Time until Action Complete

Construction operations for this alternative are estimated to take four years. Following the estimated construction time, Alternative B residual contaminant concentrations would be greater than interim targets in all SDUs and MNR is therefore unlikely to achieve RAOs in a reasonable time frame based on the MNR analysis for Alternative B presented in Appendix D.

4.2.2.6 Implementability

Alternative B would be readily implementable from both the technical and administrative standpoints. The in-river remedial action can be constructed, operated, and maintained within the Site-specific and technology-specific regulations and constraints. Remedial action of river banks can also be constructed, operated and maintained, but may be more difficult to implement where there are obstructions such as docks and nearshore infrastructure.

Ability to Construct and Operate

The in-river construction activities required for the implementation of Alternative B would be technically feasible and have been implemented at many Superfund sites around the country. Implementation of Alternative B would involve dredging and excavating approximately 628,000 cy of contaminated material and the handling and placement of 496,000 cy capping and residual management material.

Alternative B has a construction period of approximately four years, involves construction activities within 201 acres, and thus has a low potential for technical difficulties that could lead to schedule delays. Portland Harbor is a working industrial waterway that has the necessary infrastructure to support sediment remediation activities. Nevertheless, careful coordination will be required among government agencies, private entities and the community to design, schedule, and construct the cleanup actions. Further, it will be important to evaluate whether upland source control actions have been implemented to a sufficient degree before or as a part of remedy construction to limit recontamination potential.[3]

Inadequate removal of contaminated sediment and soil or the need to manage residuals remaining after dredging or excavating could require further evaluation to determine the need for additional actions. Release and residual management measures such as silt curtains and sheet piles may be difficult to construct and reliably operate in portions of the river affected by navigation traffic, deeper water, and significant current, this may lead to schedule and implementation delays.

Another technical implementability challenge is remediation under and behind piers and other above-water structures. Debris is expected to complicate, but is not likely to significantly delay, construction efforts. Maintaining flexibility in construction methods through the remedial design phase is an important consideration for these areas.

Ease of Doing More Action, if Needed

Increasing the extent of capping, dredging/excavation, in-situ treatment, or ENR would be easily implemented. Additional remedial actions on river banks could be more problematic due to factors such as adjacent land use, structures, steepness, use of the adjacent waterways, and community concerns. Depending on the scope of the additional actions, post–ROD changes may be needed.

Ability to Monitor Effectiveness

Fish consumption advisories would be required until such time as RAO 2 is achieved. After construction of Alternative B, the acceptable consumption rate is 5 eight-ounce fish meal every year (50 fish meals/10 years) based on 1×10^{-5} risk (**Figure 4.2-2**), 2.4 eight-ounce fish meal every year (24 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.3 fish meal every year (3 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). This is also presented in **Table 4.2-2**. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

RNAs are assumed for 28 acres of caps. Regular monitoring of cap performance would be conducted and evaluated on 39 acres of caps required under 5-year reviews. Inspection, maintenance, and repair/replacement of caps are relatively easy and straightforward to implement in unobstructed areas, but may be more challenging around obstructions, in the navigation channel, or in future maintenance dredge areas. If monitoring should fail to detect in a reasonable time frame a release in areas where

[3] If further action under CERCLA is warranted, then a separate decision document would be issued.

waste has been left in place, then an unacceptable release of COCs to the environment may occur.

Alternative B relies on reducing contaminant concentrations through MNR for approximately 1,966 acres. MNR requires significant administrative effort over the long term to oversee and coordinate sampling, data evaluation, and future additional actions, if any are needed. The MNR analysis conducted in Appendix D indicates that the majority of the site is neutral (transitional); therefore, there is greater uncertainty that RAOs will be achieved in a reasonable timeframe due to the remaining concentrations. For this reason, some additional future remedial actions are predicted to be more likely for Alternative B. Should future remedial actions be warranted, subsequent decision documents would be issued.

Ability to Obtain Approvals and Coordinate with Other Agencies

Coordination with the ODFW, NMFS, and USF&W would need to be conducted during construction in order to protect migrating salmon in the lower Willamette River. The current in-water fish work window established for the Willamette River is July 1 through October 31 and accounts for fish migration patterns. Extending the period of the work each year would require consultation with ODFW, NMFS, and USF&W, but should be obtainable.

Coordination with DSL and/or other property owners would need to be conducted to manage waste left in place and implement land use restriction ICs, if needed. Additionally, property owners of potential staging areas and transloading facilities would also need to be consulted and access obtained. Alternative B leaves waste in place in 2,088 acres of the Site.

Regulatory approval for off-site permitted disposal facilities as identified in **Table 2.4-2** should be readily obtainable.

Coordination with DSL and/or other property owners would need to be conducted for demolition and removal, or relocation of structures may be challenging, but should be obtainable.

Institutional controls, such as RNAs or other land use restriction mechanism, would need to be established for all in-water caps. Under Alternative B, 39 acres of caps are assumed to need RNAs and 28 acres of caps are assumed to need land use restrictions. These ICs should be straightforward and easily obtainable.

Coordination with ODFW, NMFS, and USF&W would need to be conducted during construction in order to determine mitigation requirements under CWA 404 and ESA. Onsite identification of mitigation site may be difficult to attain due to the lack of available locations within the Site and current and or future land uses. Off-site mitigation, if required, would need regulatory approvals which could likely take longer than on-site mitigation. Implementation of mitigation should be straightforward. Under

Alternative B, it is estimated that 15 acres would require some type of mitigation for costing purposes.

Availability of Adequate Off-site Treatment, Storage Capacity, and Disposal Capacity and Services

Regional upland landfills are authorized to receive contaminated sediment and have done so on several recent projects in or near the Site. Upland commercial landfills are identified in in **Table 2.4-2** have capacity relative to the volume of sediment expected to be dredged from the Site for Alternative B. The upland commercial landfills can accept wastes transported by rail, barge, or trucking. Transportation and management of materials would involve identification of sufficient space and proximity to the transportation network to the landfill facility. Several potential sites were identified in the Portland Harbor area where transload facility exists for handling material for disposal in an upland commercial landfill (Appendix F).

Availability of Specialists, Equipment and Materials

Services, equipment, and materials are locally or regionally available. Experienced environmental dredge and excavator operators, and material placement specialists would be required. Three dredges are assumed for Alternative B. Modes of transporting material offsite include barging to existing transloading facilities and transporting to an off-site disposal facility via truck or rail. Approximately 434 barge loads and 42,439 truckloads or 10,576 rail loads are assumed to transport the removed material. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally, 309 barge loads, 36,213 truckloads, or 7,834 rail loads are assumed to transport material into the Site. Columbia River dredge material may be a source of capping and residual management material, if it meets the clean fill requirements specified in the ROD.

Availability of Technologies

Technologies specific to dredging, capping, and on-site treatment are available and have been previously used at the Site for early actions.

4.2.2.7 Cost

Total capital costs estimated for this alternative are $352,097,000 over 4 years. Total periodic costs (including O&M) are $290,324,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $642,421,000, with a net present value cost of $451,460,000. Detailed costs associated with implementing Alternative B are presented in Appendix G and summarized in **Table 3.7-1**.

A sensitivity analyses (Appendix N) was performed consistent with EPA Guidance (USEPA 2000) to obtain a better understanding of those particular alternative component quantities or costs that have the greatest impact on the total costs (both constant dollar (non-discounted) costs and present value dollar (discounted) costs). A summary of the conclusions for each sensitivity analysis is presented below:

Period of Analysis Assumptions (30 years versus 100 years): The constant dollar costs for each alternative increase as the periods of analyses increase. However, the constant dollar expenditures after year 30 have minimal effects on the present value costs. The present value costs are generally not sensitive to changes to period of analysis beyond 30 years.

Monitoring Frequency Assumptions (currently assumed O&M Frequency versus 5-year frequency): Reducing the frequency of O&M has a small to moderate impact on the total present value cost.

Subtitle C/TSCA Disposal Volume Assumptions (current Subtitle C/TSCA disposal volume vs. Subtitle C disposal volume ± 15%): Reducing and increasing the volumes of Subtitle C by 15% has minimal effects on the total present value cost. There is some minor sensitivity between alternatives due to the increased volumes of overall dredging independent of the disposal assumptions.

Construction Duration Assumptions (currently assumed construction duration versus construction duration ± 50%): Reducing and increasing the construction duration assumptions has a relatively significant effect on the total present value cost compared to the other sensitivity analysis scenarios. Shortening the construction durations has a slightly higher effect on sensitivity for all alternatives compared to lengthening the construction duration.

Overdredge Assumptions (current overdredge factor assumption [1.75] vs. low/high overdredge factor [1.50/2.0]): Reducing and increasing the overdredge factor has a small to moderate impact on the total present value cost.

4.2.3 Alternative D

Same as Alternative B, although:

Alternative D would address the unacceptable risks to human health and the environment through capping, dredging, in-situ treatment and ENR of 267 acres of contaminated sediments and 13,887 lineal feet of river bank. The construction duration for this alternative is estimated to be 6 years, with no additional time required to complete dredged material processing.

4.2.3.1 Overall Protection of Human Health and the Environment

Same as Alternative B, although:

A discussion of how Alternative D performs relative to the interim targets is presented below. However, the uncertainty analysis conducted in Appendix I for the RALs selected for this alternative indicates that Alternative D is statistically distinguishable from the No Action Alternative and may have some environmental benefit. Protection of human health may be achieved through the use of fish consumption advisories and other ICs, although those may not provide sufficient protection in the short- and long-term.

<u>RAO 1</u>
Same as Alternative B, although:

The post-construction carcinogenic risks are estimated to be no higher than 2 x 10^{-5} (**Figure 4.2-1a-c**), which is within the acceptable risk range but greater than the interim target of 1 x 10^{-5}. Additional beach areas would be addressed due to the increased footprint of the SMAs.

<u>RAO 2</u>
Same as Alternative B, although:

The post-construction carcinogenic risk is greater than the interim target of 1 x 10^{-4}. The estimated post-construction risk is 3 x 10^{-4} on a Site-wide scale (**Figure 4.2-2**). On a river mile scale, post-construction risks are no higher than 1 x 10^{-3} (**Figure 4.2-3a-d**). The highest risk on an SDU scale is 8 x 10^{-4}. With the exception of 6.5E and 5W and those identified under Alternative B, all post-construction risks on an SDU scale are greater than the interim target of 1 x 10^{-4} (**Table 4.2-1**).

The post-construction HI is 29 when evaluated Site-wide, which is greater than the interim target of 10 (**Figure 4.2-4**). On a river mile scale, the post-construction HI is no higher than 30 (**Figure 4.2-5a-d**). The highest post-construction HI on an SDU scale is 23; the post-construction HI in SDUs 4.5E, 5.5E, 11E, 7W, 9W, and Swan Island Lagoon are greater than the interim target of 10 (**Table 4.2-3**).

The post-construction HI for infants is 619 on a Site-wide scale (**Figure 4.2-6**) which is achieves the Site-wide interim target of 1,320. On a river mile scale, the post-construction HI is no higher than 6,925 (**Figure 4.2-7a-d**) which is greater than the interim target of 450. The highest post-construction HI for infants on an SDU scale is 893; the post-construction HI is SDUs 7W and Swan Island Lagoon are greater than the interim target of 450 (**Table 4.2-4**).

<u>RAO 3</u>
After construction of Alternative D, all surface water COC concentrations achieve the interim target of 10 times the PRG (**Figures 4.2-8a-f**).

<u>RAO 4</u>
Alternative D addresses 23 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-20** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 5
Alternative D addresses 64 percent of the area with unacceptable benthic risks (**Figure 4.2-21** and **Table 4.2-7**), which achieves the interim target of 50 percent.

RAO 6
The post-construction HQ for BEHP is no higher than 19 on a river mile scale (**Figures 4.2-9a-e** through **4.2-17a-e**), which is greater than the interim target of 10. All post-construction HQs on an SDU scale achieve the interim target of 10 (**Table 4.2-5**). In Swan Island Lagoon, it is likely that ENR would sufficiently reduce the HQ to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

RAO 7
Same as Alternative B.

RAO 8
Alternative D addresses 23 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-20** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 9
Alternative D addresses 46 percent of the contaminated river bank through construction (**Table 4.2-8**); the remainder of the contaminated river bank would be left to no action.

4.2.3.2 Compliance with ARARs

Same as Alternative B, although:

Alternative D would comply with ARARs. Chemical-specific ARARs would be achieved over time through implementation of a combination of remedial technologies, although this alternative relies heavily on MNR.

Compliance with Chemical-Specific ARARs

Same as Alternative B, although:

Chemical specific ARARs would be achieved.

Alternative D only addresses 23 percent of the sediments impacted by groundwater.

Compliance with Location-Specific ARARs

Same as Alternative B.

Compliance with Action-Specific ARARs

Same as Alternative B; although:

Approximately 983,000 cy of dredge sediment and excavated soils are disposed in a Subtitle D landfill without treatment.

Oregon Hazardous Waste and Hazardous Materials

Same as Alternative B; although:

It assumed that up to 355,000 cy of dredged sediment (excluding sediment dredged from SDU 6W) may be managed as State-listed waste for disposal in a Subtitle D landfill without treatment.

CWA 404 and ESA

It was assumed that 25 acres would require mitigation under Alternative D.

4.2.3.3 Long-Term Effectiveness and Permanence

Alternative D permanently removes approximately 1,181,000 cy of contaminated sediment and river bank soil covering approximately 132 acres of river bottom and 13,887 lineal feet of river bank by dredging or excavating to targeted removal depths. Various caps would be placed over 71 acres of the Site. Residuals from dredging and contaminated areas subject to ENR (approximately 210 acres) would be managed with a thin layer sand cover. After construction is completed, the remediated areas would no longer pose unacceptable risks to humans and the environment. However, 88 percent of the area of contaminated sediment would require MNR to achieve PRGs and no action would be taken on 54 percent of contaminated river bank.

Magnitude of Residual Risk

Same as Alternative B, although:

Contaminants from the Site would no longer contribute additional contaminant load to the Columbia River beyond the loading from the greater Willamette River watershed.

The magnitude of residual risks for each RAO are as follows:

RAO 1

Same as Alternative B, although:

The residual risk from exposure to nearshore sediment once PRGs are achieved is 6×10^{-6}. The post-construction risk is within EPA’s acceptable risk range but is a factor of 4 greater than the residual risk estimate.

RAO 2

Same as Alternative B, although:

The Site-wide residual risk once PRGs are achieved is 8×10^{-5}. The post-construction risk is a factor of 4 greater than the residual risk estimate. On both a river mile and SDU scale, the residual risk once PRGs are achieved is 3×10^{-5}. The post-construction risk is a factor of 38 greater than the residual risk estimate on a river mile scale. All post-construction risks on an SDU scale are greater than the residual risk estimate (**Table 4.2-1**); the risk ranges from a factor of 3 to 26 greater than the residual risk estimate.

The Site-wide residual HI once PRGs are achieved is 6. The post-construction HI is a factor of 5 greater than the residual HI estimate. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 2. The post-construction HI is a factor of 15 greater than the residual HI estimate on a river mile scale. All post-construction HIs on an SDU scale exceed the residual HI estimate (**Table 4.2-3**); the HI ranges from a factor of 2 to 11 greater than the residual HI estimate.

The Site-wide residual HI for the infant once PRGs are achieved is 132. The post-construction HI is a factor of 5 greater than the residual HI estimate. On a river mile and SDU scale, the residual risk once PRGs are achieved is 45. At the completion of construction, the HI is a factor of 154 greater than the residual HI estimate on a river mile scale. All post-construction HIs on an SDU scale exceed the residual HI estimate (**Table 4.2-4**); the HI ranges from a factor of 2 to 20 greater than the residual HI estimate.

Further reductions in risk are expected through MNR and implementation of institutional controls, although the timeframe for achieving RAOs is uncertain. The acceptable consumption rates once the PRGs are attained is 30 eight-ounce fish meals every year based on 1 x 10^{-5} risk, 16 eight-ounce fish meals every year based on a non-cancer hazard, and 2 eight-ounce fish meals every year for women who may breastfeed (**Table 4.2-2**). Fish consumption advisories would be required until such time as RAO 2 is achieved. After construction of Alternative D, the acceptable consumption rate is 6 eight-ounce fish meal every year (60 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 3.2 eight-ounce fish meal every year (32 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.4 fish meal every year (4 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

<u>RAO 3</u>
Same as Alternative B, although:

After construction of Alternative D, the Site-wide surface water contaminant concentrations from contaminated sediment in the Site is a factor of 10 greater than the PRG for PCBs, a factor of 5 greater than the PRG for 2,3,7,8-TCDD eq (**Figures 4.2-8a-f**).

<u>RAO 4</u>
Same as Alternative B, although:

Approximately 77 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative D (**Figure 4.2-20** and **Table 4.2-6**).

RAO 5
Same as Alternative B, although:

Approximately 36 percent of the area with unacceptable benthic risks would not be addressed by Alternative D (**Table 4.2-7** and **Figure 4.2-21**).

RAO 6
The residual HQ once PRGs are achieved is 1 for each COC. The post-construction HQ on a river mile scale is a factor of 19 greater than the residual HQ estimate for BEHP, a factor of 4 greater than the residual HQ estimate for PCBs and TCDF, a factor of 3 greater than the residual HQ estimate for PeCDF, and a factor of 2 greater than the residual HQ estimate for HxCDF (**Figures 4.2-9a-e** through **4.2-17a-e**). On an SDU scale, the post-construction HQ varies but the maximum HQ is a factor of 8 greater than the residual HQ estimate for BEHP, a factor of 3 greater than the residual HQ estimate for PCBs, a factor of 3 greater than the residual HQ estimate for TCDF, and a factor of 2 greater than the residual HQ estimate for PeCDF (**Table 4.2-5**). In Swan Island Lagoon, it is likely that ENR would sufficiently reduce the HQ to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

RAO 7
Same as Alternative B.

RAO 8
Same as Alternative B, although:

Approximately 77 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative D (**Figure 4.2-20** and **Table 4.2-6**).

RAO 9
Same as Alternative B, although:

Approximately 54 percent of contaminated river bank soils would not be addressed by Alternative D (**Table 4.2-8**).

Adequacy and Reliability of Engineering and Institutional Controls

Same as B, although:

Alternative D would provide additional controls and be more effective in reducing exposure to risks posed by COCs in the sediments and river bank soils provided by the increased area of capped material in the site relative to Alternative B. Additional O&M, ICs and monitoring would be required than Alternative B due to the increase in the acreage of caps.

4.2.3.4 Reduction in Toxicity, Mobility and Volume through Treatment

Same as Alternative B.

Treatment Processes Used
Same as Alternative B.

Amount Destroyed or Treated
Same as Alternative B, although:

Under Alternative D, 108 acres of material would be treated in-situ (includes broadcast activated carbon, reactive caps reactive residual management covers, and significantly augmented reactive caps).

Reduction of Toxicity, Mobility or Volume
Same as Alternative B, although:

- Broadcast Activated Carbon: 3.2 acres
- Reactive Caps: 40.0 acres
- Reactive Residual Management Cover: 61.0 acres

Irreversible Treatment
Same as Alternative B.

Type and Quantity of Residuals Remaining After Treatment
Same as Alternative B, although:

Implementation of Alternative D addresses 57 percent of the PTW at the Site (**Table 4.2-9**); therefore, this alternative does not meet the statutory preference for addressing all principal threat wastes to the maximum extent practicable.

4.2.3.5 Short-Term Effectiveness
Same as Alternative B, although:

The period of construction is estimated as 4 months per year for 6 years. During the construction period, approximately 1,181,000 cy dredged sediment and excavated soil and 727,000 cy capping and residual management materials would be transported into or out of the Site and handled by workers.

Community Protection
Same as Alternative B, although:

Alternative D involves dredging of 132 acres and excavation of 13,887 lineal feet of river bank, with import of approximately 727,000 cy of capping and residual management material. Impacts would occur during construction for approximately 6 years.

Worker Protection

Same as Alternative B, although:

Potential risks to site workers during the construction period would occur for 4 months a year for 6 years.

Environmental Impacts

Same as Alternative B, although:

Short-term adverse impacts to the river and environment during construction would occur for 4 months per year for 6 years.

Time until Action Complete

Construction operations for this alternative are estimated to take 6 years. Following the estimated construction time, Alternative D residual contaminant concentrations would be the greater than interim targets in several areas of the Site and MNR is unlikely to achieve RAOs in a reasonable time frame based on the MNR analysis for Alternative D (see Appendix D).

4.2.3.6 Implementability

Alternative D would be readily implementable from both the technical and administrative standpoints.

Ability to Construct and Operate

Same as Alternative B, although:

Implementation of Alternative D would involve dredging and excavating approximately 1,181,000 cy of contaminated material and the handling and placement of 727,000 cy capping and residual management material.

Alternative D has a construction period of approximately 6 years, involves construction activities within 267 acres, and thus has a low potential for technical difficulties that could lead to schedule delays.

Ease of Doing More Action, if Needed

Same as Alternative B.

Ability to Monitor Effectiveness

Same as Alternative B, although:

Fish consumption advisories would be required until such time as RAO 2 is achieved. After construction of Alternative D, the acceptable consumption rate is 6 eight-ounce fish meal every year (60 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 3.2 eight-ounce fish meal every year (32 fish meals/10 years) based on a non-cancer hazard

(**Figure 4.2-4**) and 0.4 fish meal every year (4 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). This is also presented in **Table 4.2-2**. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

RNAs would be required on 56 acres of caps. Regular monitoring of cap performance would be conducted and evaluated on 71 acres of caps required under 5-year reviews.

Alternative D relies on reducing contaminant concentrations through MNR (approximately 1,900 acres); therefore, there is greater uncertainty that RAOs will be met in a reasonable timeframe. For this reason, some additional future remedial actions are predicted to be more likely for Alternative D. Should future remedial actions be warranted, subsequent decision documents would be issued.

Ability to Obtain Approvals and Coordinate with Other Agencies

Same as Alternative B, although:

Extending the period of the work for 6 years would require consultation with ODFW, NMFS, and USF&W, but should be obtainable.

Coordination with DSL and/or other property owners would need to be conducted to manage waste left in place and implement land use restriction ICs, if needed. Alternative D leaves waste in place in 2,032 acres of the Site.

Under Alternative D, 56 acres of caps are assumed to need RNAs and 71 acres of caps are assumed to need land use restrictions. These ICs should be straightforward and easily obtainable.

Under Alternative D, it is estimated that 25 acres would require mitigation.

Availability of Specialists, Equipment and Materials

Same as Alternative B, although:

Alternative D requires the need for specialists and equipment for 6 years and 727,000 cy of capping and residual management material.

Approximately 786 barge loads and 78,707 truckloads or 19,629 rail loads are assumed to transport the removed material. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally 472 barge loads, 56,702 truckloads, or 12,037 rail loads are assumed to transport material into the Site.

Availability of Technologies

Same as Alternative B.

4.2.3.7 Cost

Same as Alternative B, although:

Total capital costs estimated for this alternative are \$556,004,000 over 6 years. Total periodic costs (including O&M) are \$397,028,000; of which the 5-year review periodic costs are \$308,000 per event, totaling \$1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be \$953,032,000, with a net present value cost of \$653,704,000. Detailed costs associated with implementing Alternative D are presented in Appendix G and summarized in **Table 3.7-1**.

4.2.4 Alternative E

Same as Alternative B, although:

Alternative E would address the unacceptable risks to human health and the environment through capping, dredging, and ENR of 329 acres of contaminated sediments and 18,231 lineal feet of river bank. The construction duration for this alternative is estimated to be 7 years, with no additional time required to complete dredged material processing.

This alternative, unlike Alternatives B and D, also evaluates two DMM scenarios (Scenarios 1 and 2). DMM Scenario 2 evaluates exclusive offsite disposal of dredged and excavated contaminated material whereas DMM Scenario 1 evaluates offsite disposal and a CDF for onsite disposal of a portion of the dredged/excavated material. Differences in analysis between the two DMM scenarios are indicated for this alternative where pertinent.

4.2.4.1 Overall Protection of Human Health and the Environment

Alternative E may be protective of human health and the environment since the post-construction risks are at or below the interim targets in the majority of the Site and therefore MNR is likely to achieve PRGs within a reasonable time frame. A discussion of how Alternative E performs relative to the interim targets is presented below. The uncertainty analysis conducted in Appendix I for the RALs selected for this alternative indicates that Alternative E is statistically distinguishable from the No Action Alternative and would have some environmental benefit. Protection of human health may be achieved through the use of fish consumption advisories and other ICs, although those may not provide sufficient protection in the short- and long-term.

<u>RAO 1</u>
Same as Alternative B, although:

The post-construction carcinogenic risks are estimated to be no higher than 1×10^{-5} (**Figure 4.2-1a-c**), which achieves the interim target of 1×10^{-5} at the completion of construction.

<u>RAO 2</u>
Same as Alternative D, although:

The post-construction carcinogenic risk is greater than the interim target of 1 x 10^{-4}. The estimated post-construction risk is 2 x 10^{-4} on a Site-wide scale (**Figure 4.2-2**). On both a river mile scale, post-construction risks are no higher than 4 x 10^{-4} (**Figure 4.2-3a-d**). The highest post-construction risk on an SDU scale is 3 x 10^{-4}; the post-construction risk in 4.5E, 5.5E, 11E, 7W, 9W, and Swan Island Lagoon are greater than the interim target of 1 x 10^{-4} (**Table 4.2-1**). In Swan Island Lagoon, it is likely that ENR would sufficiently reduce risk to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

The post-construction HI is 21 on a Site-wide scale, which is greater than the interim target of 10 (**Figure 4.2-4**). On a river mile scale, the post-construction HI is no higher than 15 (**Figure 4.2-5a-d**), which is greater than the interim target of 10. The highest post-construction HI on an SDU scale is 12; the post-construction HI in 5.5E, and 7W are greater than the interim target of 10 (**Table 4.2-3**). In Swan Island Lagoon, it is likely that ENR would sufficiently reduce risk to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

The post-construction HI for infants is 446 on a Site-wide scale (**Figure 4.2-6**) which is achieves the Site-wide interim target of 1,320. On a river mile scale, the post-construction HI is no higher than 2,078 (**Figure 4.2-7a-d**), which is greater than the interim target of 450. All post-construction HIs for infants on an SDU scale achieve the interim target of 450 (**Table 4.2-4**). In Swan Island Lagoon, it is likely that ENR would sufficiently reduce risk to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

<u>RAO 3</u>
Same as Alternative D.

<u>RAO 4</u>
Alternative E addresses 32 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-22** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

<u>RAO 5</u>
Alternative E addresses 73 percent of the area with unacceptable benthic risks (**Figure 4.2-23** and **Table 4.2-7**); which achieves the interim target of 50 percent.

<u>RAO 6</u>
Same as Alternative D, although:

The maximum post-construction HQ for BEHP is 15 (**Figures 4.2-9a-e** through **4.2-17a-e**) on a river mile scale, which is greater than the interim target of 10. All post-construction HQs on an SDU scale achieve the interim target of 10 (**Table 4.2-5**).

RAO 7
Same as Alternative B.

RAO 8
Alternative E addresses 32 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-22** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 9
Alternative E addresses 61 percent of the contaminated river bank through construction (**Table 4.2-8**); the remainder of the contaminated river bank would be left to no action.

4.2.4.2 Compliance with ARARs

Same as Alternative D.

Compliance with Chemical-Specific ARARs

Same as Alternative D, although:

There is less reliance on MNR to achieve these ARARs than Alternative D.

Alternative E addresses 32 percent of the sediments impacted by groundwater.

In the Terminal 4 CDF Design Analysis Report (Anchor QEA 2011), a model was used to determine the contaminant concentrations 1 foot inside the berm face. The model results indicated that it would take approximately 466 years for the PCBs to exceed Oregon's water quality criteria at that point. However, the analysis was conducted using criteria that have since been superseded and this analysis would need to be revised if the CDF is selected as part of the final remedy to ensure compliance with this ARAR.

Compliance with Location-Specific ARARs

Same as Alternative B, although:

Federal Emergency Management Act
In the Terminal 4 CDF Design Analysis Report (Anchor QEA 2011), a HEC-RAS model was used to determine the potential impacts to the floodplain from construction of the CDF. The HEC-RAS model results indicate that the proposed CDF would not increase the 100-year floodplain or flood way elevations at any location relative to the existing condition. However, the impacts of sedimentation, erosion and debris were not considered in the hydraulic analysis performed, in accordance with FEMA criteria. Sedimentation and erosion can modify the channel geometry of the waterway and

possibly affect the model-predicted flood elevations. In addition, the hydraulic analysis addressed only the potential impacts of the proposed CDF to flood elevations and did not consider the issues of slope stability, bank line protection, scour or other geotechnical matters. Additional evaluations would need to be conducted in completing the design of the CDF if it is selected as part of the final remedy to ensure compliance with this ARAR.

Compliance with Action-Specific ARARs

Same as Alternative B, although:

Approximately 1,828,000 cy of dredge sediment and excavated soils are disposed in a Subtitle D landfill without treatment.

Oregon Hazardous Waste and Hazardous Materials

Same as Alternative B, although:

It was assumed that up to 907,000 cy of dredged sediment (excluding sediment dredged from SDU 6W) may be managed as State-listed waste for disposal in a Subtitle D landfill without treatment.

CWA 404 and ESA

It was assumed that 35 acres would require mitigation under Alternative E.

The siting, design, and operation of the CDF has been analyzed under the factors specified in the CWA 404(b)(1) guidelines (Appendix L) such that determination that a CDF can be sited and operated as part of the remedial action in compliance with the CWA. CWA 404(b)(1) requirements including coordination with ESA agencies on mitigation measures to avoid jeopardy will be further analyzed and determined as the final design and final compensatory mitigation determination is made. Long-term maintenance and monitoring of the CDF and necessary compensatory mitigation will comply with the CWA and ESA requirements. It was assumed that an additional 14.3 acres would require mitigation for the CDF.

Additional controls required for construction activities to minimize the impacts from the CDF would include:

- prevent berm overtopping during filling of the CDF

Oregon Solid Waste Regulations (relevant provisions of OAR 340-095 for non-municipal landfill regulations):

The CDF would be constructed, filled, maintained and monitored consistent with identified Oregon solid waste regulations for non-municipal landfills.

4.2.4.3 Long-Term Effectiveness and Permanence

Alternative E permanently removes approximately 2,024,000 cy of contaminated sediment and river bank soil covering approximately 204 acres of river bottom and 18,231 lineal feet of river bank by dredging or excavating to targeted removal depths. Various caps would be placed over 101 acres of the Site. Residuals from dredging and contaminated areas subject to ENR (approximately 250 acres) would be managed with a thin layer sand cover. After construction is completed, the remediated areas would no longer pose unacceptable risks to humans and the environment. However, 85 percent of the contaminated sediment would require MNR to achieve PRGs and no action would be taken on 39 percent of contaminated river bank.

Magnitude of Residual Risk

Same as Alternative D, although:

The magnitude of residual risks for each RAO are as follows:

<u>RAO 1</u>
Same as B, although:

The residual risk from exposure to nearshore sediment once PRGs are achieved is 6×10^{-6}. The post-construction risk is within EPA's acceptable risk range but is a factor of 2 greater than the residual risk estimate.

<u>RAO 2</u>
Same as B, although:

The Site-wide residual risk once PRGs are achieved is 8×10^{-5}. The post-construction risk is a factor of 3 greater than the residual risk estimate. On both a river mile and SDU scale, the residual risk once PRGs are achieved is 3×10^{-5}. The post-construction risk is a factor of 14 greater than the residual risk estimate on a river mile scale. With the exception of SDUs 6W and 6NAV, all SDUs are greater than the residual risk estimate (**Table 4.2-1**) at the completion of construction; the post-construction risk ranges from a factor of 2 to 11 greater than the residual risk estimate. In Swan Island Lagoon, it is likely that ENR would sufficiently reduce risk to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

The Site-wide residual HI once PRGs are achieved is 6. The post-construction HI is a factor of 4 greater than the residual HI estimate. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 2. The post-construction HI is a factor of 7 greater than the residual HI estimate on a river mile scale. All post-construction HIs on an SDU scale exceed the residual HI estimate (**Table 4.2-3**); the post-construction HI ranges from a factor of 2 to 6 greater than the residual risk estimate. In Swan Island Lagoon, it is likely that ENR would sufficiently reduce risk to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

The Site-wide residual HI for the nursing infant once PRGs are achieved is 132. The post-construction HI is a factor of 2 greater than the residual HI. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 45. The post-construction HI is a factor of 46 greater than the residual HI on a river mile scale. All post-construction HIs on an SDU scale exceed the residual HI estimate (**Table 4.2-4**); the post-construction HI ranges from a factor of 2 to 8 greater than the residual HI estimate. In Swan Island Lagoon, it is likely that ENR would sufficiently reduce risk to achieve the PRGs in the long term due to the remaining concentrations outside the SMA.

Further reductions in risk are expected through MNR and implementation of institutional controls, although the timeframe for achieving RAOs is uncertain. Fish consumption advisories would be required until such time as RAO 2 is achieved. The acceptable consumption rates once the PRGs are attained is 30 eight-ounce fish meals every year based on 1 x 10^{-5} risk, 16 eight-ounce fish meals every year based on a non-cancer hazard, and 2 eight-ounce fish meals every year for women who may breastfeed (**Table 4.2-2**). After construction of Alternative E, the acceptable consumption rate is 11 eight-ounce fish meal every year (110 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 4.6 eight-ounce fish meal every year (46 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.5 fish meal every year (5 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

<u>RAO 3</u>
Same as Alternative D, although:

After construction of Alternative E, the Site-wide surface water contaminant concentrations from contaminated sediment in the Site is a factor of 7 greater than the PRG for PCBs and a factor of 4 greater than the PRG for 2,3,7,8-TCDD eq (**Figures 4.2-8a-f**).

<u>RAO 4</u>
Same as Alternative B, although:

Approximately 68 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative E (**Figure 4.2-22** and **Table 4.2-6**).

<u>RAO 5</u>
Same as Alternative B, although:

Approximately 27 percent of the area with unacceptable benthic risks would not be addressed by Alternative E (**Table 4.2-7** and **Figure 2.2-23**).

<u>RAO 6</u>
Same as Alternative D, although:

The residual HQ once PRGs are achieved is 1 for each COC. The post-construction HQ on a river mile scale is a factor of 15 greater than the residual HQ estimate for BEHP and a factor of 2 greater than the residual HQ estimate for PCBs (**Figures 4.2-9a-e** through **4.2-17a-e**). On an SDU scale, the post-construction HQ varies but the maximum HQ is a factor of 4 greater than the residual HQ estimate for BEHP (**Table 4.2-5**).

<u>RAO 7</u>
Same as Alternative B.

<u>RAO 8</u>
Same as Alternative B, although:

Approximately 27 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative E (**Figure 4.2-22** and **Table 4.2-6**).

<u>RAO 9</u>
Same as Alternative B, although:

Approximately 39 percent of contaminated river bank soils would not be addressed by Alternative E (**Table 4.2-8**).

Adequacy and Reliability of Engineering and Institutional Controls

Same as Alternative D, although:

Alternative E would provide additional controls and be more effective in reducing exposure to risks posed by COCs in the sediments and river bank soils provided by the increased area of capped material in the site relative to Alternative D. Additional O&M, ICs and monitoring would be required than Alternative D due to the increase in the acreage of caps.

4.2.4.4 Reduction in Toxicity, Mobility and Volume through Treatment

Same as Alternative B, although:

Treatment Processes Used

Same as Alternative B.

Amount Destroyed or Treated

Same as Alternative B, although:

Under Alternative E, 109 acres would be treated in-situ (includes reactive caps, reactive residual management covers, and significantly augmented reactive caps).

Reduction of Toxicity, Mobility or Volume

Same as Alternative B, although:

- Broadcast Activated Carbon: 0 acres
- Reactive Caps: 60.0 acres
- Reactive Residual Management Cover: 45.0 acres

Irreversible Treatment
Same as Alternative B.

Type and Quantity of Residuals Remaining After Treatment
Same as Alternative B, although:

Implementation of Alternative E would address all of the PTW at the Site.

4.2.4.5 Short-Term Effectiveness
Same as Alternative B, although:

The period of construction is estimated as 4 months per year for 7 years. During the construction period, approximately 2,024,000 cy dredged sediment and excavated soil and 958,000 cy capping and residual management materials would be transported into or out of the Site and handled by workers.

Community Protection
Same as Alternative B, although:

Alternative E involves dredging of 204 acres and excavation of 18,231 lineal feet of river bank, with import of approximately 958,000 cy of capping and residual management material. Impacts would occur during construction for approximately 7 years.

Worker Protection
Same as Alternative B, although:

Potential risks to site workers during the construction period would occur for 4 months a year for 7 years.

Environmental Impacts
Same as Alternative B, although:

Short-term adverse impacts to the river and environment during construction would occur for 4 months per year for 7 years.

Time until Action Complete
Construction operations for this alternative are estimated to take 7 years. Following the estimated construction time, Alternative E residual contaminant concentrations would

be the greater than interim targets in several areas of the Site and MNR is likely to achieve RAOs in a reasonable time frame based on the MNR analysis for Alternative E (see Appendix D).

4.2.4.6 Implementability

Alternative E would be readily implementable from both the technical and administrative standpoints.

Ability to Construct and Operate

Same as Alternative B, although:

Implementation of Alternative E would involve dredging and excavating approximately 2,024,000 cy of contaminated material and the handling and placement of 958,000 cy capping and residual management material.

Alternative E has a construction period of approximately 7 years, involves construction activities within 329 acres, and thus has a low potential for technical difficulties that could lead to schedule delays.

Alternative E assumes construction of a CDF, which may pose technical and administrative challenges.

Ease of Doing More Action, if Needed

Same as Alternative B.

Ability to Monitor Effectiveness

Same as Alternative B, although:

Fish consumption advisories would be required until such time as RAO 2 is achieved. After construction of Alternative E, the acceptable consumption rate is 11 eight-ounce fish meal every year (110 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 4.6 eight-ounce fish meal every year (46 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.5 fish meal every year (5 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). This is also presented in **Table 4.2-2**. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

RNAs would be required on 81 acres of caps. Regular monitoring of cap performance would be conducted and evaluated on 101 acres of caps required under 5-year reviews.

Alternative E relies on reducing contaminant concentrations through MNR (approximately 1,838 acres); therefore, there is more certainty that RAOs will be met in a reasonable timeframe. For this reason, some additional future remedial actions are predicted to be less likely for Alternative E. Should future remedial actions be warranted, subsequent decision documents would be issued.

Construction of the CDF would impose additional monitoring requirements for this alternative.

Ability to Obtain Approvals and Coordinate with Other Agencies

Same as Alternative B, although:

Extending the period of the work for 7 years would require consultation with ODFW, NMFS, and USF&W, but should be obtainable.

Coordination with DSL and/or other property owners would need to be conducted to manage waste left in place, implement land use restriction ICs, if needed, and construct the CDF. Alternative E leaves waste in place in 1,964 acres of the Site.

Under Alternative E, 81 acres of caps are assumed to need RNAs and 101 acres of caps are assumed to need land use restrictions. These ICs should be straightforward and easily obtainable.

Under Alternative E, it is estimated that 35 acres would require mitigation. An additional 14.3 acres would require mitigation for the construction of the CDF.

Construction of the CDF would require additional coordination with ODFW, NMFS, and USF&W.

Availability of Specialists, Equipment and Materials

Same as Alternative B, although:

Alternative E requires the need for specialists and equipment for 7 years and 958,000 cy of capping and residual management material.

Under DMM 1, approximately 416 barge loads are assumed to transport the removed material to the on-site CDF and approximately 901 barge loads and 90,147 truckloads or 22,489 rail loads are assumed to transport the removed material to an off-site disposal facility. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally 1,052 barge loads, 97,571 truckloads, or 21,941 rail cars are assumed to transport material into the Site (the truckloads and rail car loads for imported materials would also require 186 barge loads of material to construct the CDF that are delivered exclusively by barge).

Under DMM 2, approximately 1,337 barge loads and 133,764 truckloads or 33,394 rail loads are assumed to transport the removed material. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally 661 barge loads, 81,676 truckloads, or 17,022 rail loads are assumed to transport material into the Site.

Availability of Technologies

Same as Alternative B, although:

Under DMM Scenario 1, 670,000 cy dredged materials would be barged to the Terminal 4 CDF site. If an on-site transloading facility is constructed, this would minimizing on-land impacts to the community, but increasing vessel traffic within the Site. If an off-site transloading facility is used, this would minimize off-site vessel traffic. Since major container terminals are located in the Willamette River near the assumed CDF site, increased barge traffic to and from the CDF site may interfere with existing commercial port traffic and increase the potential for waterborne commerce accidents. These risks can be managed through engineering and navigation controls established by the dredging and/or materials management contractor working in association with the Port of Portland and other regulatory agencies, to control traffic in and around the CDF site.

4.2.4.7 Cost

Same as Alternative B, although:

A comparison of the total costs (both constant dollar (non-discounted) costs and present value dollar (discounted) costs) for the two disposed material management (DMM) scenarios was performed to understand the cost difference (potential savings) between the two scenarios for Alternative E.

The constant dollar (non-discounted) cost difference between DMM Scenarios 2 and 1 for Alternative E that represents potential cost savings is approximately $35,290,000. The present value dollar (discounted) cost difference between DMM Scenarios 2 and 1 for Alternative E is approximately $29,070,000, $24,990,000, and $21,100,000 respectively. Additional information is provided in Appendix N.

DMM 1

Total capital costs estimated for this alternative are $748,071,000 over 7 years. Total periodic costs (including O&M) are $412,332,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $1,160,403,000, with a net present value cost of $804,120,000. Detailed costs associated with implementing Alternative E are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2

Total capital costs estimated for this alternative are $827,465,000 over 7 years. Total periodic costs (including O&M) are $412,332,000. The 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $1,239,797,000, with a net present value cost of $869,530,000. Detailed costs associated with implementing Alternative E are presented in Appendix G and summarized in **Table 3.7-1**.

4.2.5 Alternative F

Same as Alternative E, although:

Alternative F would address the unacceptable risks to human health and the environment through capping, dredging, and ENR of 533 acres of contaminated sediments and 23,305 lineal feet of river bank. The construction duration for this alternative is estimated to be 13 years, with no additional time required to complete dredged material processing.

4.2.5.1 Overall Protection of Human Health and the Environment

Alternative F may be protective of human health and the environment since the post-construction risks are at or below the interim targets in the majority of the Site and therefore MNR is likely to achieve PRGs within a reasonable time frame. A discussion of how Alternative F performs relative to the interim targets is presented below. The uncertainty analysis conducted in Appendix I for the RALs selected for this alternative further indicates that Alternative F is statistically distinguishable from the No Action Alternative and would have some environmental benefit. Protection of human health may be achieved through the use of fish consumption advisories and other ICs, although those may not provide sufficient protection in the short- and long-term.

<u>RAO 1</u>
Same as Alternative E.

<u>RAO 2</u>
Same as Alternative E, although:

The post-construction carcinogenic risk on a Site-wide scale (**Figure 4.2-2**) achieves the interim target of 1×10^{-4}. On a river mile scale, the post-construction risks are no higher than 2×10^{-4} (**Figure 4.2-3a-d**), which is greater than the interim target of 1×10^{-4}. The highest post-construction risk on an SDU scale is 2×10^{-4}. On an SDU scale, the post-construction risks in 5.5E and 7W are greater than the interim target of 1×10^{-4} (**Table 4.2-1**).

The post-construction HI is 12 when evaluated Site-wide, which is greater than the interim target of 10 (**Figure 4.2-4**). On a river mile scale, the post-construction HI achieves the interim target of 10 (**Figure 4.2-5a-d**). The post-construction interim target of 10 is achieved in all SDUs (**Table 4.2-3**).

The Site-wide interim target of 1,320 for infants is achieved after construction of Alternative F (**Figure 4.2-6**). On a river mile scale, the post-construction HI is no higher than 932 (**Figure 4.2-7a-d**) which is greater than the interim target of 450. All post-construction HIs on an SDU scale achieve the interim target of 450 (**Table 4.2-4**).

<u>RAO 3</u>
Same as Alternative D.

RAO 4
Alternative F addresses 46 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-24** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 5
Alternative F addresses 87 percent of the area with unacceptable benthic risks (**Figure 4.2-25** and **Table 4.2-7**). This is less than the interim target of 50 percent.

RAO 6
Same as Alternative D, although:

After construction of Alternative F, all post-construction HQs on a Site-wide and SDU scale achieve the interim target of 10 (**Figures 4.2-9a-e** through **4.2-17a-e, Table 4.2-5**).

RAO 7
Same as Alternative B.

RAO 8
Alternative F addresses 46 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-24** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 9
Alternative F addresses 78 percent of the contaminated river bank through construction (**Table 4.2-8**); the remainder of the contaminated river bank would be left to no action.

4.2.5.2 Compliance with ARARs

Same as Alternative D.

Compliance with Chemical-Specific ARARs

Same as Alternative D, although:

There is less reliance on MNR to achieve these ARARs than Alternative E.

Alternative F addresses 46 percent of the sediments impacted by groundwater.

Compliance with Location-Specific ARARs

Same as Alternative E.

Compliance with Action-Specific ARARs

Same as Alternative E, although:

Approximately 4,393,000 cy of dredge sediment and excavated soils are disposed in a Subtitle D landfill without treatment.

<u>Oregon Hazardous Waste and Hazardous Materials</u>

Same as Alternative B; although:

It was assumed that up to 914,000 cy of dredged sediment (excluding sediment dredged from SDU 6W) may be managed as State-listed waste for disposal in a Subtitle D landfill without treatment.

<u>CWA 404 and ESA</u>

It was assumed that 60 acres would require mitigation under Alternative F.

4.2.5.3 Long-Term Effectiveness and Permanence

Alternative F permanently removes approximately 4,586,000 cy of contaminated sediment and river bank soil covering approximately 387 acres of river bottom and 23,305 lineal feet of river bank by dredging or excavating to targeted removal depths. Various caps would be placed over 176 acres of the Site. Residuals from dredging and contaminated areas subject to ENR (approximately 380 acres) would be managed with a thin layer sand cover. After construction is completed, the remediated areas would no longer pose unacceptable risks to humans and the environment. However, 75 percent of the area of contaminated sediment would require MNR to achieve PRGs and no action would be taken on 22 percent of contaminated river bank.

Magnitude of Residual Risk

Same as Alternative D, although:

The magnitude of residual risks for each RAO are as follows:

<u>RAO 1</u>

Same as Alternative B, although:

The residual risk from exposure to nearshore sediment once PRGs are achieved is 6×10^{-6}. The post-construction risk is within EPA's acceptable risk range but is a factor of 2 greater than the residual risk estimate.

<u>RAO 2</u>

Same as Alternative E, although:

The Site-wide residual risk once PRGs are achieved is 8×10^{-5}. The post-construction Site-wide risk achieves the residual risk estimate. On both a river mile and SDU scale, the residual risk once PRGs are achieved is 3×10^{-5}. The post-construction risk is a factor of 7 greater than the residual risk estimate on a river mile scale. With the exception of SDU 6W, all SDUs are greater than the residual risk estimate (**Table**

4.2-1) at the completion of construction; the post-construction risk ranges from a factor of 2 to 6 greater than the residual risk estimate.

The Site-wide residual HI once PRGs are achieved is 6. The post-construction HI is a factor of 2 greater than the residual HI estimate. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 2. The post-construction HI is a factor of 4 greater than the residual HI estimate on a river mile scale. With the exception of SDUs 2E, 6.5E, 11E, 6W, 9W, 6NAV and Swan Island Lagoon, the post-construction HIs on an SDU scale exceed the residual HI estimate (**Table 4.2-3**); the post-construction HI ranges from a factor of 2 to 3 greater than the residual HI estimate.

The Site-wide residual HI for infants once PRGs are achieved is 132. The post-construction HI is a factor of 2 greater than the residual HI. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 45. The post-construction HI is a factor of 21 greater than the residual HI on a river mile scale. With the exception of Swan Island Lagoon, 6W, 6NAV, 9W, and Swan Island Lagoon all post-construction HIs on an SDU scale exceed the residual HI estimate (**Table 4.2-4**); the post-construction HI ranges from a factor of 2 to 4 greater than the residual HI estimate.

Further reductions in risk are expected through MNR and implementation of institutional controls, although the timeframe for achieving RAOs is uncertain. Fish consumption advisories would be required until such time as RAO 2 is achieved. The acceptable consumption rates once the PRGs are attained is 30 eight-ounce fish meals every year based on 1 x 10^{-5} risk, 16 eight-ounce fish meals every year based on a non-cancer hazard, and 2 eight-ounce fish meals every year for women who may breastfeed (**Table 4.2-2**). After construction of Alternative F, the acceptable consumption rate is 14 eight-ounce fish meal every year (140 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 7.5 eight-ounce fish meal every year (75 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.8 fish meal every year (8 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

<u>RAO 3</u>
Same as Alternative D, although:

After construction of Alternative F, the Site-wide surface water contaminant concentrations from contaminated sediment in the Site is a factor of 4 greater than the PRG for PCBs and a factor of 3 greater than the PRG for 2,3,7,8-TCDD eq (**Figures 4.2-8a-f**).

<u>RAO 4</u>
Same as Alternative B, although:

Approximately 54 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative F (**Figure 4.24** and **Table 4.2-6**).

RAO 5
Same as Alternative B, although:

Approximately 13 percent of the area with unacceptable benthic risks would not be addressed by Alternative F (**Table 4.2-7** and **Figure 4.2-25**).

RAO 6
Same as Alternative D, although:

The residual HQ once PRGs are achieved is 1 for each COC. The post-construction HQ on a river mile scale is a factor of 5 greater than the residual HQ estimate for BEHP (**Figures 4.2-9a-e** through **4.2-17a-e**). On an SDU scale, the residual risk estimate of 1 is achieved at the completion of construction (**Table 4.2-5**).

RAO 7
Same as Alternative B.

RAO 8
Same as Alternative B, although:

Approximately 46 percent of the river bottom impacted by contaminated groundwater plumes would be addressed by Alternative F (**Figure 4.2-24** and **Table 4.2-6**).

RAO 9
Same as Alternative B, although:

Approximately 22 percent of contaminated river bank soils would not be addressed by Alternative F (**Table 4.2-8**).

Adequacy and Reliability of Engineering and Institutional Controls

Same as Alternative E, although:

Alternative F would provide additional controls and be more effective in reducing exposure to risks posed by COCs in the sediments and river bank soils provided by the increased area of capped material in the site relative to Alternative E. Additional O&M, ICs and monitoring would be required than Alternative E due to the increase in the acreage of caps.

4.2.5.4 Reduction in Toxicity, Mobility and Volume through Treatment

Same as Alternative B, although:

Treatment Processes Used

Same as Alternative B.

Amount Destroyed or Treated
Same as Alternative B, although:

Under Alternative F, 145 acres would be treated in-situ (includes reactive caps, reactive residual management covers, and significantly augmented reactive caps).

Reduction of Toxicity, Mobility or Volume
Same as Alternative E, although:

- Reactive Caps: 83.2 acres

- Reactive Residual Management Cover: 58.3 acres

Irreversible Treatment
Same as Alternative B.

Type and Quantity of Residuals Remaining After Treatment
Same as Alternative E.

4.2.5.5 Short-Term Effectiveness
Same as Alternative B, although:

The period of construction is estimated as 4 months per year for 13 years. During the construction period, approximately 4,586,000 cy dredged sediment and excavated soil and 1,565,000 cy capping and residual management materials would be transported into or out of the Site and handled by workers.

Community Protection
Same as Alternative B, although:

Alternative F involves dredging of 387 acres and excavation of 23,305 lineal feet of river bank, with import of approximately 1,565,000 cy of capping and residual management material. Impacts would occur during construction for approximately 13 years.

Worker Protection
Same as Alternative B, although:

Potential risks to site workers during the construction period would occur for 4 months a year for 13 years.

Environmental Impacts
Same as Alternative B, although:

Short-term adverse impacts to the river and environment during construction would occur for 4 months per year for 13 years.

Time until Action Complete

Construction operations for this alternative are estimated to take 13 years. Following the estimated construction time, Alternative F residual contaminant concentrations achieve the interim targets within the Site and MNR is likely to achieve RAOs in a reasonable time frame based on the MNR analysis for Alternative F (see Appendix D).

4.2.5.6 Implementability

Alternative F would be readily implementable from both the technical and administrative standpoints.

Ability to Construct and Operate

Same as Alternative E, although:

Implementation of Alternative F would involve dredging and excavating approximately 4,586,000 cy of contaminated material and the handling and placement of 1,565,000 cy capping and residual management material.

Alternative F has a construction period of approximately 13 years, involves construction activities within 533 acres, and thus has a low potential for technical difficulties that could lead to schedule delays.

Ease of Doing More Action, if Needed

Same as Alternative B.

Ability to Monitor Effectiveness

Same as Alternative E, although:

Fish consumption advisories would be required until such time as RAO 2 is achieved. After construction of Alternative F, the acceptable consumption rate is 14 eight-ounce fish meal every year (140 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 7.5 eight-ounce fish meal every year (75 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.8 fish meal every year (8 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). This is also presented in **Table 4.2-2**. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

RNAs would be required on 151 acres of caps. Regular monitoring of cap performance would be conducted and evaluated on 176 acres of caps required under 5-year reviews.

Alternative F relies on reducing contaminant concentrations through MNR (approximately 1,634 acres); therefore, there is more certainty that RAOs will be met in a reasonable timeframe. For this reason, some additional future remedial actions are predicted to be less likely for Alternative F. Should future remedial actions be warranted, subsequent decision documents would be issued.

Ability to Obtain Approvals and Coordinate with Other Agencies

Same as Alternative E, although:

Extending the period of the work for 13 years would require consultation with ODFW, NMFS, and USF&W, but should be obtainable.

Coordination with DSL and/or other property owners would need to be conducted to manage waste left in place, implement land use restriction ICs, if needed, and construct the CDF. Alternative F leaves waste in place in 1,780 acres of the Site.

Under Alternative F, 151 acres of caps are assumed to need RNAs and 176 acres of caps are assumed to need land use restrictions. These ICs should be straightforward and easily obtainable.

Under Alternative F, it is estimated that 60 acres would require mitigation.

Availability of Specialists, Equipment and Materials

Same as Alternative B, although:

Alternative F requires the need for specialists and equipment for 13 years and 1,565,000 cy of capping and residual management material.

Under DMM 1, approximately 416 barge loads are assumed to transport the removed material to the on-site CDF and approximately 2,570 barge loads and 257,089 truckloads or 64,225 rail loads are assumed to transport the removed material to an off-site disposal facility. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally 1,581 barge loads, 168,315 truckloads, or 35,772 rail cars are assumed to transport material into the Site (the truckloads and rail car loads for imported materials would also require 186 barge loads of material to construct the CDF that are delivered exclusively by barge).

Under DMM 2, approximately 3,006 barge loads and 300,706 truckloads or 75,129 rail loads are assumed to transport the removed material. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally, 1,190 barge loads, 152,420 truckloads, or 30,853 rail cars are assumed to transport material into the Site.

Availability of Technologies

Same as Alternative E.

4.2.5.7 Cost

Same as Alternative E, although:

The constant dollar (non-discounted) cost difference between DMM Scenarios 2 and 1 for Alternative F that represents potential cost savings is approximately $35,290,000. The present value dollar (discounted) cost difference between DMM Scenarios 2 and 1 for Alternative F is approximately $24,990,000. Additional information is provided in Appendix N.

DMM 1

Total capital costs estimated for this alternative are $1,550,014,000 over 13 years. Total periodic costs (including O&M) are $549,512,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $2,099,526,000, with a net present value cost of $1,316,560,000. Detailed costs associated with implementing Alternative F are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2

Total capital costs estimated for this alternative are $1,629,407,000 over 13 years. Total periodic costs (including O&M) are $549,512,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $2,178,919,000, with a net present value cost of $1,371,170,000. Detailed costs associated with implementing Alternative F are presented in Appendix G and summarized in **Table 3.7-1**.

4.2.6 Alternative G

Same as Alternative E, although:

Alternative G would address the unacceptable risks to human health and the environment through capping, dredging, and ENR of 776 acres of contaminated sediments and 26,362 lineal feet of river bank. The construction duration for this alternative is estimated to be 19 years, with no additional time required to complete dredged material processing.

4.2.6.1 Overall Protection of Human Health and the Environment

Alternative G would be protective of human health and the environment since the post-construction risks are at or below the interim targets throughout the Site and therefore MNR is likely to achieve PRGs within a reasonable time frame. A discussion of how Alternative G performs relative to the interim targets is presented below. The uncertainty analysis conducted in Appendix I for the RALs selected for this alternative indicates that Alternative G is statistically distinguishable from the No Action Alternative and would have some environmental benefit. Protection of human health may be achieved through the use of fish consumption advisories and other ICs, although those may not provide sufficient protection in the short- and long-term.

<u>RAO 1</u>
Same as Alternative E.

<u>RAO 2</u>
Same as Alternative F, although:

The post-construction carcinogenic risk on a Site-wide scale (**Figure 4.2-2**) achieves the interim target of 1 x 10^{-4}. On a river mile basis, the post-construction carcinogenic risks are less than 2 x 10^{-4} (**Figure 4.2-3a-d**), which is greater than the interim target of 1 x 10^{-4}. On an SDU scale, all post-construction risks are less than the interim target of 1 x 10^{-4} (**Table 4.2-1**).

The Site-wide interim target of 10 is achieved is achieved after construction of Alternative G (**Figure 4.2-4**). On a river mile scale, the post-construction interim target of 10 is achieved (**Figure 4.2-5a-d**). The post-construction interim target of 10 is also achieved in all SDUs (**Table 4.2-3**).

The Site-wide interim target of 1,320 for infants is achieved after construction of Alternative G (**Figure 4.2-6**). On a river mile basis, post-construction HI is less than the interim target of 450 (**Figure 4.2-7a-d**). All post-construction HIs for the infant based on an SDU scale achieve the interim target of 450 (**Table 4.2-4**).

<u>RAO 3</u>
Same as Alternative D.

<u>RAO 4</u>
Alternative G would not address 38 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-26** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

<u>RAO 5</u>
Alternative G would not address 7 percent of the area with unacceptable benthic risks (**Figure 4.2-27** and **Table 4.2-7**), which achieves the interim target of 50 percent.

<u>RAO 6</u>
Same as Alternative F.

<u>RAO 7</u>
Same as Alternative B.

<u>RAO 8</u>

Alternative G would not address 38 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-26** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 9
Alternative G would not address 12 percent of the contaminated river bank through construction (**Table 4.2-8**); the remainder of the contaminated river bank would be left to no action.

4.2.6.2 Compliance with ARARs

Same as Alternative D.

Compliance with Chemical-Specific ARARs
Same as Alternative D, although:

There is less reliance on MNR to achieve these ARARs than Alternative E.

Alternative G addresses 62 percent of the sediments impacted by groundwater.

Compliance with Location-Specific ARARs
Same as Alternative E.

Compliance with Action-Specific ARARs
Same as Alternative E, although:

Approximately 7,206,000 cy of dredge sediment and excavated soils are disposed in a Subtitle D landfill without treatment.

Oregon Hazardous Waste and Hazardous Materials
Same as Alternative B; although:

It was assumed that up to 923,000 cy of dredged sediment (excluding sediment dredged from SDU 6W) may be managed as State-listed waste for disposal in a Subtitle D landfill without treatment.

CWA 404 and ESA
It was assumed that 86 acres would require mitigation under Alternative G.

4.2.6.3 Long-Term Effectiveness and Permanence

Alternative G permanently removes approximately 7,397,000 cy of contaminated sediment and river bank soil covering approximately 572 acres of river bottom and 26,362 lineal feet of river bank by dredging or excavating to targeted removal depths. Various caps would be placed over 260 acres of the Site. Residuals from dredging and contaminated areas subject to ENR (approximately 540 acres) would be managed with a thin layer sand cover. After construction is completed, the remediated areas would no longer pose unacceptable risks to humans and the environment. However, 64 percent of the area of contaminated sediment would require MNR to achieve PRGs and no action would be taken on 12 percent of contaminated river bank.

Magnitude of Residual Risk

Same as Alternative D, although:

The magnitude of residual risks for each RAO are as follows:

RAO 1

Same as B, although:

The residual risk from exposure to nearshore sediment once PRGs are achieved is 6×10^{-6}. The post-construction risk achieves the residual risk estimate.

RAO 2

Same as B, although:

The Site-wide residual risk once PRGs are achieved is 8×10^{-5}. The post-construction risk achieves the residual risk estimate. On both a river mile and SDU scale, the residual risk once PRGs are achieved is 3×10^{-5}. The post-construction risk is a factor of 5 greater than the residual risk estimate on a river mile scale. With the exception of SDUs 4.5E, 11E, 6W, 7W, 9W 6NAV and Swan Island Lagoon, the post-construction risk is greater than the residual risk estimate at the completion of construction (**Table 4.2-1**), the risk ranges from a factor of 2 to 3 greater than the residual risk estimate.

The Site-wide residual HI once PRGs are achieved is 6. The post-construction HI is a factor of 2 greater than the residual HI estimate. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 2. The post-construction HI is a factor of 3 greater than the residual HI estimate on a river mile scale. The post-construction HIs on an SDU scale exceed the residual HI estimate only in the NoSDU (**Table 4.2-3**); the HI is a factor of 2 greater than the residual HI estimate.

The Site-wide residual HI for the infant once PRGs are achieved is 132. The post-construction HI is a factor of 2 greater than the residual HI. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 45. The post-construction HI is a factor of 10 greater than the residual HI on a river mile scale. The post-construction HIs on an SDU scale exceed the residual HI estimate at 5.5E, 3.9W, and NoSDU (**Table 4.2-4**); the post-construction HI is a factor of 2 greater than the residual HI estimate.

Further reductions in risk are expected through MNR and implementation of institutional controls, although the timeframe for achieving RAOs is uncertain. Fish consumption advisories would be required until such time as RAO 2 is achieved. The acceptable consumption rates once the PRGs are attained is 30 eight-ounce fish meals every year based on 1 x 10^{-5} risk, 16 eight-ounce fish meals every year based on a non-cancer hazard, and 2 eight-ounce fish meals every year for women who may breastfeed (**Table 4.2-2**). After construction of Alternative G, the acceptable consumption rate is 19 eight-ounce fish meal every year (190 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 10.1 eight-ounce fish meal every year (101 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 1.1 fish meal every year (11 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

<u>RAO 3</u>
Same as Alternative D, although:

After construction of Alternative G, the Site-wide surface water contaminant concentration from contaminated sediment in the Site is a factor of 3 greater than the PRG for PCBs and a factor of 3 greater than the PRG for 2,3,7,8-TCDD eq (**Figures 4.2-8a-f**).

<u>RAO 4</u>
Same as Alternative B, although:

Approximately 62 percent of the river bottom impacted by contaminated groundwater plumes would be addressed by Alternative G (**Figure 4.2-26** and **Table 4.2-6**).

<u>RAO 5</u>
Same as Alternative B, although:

Approximately 93 percent of the area with unacceptable benthic risks would be addressed by Alternative G (**Table 4.2-7** and **Figure 4.2-27**).

<u>RAO 6</u>
Same as Alternative D, although:

The residual HQ once PRGs are achieved is 1 for each COC. At the completion of constructing Alternative G, the residual HQ estimate of 1 is achieved for all COCs (**Figures 4.2-9a-e** through **4.2-17a-e**). On an SDU scale, the post-construction HQ achieves the residual HQ estimate of 1 for all COCs (**Table 4.2-5**).

<u>RAO 7</u>
Same as Alternative B.

<u>RAO 8</u>
Same as Alternative B, although:

Approximately 62 percent of the river bottom impacted by contaminated groundwater plumes would be addressed by Alternative G (**Figure 4.2-26** and **Table 4.2-6**).

<u>RAO 9</u>
Same as Alternative B, although:

Approximately 88 percent of contaminated river bank soils would be addressed by Alternative G (**Table 4.2-8**).

Adequacy and Reliability of Engineering and Institutional Controls
Same as Alternative E, although:

Alternative G would provide additional controls and be more effective in reducing exposure to risks posed by COCs in the sediments and river bank soils provided by the increased area of capped material in the site relative to Alternative E. Additional O&M, ICs and monitoring would be required than Alternative E due to the increase in the acreage of caps.

4.2.6.4 Reduction in Toxicity, Mobility and Volume through Treatment
Same as Alternative B, although:

Treatment Processes Used
Same as Alternative B.

Amount Destroyed or Treated
Same as Alternative B, although:

Under Alternative G, 184 acres would be treated in-situ (includes reactive caps, reactive residual management covers, and significantly augmented reactive caps).

Reduction of Toxicity, Mobility or Volume
Same as Alternative E, although:

- <u>Reactive Caps</u>: 100.8 acres
- <u>Reactive Residual Management Cover</u>: 79.8 acres

Irreversible Treatment
Same as Alternative B.

Type and Quantity of Residuals Remaining After Treatment
Same as Alternative E.

4.2.6.5 Short-Term Effectiveness
Same as Alternative B, although:

The period of construction is estimated as 4 months per year for 19 years. During the construction period, approximately 7,397,000 cy dredged sediment and excavated soil and 2,257,000 cy capping and residual management materials would be transported into or out of the Site and handled by workers.

Community Protection

Same as Alternative B, although:

Alternative G involves dredging of 572 acres and excavation of 26,362 lineal feet of river bank, with import of approximately 2,257,000 cy of capping and residual management material. Impacts would occur during construction for approximately 19 years.

Worker Protection

Same as Alternative B, although:

Potential risks to site workers during the construction period would occur for 4 months a year for 19 years.

Environmental Impacts

Same as Alternative B, although:

Short-term adverse impacts to the river and environment during construction would occur for 4 months per year for 19 years.

Time until Action Complete

Construction operations for this alternative are estimated to take 19 years. Following the estimated construction time, Alternative G residual contaminant concentrations achieve the interim targets within the Site and MNR is likely to achieve RAOs in a reasonable time frame based on the MNR analysis for Alternative G (see Appendix D).

4.2.6.6 Implementability

Alternative G would be readily implementable from both the technical and administrative standpoints.

Ability to Construct and Operate

Same as Alternative E, although:

Implementation of Alternative G would involve dredging and excavating approximately 7,397,000 cy of contaminated material and the handling and placement of 2,257,000 cy capping and residual management material.

Alternative G has a construction period of approximately 19 years, involves construction activities within 776 acres, and thus has a low potential for technical difficulties that could lead to schedule delays.

Ease of Doing More Action, if Needed

Same as Alternative B.

Ability to Monitor Effectiveness

Same as Alternative E, although:

Fish consumption advisories would be required until such time as RAO 2 is achieved. After construction of Alternative G, the acceptable consumption rate is 19 eight-ounce fish meal every year (190 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 10.1 eight-ounce fish meal every year (101 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 1.1 fish meal every year (11 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). This is also presented in **Table 4.2-2**. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

RNAs would be required on 231 acres of caps. Regular monitoring of cap performance would be conducted and evaluated on 260 acres of caps required under 5-year reviews.

Alternative G relies on reducing contaminant concentrations through MNR (approximately 1,391 acres); therefore, there is more certainty that RAOs will be met in a reasonable timeframe. For this reason, some additional future remedial actions are predicted to be less likely for Alternative G. Should future remedial actions be warranted, subsequent decision documents would be issued.

Ability to Obtain Approvals and Coordinate with Other Agencies

Same as Alternative E, although:

Extending the period of the work for 19 years would require consultation with ODFW, NMFS, and USF&W, but should be obtainable.

Coordination with DSL and/or other property owners would need to be conducted to manage waste left in place, implement land use restriction ICs, if needed, and construct the CDF. Alternative G leaves waste in place in 1,596 acres of the Site.

Under Alternative G, 231 acres of caps are assumed to need RNAs and 260 acres of caps are assumed to need land use restrictions. These ICs should be straightforward and easily obtainable.

Under Alternative G, it is estimated that 86 acres would require mitigation.

Availability of Specialists, Equipment and Materials

Same as Alternative B, although:

Alternative G requires the need for specialists and equipment for 19 years and 2,257,000 cy of capping and residual management material.

Under DMM 1, approximately 416 barge loads are assumed to transport the removed material to the on-site CDF and approximately 4,401 barge loads and 440,223 truckloads or 110,008 rail loads are assumed to transport the removed material to an off-site disposal facility. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally 2,171 barge loads, 247,217 truckloads, or 51,265 rail cars are assumed to transport material into the Site (the truckloads and rail car loads for imported materials would also require 186 barge loads of material to construct the CDF that are delivered exclusively by barge).

Under DMM 2, approximately 4,838 barge loads and 483,840 truckloads or 120,913 rail loads are assumed to transport the removed material. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally 1,780 barge loads, 231,322 truckloads, or 46,346 rail cars are assumed to transport material into the Site.

Availability of Technologies

Same as Alternative E.

4.2.6.7 Cost

Same as Alternative E, although:

The constant dollar (non-discounted) cost difference between DMM Scenarios 2 and 1 for Alternative G that represents potential cost savings is approximately $35,290,000. The present value dollar (discounted) cost difference between DMM Scenarios 2 and 1 for Alternative G is approximately $ $21,100,000. Additional information is provided in Appendix N.

DMM 1

Total capital costs estimated for this alternative are $2,421,152,000 over 19 years. Total periodic costs (including O&M) are $708,114,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $3,129,266,000, with a net present value cost of $1,731,110,000. Detailed costs associated with implementing Alternative I are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2

Total capital costs estimated for this alternative are $2,500,545,000 over 19 years. Total periodic costs (including O&M) are $708,114,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $3,208,659,000, with a net present value cost of

$1,777,320,000. Detailed costs associated with implementing Alternative I are presented in Appendix G and summarized in **Table 3.7-1**.

4.2.7 Alternative I

Same as Alternative E, although:

Alternative I would address the unacceptable risks to human health and the environment through capping, dredging, and ENR of 291 acres of contaminated sediments and 19,472 lineal feet of river bank. The construction duration for this alternative is estimated to be 7 years, with no additional time required to complete dredged material processing.

4.2.7.1 Overall Protection of Human Health and the Environment

Alternative I may be protective of human health and the environment since the post-construction risks are at or below the interim targets in the majority of the Site and therefore MNR is likely to achieve PRGs within a reasonable time frame. A discussion of how Alternative I performs relative to the interim targets is presented below.

<u>RAO 1</u>
Same as Alternative E.

<u>RAO 2</u>
Same as Alternative E, although:

The post-construction carcinogenic risk on a Site-wide scale is 2 x 10^{-4} (**Figure 4.2-2**) which is greater than the interim target of 1 x 10^{-4}. On a river mile scale, post-construction carcinogenic risks are no higher than 4 x 10^{-4} (**Figure 4.2-3a-d**), which is greater than the interim target of 1 x 10^{-4}. The highest post-construction risk on an SDU scale is 2 x 10^{-4}; the post-construction risk in 4.5E, 5.5E, 11E, 7W, 9W and Swan Island Lagoon are greater than the interim target of 1 x 10^{-4} (**Table 4.2-1**).

The post-construction HI is 21 when evaluated Site-wide, which is greater than the interim target of 10 (**Figure 4.2-4**). On a river mile scale, the post-construction HI is 16, which is greater than the interim target of 10 (**Figure 4.2-5a-d**). The post-construction HI achieves the interim target of 10 in all SDUs (**Table 4.2-3**).

The post-construction HI for the infant achieves the Site-wide interim target of 1,320 (**Figure 4.2-6**). On a river mile scale, the post-construction HI is less than 1,027 (**Figure 4.2-7a-d**) which is greater than the interim target of 450. All post-constructions HIs on an SDU scale achieve the interim target of 450 (**Table 4.2-4**).

<u>RAO 3</u>
Same as Alternative D.

RAO 4
Alternative I addresses 33 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-28** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 5
Alternative I addresses 64 percent of the area with unacceptable benthic risks (**Figure 4.2-29** and **Table 4.2-7**), which achieves the interim target of 50 percent.

RAO 6
Same as Alternative D, although:

After construction of Alternative I, the maximum post-construction HQ for BEHP is 19 (**Figures 4.2-9a-e** through **4.2-17a-e**), which is greater than the interim target of 10. All post-construction HIs on an SDU scale achieve the interim target of 10 (**Table 4.2-5**).

RAO 7
Same as Alternative B.

RAO 8
Alternative I addresses 33 percent of the river bottom impacted by groundwater plumes through construction (**Figure 4.2-28** and **Table 4.2-6**); the remainder of the contaminated groundwater would be left to MNA and more dependent on the adequacy of the source control.

RAO 9
Alternative I addresses 65 percent of the contaminated river bank through construction (**Table 4.2-8**); the remainder of the contaminated river bank would be left to no action.

4.2.7.2 Compliance with ARARs

Same as Alternative D.

Compliance with Chemical-Specific ARARs

Same as Alternative D, although:

There is less reliance on MNR to achieve these ARARs than Alternative E.

Alternative I addresses 33 percent of the sediments impacted by groundwater.

Compliance with Location-Specific ARARs

Same as Alternative E.

Compliance with Action-Specific ARARs

Same as Alternative E, although:

Approximately 1,557,000 cy of dredge sediment and excavated soils are disposed in a Subtitle D landfill without treatment.

Oregon Hazardous Waste and Hazardous Materials

Same as Alternative B; although:

It was assumed that up to 901,000 cy of dredged sediment (excluding sediment dredged from SDU 6W) may be managed as State-listed waste for disposal in a Subtitle D landfill without treatment.

CWA 404 and ESA

It was assumed that 34 acres would require mitigation under Alternative I.

4.2.7.3 Long-Term Effectiveness and Permanence

Alternative I permanently removes approximately 1,753,000 cy of contaminated sediment and river bank soil covering approximately 291 acres of river bottom and 19,472 lineal feet of river bank by dredging or excavating to targeted removal depths. Various caps would be placed over 102 acres of the Site. Residuals from dredging and contaminated areas subject to ENR (approximately 210 acres) would be managed with a thin layer sand cover. After construction is completed, the remediated areas would no longer pose unacceptable risks to humans and the environment. However, 87 percent of the area of contaminated sediment would require MNR to achieve PRGs and no action would be taken on 35 percent of contaminated river bank.

Magnitude of Residual Risk

Same as Alternative D, although:

The magnitude of residual risks for each RAO are as follows:

RAO 1

Same as Alternative B, although:

The residual risk once PRGs are achieved is 6×10^{-6}. The post-construction risk is within EPA's acceptable risk range but is a factor of 3 greater than the residual risk estimate.

RAO 2

Same as Alternative E, although:

The Site-wide residual risk once PRGs are achieved is 8×10^{-5}. The post-construction risk is a factor of 3 greater than the residual risk estimate. On both a river mile and SDU scale, the residual risk once PRGs are achieved is 3×10^{-5}. The post-construction risk is a factor of 13 greater than the residual risk estimate on a river mile scale. All SDUs exceed the residual risk estimate (**Table 4.2-1**) at the completion of construction; the post-construction risk is a factor of 3 to 7 greater than the residual risk estimate.

The Site-wide residual HI once PRGs are achieved is 6. The post-construction HI is a factor of 4 greater than the residual HI estimate. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 2. The post-construction HI is a factor of 8 greater than the residual HI estimate on a river mile scale. All post-construction HIs on an SDU scale exceed the residual HI estimate (**Table 4.2-3**); the post-construction HI ranges from a factor of 2 to 4 greater than the residual HI estimate.

The Site-wide residual HI for the infant once PRGs are achieved is 132. The post-construction HI is a factor of 3 greater than the residual HI. On both a river mile and SDU scale, the residual HI once PRGs are achieved is 45. The post-construction HI is a factor of 23 greater than the residual HI on a river mile scale. All post-construction HIs on an SDU scale exceed the residual HI estimate (**Table 4.2-4**); the post-construction HI ranges from a factor of 2 to 5 greater than the residual HI estimate.

Further reductions in risk are expected through MNR and implementation of institutional controls, although the timeframe for achieving RAOs is uncertain. Fish consumption advisories would be required until such time as RAO 2 is achieved. The acceptable consumption rates once the PRGs are attained is 30 eight-ounce fish meals every year based on 1×10^{-5} risk, 16 eight-ounce fish meals every year based on a non-cancer hazard, and 2 eight-ounce fish meals every year for women who may breastfeed (**Table 4.2-2**). After construction of Alternative I, the acceptable consumption rate is 9 eight-ounce fish meal every year (90 fish meals/10 years) based on 1×10^{-5} risk (**Figure 4.2-2**), 4.4 eight-ounce fish meal every year (44 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.5 fish meal every year (5 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

<u>RAO 3</u>
Same as Alternative D, although:

After construction of Alternative I, the Site-wide surface water contaminant concentration from contaminated sediment in the Site is a factor of 7 greater than the PRG for PCBs and a factor of 5 greater than the PRG for 2,3,7,8-TCDD eq (**Figure 4.2-8a-f**).

<u>RAO 4</u>
Same as Alternative B, although:

Approximately 67 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative I (**Figure 4.2-28** and **Table 4.2-6**).

<u>RAO 5</u>
Same as Alternative B, although:

Approximately 36 percent of the area with unacceptable benthic risks would not be addressed by Alternative I (**Table 4.2-7** and **Figure 4.2-29**).

<u>RAO 6</u>
Same as Alternative D, although:

The residual HQ once PRGs are achieved is 1 for each COC. At the completion of constructing Alternative I, the post-construction HQ on a river mile scale is a factor of 19 greater than the residual HQ estimate for BEHP and a factor of 2 greater than the residual HQ estimate for PCBs (**Figures 4.2-9a-e** through **4.2-17a-e**). On an SDU scale, the post-construction HQ is a factor of 4 greater than the residual HQ estimate for BEHP (**Table 4.2-5**).

<u>RAO 7</u>
Same as Alternative B.

<u>RAO 8</u>
Same as Alternative B, although:

Approximately 67 percent of the river bottom impacted by contaminated groundwater plumes would not be addressed by Alternative I (**Figure 4.2-28** and **Table 4.2-6**).

<u>RAO 9</u>
Same as Alternative B, although:

Approximately 35 percent of contaminated river bank soils would be addressed by Alternative I (**Table 4.2-8**).

Adequacy and Reliability of Engineering and Institutional Controls
Same as E, although:

Alternative I would provide additional controls and be more effective in reducing exposure to risks posed by COCs in the sediments and river bank soils provided by the increased area of capped material in the site relative to Alternative E.

4.2.7.4 Reduction in Toxicity, Mobility and Volume through Treatment

Same as Alternative B, although:

Treatment Processes Used
Same as Alternative B.

Amount Destroyed or Treated
Same as Alternative B, although:

Under Alternative I, 113 acres would be treated in-situ (includes reactive caps, reactive residual management covers, and significantly augmented reactive caps).

Reduction of Toxicity, Mobility or Volume
Same as Alternative E, although:

- Reactive Caps: 63.8 acres
- Reactive Residual Management Cover: 45.5 acres

Irreversible Treatment
Same as Alternative B.

Type and Quantity of Residuals Remaining After Treatment
Same as Alternative E.

4.2.7.5 Short-Term Effectiveness

Same as Alternative B, although:

The period of construction is estimated as 4 months per year for 7 years. During the construction period, approximately 1,753,000 cy dredged sediment and excavated soil and 900,000 cy capping and residual management materials would be transported into or out of the Site and handled by workers.

Community Protection
Same as Alternative B, although:

Alternative I involves dredging of 167 acres and excavation of 19,472 lineal feet of river bank, with import of approximately 900,000 cy of capping and residual management material. Impacts would occur during construction for approximately 7 years.

Worker Protection
Same as Alternative B, although:

Potential risks to site workers during the construction period would occur for 4 months a year for 7 years.

Environmental Impacts
Same as Alternative B, although:

Short-term adverse impacts to the river and environment during construction would occur for 4 months per year for 7 years.

Time until Action Complete

Construction operations for this alternative are estimated to take 7 years. Following the estimated construction time, Alternative I residual contaminant concentrations achieve the interim targets within the Site and MNR is likely to achieve RAOs in a reasonable time frame based on the MNR analysis for Alternative I (see Appendix D).

4.2.7.6 Implementability

Alternative I would be readily implementable from both the technical and administrative standpoints.

Ability to Construct and Operate

Same as Alternative E, although:

Implementation of Alternative I would involve dredging and excavating approximately 1,753,000 cy of contaminated material and the handling and placement of 900,000 cy capping and residual management material.

Alternative I has a construction period of approximately 7 years, involves construction activities within 291 acres, and thus has a low potential for technical difficulties that could lead to schedule delays.

Ease of Doing More Action, if Needed

Same as Alternative B.

Ability to Monitor Effectiveness

Same as Alternative E, although:

Fish consumption advisories would be required until such time as RAO 2 is achieved. After construction of Alternative I, the acceptable consumption rate is 9 eight-ounce fish meal every year (90 fish meals/10 years) based on 1 x 10^{-5} risk (**Figure 4.2-2**), 4.4 eight-ounce fish meal every year (44 fish meals/10 years) based on a non-cancer hazard (**Figure 4.2-4**) and 0.5 fish meal every year (5 fish meals/10 years) for women who may breastfeed (**Figure 4.2-6**). This is also presented in **Table 4.2-2**. Outreach would be conducted to educate the public about the fish consumption advisories. Informational materials will be needed and evaluated to determine advisory effectiveness.

RNAs would be required on 81 acres of caps. Regular monitoring of cap performance would be conducted and evaluated on 102 acres of caps required under 5-year reviews.

Alternative I relies on reducing contaminant concentrations through MNR (approximately 1,876 acres); therefore, there is more certainty that RAOs will be met in a reasonable timeframe. For this reason, some additional future remedial actions are predicted to be less likely for Alternative I. Should future remedial actions be warranted, subsequent decision documents would be issued.

Ability to Obtain Approvals and Coordinate with Other Agencies
Same as Alternative E, although:

Extending the period of the work for 7 years would require consultation with ODFW, NMFS, and USF&W, but should be obtainable.

Coordination with DSL and/or other property owners would need to be conducted to manage waste left in place, implement land use restriction ICs, if needed, and construct the CDF. Alternative I leaves waste in place in 2,000 acres of the Site.

Under Alternative I, 81 acres of caps are assumed to need RNAs and 102 acres of caps are assumed to need land use restrictions. These ICs should be straightforward and easily obtainable.

Under Alternative I, it is estimated that 34 acres would require mitigation.

Availability of Specialists, Equipment and Materials
Same as Alternative B, although:

Alternative I requires the need for specialists and equipment for 7 years and 900,000 cy of capping and residual management material.

Under DMM 1, approximately 416 barge loads are assumed to transport the removed material to the on-site CDF and approximately 724 barge loads and 72,501 truckloads or 18,078 rail loads are assumed to transport the removed material to an off-site disposal facility. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally 1,002 barge loads, 90,527 truckloads, or 20,578 rail cars are assumed to transport material into the Site (the truckloads and rail car loads for imported materials would also require 186 barge loads of material to construct the CDF that are delivered exclusively by barge).

Under DMM 2, approximately 1,160 barge loads and 116,118 truckloads or 28,982 rail loads are assumed to transport the removed material. If an on-site transloading facility were constructed, approximately the same number of truckloads and/or rail loads are assumed for off-site disposal. Additionally 611 barge loads, 74,632 truckloads, or 15,659 rail cars are assumed to transport material into the Site.

Availability of Technologies
Same as Alternative E.

4.2.7.7 Cost

Same as Alternative E, although:

The constant dollar (non-discounted) cost difference between DMM Scenarios 2 and 1 for Alternative I that represents potential cost savings is approximately $35,290,000. The present value dollar (discounted) cost difference between DMM Scenarios 2 and 1 for Alternative I is approximately $29,070,000. Additional information is provided in Appendix N

DMM 1

Total capital costs estimated for this alternative are $671,966,000 over 7 years. Total periodic costs (including O&M) are $421,940,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $1,093,906,000, with a net present value cost of $745,890,000. Detailed costs associated with implementing Alternative G are presented in Appendix G and summarized in **Table 3.7-1**.

DMM 2

Total capital costs estimated for this alternative are $751,359,000 over 7 years. Total periodic costs (including O&M) are $421,940,000; of which the 5-year review periodic costs are $308,000 per event, totaling $1,848,000 over 30 years. The total undiscounted alternative cost is estimated to be $1,173,299,000, with a net present value cost of $811,290,000. Detailed costs associated with implementing Alternative I are presented in Appendix G and summarized in **Table 3.7-1**.

4.3 COMPARATIVE ANALYSIS

The following discussion provides a comparative analysis of the remedial alternatives for each of the seven NCP criteria discussed in the preceding section. A summary of the comparative analysis of alternatives is presented in **Tables 4.3-1** and **4.3-2**. A qualitative depiction of the summary is presented in **Table 4.3-3**, where the threshold criteria are depicted as being achieved or not, and each of the balancing criteria are ranked from lowest relative rank to the highest relative rank.

4.3.1 Overall Protection of Human Health and the Environment

Alternative A would not be protective of human health and the environment and contaminated sediments in the site would continue to impact surface sediments, surface water, and biota and pose unacceptable risks to human health and the environment for the foreseeable future. Because no further action is taken, Alternative A would result in minimal reductions in COC concentration and related residual risks. Natural recovery process would result in reduction in the COC concentrations over time, but are unlikely to achieve all PRGs for COCs or meet all RAOs in a reasonable time frame. Because

Alternative A is not protective, it is not carried forward in the comparative analysis of the alternatives.

All remaining alternatives, in conjunction with MNR and institutional controls, are expected to be protective of human health. Since institutional controls should be relied upon to the minimum extent practicable, the less reliant an alternative is on institutional controls the more protective the alternative. Reliance on fish advisories is greatest with Alternative B and decreases through Alternatives D, I, E, F, then G, while reliance on RNAs and land use restrictions is greatest with Alternative G and decreases through Alternatives F, E, I, D, then B. Additionally, Alternatives E, F, G and I, in conjunction with MNR, are expected be protective of the environment. Alternatives B and D may not be protective of the environment because of the time frame needed to achieve PRGs through MNR and ICs would not provide protection ecological receptors during this time period. A summary of how the alternatives perform relative to interim targets to determine overall protectiveness is presented as follows:

<u>RAO 1</u>
Alternatives B, D, and I do not achieve the carcinogenic risk interim target of 1 x 10^{-5}, all other alternatives achieve the interim target.

<u>RAO 2</u>
Carcinogenic risks on a Site-wide scale do not achieve the interim target of 1 x 10^{-4} with Alternatives B, D, E and I; the interim target is achieved with Alternatives F and G. On a river mile scale, none of the alternatives achieve the carcinogenic risk interim target of 1 x 10^{-4}. On an SDU scale, Alternatives B, D, E, F, and I do not achieve the carcinogenic risk interim target of 1 x 10^{-4}; Alternative G achieves the interim target.

Alternative G is the only alternative that achieves the interim target HI of 10 on a Site-wide scale; all other Alternatives do not achieve the interim HI target. On a river mile scale, Alternatives B, D, E, and I do not achieve the interim HI target of 10; the interim target is achieved in Alternatives F and G. On an SDU scale, Alternatives B, D, and E do not achieve the interim HI target of 10; the interim target is achieved in Alternatives F, G and I.

All alternatives achieve the infant interim target HI of 1,250 on a Site-wide scale. Alternative G is the only alternative that achieves the infant HI interim target of 920 on a river mile scale; all other Alternatives do not achieve the interim target. Alternative B is the only alternative that does not achieve the infant HI interim target of 920 on an SDU scale; all other alternatives achieve the interim target.

<u>RAO 3</u>
Alternative B is the only alternative that does not achieve the Site-wide interim target of 10 times the PRG for each COC; all other alternatives achieve the interim target. There is insufficient information to evaluate this RAO on an SDU scale.

<u>RAO 4</u>

Post-construction, the estimated contaminated groundwater area addressed by each alternative increases as the footprint of the SMAs increases (Alternative B to G; Alternative I addresses 1 percent more than Alternative E).

RAO 5
Alternative B is the only alternative that does not achieve the interim target of addressing 50 percent of the benthic risk area; all other alternatives achieve the interim target.

RAO 6
Alternative B, D, E and I do not achieve the ecological HQ interim target of 10; Alternatives F and G achieve the interim target.

RAO 7
There is insufficient information to evaluate this RAO on a Site-wide or SDU scale.

RAO 8
Post-construction, the estimated contaminated groundwater area addressed by each alternative increases as the footprint of the SMAs increases (Alternative B to G; Alternative I addresses 1 percent more than Alternative E).

RAO 9
Post-construction, the estimated contaminated river bank addressed by each alternative increases as the footprint of the SMAs increases (Alternative B to G; Alternative I addresses 4 percent more than Alternative E).

4.3.2 Compliance with ARARs

Compliance with ARARs addresses whether a remedy will achieve all of the applicable or relevant and appropriate requirements of other Federal and State environmental statutes or provides a basis for invoking a waiver. Alternatives B through G had common ARARs associated with the construction of the alternative since they are all essentially the same remedial technologies with varying degrees of area and scope. Alternative B does not achieve chemical-specific ARARs in a reasonable time frame, but will attain the action-specific and location-specific ARARs. All other alternatives will attain their respective Federal and State ARARs.

4.3.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence refers to expected residual risk and the ability of an alternative to maintain reliable protection of human health and the environment over time once PRGs are achieved. The magnitude of residual risk is defined as the estimated residual risk based on the PRGs and is RAO specific. The post-construction risk is greatest for Alternative B and decreases with implementation of alternatives with larger SMA footprints. A summary of the residual risk estimates for each RAO and the post-construction risks for each Alternative is as follows:

RAO 1

The estimated Site-wide residual risk for sediment is 6×10^{-6}. Post-construction risk for Alternative B exceeds the residual risk estimate by an order of magnitude. Post-construction risk for the other alternatives is within an order of magnitude of the residual risk estimate. Post-construction risk decreases in the following order: Alternative B, D, I, E, F then G.

The estimated residual risk for beaches is 9×10^{-6}. Post-construction risks cannot be quantified due to the lack of data.

RAO 2

The estimated Site-wide residual risk is 8×10^{-5}. Post-construction risks for each alternative are within an order of magnitude of the residual risk estimate. Post-construction risk decreases in the following order: Alternative B, D, E and I (Alternatives E and I are equal), then F and G. Alternatives F and G achieve the residual risk estimates.

On both a river mile and SDU scale, the estimated residual risk is 3×10^{-5}. Post-construction risks are an order of magnitude greater than the residual risk estimate for both Alternatives B and D, within an order of magnitude for Alternatives E, F and I, and achieve the residual risk estimate for Alternative G. On a river mile scale, the post-construction risk decreases in the following order: Alternatives E and I are equal, Alternative F then Alternative G. On an SDU scale, the post-construction risks decreases in the following order: Alternative B, D, E, I, F then G.

The estimated Site-wide residual HI is 6. Post-construction HIs for each alternative are within an order of magnitude of the residual HI estimate. Post-construction HI decreases in the following order: Alternative B, D, Alternatives E and I are equal, and Alternatives F and G are equal.

On both a river mile and SDU scale, the estimated residual HI is 2. Post-construction HIs for both Alternatives B and D are an order of magnitude greater than the residual HI estimate. Post-construction HIs for the other alternatives are within an order of magnitude of the residual HI estimate. On a river mile scale, the post-construction HI decreases in the following order: Alternative B, D, I, E, F then G. On an SDU scale, the post-construction HI decreases in the following order: Alternative B, D, E, I, F then G.

The estimated Site-wide residual HI for the infant is 132. Post-construction HIs for each alternative are within an order of magnitude of the residual HI estimate. Post-construction HI decreases in the following order: Alternative B, D, Alternatives E and I are equal, and Alternatives F and G are equal.

On both a river mile and SDU scale, the estimated residual HI for the infant is 45. Post-construction HIs on a river mile scale are two orders of magnitude greater than the residual HI estimate for Alternatives B and D, an order of magnitude greater for Alternatives E, F and I, and within an order of magnitude for Alternative G. Post-construction HIs decrease in the following order: Alternative B, D, E, I, F then G. Post-construction HIs on an SDU scale are two orders of magnitude greater than the residual HI estimate for Alternative B, an order of magnitude greater for Alternative D, within and order of magnitude for Alternatives E, F and I, and achieves the residual risk estimate for Alternative G. Post-construction HI decreases in the following order: Alternative B, D, E, F and I are equal, then G.

<u>RAO 3</u>
The PRG for PCBs is 0.000006 µg/L. Post-construction concentrations are an order of magnitude greater than the PRG for Alternatives B and D and within an order of magnitude for the other alternatives. Post-construction concentrations decrease in the following order: Alternative B, D, E and I are equal, F then G.

The PRG for 2,3,7,8-TCDD eq is 0.0000000005 µg/L. Post-construction concentrations are within an order of magnitude for each alternative. Post-construction concentrations decrease in the following order: Alternative B, D and I are equal, E, then F and G are equal.

The PRG for cPAHs is 0.0001 µg/L. Post-construction concentrations are within an order of magnitude for Alternative B and the PRG is achieved for all other alternatives.

<u>RAO 4</u>
The magnitude of residual risk is uncertain because it is likely that not all contaminated pore water will be addressed by any alternative. Post-construction, the area of sediment impacted by contaminated groundwater decreases with the increasing SMA footprint for each alternative in the following order: Alternative B, D, E, I, F then G.

<u>RAO 5</u>
The magnitude of residual risk is uncertain because it is likely that not all benthic risk will be addressed by any alternative. Post-construction, the area of sediment that poses unacceptable risk to the benthos decreases with increasing SMA footprint for each alternative in the following order: Alternative B, D and I are equal, E, F then G.

<u>RAO 6</u>
The residual HQ once PRGs are achieved is 1 for each COC.

Post-construction HQs for BEHP on a river mile scale are an order of magnitude greater than the residual HQ estimate for Alternatives B, D, E and I, within an order of magnitude for Alternative F, and achieves the PRG for Alternative G. On an SDU scale, post-construction HQs are an order of magnitude greater than the residual HQ estimate for Alternative B, within an order of magnitude for Alternatives D, E and I, and achieves the PRG for Alternatives F and G.

Post-construction HQs for PCBs on a river mile scale are within an order of magnitude for Alternatives B, D, E and I, and achieves the PRG for Alternatives F and G. On an

SDU scale, post-construction HQs are within an order of magnitude for Alternatives B and D, and achieves the PRG for all other alternatives.

Post-construction HQs for HxCDF on a river mile scale are within an order of magnitude for Alternatives B and D, and achieves the PRG for all other alternatives. On an SDU scale, post-construction HQs are within an order of magnitude for Alternative B, and achieves the PRG for all other alternatives.

Post-construction HQs for PeCDF on both a river mile and SDU scale are within an order of magnitude for Alternatives B and D, and achieves the PRG for all other alternatives.

Post-construction HQs for TCDF on both a river mile and SDU scale are within an order of magnitude for Alternatives B and D, and achieves the PRG for all other alternatives.

<u>RAO 7</u>
There is insufficient information to evaluation this RAO on a Site-wide or SDU scale.

<u>RAO 8</u>
The magnitude of residual risk is uncertain because it is likely that not all contaminated pore water will be addressed by any alternative. Post-construction, the area of sediment impacted by contaminated groundwater decreases with the increasing SMA footprint for each alternative in the following order: Alternative B, D, E, I, F then G.

<u>RAO 9</u>
The magnitude of residual risk is uncertain because it is likely that not all contaminated river bank will be addressed by any alternative. Post-construction, the area of contaminated river bank decreases with the increasing SMA footprint for each alternative in the following order: Alternative B, D, E, I, F then G.

The technologies used in Alternatives B through I are the same, but vary in degree of use. Off-site treatment and land-based disposal facilities are in operation and have proven to be reliable technologies. On-site water treatment and CDF are reliable and proven technologies as long as they are designed to deal with the specific contaminated media. Dredging, excavating, capping, in-situ treatment, and thin layer covers are reliable and proven technologies as long as they are designed for the appropriate environmental and anthropogenic conditions.

Since the majority of the contamination within the SMAs is either capped or removed, the overall concentrations of contaminated sediment and soil available for resuspension is greatest with Alternative B and decreases with increasing SMA footprint of each alternative. Thus, as the size of the SMA footprint increases, there is less reliance on MNR processes to achieve RAOs and less potential for recontamination of capped/dredged areas. The time needed for MNR to achieve the RAOs for each alternative is uncertain, but is likely to occur more quickly in areas of deposition and for alternatives with a larger remedial footprint.

Operation and maintenance activities, ICs and long-term monitoring need to be implemented for all alternatives to assure protectiveness and reliability of caps and would continue in perpetuity. Monitoring and maintenance of caps are directly related to the acreage of caps. The greater the acreage, the more monitoring and maintenance of caps and the related ICs such as RNAs would be required to ensure the contaminated sediment is adequately controlled. Since Alternative B has the smallest acreage of caps, it would require the least amount of monitoring and maintenance while Alternative G would require the greatest amount. Alternatives E, F, G and I also present the option of an on-site CDF. Should a CDF be constructed and used as a repository for contaminated sediment from the Site, additional monitoring and maintenance requirements would be needed in perpetuity to ensure the material is reliably contained.

The amount of area requiring land use restrictions is also directly proportional to the acreage capped, which is least for Alternative B and is greatest with Alternative G. Land use restrictions, including RNAs, have been used at many sediment sites and can be effective as long as they are administered by entities that possess the legal authority, and are capability and willing to implement the control.

4.3.4 Reduction in Toxicity, Mobility or Volume through Treatment

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. All retained alternatives include in-situ and ex-situ treatment technologies. PTW and groundwater contamination is addressed through treatment to varying degrees in all alternatives and as a result, the preference for treatment as a principle element of the remedial action is achieved for all alternatives.

As the construction acreage increases, the reduction in toxicity, mobility or volume increases. Reduction in the mobility or volume of contaminants in groundwater entering the river would be through the use of reactive caps where the reactive layer would isolate the contaminants as the groundwater fluxes through the cap. Likewise, reactive caps would be used to reduce the mobility of PTW contained in place. Ex-situ treatment of sediment and soil removed from the site will further result in reduction of toxicity, mobility and volume of contaminants in sediment and soil.

In general, the reduction of toxicity, mobility or volume increases in direct proportion to the construction acreage, where Alternative B would provide the least reduction and Alternative G would provide the most reduction. All PTW at the Site would be addressed by Alternatives E, F, G and I. Reduction in mobility of contamination not considered to be PTW would be through removal and sequestration in a permitted landfill or CDF, or sequestration under in-situ caps; however, there would be no reduction of toxicity or volume through permanent or irreversible treatment.

Ex-situ treatment of PTW in contaminated sediments and river bank soils is determined by the action-specific ARARs, such as LDRs as well as the NCP expectation of treatment for PTW. All PTW treated ex-situ is assumed to be disposed at a RCRA Subtitle C facility. The specific methods of treatment and associated treatment target concentrations of contaminants will be determined by the facility based on requirements of action-specific ARARs, such as identification of hazardous waste and compliance with LDRs under RCRA. The Subtitle C disposal facility selected as a representative process option (Chemical Waste Management in Arlington, Oregon) uses treatment processes such as cement stabilization or low temperature thermal desorption, as needed, to meet LDRs for hazardous waste. The actual amount of removed material subject to ex-situ treatment would depend on the results of waste characterization testing during the design phase. In addition, the mobility of contaminants would be further reduced by placing the removed material in a permitted landfill (through sequestration in a landfill cell), although it is not due to permanent and irreversible treatment.

4.3.5 Short-Term Effectiveness

Short-term effectiveness addresses the period of time needed to implement the remedy and any adverse impacts that may be posed to workers, the community and the environment during construction and operation of the remedy until cleanup levels are achieved.

During construction, impacts to the community, workers, and the environment would occur for 4 months per year for the duration of the construction project for every retained alternative. Since Alternative B has the shortest construction duration (4 years), implementation of Alternative B would have the least impact to the community, workers, and the environment during construction. As the construction duration increases with the increasing SMA footprint of each alternative, impacts would also increase. Alternative G would have the longest construction duration (19 years) and, thus, would have the most impact to the community, workers and the environment during construction. If an on-site CDF is constructed, an additional 24 months of construction would be required prior to beginning remediation to construct the berm face and 12 months after remediation in completed to construct the CDF cap. Further, construction of an on-site transloading facility or treatment plant would have added impacts.

Short-term impacts would be controlled through use of construction BMPs and health and safety plans. Measures such as air monitoring on-site and at the site boundary, and engineering controls would be implemented to control the potential for exposure. Workers would be required to wear appropriate levels of protection to avoid exposure during excavation and treatment activities. Appropriate precautions and controls will be used to prevent incidental and accidental discharges of toxic materials from entering the water column as a result of in-water work. The application of emissions reduction strategies during implementation of this alternative can reduce short-term impacts posed to the environment and promote technologies and practices that are sustainable according to the EPA Region 10 Clean and Green Policy. Elevated fish tissue concentrations from construction activities would also be dependent on the construction duration and would be shortest for Alternative B and longest for Alternative G. Fish consumption advisories would be required under each alternative until construction is complete.

Post-construction, environmental impacts would continue until RAOs are achieved. Alternative B relies more on MNR to achieve PRGs and would have the longest impact to the community and environment until RAOs are achieved. As the footprint of the SMAs increases in each alternative, MNR is relied on less to achieve RAOs and the short-term impacts to the community and environment would decrease. Alternative G achieves environmental RAOs, so there would be no impacts to the environment post-construction. Environmental impacts would include elevated contaminant concentrations in fish until RAOs are achieved. Fish consumption advisories would be implemented to control the exposure to humans during this timeframe.

4.3.6 Implementability

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. The construction activities required for the implementation of all retained alternatives would be technically feasible and have been implemented at many Superfund sites around the country. Materials, services and equipment necessary for construction are readily commercially available. Disposal facilities are also readily available and have adequate capacity for the volumes of material being removed.

In general, the potential for technical problems and schedule delays increases in direct proportion to the duration, and amount of active remediation. As the construction acreage of the alternative increases, the construction period, required administrative coordination, and the potential for technical problems leading to schedule delays increases. The site logistics of implementation also increases in difficulty as more construction acreage is added in each alternative.

Conversely, alternatives with the smallest acreage of construction have a greater potential for triggering additional actions if monitoring data indicates inadequate performance in achieving all cleanup objectives. The risk of monitoring failing to detect a release of COCs to the environment in areas where waste has been left in place (caps, ENR or MNR areas) in a reasonable time frame is indirectly proportional to the acreage of contaminated sediment or soil capped.

Installation of the treatment, storage and transfer facility would require cooperation from the landowner and coordination with local authorities for the construction of utilities within existing right-of-ways.

The CDF component of DMM Scenario 1 in Alternatives E, F, G, and I would be logistically and administratively challenging. Construction of a CDF increases the duration of construction for Alternatives E, F, G, and I and will require sequencing remedial projects for effective CDF use and the potential disruption of navigation and other waterway uses throughout construction, filling, and closure. There also could be increased time associated with obtaining legal agreements among multiple parties for use of the CDF; as well as increased costs for maintenance and liability protections. Conversely, disposing of at least 670,000 cy of removed material in the onsite CDF reduces the number of barges needed and distance for the barges to transport the removed material to the appropriate transload facility increasing implementability.

4.3.7 Cost

The cost of each alternative increases as the degree of construction increases. The estimated present value costs for the alternatives range from $451 million for Alternative B to $1.77 billion for Alternative G.

4.3.8 Summary

The following provides a summary of the comparative analysis of alternatives and describes the benefits and limitations of the alternatives relative to one another.

All alternatives equally rely on the adequacy of DEQ's source control to achieve PRGs and RAOs and to prevent recontamination of the Site. Addressing river banks will also help prevent recontamination of the Site.

Alternatives E, F, G and I all meet the threshold criteria of Overall Protection of Human Health and the Environment and Compliance with ARARs. Alternative D may meet the threshold criteria, although there is more uncertainty with this alternative. Alternatives A and B do not meet the threshold criteria, therefore will not be further discussed.

Alternatives E, F, G, and I address all PTW at the Site and achieve the statutory preference for treatment, when applicable. Alternative D does not address all PTW at the Site.

Alternatives E and I both provide approximately an order of magnitude risk reduction from the no action alternative at completion of construction. Both of these alternatives control the major sources of sediment contamination by sequestering higher contaminant concentrations under engineered caps or removing the material and containing it in a disposal facility, which are maintained in perpetuity. Post-construction risks for Alternative D are nearly twice those for the risk of Alternatives E and I. Alternatives F and G achieve the risks associated with the PRGs at completion of construction. However, Alternatives F and G have greater impacts to the environment than Alternatives E and I due to the increased construction footprints and time to construct (2-3 times longer to implement), which would increase impacts to the community and workers implementing the remedy.

During construction of the alternatives, people would be advised to eat no more than 6 fish meals every 10 years for most populations and 1 fish meal every 10 years for women who may breastfeed, assuming an HI of 1. Alternatives E and I would require this advisory for 7 years, while Alternatives F and G would require this advisory for 13 and 19 years, respectively. After 7 years of construction for both Alternatives E and I, the fish advisory would be relaxed to allow for approximately 8 times as much fish (46 fish meals every 10 years) to be safely consumed from the Site for most populations at completion of construction and 5 times as much fish for women who may breastfeed (5 fish meals every 10 years). While Alternative D has a shorter initial advisory during construction (4 years), only 5 times as much fish (32 fish meals every 10 years) can be safely consumed for most populations, and 4 times as much fish for women who may breastfeed (4 fish meals every 10 years). Since concentrations of contamination post-construction left to MNR are greater for Alternative D, it is expected that a longer period of recovery would be necessary to meet PRGs and RAOs and thus fish advisories would occur for a longer period of time. All CERCLA-related fish advisories will be removed once PRGs and RAOs are achieved, although OHA may still impose an advisory based on broader watershed risks.

Engineered caps would be effective in limiting the long-term exposure to COCs in the Site sediment and soil provided they are properly designed and the integrity of the caps are maintained. Therefore, monitoring and maintenance of the caps would be required in perpetuity. Caps also require river use restrictions and, where appropriate, armoring to prevent cap erosion, which may require mitigation. Alternatives E and I both have approximately the same capped area (81 acres). Alternative D has less capped area (56 acres), but does not reliably contain all PTW remaining in the river. Compared to Alternatives E and I, Alternative F has almost twice the capped area (150 acres) and Alternative G has more than two and half times the capped area (231 acres). As the area to be capped increases, impacts to the benthic community increase and more long-term monitoring, maintenance, and river use restrictions would be required.

All the alternatives achieve reduction of toxicity, mobility, or volume through treatment by using in-situ and ex-situ treatment technologies that have been demonstrated to be effective at Superfund sites around the country. In all alternatives, 192,000 cy of removed sediment and soil is treated ex-situ at the off-site disposal facility using low temperature thermal desorption or cement solidification/stabilization. In-situ treatment is applied to areas where PTW is left in place or where residual groundwater plumes may be discharging to the river. Under Alternative I, in-situ treatment is applied to 113 acres of the Site through the addition of reactive components to caps and residual layers. This area is more than Alternatives D (108 acres) and E (109 acres). Alternative I would ensure that the preference for treatment is achieved for all PTW and increases protection from impacts from contaminated groundwater plumes discharging into the Site. While Alternatives F (139 acres) and G (238 acres) address an increased footprint of the contaminated groundwater plume area, these alternatives would also have greater impacts to the benthic community due to the larger construction footprints. There is uncertainty regarding the overall area of the Site impacted by contaminated groundwater, therefore, the need for in situ treatment to address contaminated groundwater will be refined during remedial design.

Alternatives E and I, with a construction duration of 4 months per year for 7 years, would reduce impacts from construction to the community, workers implementing the remedy, and the environment compared to 4 Alternative F (13 years) and Alternative G (19 years). Since Alternative I also involves less construction than Alternative E, Alternative I would have less short-term impact on the community, workers, and the environment. Impacts to the environment and community would continue until MNR achieves PRGs and RAOs. Alternative I achieves more interim targets than Alternative D and is therefore more reliable in achieving PRGs and RAOs in a reasonable time frame because it relies less on natural processes.

Since ICs are not applicable to ecological receptors, it is ideal to address all ecological risks at construction completion. While none of the alternatives address all ecological risks, Alternative G addresses the most ecological risks at the completion of construction although it impacts their habitat for the longest period of time during construction (19 years) and would take the longest time for benthic populations to recover due to the large area of habitat impacted (776 acres). Alternatives D, E, F and I address greater than 50 percent of the benthic risk area, which is sufficient to ensure risks would not occur to the benthic population as a whole. While Alternative I does not achieve ecological PRGs for RAO 6 at construction completion for BEHP on an SDU scale and BEHP and PCBs on a river mile scale, most of this remaining risk is in Swan Island Lagoon and will be addressed through ENR. There would still be some remaining risk at RM 4W from BEHP (HQ less than 7), RM 8W from BEHP (HQ less than 3) and 9W from PCBs (HQ less than 2) that would be addressed through MNR. Implementing Alternative I will eliminate the need to disrupt 485 acres of habitat for 12 additional years that implementation of Alternative G would require, which would delay the re-establishment of ecological communities.

The sources of contaminated groundwater plumes are expected to be controlled though cleanup actions and monitoring under DEQ oversight. It is EPA's expectation that the majority of the current identified groundwater plumes will be addressed by DEQ's actions and the alternatives will only need to address the portion of the plumes that extend into the river. Since the extent of these plumes impacting pore water is not currently known, these areas will need to be refined during remedial design and at that point it will be determined which residual groundwater plumes will need to be addressed in the river. Alternatives E and I both address 33 percent of the contaminated groundwater area as currently delineated. Alternative D addresses 23 percent of this area, Alternative F addresses 46 percent, and Alternative G addresses 62 percent.

Removing contaminated sediment and river bank soil out of the river has long term benefits for the Site, but there are also impacts to the environment and community associated with transporting the removed material to a disposal facility. Alternatives E and I have similar removed material volumes (approximately 2,024,000 cy and 1,752,000 cy, respectively) and achieve similar risk reductions and long term benefits post-construction compared to the other alternatives. While Alternatives F and G achieve higher risk reduction post-construction compared with current risks; however, removed material volumes are more than 3-4 times greater (approximately 4,585,000 cy and 7,397,000 cy, respectively) than Alternatives D, E and I. This means that implementing Alternatives F and G would impose significantly greater impacts to the environment and community and have much greater costs (1.5-2 times more than Alternatives E and I) that are not commensurate with the additional risk reduction relative to Alternatives E and I. Depending on which form of transportation is used for the removed material, these impacts include increased barge traffic on the river, which would impact commercial and recreational use of the river, increased traffic on the roads in the community if trucking is used, and increased traffic on the rail lines if rail is used. There are also increased environmental impacts, such as potential spills and sediment disturbance from wake waves and propwash, associated with transporting such large volumes of material.

Approximately 206,400 cy of contaminated sediment and soil are assumed to be sent to a Subtitle C landfill for all alternatives and DMM scenarios. This material would be barged to an off-site transload facility and trucked to the landfill because it would not meet the criteria for disposal in a Subtitle D landfill or a CDF. Alternatives E, F, G and I include DMM Scenario1, which includes disposal of approximately 670,000 cy of removed material in the Terminal 4 CDF. The construction of a CDF would destroy approximately 14 acres of habitat within the Site and mitigation will be required for this lost acreage. Disposing approximately 670,000 cy of removed material in the onsite CDF reduces the number of barges needed and distance for the barges to transport the removed material to the appropriate transload facility. Reducing the transport distance for disposal also reduces the chance that accidents could occur as well as reducing the number of impacted communities. Removed material not disposed of in a Subtitle C landfill or a CDF is assumed to be disposed of in an off-site Subtitle D landfill. This material would be barged to an off-site transload facility and trucked to the landfill. If an on-site transload facility were constructed, the number of barges would be reduced, but the volume of truck and rail traffic through communities would be increased.

On a Site-wide scale, none of the alternatives achieve surface water PRGs for PCBs and 2,3,7,8-TCDD eq; however, surface water concentrations from contaminated sediment are within an order of magnitude of the PRGs for Alternatives D, E, F, G, and I. Alternatives F and G contaminant concentrations are within a factor of 5 of the PRGs. It is expected that MNR in conjunction with ICs and source control, including control of upriver sources, is necessary to achieve surface water RAOs.

Delivery of construction material to the Site is assumed to be conducted via barge, although other modes of transportation (truck and rail) may be used. Impacts from transporting construction materials to the site, such as truck or barge traffic, are directly related to the size and thickness of the caps, the construction of an on-site CDF and the volume of materials required. Alternatives E and I would require twice the materials needed than Alternative D and would require additional year of construction. Alternative F would require three times and Alternative G would require almost five times the volume of material as Alternatives E and I and construction durations are significantly longer (2-3 times as long).

MNR is expected to occur as cleaner upriver sediments deposit on surface sediment in the Site during low-flow periods and mix and disperse downstream during higher flow periods. This transitional process is expected to occur until static equilibrium is reached in the river system. In order to achieve PRGs in a reasonable time frame, the surface sediment concentrations need to be low enough that these processes will be able to reduce the exposure to contaminants in a reasonable time frame. Since much of the Site has lower concentrations of contamination, the greatest footprint is assigned this technology in all alternatives. However, as the footprint for MNR decreases, the area of disturbance of the aquatic environment due to construction increases, the longer these disturbances occur, and the more the alternative costs. Alternatives D, E and I have about the same MNR footprint (88, 85 and 87 percent of the Site, respectively) while Alternatives F and G have a 10 and 20 percent smaller MNR footprint, respectively. The Site-wide post-construction sediment PCB concentrations (contaminant that poses the greatest risk) are the same for Alternatives E and I (81 percent), which is 7 percent more than Alternative D. Further, the Site-wide post-construction sediment PCB concentrations would decrease by an additional 7 and 11 percent for Alternatives F and G, respectively, but will have 35-50 percent greater impact on the aquatic environment due to the increased constructed footprint than Alternatives E and I.

MNR is not considered to be effective within Swan Island Lagoon because water circulation is limited, and thus it does not receive sufficient cleaner sediment from upstream to allow natural recovery to occur in areas with lower contaminant concentrations. For this reason, ENR, which involves placing a sand layer on the contaminated sediment, will be used to further reduce contaminant concentrations in these areas. This sand layer will mix with underlying contaminated sediment, resulting in overall lower contaminant concentrations at the surface. For this process to be effective, a sufficient amount of capping/dredging in areas with higher contaminant concentrations is needed in Swan Island Lagoon. As the areas of construction for each alternative increase, the certainty that ENR will achieve PRGs also increases. Although decreasing the ENR footprint and increasing the area of construction provides for a more permanent and reliable remedial alternative, the added cost of dredging, capping, and long-term maintenance is not commensurate with the added protections gained from these technologies at lower sediment concentrations. Alternative D has the largest ENR footprint (74 percent of the area within Swan Island Lagoon), E and I have the same ENR footprint (51 percent) while Alternatives F and G have the smallest ENR footprints (24 and 16 percent, respectively). Post-construction risks for Alternative D (5×10^{-4} cancer risk, HI is 22, and HI for infants is 476) are greater than interim targets. The ability of ENR in Swan Island Lagoon to achieve long-term effectiveness is uncertain since the volume of clean sand needed to dilute the remaining contaminated sediment is greater than Alternatives E, I, F and G, and several applications may be necessary. This would have greater disruption to the benthic population in Swan Island Lagoon for a longer period of time. Post-construction risks for Alternatives F and G are lower than the residual risk estimates, thus ENR would not be necessary. Post-construction risk estimates for Alternatives E and I are within a factor of 5 of the residual risk. Because the remaining concentrations in Swan Island Lagoon outside the SMA are sufficiently close to the PRGs, ENR would be sufficient to achieve and maintain protective levels in the long term and would reduce the costs from implementing Alternatives F and G.

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