30% Remedial Design Basis of Design Report

Appendix H
Engineered Cap Chemical Isolation Design Analysis and Area-Specific Technology Evaluation

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ABBREVIATIONS

µg/kg	microgram per kilogram
µg/L	microgram per liter
AST	area-specific technology
BBP	butyl benzyl phthalate
BODR	*Basis of Design Report*
cfs	cubic foot per second
cm	centimeter
cm/hr	centimeter per hour
cm/yr	centimeter per year
cm^2/s	square centimeter per second
cm^2/yr	square centimeter per year
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
EPA	U.S. Environmental Protection Agency
ESD	explanation of significant differences
f_{OC}	fraction organic carbon
FNC	federal navigation channel
g/cm^3	gram per cubic centimeter
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
K_d	equilibrium partition coefficient
K_{OC}	organic carbon partition coefficient
K_{OW}	octanol-water partition coefficient
L/kg	liter per kilogram
LDW	Lower Duwamish Waterway
mg/kg	milligram per kilogram
MLLW	mean lower low water
N/A	not applicable
ng/kg	nanogram per kilogram
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PD&C	partial dredge and cap
RAA	remedial action area
RAL	remedial action level
RC	recovery category
RD	remedial design

RM	river mile
ROD	*Record of Decision*
SVOC	semivolatile organic compound
TEQ	toxic equivalents
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers

1 Introduction

This appendix documents chemical isolation modeling was conducted to evaluate engineered capping and covers to address elevated contaminants of concern (COCs) in the sediment of the middle reach of Lower Duwamish Waterway (LDW).

Two types of engineered caps will be placed in the middle reach of LDW—a standard cap and a modified caps in habitat areas. The Preliminary 30% remedial design (RD) for a standard cap consists of a chemical isolation layer overlain by a 6-inch-minimum-thickness filter layer and a 1-foot-minimum-thickness erosion protection (i.e., armor) layer. Standard caps are proposed in 13 remedial action areas (RAAs): RAAs 1B, 9J, 14, 15B, 22, 23A, 30A, 30B, 30D, 30E, 30F, 31B, and 31C. The modified cap in habitat areas consists of a chemical isolation layer overlain by a 0.5-foot-minimum-thickness armor layer and a 1.5-foot-minimum-thickness habitat layer. The modified caps are proposed in eight RAAs: RAAs 5B, 8B, 9A, 9D, 20C, 24I, 26, and 31D. More detailed descriptions on the design of the engineered caps can be found in Section 9.3 of the Preliminary (30%) RD *Basis of Design Report* (BODR).

Additionally, as described in Section 9.6 of the main report, area-specific technologies (ASTs) are required for areas with restrictions that prevent standard application of remedial technologies to an RAA. RAAs 9K and 30C are located within the federal navigation channel (FNC) and include utility crossings that prevent dredging to a depth that would allow placement of a standard cap and meet the *Record of Decision* (ROD; EPA 2014) requirement of top of cap elevation being 4 feet below the FNC authorized depth. Instead of a standard cap, an AST (i.e., utility crossing cover) will be placed after partial dredging of the RAAs. The evaluation of AST for the RAAs with utility crossings was performed using the same framework as for the standard caps and is documented herein. A map of the RAAs proposed for capping and AST can be found in Figures 5-2a and 5-2b of the BODR.

There are a total of 42 COCs for the LDW: 4 COCs based on risk to human health, 40 COCs based on risk to benthic invertebrates, and 1 COC for wildlife (i.e., river otters). COCs that exceeded remedial action levels (RALs) set forth in the ROD (EPA 2014) and explanation of significant difference (ESD; EPA 2021)[1] in sediments that will remain beneath the proposed engineered cap or AST in at least one of the RAAs include the following: polychlorinated biphenyls (PCBs), dioxins/furans, carcinogenic polycyclic aromatic hydrocarbons (cPAHs), mercury, zinc, butyl benzyl phthalate (BBP), 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, 2,4-dimethylphenol, total high-molecular-weight polycyclic aromatic hydrocarbons (HPAHs), and 11 individual polycyclic aromatic hydrocarbons (PAHs).

Chemical transport modeling was therefore conducted to identify the thickness and composition (e.g., amendment needs) for the chemical isolation component of an engineered cap that will meet

[1] RAL exceedances were determined based on the 2014 ROD for all COCs, with the exception of carcinogenic polycyclic aromatic hydrocarbons (cPAHs), which is based on the 2021 ESD.

RALs for a long period of time (defined as 100 years). In the RAAs where utility crossing AST is used (i.e., partial dredging and cover), the evaluation was conducted to predict the concentrations that may be expected at the top of the cover over the 100-year time frame.

RAAs that were evaluated for engineered caps and the utility crossing ASTs are listed in Tables H1-1 and H1-2, respectively. These tables include the COC(s) evaluated due to RAL exceedances measured in sediments that will remain (i.e., following removal where applicable) beneath the sediment engineered cap. No RAL exceedances were measured directly below the planned dredge horizon in RAAs 9A, 30D, and 30E during Phase I and Phase II pre-design investigation sampling. However, because COC concentrations increase with depth in these areas, it is possible that there could be RAL exceedances below the sampled depth. Due to this uncertainty, an engineered cap was proposed for these RAAs in the Preliminary (30%) RD. However, because COC concentrations are not currently known to exceed the RALs, these RAAs were excluded from this capping evaluation and will be revisited in the future once additional data are collected. Furthermore, RAAs 31B and 31C are located in the slide slope of RAAs 30D and 30E. The depth of contamination within portions of RAAs 31B and 31C are not fully characterized; however, the preliminary dredge depths in these areas are significantly deeper than the anticipated vertical limits of contamination. Therefore, RAAs 31B and 31C were not evaluated during Preliminary (30%) RD, were assumed to be similar to RAA 30D, and will be revised in the Intermediate (60%) RD. In addition, the area type (i.e., intertidal, subtidal, or shoaled area) and recovery category (RC) for each RAA are provided in Tables H1-1 and H1-2 because the information is relevant for the selection of applicable RALs for the evaluation. The depth interval of COC concentrations to be evaluated also varies by RC (further discussed in Section 2.2).

Table H1-1
List of RAAs, Cap Type, and COCs Included in the Engineered Cap Evaluation

RAA[1]	RM[2]	Area Type[3]	RC	Selected Remedial Technology	Dredge Depth (feet) or Elevation (feet MLLW)	Engineered Cap Type	COC(s) with RAL Exceedances Below the Cap
1B	2.9	Subtidal	1	PD&C	-24 feet MLLW	Standard cap	Total PCBs
5B	2.8	Intertidal	2	PD&C	3 feet	Modified cap	Total PCBs
8B	2.8	Intertidal	1	PD&C	4.5 feet	Modified cap	1,2,4-trichlorobenzene, 1,4-dichlorobenzene
9D	2.7	Intertidal	2	PD&C	4 feet	Modified cap	Total PCBs
9J	2.7	FNC Shoal	3	PD&C	-29 feet MLLW	Standard cap	Total PCBs, dioxin/furan TEQ
14	2.5	FNC Shoal	3	PD&C	-29 feet MLLW	Standard cap	Total PCBs
15B	2.5	Subtidal	1	PD&C	-26 feet MLLW	Standard cap	Total PCBs

RAA[1]	RM[2]	Area Type[3]	RC	Selected Remedial Technology	Dredge Depth (feet) or Elevation (feet MLLW)	Engineered Cap Type	COC(s) with RAL Exceedances Below the Cap
20C	2.4	Intertidal	1	PD&C	3 feet	Modified cap	Total PCBs, dioxin/furan TEQ
22	2.2	FNC Shoal	3	PD&C	-29 feet MLLW	Standard cap	Total PCBs
23A	2.3	Subtidal	1	PD&C	-20 feet MLLW	Standard cap	Total PCBs
24I	2.2	Intertidal	2	PD&C	4 feet	Modified cap	Total PCBs
26	2.1	Intertidal	2	Cap only	none	Modified cap	cPAHs, dioxin/furan TEQ, zinc, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, total benzofluoranthenes, total HPAHs, BBP, 2,4-dimethylphenol
30A	2.1	Subtidal	1	Cap only	none	Standard cap	Total PCBs, mercury
30B	2.0	FNC Shoal	1	PD&C	-29 feet MLLW	Standard cap	Total PCBs, dioxin/furan TEQ
30F	1.8	FNC Shoal	3	PD&C	-39 feet MLLW	Standard cap	Total PCBs

Notes:

1. RAAs 9A, 30D, 30E, 31B, 31C, and 31D were not evaluated as part of Preliminary (30%) RD; they will be evaluated during Intermediate (60%) RD. Preliminary cap design for those areas is discussed in BODR Section 9.3.
2. RMs approximated to represent the centroid of the RAA.
3. If an RAA overlapped with both intertidal and subtidal areas, it was specified as intertidal and evaluated under a higher range of seepage rates to be conservative (see Section 3.3).

BBP: butyl benzyl phthalate
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
FNC: federal navigation channel
HPAH: high-molecular-weight polycyclic aromatic hydrocarbon
MLLW: mean lower low water
PCB: polychlorinated biphenyl
PD&C: partial dredge and cap
RAA: remedial action area
RAL: remedial action level
RC: recovery category
RM: river mile
TEQ: toxic equivalents

Table H1-2
List of RAAs, Placement Thickness, and COCs Included in the Utility Crossing AST Evaluation

RAA	RM[1]	Area Type	RC	Dredge Elevation (feet MLLW)	Placement (Thickness)	COC(s) with RAL Exceedances Below the AST Cover
9K	2.8	FNC Shoal	3	-22 MLLW	AST Cover (2 feet)	Total PCBs
30C	2.0	FNC Shoal	1	-35 MLLW	AST Cover (2 feet)	Total PCBs, dioxin/furan TEQ

Notes:
1. RMs approximated to represent the centroid of the RAA.
AST: area-specific technology
COC: contaminant of concern
FNC: federal navigation channel
MLLW: mean lower low water
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
RC: recovery category
RM: river mile
TEQ: toxic equivalents

The modeling analyses described in this appendix were performed in accordance with guidance on cap design set forth by the U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (Palermo et al. 1998) and the Interstate Technology and Regulatory Council (2014, 2023).

The following sections document the modeling conducted for the evaluation of the engineered cap and utility crossing ASTs. Section 2 describes the modeling approach for the evaluation. Section 3 describes the inputs used for the model simulations for both the engineered cap and utility crossing AST evaluations. Section 4 describes model simulation results for the given chemical isolation layer design and whether RAL exceedances are predicted to occur in the utility crossing AST covers at the end of 100 years.

2 Cap Modeling Approach

This section describes the cap model framework and the cap modeling approach for the engineered caps and the utility crossing ASTs. The modeling approach used in the middle reach of LDW is generally consistent with the EPA-approved modeling for the upper reach (Anchor QEA and Windward 2024).

2.1 Model Framework

The 1D model of chemical transport within sediment caps, CapSim (version 4.2.3; Reible 2023),[2] was used for this evaluation. This model simulates the time-variable fate and transport of chemicals (dissolved and sorbed phases) under the processes of advection, diffusion/dispersion, biodegradation, bioturbation/bioirrigation, and exchange with the overlying surface water within a sediment cap. This model and its predecessor versions have been used to support the evaluation and design of sediment caps at numerous cleanup sites around the United States and internationally. Details on the model structure and underlying theory and equations are provided in Lampert and Reible (2009), Go et al. (2009), and Shen et al. (2018).

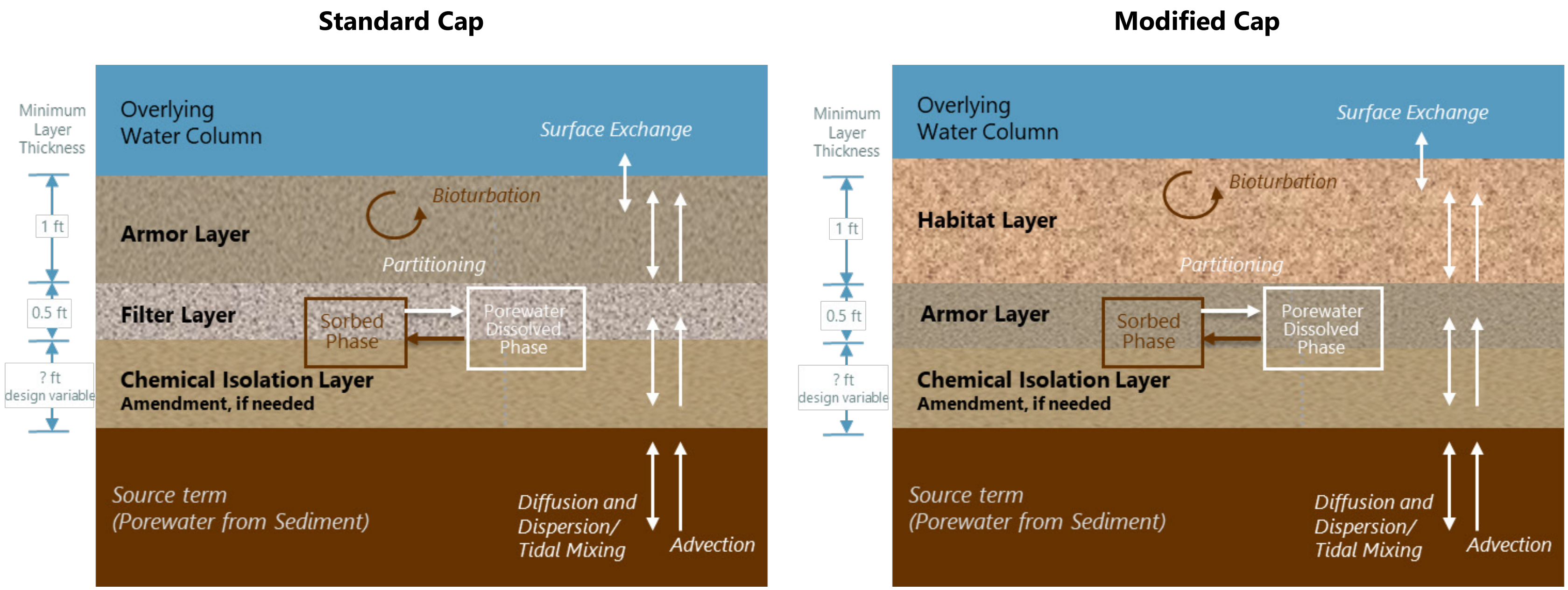
2.2 Simulation Approach for the Engineered Caps

As shown in the schematic in the left panel of Figure H2-1, the initial model configuration (i.e., layers included in the simulation) for a standard cap consisted of a chemical isolation layer, overlain by a 0.5-foot-minimum-thickness filter layer and a 1-foot-minimum-thickness erosion protection (i.e., armor) layer. The armor layer is specified as a cobble and gravel layer, as discussed in Section 9.3 and Appendix I to the BODR. It is assumed that the interstitial spaces of the armor layer will become filled in from deposition of suspended river sediments having finer grain size.

The initial model configuration for a modified cap was somewhat different from that for a standard cap. As shown in the right panel of Figure H2-1, the modified cap consists of a chemical isolation layer overlain by a 0.5-foot-minimum-thickness armor layer and a 1.5-foot-minimum-thickness habitat layer in potential clamming areas. The habitat layer is preliminarily specified as sandy gravel, as discussed in Section 9.5.1 of the BODR. Because the habitat layer was not designed to withstand the full range of potential shear forces that may occur in the area, it is possible that the habitat layer thickness may vary over time, with declines following high energy (erosion) events, followed by increases during periods of deposition. Therefore, only the lower 1-foot of the habitat layer thickness was represented in the model to be conservative.

[2] A newer version of CapSim (version 4.2.6) is available; however, the functionality of the model used in these evaluations has not changed in the newer version.

Figure H2-1
Engineered Cap Layer Configuration and Processes Simulated in the Model



Notes:
The modeling approach conservatively ignored net sedimentation (i.e., addition of material on top of the cap, which would add thickness to the model domain) but does assume that the cap surface will become infilled with depositing sediment. The model uses a porosity for the armor that assumes the infilling is complete at the beginning of the simulation, which is a reasonable assumption given the relatively short time it will take for infilling to occur compared with the long-term simulation period of 100 years. Consolidation of underlying sediments was not simulated; consolidation was assumed to be negligible due to dredging before material placement. See Section 7 and Appendix F of the BODR for further details.
A 1-foot habitat layer thickness was represented in the model to be conservative, whereas a minimum thickness of 1.5 feet of habitat layer was proposed in the Preliminary (30%) RD.

The cap evaluation was conducted for all RAAs listed in Table H1-1 that will receive a cap. The evaluation included all COCs with concentrations greater than their respective surface RAL remaining in sediments beneath the cap. These COCs are listed in Table H1-1. For a given COC, the highest calculated porewater concentration below the cap based on sediment sampling data was used as the contaminant source for the modeling to be conservative. PCBs were simulated as PCB homologs in the model to account for the differences in mobility among PCB congeners.[3] Similarly, the individual dioxin/furan congeners and PAH compounds were simulated individually and the respective results were used to calculate dioxin/furan toxic equivalents (TEQ), cPAHs, and total HPAHs by summation (with multiplication by toxicity factors as applicable for dioxin/furan TEQ and cPAHs).

Model simulations were conducted to identify the chemical isolation layer thickness and/or the amount of amendment required to maintain COC concentrations less than the corresponding RALs for the period of 100 years and incorporated into the Preliminary (30%) RD. Initial model simulations started with a chemical isolation layer thickness of 0.5 foot. Model-predicted COC concentrations in the surface of the cap (i.e., within the armor or habitat layer as shown on Figure H2-1) were computed and compared with applicable RALs from various depth intervals, as discussed subsequently. If a 0.5-foot chemical isolation layer was not sufficient to maintain predicted COC concentrations less than the applicable RALs, then the model simulations were conducted iteratively, to determine the required thickness or sorptive amendment dosage necessary to achieve the applicable RALs. RALs were applied as follows:

- Intertidal Areas: Model-predicted concentrations in the top 10 centimeters (cm) and top 45 cm of the sediment were compared to the corresponding RALs. This was applied to RAAs 5B, 8B, 9D, 20C, 24I, and 26 (all receiving a modified cap). As set forth in the ROD, the 0- to 45-cm RALs in intertidal areas vary by RC, where RC 1 denotes areas with limited recovery and RC 2 denotes areas with less certainty of recovery.
- Subtidal Areas Outside Shoaled Areas: Model-predicted concentrations in the top 10 cm of the sediment were compared to the corresponding RALs. This was applied to RAAs 1B, 15B, 23A, and 30A (all receiving a standard cap). The 0- to 60-cm RALs were not evaluated in these areas because the armored layer in these RAAs will protect against erosion/scour.
- Subtidal Areas Within FNC Shoaled Areas: Model-predicted concentrations in the top 10 cm of the sediment were compared to the corresponding RALs for the shoaled areas. This was applied to RAAs 9J, 14, 22, 30B, and 30F (all receiving a standard cap). Shoaled areas are those in the FNC with sediment accumulation to elevations above the authorized navigation depth, including a 2-foot overdredge depth (EPA 2014). Given the proposed dredging in these RAAs

[3] PCB concentrations were measured using an Aroclor-based method. To account for the range in mobility of the PCB congeners that make up an Aroclor, detected Aroclor PCB concentrations in sediment were converted to homolog concentrations based on the average fraction of each homolog group associated with each Aroclor developed from several published studies (Rushneck et al. 2004; Schulz-Bull et al. 1989; Frame et al. 1996; EPA 1995).

will remove sediments to 9 feet below the authorized navigation depth,[4] the post-remedial surface will be below the horizon of the 2-foot overdredge that the U.S. Army Corps of Engineers (USACE) uses to maintain the channel for navigation purposes. Thus, the evaluation was limited to the top 10 cm of the cap material.

A listing of the RALs used in the engineered cap modeling evaluation is provided in Table H2-1.

Table H2-1
RALs for Engineered Cap Evaluation

COC	Unit	Intertidal Area (RC 1)		Intertidal Area (RC 2/3)		Subtidal/ Shoaled Area[1]
		0–10 cm	0–45 cm	0–10 cm	0–45 cm	0–10 cm
Total PCBs	mg/kg OC	12	12	12	65	12
cPAHs	µg/kg	5,500	5,900	5,500	5,900	5,500
Dioxin/furan TEQ	ng/kg	25	28	25	28	25
Mercury	mg/kg	0.41	0.41	0.82	--	0.41
Zinc	mg/kg	410	410	820	--	410
Anthracene	mg/kg OC	220	220	440	--	220
Benzo(a)anthracene	mg/kg OC	110	110	220	--	110
Benzo(a)pyrene	mg/kg OC	99	99	198	--	99
Benzo(g,h,i)perylene	mg/kg OC	31	31	62	--	31
Chrysene	mg/kg OC	110	110	220	--	110
Dibenzo(a,h)anthracene	mg/kg OC	12	12	24	--	12
Fluoranthene	mg/kg OC	160	160	320	--	160
Indeno(1,2,3-cd)pyrene	mg/kg OC	34	34	68	--	34
Phenanthrene	mg/kg OC	100	100	200	--	100
Pyrene	mg/kg OC	1,000	1,000	2,000	--	1,000
Total benzofluoranthenes	mg/kg OC	230	230	460	--	230
Total HPAHs	mg/kg OC	960	960	1,920	--	960
BBP	mg/kg OC	4.9	4.9	9.8	--	4.9
2,4-dimethylphenol	µg/kg	29	29	58	--	29

Notes:
1. RAAs within the subtidal areas are all in RC 1 and have the same 0- to 10-cm RAL as those within the shoaled area (which is independent of RC).

µg/kg: microgram per kilogram
BBP: butyl benzyl phthalate
cm: centimeter

[4] For RAAs 9J, 14, and 22, dredging will be conducted down to -29 feet mean lower low water (MLLW) whereas the authorized navigation depth is -20 feet MLLW in that area. Similarly, dredging will be conducted down to -39 feet MLLW for RAAs 30B and 30F whereas the authorized navigation depth is -30 feet MLLW in that area.

COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
HPAH: high-molecular-weight polycyclic aromatic hydrocarbon
mg/kg: milligram per kilogram
ng/kg: nanogram per kilogram
OC: organic carbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
RC: recovery category
TEQ: toxic equivalents

2.3 Simulation Approach for the Utility Crossing AST

As described in Section 1, the evaluation of the utility crossing AST was performed for RAAs 9K and 30C, both of which are in FNC shoaled areas. The dredge depths at each utility crossing are limited by a vertical offset from the assumed location of the utility. The configuration of the utility crossing AST for each of these RAAs is as follows:

- RAA 9K: Dredging will remove sediments down to an elevation of -22 feet mean lower low water (MLLW), followed by a placement of a 2-foot-minimum thickness of AST cover specified as sandy gravel.
- RAA 30C: Dredging will remove sediments down to an elevation of -35 feet MLLW, followed by a placement of 2-foot-minimum thickness of AST cover specified as sandy gravel.

The utility crossing AST evaluation was conducted for RAAs 9K and 30C separately. The highest COC concentration below the AST cover in these RAAs based on sediment sampling data was used as the contaminant source for the modeling. The simulations were performed for 100 years to assess the predicted COC concentrations in the AST cover material relative to the respective RALs. The model-predicted concentrations in the top 10 cm of AST cover material were compared to the RALs, as summarized in Table H2-2. For RAA 9K, the 2-foot AST cover will bring the bed elevation to -20 feet MLLW, which is at the authorized navigation depth in this area. For RAA 30C, the post-cover elevation will be at -33 feet MLLW, which is already 3 feet below the authorized navigation depth and 1 foot below the overdredge allowance for the maintenance of FNC by USACE for the shoaled areas.

Table H2-2
Summary of RALs for Utility Crossing AST Evaluation

RAA	Depth Interval	RAL	
		Total PCBs (mg/kg OC)	Dioxin/Furan TEQ (ng/kg)
9K	0 to 10 cm	12	N/A[1]
30C	0 to 10 cm	12	25

Notes:

1. No RAL exceedances for dioxins/furans in RAA 9K.

AST: area-specific technology
cm: centimeter
mg/kg: milligram per kilogram
N/A: not applicable
ng/kg: nanogram per kilogram
OC: organic carbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
TEQ: toxic equivalents

3 Model Inputs

The CapSim model uses several input parameters that describe chemical-specific properties, sediment cap material properties (or cover in the case of the utility crossing AST), and chemical mass transfer rates. These input parameters were developed based on site-specific data, information from literature, and experience with cap design at other similar sites, including the upper reach of the LDW final designs. A list of model input parameters, values used for this modeling assessment, and source(s) from which they were derived is provided in Table H3-1. More details describing certain key model inputs are provided in Sections 3.1 through 3.3.

Table H3-1
Input Parameter Values for the Chemical Isolation Cap Model

Model Input Parameter	Value	Data Source
Chemical-Specific Properties		
COC porewater concentrations	Table H.1.1 (Attachment H.1)	Based on the maximum COC porewater concentration calculated from sediment sampling data. For organic chemicals, porewater concentrations were calculated based on bulk sediment COC and TOC concentrations and COC-specific organic carbon partition coefficients. For total PCBs, PCB homolog concentrations were estimated from individual PCB Aroclor concentrations based on composition reported in literature. For metals, porewater concentrations were calculated based on bulk sediment COC concentrations and equilibrium partition coefficients. The model assumes a fixed concentration at the bottom boundary of the model (i.e., infinite source). See Section 3.2 for more detail.
Partition coefficients for organic chemicals, log KOC (log L/kg)	Table H3-2	Partition coefficients for PCB homologs were developed as part of the Pre-Design Studies (Windward 2020). Sources of partition coefficients for the remaining organic COCs were based on literature as follows: PAH compounds (EPA 2003), dioxin/furan congeners (Aberg et al. 2008), and SVOCs (EPA 2008). See Section 3.1 for more detail.
Partition coefficients for metals, log K_d (log L/kg)	Table H3-2	Partition coefficients based on literature (EPA 2005). See Section 3.1 for more detail.
Molecular diffusivity (10^{-6} cm^2/s)	PCBs: 3.3 to 6.5 Dioxins/furans: 3.5 to 4.6 PAHs: 5.0 to 7.6 Metals: 2.8 to 3.6 SVOCs: 4.6 to 8.9	For organic compounds, values were calculated based on molecular weight using the correlation from Schwarzenbach et al. (1993). For metals, values were calculated based on Hayduk and Laudie (1974) as a function of molar volume. The model calculates an effective diffusion coefficient using this chemical-specific input value for the molecular diffusivity and an empirical equation based on the cap material porosity using the approach developed by Millington and Quirk (1961).

Model Input Parameter	Value	Data Source
Chemical biodegradation rate (per year)	0	Assumed no biodegradation, which is conservative for some COCs that have been shown to degrade in sediment such as some of the PAHs and SVOCs evaluated herein.
Armor Layer Properties (applicable to standard caps only)		
Thickness (cm)	30	Minimum armor layer thickness.
Total porosity	0.35	The armor layer material consists of cobble and gravel. The porosity represents a typical value for these materials, assuming the interstitial spaces in this matrix will become filled in from future fine-grained sediment deposition (e.g., Domenico and Schwartz 1990).
Dry bulk density (g/cm^3)	1.69	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.35 (see previous row).
Fraction OC of bioturbation zone (%)	1	Assumed 1% within the 10-cm bioturbation zone based on experience from other sites and the assumption that over time, the interstitial spaces of the armor stone will fill in and the f_{OC} will increase toward levels similar to (but less than) those of the current surface sediment, which averages 1.9%. f_{oc} of 1% was also the value used for the cap evaluation for the upper reach of the LDW.
Fraction OC of cap material below bioturbation zone (%)	0.1	Represents the sorptive capacity of the cap material within the 10- to 30-cm depth interval. A typical lower-bound estimate to represent quarry material, in which sorption to mineral fractions can also occur (Karickhoff 1984; EPA 2000), was used. This is conservative because the armor may be filled in completely with depositional material having a higher fraction of OC.
Habitat Layer Properties (applicable to modified caps only)		
Thickness (cm)	30	Conservatively simulated 30 cm of the 45 cm of habitat material that will be placed, assuming that some of the habitat material may be eroded away over time (recognizing that deposition following such erosion could likely occur).
Total porosity	0.35	The habitat layer material consists of sandy gravel. The porosity represents a typical value for these materials (e.g., Domenico and Schwartz 1990).
Dry bulk density (g/cm^3)	1.69	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.35 (see previous row).
Fraction OC of bioturbation zone (%)	1	Assumed 1% within the 10-cm bioturbation zone based on experience from other sites and the assumption that over time, depositional sediment will mix with the habitat layer material to some extent and the f_{OC} will increase toward levels similar to (but less than) those of the current surface sediment, which averages 1.9%.
Fraction OC of cap material below bioturbation zone (%)	0.1	Assumed 0.1% within the 10- to 30-cm depth interval of the habitat material (below the bioturbation zone), which is a lower-bound estimate typically used to represent quarry materials in which sorption to mineral fractions can also occur (Karickhoff 1984; EPA 2000).

Model Input Parameter	Value	Data Source
Filter Layer Properties (applicable to standard caps only)		
Thickness (cm)	15	Minimum thickness of 15 cm (0.5 foot).
Total porosity	0.35	Typical value for gravel (e.g., Domenico and Schwartz 1990).
Dry bulk density (g/cm^3)	1.69	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.35 for gravel.
Fraction OC of cap material (%)	0.1	A lower-bound estimate typically used to represent quarry sand in which sorption to mineral fractions can also occur (Karickhoff 1984; EPA 2000).
Armor Layer Properties (applicable to modified caps only)		
Thickness (cm)	15	Minimum thickness of 15 cm (0.5 foot).
Total porosity	0.35	Typical value for gravel (e.g., Domenico and Schwartz 1990).
Dry bulk density (g/cm^3)	1.69	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.35 for gravel.
Fraction OC of cap material (%)	0.1	A lower-bound estimate typically used to represent quarry sand in which sorption to mineral fractions can also occur (Karickhoff 1984; EPA 2000).
Chemical Isolation Layer Properties		
Thickness (cm)	Design variable	Design variable. Started with a minimum thickness of 15 cm (0.5 foot) and increased as necessary to meet the applicable RALs.
Total porosity	0.4 (standard cap) 0.35 (modified cap)	Typical values for sand and gravel (e.g., Domenico and Schwartz 1990) for the standard cap and modified cap, respectively.
Dry bulk density (g/cm^3)	1.56 (standard cap) 1.69 (modified cap)	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.4 for the standard cap and 0.35 for the modified cap (see previous row).
Fraction OC of chemical isolation cap material (%)	Design variable	Represents sorptive capacity of the cap material. Started with a nominal value of 0.1%. If a RAL was predicted not to be met with sand alone, this value was increased as necessary to represent an OC amendment needed to meet the RALs.
AST Cover Layer Properties (applicable to utility crossing ASTs only)		
Thickness (cm)	60	Minimum layer thickness
Total porosity	0.35	Typical value for sandy gravel.
Dry bulk density (g/cm^3)	1.69	Calculated based on typical particle density of 2.6 g/cm^3 and porosity of 0.35 (see previous row).
Fraction OC of bioturbation zone (%)	1	Assumed 1% within the 10-cm bioturbation zone of the cover material, based on experience from other sites and the assumption that over time, the f_{OC} will increase toward levels similar to (but less than) those of the current surface sediment due to mixing with depositional sediment.
Fraction OC of cap material below bioturbation zone (%)	0.1	Assumed 0.1% within the 10- to 60-cm depth interval (below the bioturbation zone), which is a lower-bound estimate typically used to represent quarry materials in which sorption to mineral fractions can also occur (Karickhoff 1984; EPA 2000).

Model Input Parameter	Value	Data Source
Mass Transport Properties		
Boundary layer mass transfer coefficient (cm/hr)	0.3	Midpoint of range of values compiled from laboratory and field site measurements reported in the literature (e.g., Thibodeaux et al. 2001; Martinez et al. 2010; Erickson et al. 2005) and values calibrated as part of models (1D and system-wide) of sediment/water exchange at other sites (e.g., Anchor QEA and GZA 2015; Connolly et al. 2000; EPA 2006).
Groundwater seepage rate (cm/yr)	100, 400, and 800	Range of values estimated from MODFLOW model predictions developed by Fabritz et. al. (1998). Seepage rates of 400 and 800 cm/yr were used for RAAs in the intertidal and subtidal areas. Seepage rates of 100 and 400 cm/yr were used for RAAs in the middle of the channel, defined by the FNC. See Section 3.3 for detail.
Net sedimentation rate (cm/yr)	0	Conservatively assumed no future net sedimentation in the model, which would add material on top of the cap or cover, adding thickness to the model domain. Instead, the model assumes a porosity of material in the top of the cap that accounts for infilling (in the case of armor stone for the standard cap) at the beginning of the simulation, which is a reasonable assumption, given the relatively short time it will take for infilling to occur compared with the long-term simulation period of 100 years.
Dispersion length (cm)	12	Based on 20% of the model domain length (general cap thickness of 60 cm). See Section 3.3 for detail.
Bioturbation zone thickness (cm)	10	The RI (Windward 2010) concluded that 10 cm can be reasonably estimated as the depth of bioturbation in the LDW.
Particle biodiffusion coefficient (cm^2/yr)	1	Parameter represents bioturbation rate applied to the particulate phase; order of magnitude estimate represents midpoint between freshwater rivers and intertidal areas (Thibodeaux and Mackay 2011).
Porewater biodiffusion coefficient (cm^2/yr)	100	Parameter represents bioturbation rate applied to dissolved phase. Typical cap modeling approach is to use 100 times the particle biodiffusion coefficient (see previous row; Reible 2012).
Consolidation (cm)	0	Consolidation is not expected to occur as dredging of sediments will occur prior to placing a cap or cover for most RAAs; therefore, no consolidation is expected. Also see Section 7 and Appendix F of the BODR for further details.

Note:
AST: area-specific technology
cm: centimeter
cm/hr: centimeter per hour
cm/yr: centimeter per year
cm^2/s: square centimeter per second
cm^2/yr: square centimeter per year
COC: contaminant of concern
f_{OC}: fraction organic carbon
FNC: federal navigation channel
g/cm^3: gram per cubic centimeter
K_{OC}: organic carbon partition coefficient
K_d: equilibrium partition coefficient
L/kg: liter per kilogram
LDW: Lower Duwamish Waterway
OC: organic carbon
PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
RI: remedial investigation
SVOC: semivolatile organic compound
TOC: total organic carbon

3.1 Partitioning Coefficients

Partitioning of chemicals between the dissolved and sorbed (i.e., cap or cover material) phases is described in the model by the chemical-specific equilibrium partition coefficient (K_d). This approach assumes sorption follows a linear isotherm and is not rate-limited and reversible. For organic compounds, such as PCBs, dioxins/furans, PAHs, and semivolatile organic compounds (SVOCs; i.e., BBP and 2,4-dimethylphenol), the partition coefficient is calculated in the model based on the customary $K_d = f_{OC} * K_{OC}$ approach (e.g., Karickhoff 1984), where K_{OC} is the compound's OC partition coefficient and f_{OC} is the OC fraction of the solid phase (i.e., cap material).

The partition coefficients for all COCs used in the cap modeling are listed in Table H3-2. For PCBs, model simulations were performed at the homolog level to represent the range of chemical mobility associated with the congeners that make up the total Aroclors, as discussed previously. Log K_{OC} values for each PCB homolog group were calculated from the empirical relationship developed from the data collected as part of the pre-design studies ($\log K_{OC} = 0.77 \times \log K_{OW} + 1.5$) using the K_{OW} values from Hawker and Connell (1988) (Windward 2020). Windward (2020) confirmed that effects from black carbon on partitioning within site sediments were minimal; therefore, these site-specific partition coefficients were used to represent partitioning between porewater and sediments as well as cap and cover materials. For SVOCs (i.e., BBP, 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, and 2,4-dimethylphenol), K_{OC} values were calculated using the K_{OW} values from EPA 2008 and the relationship between K_{OW} and K_{OC} based on Di Toro (1985). For PAHs and metals, K_{OC} and K_d values were based on literature values in EPA 2003 and EPA 2005, respectively. Literature-based K_{OC} and K_d values for SVOCs, PAHs, and metals were also used to represent partitioning between porewater and sediments as well as cap and cover materials.

Table H3-2
Partition Coefficients Used in the Cap Model

Chemical Group	Chemical Name	Log K_{OC} (log L/kg)	Chemical Group	Chemical Name	Log K_{OC} (log L/kg)	Chemical Group	Chemical Name	Log K_d (log L/kg)
PCBs	PCB-Mono	5.1	Dioxins/ Furans	2,3,7,8-TCDD	6.4	Metals	Mercury	4.9
	PCB-Di	5.4		1,2,3,7,8-PeCDD	6.9		Zinc	4.1
	PCB-Tri	5.8		1,2,3,4,7,8-HxCDD	7.3			
	PCB-Tetra	6.1		1,2,3,6,7,8-HxCDD	7.3			
	PCB-Penta	6.4		1,2,3,4,7,8,9-HxCDD	7.3			
	PCB-Hexa	6.7		1,2,3,4,6,7,8-HpCDD	7.9			
	PCB-Hepta	7.0		OCDD	8.2			
	PCB-Octa	7.3		2,3,7,8-TCDF	6.1			
	PCB-Nona	7.5		1,2,3,7,8-PeCDF	6.5			
	PCB-Deca	7.8		2,3,4,7,8-PeCDF	6.5			
PAHs	Acenaphthene	3.9		1,2,3,4,7,8-HxCDF	6.9			
	Benzo(a)anthracene	5.6		1,2,3,6,7,8-HxCDF	6.9			
	Benzo(a)pyrene	6.0		1,2,3,7,8,9-HxCDF	6.9			
	Benzo(g,h,i)perylene	6.4		2,3,4,6,7,8-HxCDF	6.9			
	Chrysene	5.6		1,2,3,4,6,7,8-HpCDF	7.3			
	Dibenzo(a,h)anthracene	6.6		1,2,3,4,7,8,9-HpCDF	7.3			
	Fluoranthene	5.0		OCDF	7.7			
	Indeno(1,2,3-cd)pyrene	6.6	SVOCs	BBP	4.8			
	Phenanthrene	4.5		2,4-dimethylphenol	2.3			
	Pyrene	4.8		1,2,4-trichlorobenzene	3.9			
	Total benzofluoranthenes[1]	6.2		1,4-dichlorobenzene	3.4			

Notes:
1. K_{OC} for total benzofluoranthenes were estimated by averaging K_{OC} from benzo(b)fluoranthene, benzo(b)fluoranthene, and benzo(b)fluoranthene.
BBP: butyl benzyl phthalate

K_d: partition coefficient
K_{OC}: organic carbon partition coefficient
L/kg: liter per kilogram
PAH: polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
SVOC: semivolatile organic compound

3.2 Porewater Concentrations

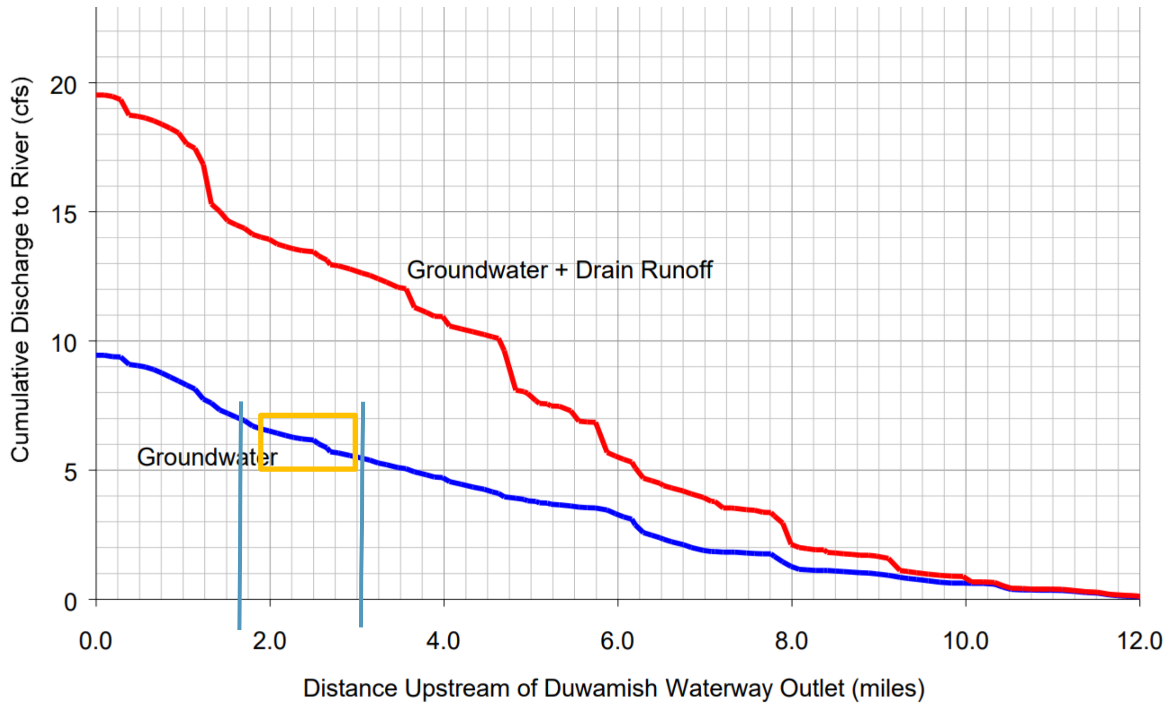
The porewater concentration input defines the source term in the CapSim model and corresponds to the contaminant concentrations present in the porewater immediately beneath the cap or cover. Porewater was not sampled in the RAAs proposed for engineered caps or the utility crossing AST; therefore, COC concentrations in sediment porewater were calculated from measured sediment concentrations and sample-specific TOC and using the COC-specific equilibrium partitioning coefficients discussed in Section 3.1.

For each RAA, concentrations from sediment samples collected below the cap were used for the evaluation of the engineered cap and utility crossing AST. Conservatively, simulations were conducted using the maximum calculated porewater concentrations in each RAA. The porewater concentrations used in the engineered cap and utility crossing AST evaluations, along with the sample IDs of the sediment samples used to estimate porewater concentrations, are provided in Tables H.1.1 and H.1.2 of Attachment H.1, respectively.

3.3 Groundwater Seepage and Dispersion

Direct measurements of groundwater seepage rates in the project area were not available. Therefore, seepage rates were estimated from the groundwater flow modeling study documented by Fabritz et. al. (1998). In this study, a 3D model of the Duwamish River Basin was developed using the U.S. Geological Survey MODFLOW framework. As part of that study, predicted cumulative discharge to LDW was presented as a function of location along 12 miles of river (see Figure H3-1, which is adapted from Figure 11 of Fabritz et al. [1998]). To estimate the seepage rate in the middle reach cap design areas, the change in cumulative discharge with distance in the project area, as shown in Figure H3-1, was reviewed. The increase in discharge with distance appears to differ somewhat among three sections of the river. Discharge is predicted to be the greatest from the river outlet to river mile (RM) 2.75, as illustrated by the steeper slope shown in Figure H3-1. Discharge is predicted to be lower moving upstream as the slope becomes flatter from RM 2.75 to RM 5, and further decline from RM 6 to RM 9.5. The middle reach cap areas are located between RMs 1.8 and 2.9 (identified by the yellow rectangle in Figure H3-1), which is nearly the entire extent of the middle reach (between RMs 1.6 and 3.0). Thus, the estimated groundwater seepage rate for the entire middle reach was used for the cap evaluation.

Figure H3-1
Cumulative Discharge to the Lower Duwamish Waterway Predicted by MODFLOW Model

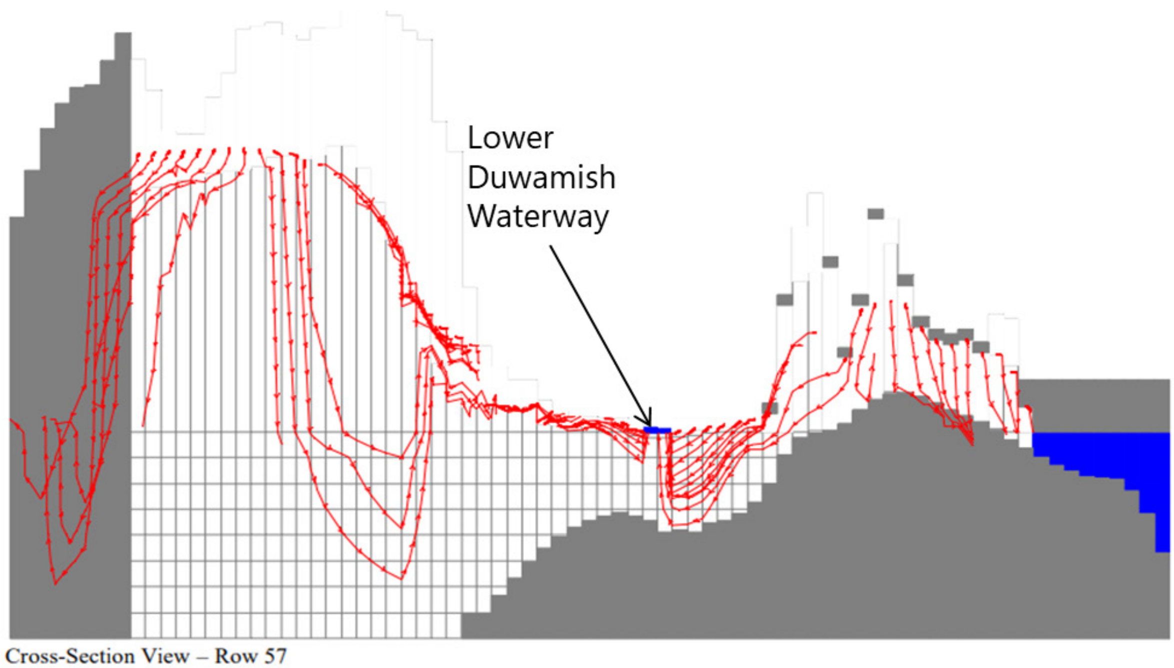


Notes:
Source: Fabritz et. al. (1998), Figure 11
The vertical blue lines and yellow box were not part of original figure.
The cap design area is represented by the yellow box. Seepage was calculated as the change in cumulative discharge between the two vertical blue lines (i.e., the extent of the middle reach of 1.4 miles).

Within the middle reach, discharge changes by approximately 1.5 cubic feet per second (cfs) over 1.4 miles (7,392 feet). The LDW is approximately 530 feet wide in this section. The seepage rate can therefore be calculated as the change in discharge over a specified distance (1.5 cfs), divided by surface area, which equals the specified distance (7,392 feet) multiplied by the width of the river (530 feet). The resulting seepage rate is approximately 368 centimeters per year (cm/yr). For the cap modeling, the value was rounded up to a seepage rate of 400 cm/yr to be conservative.

This calculation assumes the flow to the river is distributed evenly across its width. Figure H3-2, which is adapted from Figure 8 of Fabritz et. al. (1998), shows a cross-section view of the river approximately 1 to 2 miles upstream of the cap design areas of the middle reach, with model-predicted groundwater flow paths. Based on this figure, the majority of the flow is expected to discharge in the nearshore areas (which is consistent with hydrogeological principles based on the break in free surface slope that occurs between the upland and offshore, and further affected by any density differences between estuarine water in the LDW and fresher groundwater). Thus, the seepage rate closer to the center of the channel could be closer to 100 cm/yr or less, whereas closer to shore within the cap design areas, the seepage rates could be closer to 800 cm/yr (assuming the majority of flow discharges to half the area along shore). Because of the uncertainty and spatial variability associated with the estimated value of 400 cm/yr, the model simulations were conducted using values of 400 and 800 cm/yr in RAAs located in the intertidal and subtidal areas (i.e., RAAs 5B, 8B, 9A, 9D, 15B, 20C, 23A, 24I, 26, and 30A), and 100 and 400 cm/yr in RAAs located in the middle of the channel, defined by the FNC (i.e., RAAs 1B, 9J, 9K, 14, 22, 30B, 30C, and 30F). Each of these values is considered equally valid in the absence of site-specific measurements.

Figure H3-2
Flow Paths to Lower Duwamish Waterway Predicted by MODFLOW Model



Note:
Source: Fabritz et. al. (1998), Figure 8

Seepage rates assumed in cap design evaluations performed for other portions of the LDW range from 56.8 to 590 cm/yr, as shown in Table H3-3, which are generally consistent with the range considered here. The seepage rates of 100 to 800 cm/yr are also consistent with the range used in the Final (100%) RD for the upper reach of the LDW (Table H3-3).

Table H3-3
Seepage Rates Assumed for Modeling Conducted for Cap Design at Other Nearby Sites

Site	Assumed Seepage Rate (cm/yr)	Reference
EMJ Jorgensen	250	USACE (2016)
Duwamish Diagonal	56.8	Anchor Environmental (2003)
Slip 4 100% Design	312	Integral (2007)
LDW FS	250 (106–590)	AECOM (2010)
LDW upper reach Final (100%) RD	400 (100–800)	Anchor QEA and Windward (2024)

Notes:
cm/yr: centimeter per year
FS: feasibility study
LDW: Lower Duwamish Waterway
RD: remedial design
USACE: U.S. Army Corps of Engineers

The water levels in the LDW are influenced by tidal fluctuations. At low tides, seepage rates could be greater than the daily average, and at high tides, seepage rates could be less than the daily average. Extreme conditions, such as king tides, would result in even lower and higher seepage rates as compared to the long-term average. Despite the short-term variation, using the long-term average seepage rates is representative of the overall migration of porewater, which typically has a time scale of decades.

Dissolved-phase transport within the cap may be influenced by tidal fluctuations in the LDW, which can result in daily reversals in hydraulic gradient and advective flow. Representing such tidal mixing with a dispersion coefficient is a common approach in groundwater modeling (e.g., La Licata et al. 2011). Dispersivity values for flow in porous media over relatively short distances are typically in the range of 1% of the domain length (consistent with typical value used in cap modeling [Reible 2012]), whereas those associated with large-scale groundwater plumes are on the order of 10% (Gelhar et al. 1992; Neuman 1990).

The hydrodynamic dispersivity for this modeling evaluation was set to a higher value of 20% of the cap or cover thickness to represent hydraulic gradient variations and reversals from tidal fluctuations as a dispersion process. This dispersivity value (i.e., 20% of domain length) is consistent with the value used in the RD for the LDW upper reach (Anchor QEA and Windward 2024). It is also consistent with values used in the final cap designs conducted at other tidally influenced sites, such as the Former Portland Gas Manufacturing Site (located on the Lower Willamette River just upstream of Portland Harbor, Oregon), where dispersivity was estimated based on the comparative strengths of tidal signals in hourly seepage meter measurements (Appendix C of Anchor QEA 2020), and

Gloucester Harbor, Massachusetts, where dispersivity was derived from model calibrations to vertical profiles of salinity in porewater (Anchor QEA and GZA 2015; Reidy et al. 2015).

4 Model Results

Modeling was conducted to evaluate the effectiveness of an engineered cap (and cover as part of the utility crossing AST) in each RAA evaluated (listed in Tables H1-1 and H1-2, respectively). The modeling was conducted for a range of seepage rates: a lower-bound and upper-bound seepage rate of 100 cm/yr and 400 cm/yr for RAAs in the FNC areas, and 400 cm/yr and 800 cm/yr for RAAs outside the FNC areas, as described in Section 3.3. Model-predicted concentrations at the end of the 100-year simulation period were compared to the RALs for each COC (see Tables H2-1 and H2-2) over the applicable depth interval(s) to evaluate the performance of the engineered cap or cover and to evaluate whether concentrations were predicted to exceed the RALs (and if so, when).

4.1 Standard Cap

Table H4-1 summarizes the model results for each standard cap simulation (for both groundwater seepage rates), indicating the following:

- The driving COC(s), if any, that correspond to the COC(s) for which concentrations were predicted to exceed the RAL for a given scenario. For cases in which RAL exceedance was predicted, the predicted time for such exceedance is provided as well.
- The chemical isolation layer thickness and amendment content (if any) determined through iterative modeling to produce no predicted RAL exceedances for cases in which they were initially predicted for the starting case of a 15-cm sand only chemical isolation layer.

For the evaluation of standard caps, model-predicted concentrations for the top 10 cm of the armor layer were averaged. Model-predicted COC concentrations at the end of the 100-year simulation for each RAA and seepage rate presented in Table H4-1, along with the applicable RALs, are provided in Table H.2.1 of Attachment H.2.

Table H4-1
Summary of Standard Cap Model Scenarios and Model Results

RAA	Chemical Isolation Layer		Seepage Rate (cm/yr)	Modeled COC	Time to Exceed Top 10 cm RAL (years)	COC that Exceeded RAL in less than 100 Years
	Thickness and Material	Amendment				
1B	15 cm sand	None	100	Total PCBs	>100	None
			400		>100	None
9J	15 cm sand	None	100	Total PCBs, dioxin/furan TEQ	>100	None
			400		>100	None
14	15 cm sand	None	100	Total PCBs	>100	None
			400		>100	None

RAA	Chemical Isolation Layer		Seepage Rate (cm/yr)	Modeled COC	Time to Exceed Top 10 cm RAL (years)	COC that Exceeded RAL in less than 100 Years
	Thickness and Material	Amendment				
15B	15 cm sand	None	400	Total PCBs	>100	None
			800		>100	None
22	15 cm sand	None	100	Total PCBs	>100	None
			400		>100	None
23A	15 cm sand	None	400	Total PCBs	>100	None
			800		>100	None
30A	15 cm sand	None	400	Total PCBs, mercury	>100	None
			800		>100	None
30B	15 cm sand	None	100	Total PCBs, dioxin/furan TEQ	>100	None
			400		>100	None
30F	15 cm sand	None	100	Total PCBs	>100	None
			400		>100	None

Notes:
cm: centimeter
cm/yr: centimeter per year
COC: contaminant of concern
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
TEQ: toxic equivalents

Model results shown in Table H4-1 indicate that a 15-cm (0.5-foot) sand chemical isolation layer with no amendment is sufficient to maintain model-predicted COC concentrations less than the RALs for more than 100 years under both seepage rates evaluated. Additional details on the results, which are contained in Table H.2.1 of Attachment H.2, are as follows:

- Model results indicated that in RAAs 1B, 14, 15B, 22, 23A, 30B, and 30F, which were evaluated for total PCBs only, model-predicted concentrations at 100 years, at the highest seepage rate for each RAA, are a factor of 41, 11, 4.2, 6.7, 1.7, 8.4, and 16 times less than the 0- to 10-cm RAL, respectively (see Table H.2.1 in Attachment H.2 for the predicted concentrations and the corresponding RALs).
- Model results indicated that in RAA 9J, which was evaluated for total PCBs and dioxin/furan TEQ, model-predicted total PCB and dioxin/furan TEQ concentrations at 100 years, at the highest seepage rate, are a factor of 15 and 10,000 times less than the surface (top 10-cm) RALs, respectively (see Table H.2.1 in Attachment H.2).
- Model results indicated that in RAA 30A, which was evaluated for total PCBs and mercury, model-predicted total PCB concentrations at 100 years, at the highest seepage rate, are a

factor of 1.6 times less than the surface (top 10-cm) RAL, whereas mercury is not predicted to be present at meaningful concentrations within the top 10 cm of the cap (see Table H.2.1 in Attachment H.2).

4.2 Modified Cap

Table H4-2 summarizes the model results for each modified cap simulation, indicating which COC(s) were predicted to exceed the RAL for the starting cap configuration, if any, and when, as well as increased cap thickness or amendment values needed to achieve predicted concentrations within the RALs for cases in which such exceedances were predicted. Model-predicted COC concentrations for each simulation presented in Table H4-2, along with the applicable RALs, are provided in Table H.2.2 of Attachment H.2. RAAs proposed for modified cap were first evaluated for a 15-cm chemical isolation layer without amendment. Further evaluations were performed with a thicker chemical isolation layer and/or with amendment if a RAL exceedance was predicted within 100 years for a given RAA and COC. Model results show that a 15-cm gravel chemical isolation layer was predicted to be sufficient to meet the RALs in one of the six modified caps (RAA 20C) for more than 100 years. In the other five RAAs, additional thickness and/or an amendment was predicted to be needed to meet the RALs for more than 100 years, as discussed in the paragraphs that follow.

Model results indicated that for RAA 5B, both 15-cm and 30-cm chemical isolation layer thicknesses were insufficient for meeting the RALs for more than 100 years and that an amendment is required. For a 15-cm chemical isolation layer, an amendment content equivalent to 2% TOC was predicted to meet both the 0- to 10-cm and 0- to 45-cm RAL for PCBs at both seepage rates. For a 30-cm chemical isolation layer, an amendment content equivalent to 1% TOC was predicted to meet the RALs at both seepage rates (Table H4-2). At the higher seepage rate and a 15-cm chemical isolation layer amended with 2% TOC, model results show that 100-year concentrations in the top 10 cm and top 45 cm of the cap are 16 and 4.1 times less than the corresponding RALs, respectively (Table H.2.2 of Attachment H.2). At the higher seepage rate and a 30-cm chemical isolation layer amended with 1% TOC, model results show that the 100-year concentrations in the top 10 and top 45 cm are 5.6 and 1.2 times less than the corresponding RALs, respectively (Table H.2.2 of Attachment H.2). The TOC requirement could be met with various carbon-based sorbents, some of which sorb more strongly than natural TOC such that their equivalent contents would be less (e.g., granular activated carbon or powdered activated carbon).

Model results indicated that in RAA 8B, a chemical isolation layer thickness of 75 cm (2.5 feet) with an amendment content equivalent to 73% TOC is predicted to meet the top 10- and 45-cm RALs at both seepage rates (Table H4-2). At the higher seepage rate, the 100-year concentration of 1,2,4-trichlorobenzene is essentially zero in the top 10- and 45-cm intervals, while the 100-year concentration of 1,4-dichlorobenzene is 1.6 and 1.03 times lower than the top 10- and 45-cm RALs, respectively (Table H2.2 of Attachment H.2). It is noted that for a thinner chemical isolation layer thickness of 60 cm (2 feet) and the amendment content equivalent to 100% TOC, the predicted top 10- and top 45-cm 1,4-dichlorobenzene concentrations were below the corresponding RALs for over 100 years under the lower seepage rate. Under the higher seepage rate, the predicted top 10-cm concentration was also below the RAL; however, the predicted top 45-cm concentration exceeded the RAL in Year 96.

Model results indicated that in RAA 9D, for a 15-cm chemical isolation layer thickness, an amendment content equivalent to 1% TOC is predicted to meet the top 10- and top 45-cm RALs at both seepage rates. For a 30-cm chemical isolation layer, no amendment was needed to meet the top 10- and top 45-cm RALs at either seepage rate (Table H4-2). For a 15-cm chemical isolation layer with amendment content equivalent to 1% TOC at the higher seepage rate, the 100-year total PCB concentrations in the top 10- and top 45-cm were 4.0 and 3.9 times less than the corresponding RALs, respectively. For a 30-cm chemical isolation layer with no amendment at the higher seepage rate, the 100-year total PCB concentrations in the top 10 and top 45 cm were 1.4 and 1.2 times less than the corresponding RALs, respectively (Table H.2.2 of Attachment H.2).

Model results indicated that in RAA 20C, a 15-cm chemical isolation layer with no amendment was predicted to be sufficient to meet the top 10-cm and top 45-cm RALs at both seepage rates (Table H4-2). For a 15-cm chemical isolation layer at the higher seepage rate, the 100-year total PCB concentrations in the top 10- and 45-cm were 18 and 3.1 times less than the corresponding RALs, respectively, whereas the dioxin/furan TEQ concentrations in the top 10- and top 45-cm were 160 and 8.2 times less than the corresponding RALs, respectively (Table H.2.2 of Attachment H.2).

Model results indicated that in RAA 24I, for a 15-cm chemical isolation layer thickness, an amendment content equivalent to 1% TOC is predicted to meet the top 10- and top 45-cm RALs at both seepage rates. For a 30-cm chemical isolation layer, no amendment was needed to meet the top 10- and top 45-cm RALs at either seepage rate (Table H4-2). For a 15-cm chemical isolation layer with an amendment content equivalent to 1% TOC at the higher seepage rate, the 100-year total PCB concentrations in the top 10- and top 45-cm were 2.7 and 3.1 times less than the corresponding RALs, respectively. For a 30-cm chemical isolation layer with no amendment at the higher seepage rate, the 100-year total PCB concentrations in the top 10 and top 45 cm were 1.1 and 1.2 times less than the corresponding RALs, respectively (Table H.2.2 of Attachment H.2).

In RAA 26, a 15-cm chemical isolation layer with no amendment was predicted to be sufficient to meet applicable RALs at both seepage rates for all evaluated COCs, except for BBP. Model results indicated that with a 15-cm chemical isolation layer, an amendment content equivalent to 48% TOC was needed to meet the applicable RALs for both the lower and upper seepage rates (Table H4-2). At 100 years, model results indicate a top 10-cm average BBP concentration of 9.3 milligrams per kilogram (mg/kg) OC, which is less than the RAL of 9.8 mg/kg OC. At the higher seepage rate, the predicted COC concentrations at 100 years for anthracene, fluoranthene, phenanthrene, pyrene, total

HPAHs, BBP, and 2,4-dimethylphenol are a factor of 61, 627, 35, 870, 640, 1.1, and 2.5 less than the surface (top 10-cm) RAL, respectively, whereas concentrations for the remaining COCs are very small or essentially zero (Table H.2.2 of Attachment H.2). A similar level of protection can also be achieved by a 30-cm chemical isolation layer with an amendment content equivalent to 14% TOC (Table H4-2). At the higher seepage rate, the predicted COC concentrations at 100 years for anthracene, fluoranthene, phenanthrene, pyrene, total HPAHs, BBP, and 2,4-dimethylphenol are a factor of 55, 1,000, 32, 1,000, 800, 1.1, and 2.5 less than the surface (top 10-cm) RAL, respectively, whereas concentrations for the remaining COCs are very small or essentially zero (Table H.2.2 of Attachment H.2).

The changes in model-predicted BBP concentrations over time within the top 10-cm of the cap in RAA 26 are shown in Figures H4-1a and H4-1b for lower and higher seepage rates evaluated, respectively. A subset of the chemical isolation layer configurations listed in Table H4-2 were included in these figures: the 15-cm, 30-cm, and amended 15-cm chemical isolation layer. At the lower seepage rate, the top 10-cm average BBP concentration is predicted to exceed the surface RAL in 6 years and 8 years for the 15- and 30-cm unamended chemical isolation layer, respectively. When the 15-cm chemical isolation layer is amended with 48% TOC, the top 10-cm average BBP concentration is below the RAL during the 100-year evaluation period (Figure H4-1a). Under the higher seepage rate, the top 10-cm average BBP concentration is predicted to exceed the surface RAL sooner for the 15- and 30-cm unamended chemical isolation layer compared to the lower seepage rate condition, and gradually approached the surface RAL by the end of Year 100 for the amended 15-cm chemical isolation layer (Figure H4-1b).

Table H4-2
Summary of Modified Cap Model Scenarios and Model Results

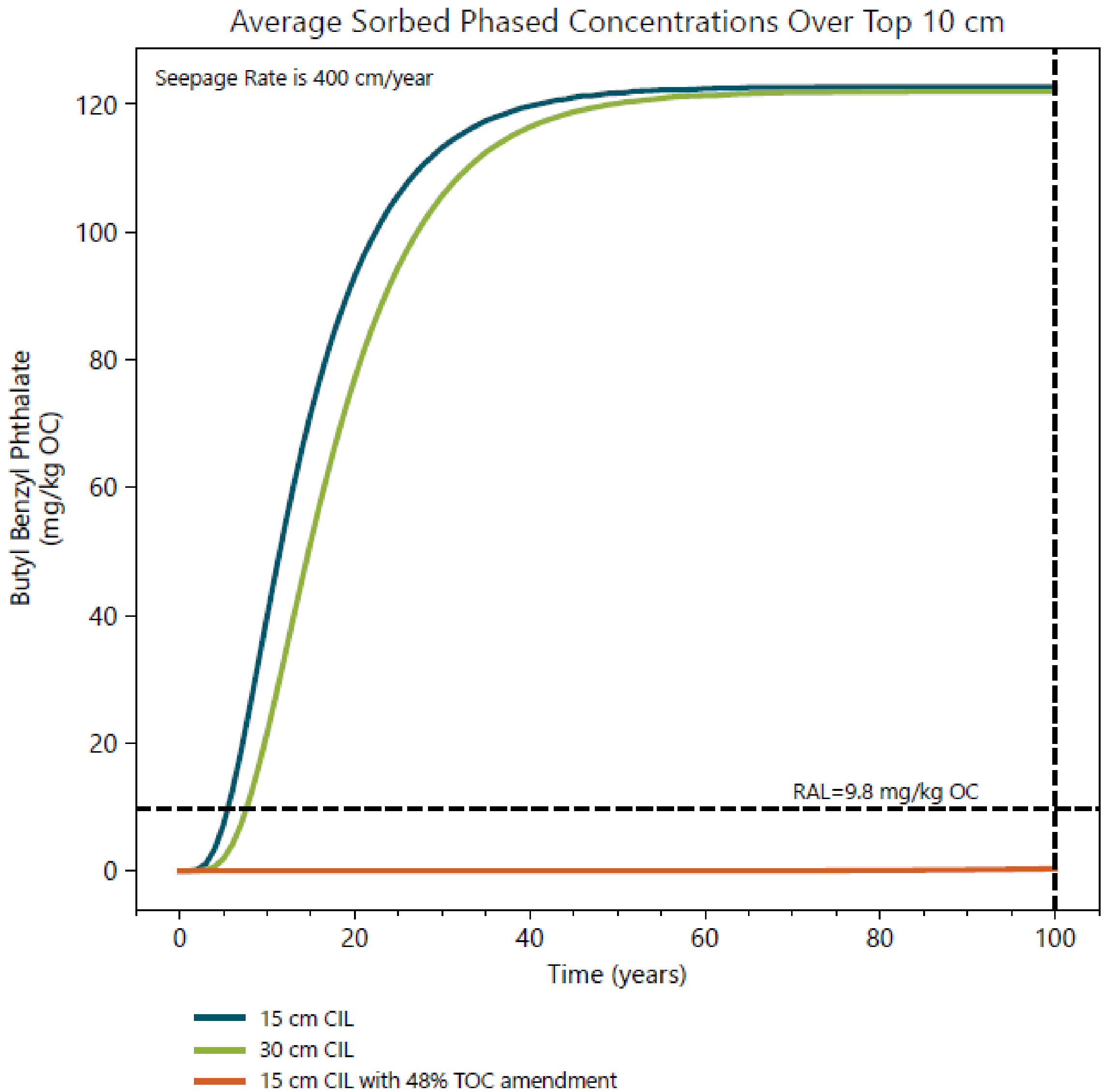
RAA	Chemical Isolation Layer: Thickness and Material	Chemical Isolation Layer: Amendment	Seepage Rate (cm/yr)	Modeled COC	Time to Exceed RAL (years): Top 10 cm	Time to Exceed RAL (years): Top 45 cm	COC that Exceeded RAL in less than 100 Years
5B	15 cm gravel	None	400	Total PCBs	>100	26	Total PCBs
			800		63	13	Total PCBs
	15 cm gravel	1% TOC	400		>100	>100	None
			800		>100	62	Total PCBs
	15 cm gravel	2% TOC	400		>100	>100	None
			800		>100	>100	None
	30 cm gravel	None	400		>100	59	Total PCBs
			800		85	30	Total PCBs
	30 cm gravel	1% TOC	400		>100	>100	None
			800		>100	>100	None
8B	15 cm gravel	None	400	1,2,4-trichlorobenzene, 1,4-dichlorobenzene	1	1	1,2,4-trichlorobenzene, 1,4-dichlorobenzene
			800		1	1	1,2,4-trichlorobenzene, 1,4-dichlorobenzene
	15 cm gravel	100% TOC	400		24	19	1,2,4-trichlorobenzene, 1,4-dichlorobenzene
			800		11	9	1,2,4-trichlorobenzene, 1,4-dichlorobenzene
	30 cm gravel	100% TOC	400		78	63	1,4-dichlorobenzene
			800		37	31	1,4-dichlorobenzene
	60 cm gravel	100% TOC	400		>100	>100	None
			800		>100	96	1,4-dichlorobenzene

RAA	Chemical Isolation Layer		Seepage Rate (cm/yr)	Modeled COC	Time to Exceed RAL (years)		COC that Exceeded RAL in less than 100 Years
	Thickness and Material	Amendment			Top 10 cm	Top 45 cm	
8B (cont.)	75 cm gravel	36% TOC	400	1,2,4-trichlorobenzene, 1,4-dichlorobenzene (cont.)	>100	>100	None
			800		57	50	1,4-dichlorobenzene
	75 cm gravel	73% TOC	400		>100	>100	None
			800		>100	>100	None
9D	15 cm gravel	None	400	Total PCBs	>100	>100	None
			800		89	68	Total PCBs
	15 cm gravel	1% TOC	400		>100	>100	None
			800		>100	>100	None
	30 cm gravel	None	400		>100	>100	None
			800		>100	>100	None
20C	15 cm gravel	None	400	Total PCBs, dioxin/furan TEQ	>100	>100	None
			800		>100	>100	None
24I	15 cm gravel	None	400	Total PCBs	>100	>100	None
			800		77	68	Total PCBs
	15 cm gravel	1% TOC	400		>100	>100	None
			800		>100	>100	None
	30 cm gravel	None	400		>100	>100	None
			800		>100	>100	None

RAA	Chemical Isolation Layer: Thickness and Material	Chemical Isolation Layer: Amendment	Seepage Rate (cm/yr)	Modeled COC	Time to Exceed RAL (years): Top 10 cm	Time to Exceed RAL (years): Top 45 cm	COC that Exceeded RAL in less than 100 Years
26	15 cm gravel	None	400	cPAHs, dioxin/furan TEQ, zinc, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, total benzofluoranthenes, total HPAHs, BBP, 2,4-dimethylphenol	6	>100	BBP
			800		3	>100	BBP
	30 cm gravel	None	400		8	>100	BBP
			800		4	>100	BBP
	15 cm gravel	48% TOC	400		>100	>100	None
			800		>100	>100	None
	30 cm gravel	14% TOC	400		>100	>100	None
			800		>100	>100	None

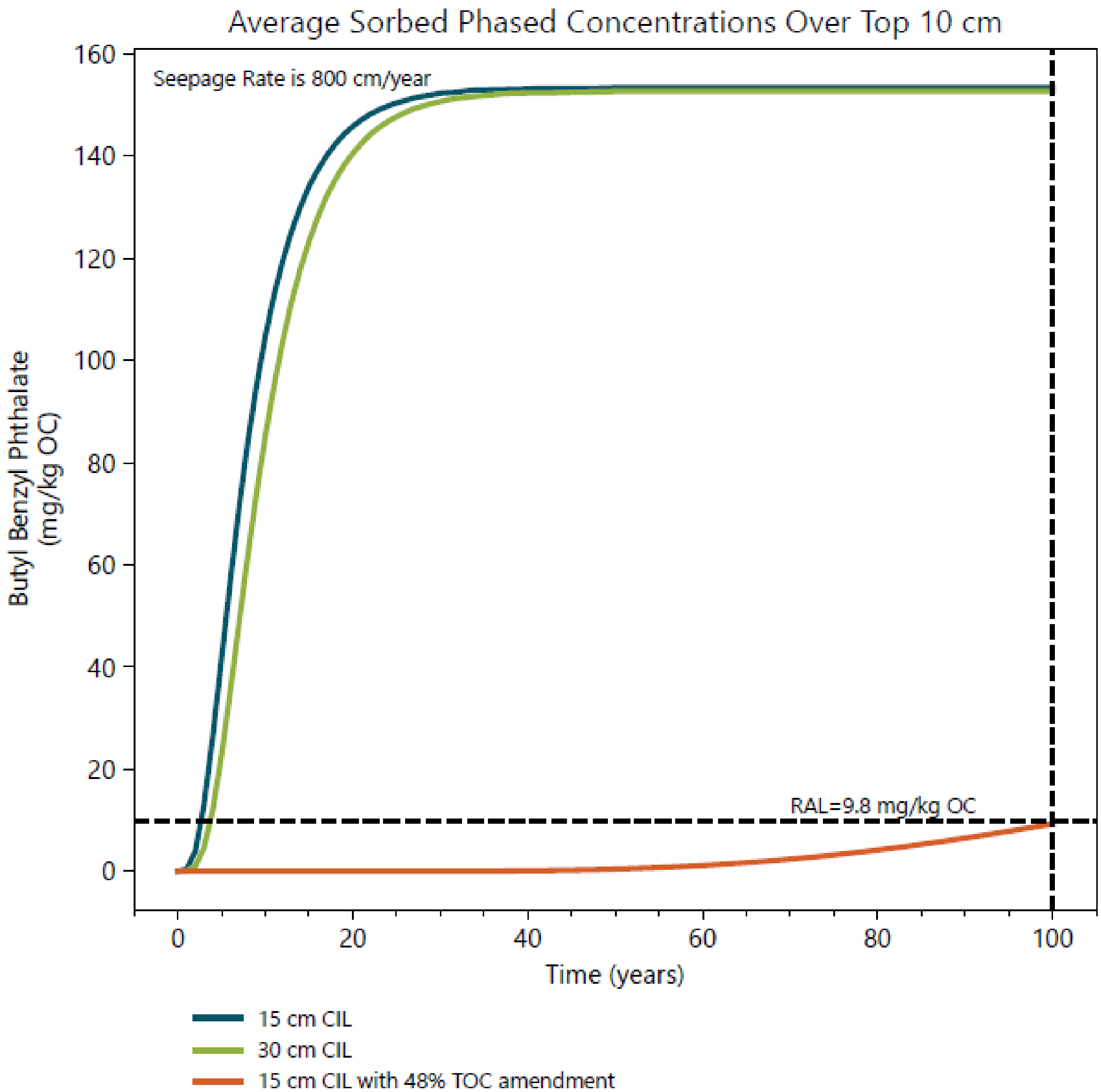
Notes:
BBP: butyl benzyl phthalate
cm: centimeter
cm/yr: centimeter per year
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
HPAH: high-molecular-weight polycyclic aromatic hydrocarbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
TEQ: toxic equivalents
TOC: total organic carbon

Figure H4-1a
Temporal Profile of Butyl Benzyl Phthalate Within the Surface of the RAA 26 Cap



Notes:
The vertical dashed line at 100 years represents the end of the assessment period
The horizontal dashed line represents the top 10-cm RAL.
CIL: chemical isolation layer
mg/kg: milligram per kilogram
OC: organic carbon
RAA: remedial action area
RAL: remedial action level
TOC: total organic carbon

Figure H4-1b
Temporal Profile of Butyl Benzyl Phthalate Within the Surface of the RAA 26 Cap



Notes:
The vertical dashed line at 100 years represents the end of the assessment period.
The horizontal dashed line represents the top 10-cm RAL.
CIL: chemical isolation layer
cm: centimeter
mg/kg: milligram per kilogram
OC: organic carbon
RAA: remedial action area
RAL: remedial action level
TOC: total organic carbon

4.3 Utility Crossing AST

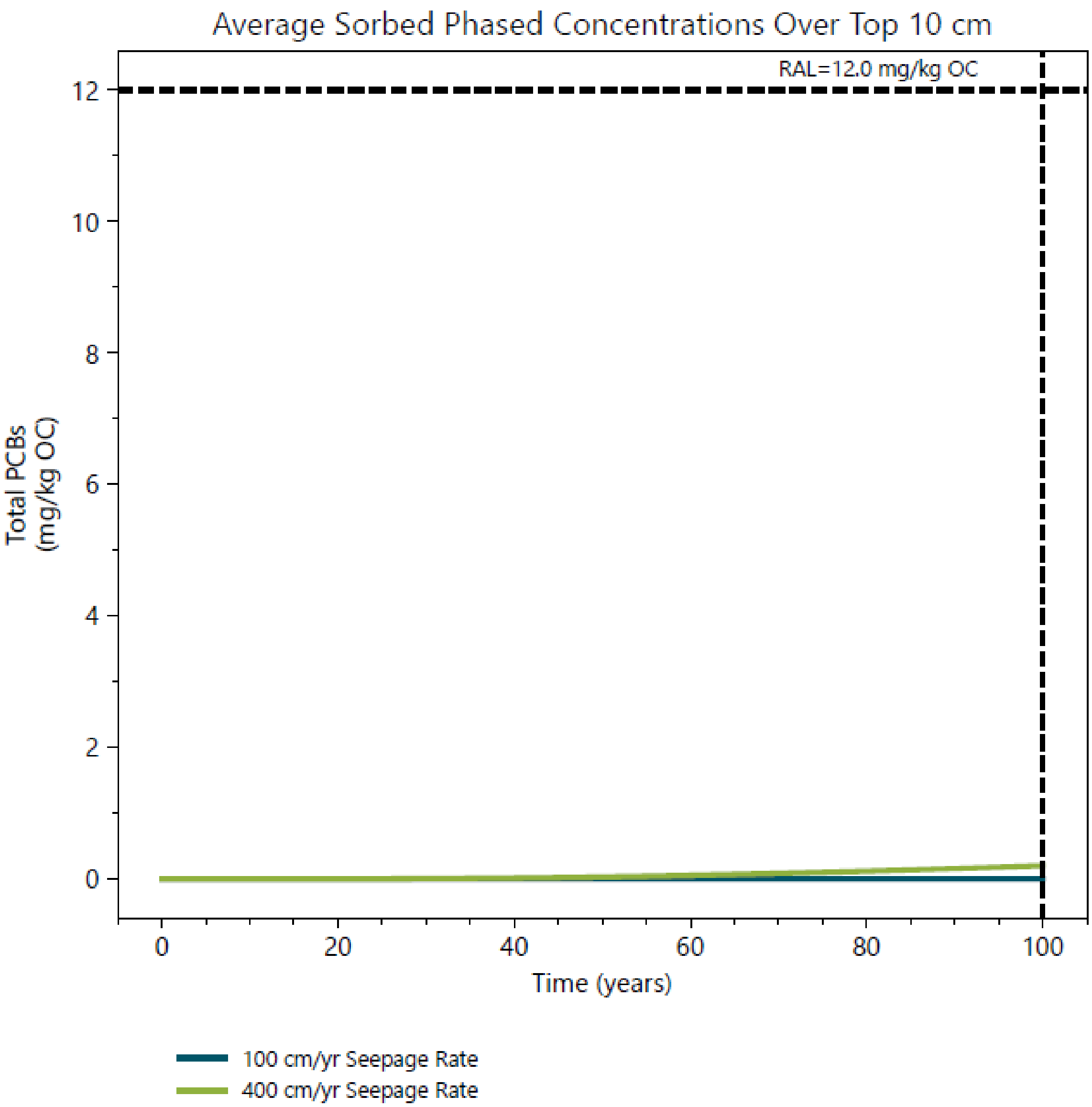
Table H4-3 summarizes the model results for each utility crossing AST simulation, indicating which COCs were predicted to exceed the RAL for each scenario, if any. Model results for each scenario and COC, along with the applicable RALs, are provided in Table H.2.3 of Attachment H.2. Model results indicated that the top 10-cm RALs would not be exceeded at 100 years under either seepage rate for RAAs 9K and 30C. RAA 9K was evaluated for total PCBs, and the predicted 100-year concentration within the top 10 cm of the cap was 2 to 6 times less than the applicable RALs for the range of seepages rates evaluated. RAA 30C was evaluated for total PCBs and dioxin/furan TEQ, and the predicted 100-year concentration in the top 10 cm of the AST cover was more than 80 and 13,000 times less than the total PCB and dioxin/furan TEQ RALs, respectively (Table H.2.3 of Attachment H.2). Figures H4-2 and H4-3 show the change in model-predicted PCB concentrations over time within the top 10-cm of the AST cover for RAAs 9K and 30C, respectively. Throughout the 100-year simulation, the model-predicted concentrations in the top 10-cm of the AST cover for both RAAs were less than the surface RAL under the range of seepage rates evaluated, with the higher seepage rate model scenario resulting in slightly higher concentrations compared with the lower seepage rate.

Table H4-3
Summary of Utility Crossing AST Model Scenarios and Model Results

RAA	Cover		Seepage Rate (cm/yr)	Modeled COC	Time to Exceed Top 10 cm RAL (years)	COC that Exceeded RAL in less than 100 years
	Thickness and Material	Amendment				
9K	60 cm sandy gravel	None	100	Total PCBs	>100	None
			400		>100	None
30C	60 cm sandy gravel	None	100	Total PCBs	>100	None
			400		>100	None
			100	Dioxin/Furan TEQ	>100	None
			400		>100	None

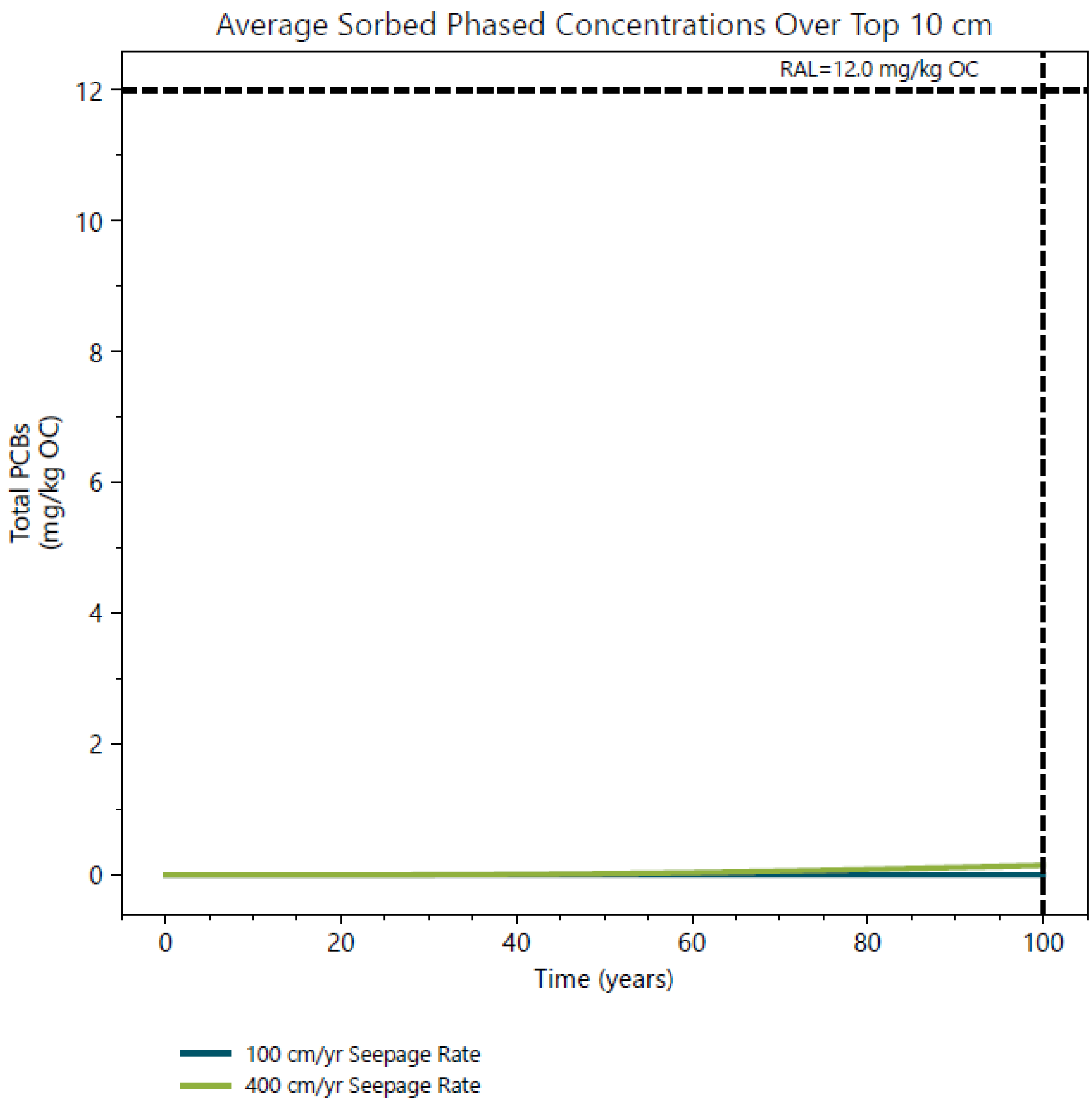
Notes
cm: centimeter
cm/yr: centimeter per year
COC: contaminant of concern
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
TEQ: toxic equivalents quotient

Figure H4-2
Temporal Profile of PCBs Within the Surface of the RAA 9K AST Cover



Notes:
The vertical dashed line at 100 years represents the end of the assessment period.
The horizontal dashed line represents the top 10-cm RAL for total PCBs.
AST: area-specific technology
cm: centimeter
mg/kg: milligram per kilogram
OC: organic carbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level

Figure H4-3
Temporal Profile of PCBs Within the Surface of the RAA 30C AST Cover



Notes:
The vertical dashed line at 100 years represents the end of the assessment period.
The horizontal dashed line represents the top 10-cm RAL for total PCBs.
AST: area-specific technology
cm: centimeter
mg/kg: milligram per kilogram
OC: organic carbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level

5 Summary

Chemical transport modeling was conducted to evaluate the performance of the proposed engineered caps and utility crossing AST covers to maintain concentrations less than RALs for more than 100 years. For the middle reach of the LDW, nine RAAs were evaluated for a standard cap, six for a modified cap, and two for the utility crossing AST.

For the standard cap, modeling indicates that a 15-cm sand chemical isolation layer is predicted to meet the applicable RALs for more than 100 years in all nine RAAs. For the modified cap, a range of thickness and amendments are evaluated for the six RAAs to meet the applicable RALs for more than 100 years under both the lower and upper seepage rate. A 15-cm gravel chemical isolation layer with no amendment was sufficient for RAA 20C, whereas either a 15-cm gravel chemical isolation layer with an amendment content equivalent to 1% TOC or a 30-cm gravel chemical isolation layer with no amendment was needed for RAAs 9D and 24I. Similarly for RAA 5B, either a 15-cm gravel chemical isolation layer with amendment content equivalent to 2% TOC or a 30-cm gravel chemical isolation layer with amendment content equivalent to 1% TOC was needed. For RAA 26, either a 15- or 30-cm gravel chemical isolation layer with an amendment content equivalent to 48% TOC and 14% TOC, respectively, was needed to slow down the transport of a relatively mobile COC (BBP) below the cap. Lastly for RAA 8B, a 75-cm of gravel chemical isolation layer with an amendment content equivalent to 73% TOC was needed to slow down the transport of 1,4-dichlorobenzene (another relatively mobile COC) below the cap. However, due to the possible limitation on dredge depth at this RAA, a 60-cm of gravel chemical isolation layer with an amendment content equivalent to 100% TOC was selected for the 30% design. This configuration is predicted to meet the top 10- and top 45-cm RALs for all COCs throughout 100 years under both the lower and upper seepage rates, with the exception of 1,4-dichlorobenzene, for which RAL exceedances will not occur until Year 96 under the higher seepage rate (i.e., 800 cm/yr). For the utility crossing AST, the predicted COC concentrations within the cover are predicted to meet the applicable RALs for more than 100 years in both RAAs 9K and 20C.

Some uncertainties in the modeling include the use of the following: 1) calculated porewater concentrations using sediment data and literature-based partition coefficients; and 2) seepage rates that are based on MODFLOW predicted discharge and an assumed range[5] Although these uncertainties exist, these simulations are still considered conservative. Examples of the conservative assumptions include the following:

- The cap thickness represented in the modeling is based on the thinnest cap thicknesses (though it could be 30 to 45 cm thicker than simulated for the standard cap and modified cap, respectively, in some areas due to overplacement allowances).

[5] As discussed in Section 3.3, the range of groundwater seepages was based on the particle tracking results shown in Figure H3-2 that show greater seepage nearshore compared with the middle of the channel.

- Maximum COC concentrations based on the single highest measurement within a given cap area were assumed for the source term.
- Infinite source of a COC was implemented in the modeling.
- Net sedimentation atop the armor layer, habitat layer material, or AST cover, which would increase the thickness of the model domain, was ignored.
- No degradation was simulated in the cap modeling, which is conservative for some COCs that have been shown to degrade in sediment, such as some of the PAHs and SVOCs evaluated herein.

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Appendix H – Engineered Cap Chemical Isolation Design Analysis and Area-Specific Technology Evaluation

Attachment H.1
Input of Porewater Concentrations for the Cap Model

Table H.1.1
Porewater Concentrations Used in the Cap Model for the Engineered Cap Evaluation

RAA	Sample ID	Chemical Name	Sediment Concentration (µg/kg)	Porewater Concentration (µg/L)
1B	LDW24-SC1582E	PCB-Mono	0.084	2.8E-05
		PCB-Di	2.6	4.5E-04
		PCB-Tri	40	2.7E-03
		PCB-Tetra	132	4.4E-03
		PCB-Penta	185	3.1E-03
		PCB-Hexa	130	1.1E-03
		PCB-Hepta	58	2.4E-04
		PCB-Octa	12	2.4E-05
		PCB-Nona	1.1	1.4E-06
		PCB-Deca	0.079	5.3E-08
5B	LDW24-IT1560D	PCB-Mono	0.087	6.9E-04
		PCB-Di	2.5	1.0E-02
		PCB-Tri	34	5.4E-02
		PCB-Tetra	152	1.2E-01
		PCB-Penta	307	1.2E-01
		PCB-Hexa	195	3.9E-02
		PCB-Hepta	67	6.7E-03
		PCB-Octa	13	6.3E-04
		PCB-Nona	1.2	3.7E-05
		PCB-Deca	0.083	1.3E-06
8B	LDW24-IT1562E	1,2,4-trichlorobenzene	42	1.3
		1,4-dichlorobenzene	180	21
9D	LDW24-IT1551D	PCB-Mono	0.16	3.7E-04
		PCB-Di	4.3	5.0E-03
		PCB-Tri	57	2.7E-02
		PCB-Tetra	247	5.8E-02
		PCB-Penta	499	5.8E-02
		PCB-Hexa	366	2.1E-02
		PCB-Hepta	155	4.6E-03
		PCB-Octa	31	4.5E-04
		PCB-Nona	2.8	2.6E-05
		PCB-Deca	0.21	9.7E-07

RAA	Sample ID	Chemical Name	Sediment Concentration (µg/kg)	Porewater Concentration (µg/L)
9J	LDW24-SC1542I	PCB-Mono	0.17	7.1E-05
		PCB-Di	5.8	1.2E-03
		PCB-Tri	92	7.6E-03
		PCB-Tetra	285	1.2E-02
		PCB-Penta	341	7.1E-03
		PCB-Hexa	196	2.0E-03
		PCB-Hepta	72	3.8E-04
		PCB-Octa	14	3.6E-05
		PCB-Nona	1.3	2.1E-06
		PCB-Deca	0.094	7.8E-08
	LDW24-SC1542K	2,3,7,8-TCDD	0.00033	5.2E-09
		1,2,3,7,8-PeCDD	0.0019	9.7E-09
		1,2,3,4,7,8-HxCDD	0.0020	4.0E-09
		1,2,3,6,7,8-HxCDD	0.022	4.5E-08
		1,2,3,7,8,9-HxCDD	0.006	1.2E-08
		1,2,3,4,6,7,8-HpCDD	0.45	2.2E-07
		OCDD	3.7	9.4E-07
		2,3,7,8-TCDF	0.0036	1.1E-07
		1,2,3,7,8-PeCDF	0.0022	2.7E-08
		2,3,4,7,8-PeCDF	0.010	1.3E-07
		1,2,3,4,7,8-HxCDF	0.11	5.4E-07
		1,2,3,6,7,8-HxCDF	0.019	9.3E-08
		1,2,3,7,8,9-HxCDF	0.013	6.7E-08
		2,3,4,6,7,8-HxCDF	0.028	1.4E-07
		1,2,3,4,6,7,8-HpCDF	0.25	5.0E-07
		1,2,3,4,7,8,9-HpCDF	0.037	7.4E-08
		OCDF	0.24	1.9E-07
14	LDW24-SC1489J	PCB-Mono	0.30	8.8E-05
		PCB-Di	11	1.6E-03
		PCB-Tri	177	1.0E-02
		PCB-Tetra	503	1.5E-02
		PCB-Penta	462	6.8E-03
		PCB-Hexa	229	1.7E-03
		PCB-Hepta	79	2.9E-04
		PCB-Octa	15	2.8E-05
		PCB-Nona	1.4	1.7E-06

RAA	Sample ID	Chemical Name	Sediment Concentration (µg/kg)	Porewater Concentration (µg/L)
14 (cont.)	LDW24-SC1489J (cont.)	PCB-Deca	0.11	6.2E-08
15B	LDW24-SC1493G	PCB-Mono	0.22	6.5E-05
		PCB-Di	7.2	1.1E-03
		PCB-Tri	113	6.8E-03
		PCB-Tetra	338	1.0E-02
		PCB-Penta	376	5.7E-03
		PCB-Hexa	249	1.9E-03
		PCB-Hepta	113	4.3E-04
		PCB-Octa	23	4.3E-05
		PCB-Nona	2.1	2.5E-06
		PCB-Deca	0.16	9.5E-08
20C	LDW24-IT1470E	PCB-Mono	0.053	2.1E-05
		PCB-Di	1.3	2.5E-04
		PCB-Tri	18	1.4E-03
		PCB-Tetra	61	2.4E-03
		PCB-Penta	104	2.0E-03
		PCB-Hexa	115	1.1E-03
		PCB-Hepta	70	3.4E-04
		PCB-Octa	15	3.6E-05
		PCB-Nona	1.4	2.1E-06
		PCB-Deca	0.10	7.9E-08
		2,3,7,8-TCDD	0.0026	5.0E-08
		1,2,3,7,8-PeCDD	0.041	2.5E-07
		1,2,3,4,7,8-HxCDD	0.12	3.0E-07
		1,2,3,6,7,8-HxCDD	0.72	1.8E-06
		1,2,3,7,8,9-HxCDD	0.20	5.0E-07
		1,2,3,4,6,7,8-HpCDD	12	7.4E-06
		OCDD	63	1.9E-05
		2,3,7,8-TCDF	0.026	1.0E-06
		1,2,3,7,8-PeCDF	0.014	2.1E-07
		2,3,4,7,8-PeCDF	0.016	2.5E-07
		1,2,3,4,7,8-HxCDF	0.19	1.2E-06
		1,2,3,6,7,8-HxCDF	0.10	5.9E-07
		1,2,3,7,8,9-HxCDF	0.051	3.1E-07
		2,3,4,6,7,8-HxCDF	0.056	3.5E-07

RAA	Sample ID	Chemical Name	Sediment Concentration (µg/kg)	Porewater Concentration (µg/L)
20C (cont.)	LDW24-IT1470E (cont.)	1,2,3,4,6,7,8-HpCDF	2.3	5.6E-06
		1,2,3,4,7,8,9-HpCDF	0.25	6.1E-07
		OCDF	3.87	3.8E-06
22	LDW24-SC1431L	PCB-Mono	0.46	1.5E-04
		PCB-Di	16	2.7E-03
		PCB-Tri	265	1.7E-02
		PCB-Tetra	757	2.5E-02
		PCB-Penta	720	1.2E-02
		PCB-Hexa	385	3.2E-03
		PCB-Hepta	146	6.0E-04
		PCB-Octa	28	5.9E-05
		PCB-Nona	2.7	3.5E-06
		PCB-Deca	0.20	1.3E-07
23A	LDW24-SC1432I	PCB-Mono	0.41	1.5E-04
		PCB-Di	14	2.6E-03
		PCB-Tri	219	1.6E-02
		PCB-Tetra	678	2.5E-02
		PCB-Penta	800	1.5E-02
		PCB-Hexa	461	4.3E-03
		PCB-Hepta	170	8.0E-04
		PCB-Octa	33	7.7E-05
		PCB-Nona	3.0	4.5E-06
		PCB-Deca	0.22	1.7E-07
24I	LDW24-IT1428E	PCB-Mono	0.81	4.3E-04
		PCB-Di	27	7.1E-03
		PCB-Tri	420	4.4E-02
		PCB-Tetra	1,270	6.7E-02
		PCB-Penta	1,458	3.9E-02
		PCB-Hexa	960	1.3E-02
		PCB-Hepta	428	2.9E-03
		PCB-Octa	86	2.9E-04
		PCB-Nona	8.1	1.7E-05
		PCB-Deca	0.60	6.3E-07
26	STM-BS-3	Anthracene	3,500	1.8E+00
		Benzo(a)anthracene	4,800	1.9E-01
		Benzo(a)pyrene	6,000	8.8E-02

RAA	Sample ID	Chemical Name	Sediment Concentration (µg/kg)	Porewater Concentration (µg/L)
26 (cont.)	STM-BS-3 (cont.)	Benzo(g,h,i)perylene	10,000	5.9E-02
		Total benzofluoranthenes	10,000	9.9E-02
		Chrysene	6,300	2.3E-01
		Dibenzo(a,h)anthracene	2,200	8.2E-03
		Fluoranthene	13,000	1.9E+00
		Indeno(1,2,3-cd)pyrene	7,600	2.8E-02
		Phenanthrene	3,200	1.5E+00
		Pyrene	11,000	2.4E+00
		BBP	23,000	5.9E+00
		2_4-Dimethylphenol	330	2.4E+01
		Zinc	1,120,000	8.9E+01
		2,3,7,8-TCDD	0.00036	2.1E-09
		1,2,3,7,8-PeCDD	0.0054	1.0E-08
		1,2,3,4,7,8-HxCDD	0.015	1.1E-08
		1,2,3,6,7,8-HxCDD	0.11	8.2E-08
		1,2,3,7,8,9-HxCDD	0.033	2.4E-08
		1,2,3,4,6,7,8-HpCDD	7.1	1.3E-06
		OCDD	71	6.6E-06
		2,3,7,8-TCDF	0.0042	4.9E-08
		1,2,3,7,8-PeCDF	0.0079	3.7E-08
		2,3,4,7,8-PeCDF	0.0071	3.3E-08
		1,2,3,4,7,8-HxCDF	0.025	4.7E-08
		1,2,3,6,7,8-HxCDF	0.010	1.8E-08
		1,2,3,7,8,9-HxCDF	0.012	2.2E-08
		2,3,4,6,7,8-HxCDF	0.014	2.6E-08
		1,2,3,4,6,7,8-HpCDF	0.31	2.3E-07
		1,2,3,4,7,8,9-HpCDF	0.025	1.9E-08
		OCDF	1.4	4.1E-07
30A	LDW24-SC1388H	PCB-Mono	0.41	1.7E-04
		PCB-Di	13	2.7E-03
		PCB-Tri	200	1.6E-02
		PCB-Tetra	654	2.7E-02
		PCB-Penta	890	1.8E-02
		PCB-Hexa	606	6.2E-03
		PCB-Hepta	263	1.4E-03
		PCB-Octa	52	1.4E-04

RAA	Sample ID	Chemical Name	Sediment Concentration (µg/kg)	Porewater Concentration (µg/L)
30A (cont.)	LDW24-SC1388H (cont.)	PCB-Nona	4.9	8.0E-06
		PCB-Deca	0.36	2.9E-07
	LDW24-SC1388F	Mercury	530	6.7E-03
30B	LDW24-SC1382C	PCB-Mono	0.34	1.3E-04
		PCB-Di	11	2.1E-03
		PCB-Tri	169	1.3E-02
		PCB-Tetra	544	2.1E-02
		PCB-Penta	716	1.4E-02
		PCB-Hexa	459	4.5E-03
		PCB-Hepta	187	9.2E-04
		PCB-Octa	37	9.0E-05
		PCB-Nona	3.42	5.3E-06
		PCB-Deca	0.25	2.0E-07
	LDW24-SC1383E	2,3,7,8-TCDD	0.00021	1.2E-09
		1,2,3,7,8-PeCDD	0.00044	8.2E-10
		1,2,3,4,7,8-HxCDD	0.00057	4.2E-10
		1,2,3,6,7,8-HxCDD	0.016	1.2E-08
		1,2,3,7,8,9-HxCDD	0.0034	2.5E-09
		1,2,3,4,6,7,8-HpCDD	0.47	8.7E-08
		OCDD	3.7	3.5E-07
		2,3,7,8-TCDF	0.0011	1.3E-08
		1,2,3,7,8-PeCDF	0.0027	1.3E-08
		2,3,4,7,8-PeCDF	0.015	7.1E-08
		1,2,3,4,7,8-HxCDF	0.079	1.5E-07
		1,2,3,6,7,8-HxCDF	0.012	2.3E-08
		1,2,3,7,8,9-HxCDF	0.013	2.4E-08
		2,3,4,6,7,8-HxCDF	0.018	3.4E-08
		1,2,3,4,6,7,8-HpCDF	0.25	1.8E-07
		1,2,3,4,7,8,9-HpCDF	0.044	3.3E-08
		OCDF	0.71	2.1E-07
30F	LDW24-SC1325K	PCB-Mono	0.20	7.0E-05
		PCB-Di	6.6	1.1E-03
		PCB-Tri	100	6.9E-03
		PCB-Tetra	332	1.2E-02
		PCB-Penta	461	8.1E-03
		PCB-Hexa	293	2.6E-03

RAA	Sample ID	Chemical Name	Sediment Concentration (µg/kg)	Porewater Concentration (µg/L)
30F (cont.)	LDW24-SC1325K (cont.)	PCB-Hepta	115	5.0E-04
		PCB-Octa	22	4.9E-05
		PCB-Nona	2.1	2.9E-06
		PCB-Deca	0.15	1.1E-07

Notes:
µg/kg: microgram per kilogram
µg/L: microgram per liter
BBP: butyl benzyl phthalate
HpCDD: heptachlorinated dibenzo-p-dioxin
HpCDF: heptachlorinated dibenzofuran
HxCDD: hexachlorinated dibenzo-p-dioxin
HxCDF: hexachlorinated dibenzofuran
OCDD: octachlorinated dibenzo-p-dioxin
OCDF: octachlorinated dibenzofuran
PCB: polychlorinated biphenyl
PeCDD: pentachlorinated dibenzo-p-dioxin
PeCDF: pentachlorinated dibenzofuran
RAA: remedial action area
TCDD: tetrachlorinated dibenzo-p-dioxin
TCDF: tetrachlorinated dibenzofuran

Table H.1.2
Porewater Concentrations Used in the Cap Model for the AST Evaluation

RAA	Sample ID	Chemical Name	Sediment Concentration (µg/kg)	Porewater Concentration (µg/L)
9K	LDW24-SC1558	PCB-Mono	0.055	1.9E-05
		PCB-Di	1.8	3.1E-04
		PCB-Tri	27	1.9E-03
		PCB-Tetra	92	3.2E-03
		PCB-Penta	133	2.4E-03
		PCB-Hexa	82	7.3E-04
		PCB-Hepta	31	1.4E-04
		PCB-Octa	6	1.3E-05
		PCB-Nona	0.54	7.6E-07
		PCB-Deca	0.040	2.8E-08
30C	LDW24-SC1346F	PCB-Mono	0.047	1.7E-05
		PCB-Di	1.3	2.4E-04
		PCB-Tri	19	1.4E-03
		PCB-Tetra	65	2.4E-03
		PCB-Penta	102	1.9E-03
		PCB-Hexa	87	8.0E-04
		PCB-Hepta	45	2.1E-04
		PCB-Octa	9	2.2E-05
		PCB-Nona	0.87	1.3E-06
		PCB-Deca	0.064	4.7E-08
	LDW24-SC1346F	2,3,7,8-TCDD	0.00048	8.9E-09
		1,2,3,7,8-PeCDD	0.0016	9.2E-09
		1,2,3,4,7,8-HxCDD	0.0023	5.3E-09
		1,2,3,6,7,8-HxCDD	0.032	7.4E-08
		1,2,3,7,8,9-HxCDD	0.0058	1.3E-08
		1,2,3,4,6,7,8-HpCDD	1.0	6.1E-07
		OCDD	8.5	2.5E-06
		2,3,7,8-TCDF	0.0020	7.3E-08
		1,2,3,7,8-PeCDF	0.048	7.1E-07
		2,3,4,7,8-PeCDF	0.015	2.1E-07
		1,2,3,4,7,8-HxCDF	0.10	6.0E-07
		1,2,3,6,7,8-HxCDF	0.017	9.9E-08
		1,2,3,7,8,9-HxCDF	0.017	1.0E-07
		2,3,4,6,7,8-HxCDF	0.0041	2.4E-08

RAA	Sample ID	Chemical Name	Sediment Concentration (μg/kg)	Porewater Concentration (μg/L)
30C (cont.)	LDW24-SC1346F	1,2,3,4,6,7,8-HpCDF	0.54	1.3E-06
		1,2,3,4,7,8,9-HpCDF	0.074	1.7E-07
		OCDF	2.7	2.5E-06

Notes:
μg/kg: microgram per kilogram
μg/L: microgram per liter
AST: area-specific technology
HpCDD: heptachlorinated dibenzo-p-dioxin
HpCDF: heptachlorinated dibenzofuran
HxCDD: hexachlorinated dibenzo-p-dioxin
HxCDF: hexachlorinated dibenzofuran
OCDD: octachlorinated dibenzo-p-dioxin
OCDF: octachlorinated dibenzofuran
PCB: polychlorinated biphenyl
PeCDD: pentachlorinated dibenzo-p-dioxin
PeCDF: pentachlorinated dibenzofuran
RAA: remedial action area
TCDD: tetrachlorinated dibenzo-p-dioxin
TCDF: tetrachlorinated dibenzofuran

Appendix H – Engineered Cap Chemical Isolation Design Analysis and Area-Specific Technology Evaluation

Attachment H.2
Model Simulation Results in Year 100

Table H.2.1
Model-Predicted COC Concentrations in Year 100 for the Standard Cap Evaluation

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
1B	15 cm sand; no amendment	100	Total PCBs	mg/kg OC	12	--	0.0051	--
		400	Total PCBs	mg/kg OC	12	--	0.29	--
9J	15 cm sand; no amendment	100	Total PCBs	mg/kg OC	12	--	0.014	--
			Dioxin/furan TEQ	ng/kg	25	--	3.2E-07	--
		400	Total PCBs	mg/kg OC	12	--	0.81	--
			Dioxin/furan TEQ	ng/kg	25	--	0.0025	--
14	15 cm sand; no amendment	100	Total PCBs	mg/kg OC	12	--	0.019	--
		400	Total PCBs	mg/kg OC	12	--	1.1	--
15B	15 cm sand; no amendment	400	Total PCBs	mg/kg OC	12	--	0.71	--
		800	Total PCBs	mg/kg OC	12	--	2.9	--
22	15 cm sand; no amendment	100	Total PCBs	mg/kg OC	12	--	0.031	--
		400	Total PCBs	mg/kg OC	12	--	1.8	--
23A	15 cm sand; no amendment	400	Total PCBs	mg/kg OC	12	--	1.7	--
		800	Total PCBs	mg/kg OC	12	--	7.0	--
30A	15 cm sand; no amendment	400	Total PCB	mg/kg OC	12	--	1.8	--
			Mercury	mg/kg	0.41	--	0	--
		800	Total PCB	mg/kg OC	12	--	7.4	--
			Mercury	mg/kg	0.41	--	0	--
30B	15 cm sand; no amendment	100	Total PCB	mg/kg OC	12	--	0.025	--
		400	Total PCB	mg/kg OC	12	--	1.4	--
30F	15 cm sand; no amendment	100	Total PCB	mg/kg OC	12	--	0.013	--
		400	Total PCB	mg/kg OC	12	--	0.76	--

Notes:
--: not applicable
BBP: butyl benzyl phthalate
cm: centimeter
cm/yr: centimeter per year
COC: contaminant of concern
mg/kg: milligram per kilogram
ng/kg: nanogram per kilogram
OC: organic carbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
TEQ: toxic equivalents quotient

Table H.2.2
Model-Predicted COC Concentrations in Year 100 for the Modified Cap Evaluation

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
5B	15 cm gravel; no amendment	400	Total PCBs	mg/kg OC	12	12	6.6	97
		800	Total PCBs	mg/kg OC	12	12	31	190
	15 cm gravel; 1% TOC	400	Total PCBs	mg/kg OC	12	12	0.76	7.3
		800	Total PCBs	mg/kg OC	12	12	6.1	34
	15 cm gravel; 2% TOC	400	Total PCBs	mg/kg OC	12	12	0.23	1.6
		800	Total PCBs	mg/kg OC	12	12	2.1	10
	30 cm gravel; no amendment	400	Total PCBs	mg/kg OC	12	12	2.8	36
		800	Total PCBs	mg/kg OC	12	12	17	110
	30 cm gravel; 1% TOC	400	Total PCBs	mg/kg OC	12	12	0.070	0.34
		800	Total PCBs	mg/kg OC	12	12	0.75	2.9
8B	15 cm gravel; no amendment	400	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	4.3	7.6
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	19	33
		800	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	5.1	8.1
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	22	35
	15 cm gravel; 100% TOC	400	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	0.91	1.7
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	16	28
		800	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	2.8	4.5
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	22	34
	30 cm gravel; 100% TOC	400	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	0.0074	0.014
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	5.3	9.4
		800	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	0.27	0.44
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	15	23

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	**0–45 cm**	**0–10 cm**	**0–45 cm**
8B (cont.)	60 cm gravel; 100% TOC	400	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	1.6E-10	3.5E-10
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	0.061	0.11
		800	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	3.2E-05	5.5E-05
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	2.3	3.6
	75 cm gravel; 36% TOC	400	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	5.7E-06	1.2E-05
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	1.7	3.0
		800	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	0.013	0.021
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	11	18
	75 cm gravel; 73% TOC	400	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	3.6E-12	8.2E-12
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	0.031	0.055
		800	1,2,4-trichlorobenzene	mg/kg OC	0.81	0.81	5.9E-06	1.0E-05
			1,4-dichlorobenzene	mg/kg OC	3.1	3.1	1.9	3.0
9D	15 cm gravel; no amendment	400	Total PCBs	mg/kg OC	12	65	3.2	47
		800	Total PCBs	mg/kg OC	12	65	15	94
	15 cm gravel; 1% TOC	400	Total PCBs	mg/kg OC	12	65	0.38	0.35
		800	Total PCBs	mg/kg OC	12	65	3.0	16
	30 cm gravel; no amendment	400	Total PCBs	mg/kg OC	12	65	1.4	17
		800	Total PCBs	mg/kg OC	12	65	8.4	52
20C	15 cm gravel; no amendment	400	Total PCBs	mg/kg OC	12	12	0.15	2.0
			Dioxin/furan TEQ	ng/kg	25	28	0.020	0.99
		800	Total PCBs	mg/kg OC	12	12	0.65	3.9
			Dioxin/furan TEQ	ng/kg	25	28	0.16	3.4

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
20C (cont.)	30 cm gravel; no amendment	400	Total PCBs	mg/kg OC	12	12	0.068	0.76
			Dioxin/furan TEQ	ng/kg	25	28	0.0037	0.18
		800	Total PCBs	mg/kg OC	12	12	0.38	2.1
			Dioxin/furan TEQ	ng/kg	25	28	0.068	0.81
24I	15 cm gravel; no amendment	400	Total PCBs	mg/kg OC	12	65	4.6	48
		800	Total PCBs	mg/kg OC	12	65	19	88
	15 cm gravel; 1% TOC	400	Total PCBs	mg/kg OC	12	65	0.57	5.1
		800	Total PCBs	mg/kg OC	12	65	4.4	21
	30 cm gravel; no amendment	400	Total PCBs	mg/kg OC	12	65	2.1	21
		800	Total PCBs	mg/kg OC	12	65	11	55
26	15 cm gravel; no amendment	400	cPAHs	ug/kg	5,500	5,900	42	350
			Dioxin/furan TEQ	ng/kg	25	28	9.8E-04	0.061
			Zinc	mg/kg	820	--	1.1E-08	--
			Anthracene	mg/kg OC	440	--	19	--
			Benzo(a)anthracene	mg/kg OC	220	--	13	--
			Benzo(a)pyrene	mg/kg OC	198	--	2.7	--
			Benzo(g,h,i)perylene	mg/kg OC	62	--	0.084	--
			Chrysene	mg/kg OC	220	--	16	--
			Dibenzo(a,h)anthracene	mg/kg OC	24	--	5.3E-04	--
			Fluoranthene	mg/kg OC	320	--	65	--
			Indeno(1,2,3-cd)pyrene	mg/kg OC	68	--	0.0015	--
			Phenanthrene	mg/kg OC	200	--	18	--
			Pyrene	mg/kg OC	2,000	--	58	--
			Total benzofluoranthenes	mg/kg OC	460	--	1.1	--

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
26 (cont.)	15 cm gravel; no amendment (cont.)	400 (cont.)	Total HPAHs	mg/kg OC	1,920	--	160	--
			BBP	mg/kg OC	9.8	--	120	--
			2,4-Dimethylphenol	ug/kg	58	--	19	--
		800	cPAHs	ug/kg	5,500	5,900	170	570
			Dioxin/furan TEQ	ng/kg	25	28	0.0091	0.20
			Zinc	mg/kg	820	--	9.3E-04	--
			Anthracene	mg/kg OC	440	--	24	--
			Benzo(a)anthracene	mg/kg OC	220	--	25	--
			Benzo(a)pyrene	mg/kg OC	198	--	13	--
			Benzo(g,h,i)perylene	mg/kg OC	62	--	2.3	--
			Chrysene	mg/kg OC	220	--	32	--
			Dibenzo(a,h)anthracene	mg/kg OC	24	--	0.068	--
			Fluoranthene	mg/kg OC	320	--	85	--
			Indeno(1,2,3-cd)pyrene	mg/kg OC	68	--	0.21	--
			Phenanthrene	mg/kg OC	200	--	22	--
			Pyrene	mg/kg OC	2,000	--	73	--
			Total benzofluoranthenes	mg/kg OC	460	--	10	--
			Total HPAHs	mg/kg OC	1,920	--	250	--
			BBP	mg/kg OC	9.8	--	150	--
			2,4-Dimethylphenol	ug/kg	58	--	23	--
	30 cm gravel; no amendment	400	cPAHs	ug/kg	5,500	5,900	19	190
			Dioxin/furan TEQ	ng/kg	25	28	1.8E-04	0.010
			Zinc	mg/kg	820	--	7.8E-15	--
			Anthracene	mg/kg OC	440	--	19	--

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
26 (cont.)	30 cm gravel; no amendment (cont.)	400 (cont.)	Benzo(a)anthracene	mg/kg OC	220	--	9.8	--
			Benzo(a)pyrene	mg/kg OC	198	--	0.77	--
			Benzo(g,h,i)perylene	mg/kg OC	62	--	0.0028	--
			Chrysene	mg/kg OC	220	--	11	--
			Dibenzo(a,h)anthracene	mg/kg OC	24	--	2.4E-06	--
			Fluoranthene	mg/kg OC	320	--	65	--
			Indeno(1,2,3-cd)pyrene	mg/kg OC	68	--	6.3E-06	--
			Phenanthrene	mg/kg OC	200	--	18	--
			Pyrene	mg/kg OC	2,000	--	57	--
			Total benzofluoranthenes	mg/kg OC	460	--	0.16	--
			Total HPAHs	mg/kg OC	1,920	--	150	--
			BBP	mg/kg OC	9.8	--	120	--
			2,4-Dimethylphenol	ug/kg	58	--	19	--
		800	cPAHs	ug/kg	5,500	5,900	108	430
			Dioxin/furan TEQ	ng/kg	25	28	0.0035	0.052
			Zinc	mg/kg	820	--	2.8E-07	--
			Anthracene	mg/kg OC	440	--	24	--
			Benzo(a)anthracene	mg/kg OC	220	--	24	--
			Benzo(a)pyrene	mg/kg OC	198	--	7.8	--
			Benzo(g,h,i)perylene	mg/kg OC	62	--	0.46	--
			Chrysene	mg/kg OC	220	--	29	--
			Dibenzo(a,h)anthracene	mg/kg OC	24	--	0.0046	--
			Fluoranthene	mg/kg OC	320	--	84	--
			Indeno(1,2,3-cd)pyrene	mg/kg OC	68	--	0.014	--

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
26 (cont.)	30 cm gravel; no amendment (cont.)	800 (cont.)	Phenanthrene	mg/kg OC	200	--	22	--
			Pyrene	mg/kg OC	2,000	--	72	--
			Total benzofluoranthenes	mg/kg OC	460	--	4.2	--
			Total HPAHs	mg/kg OC	1,920	--	230	--
			BBP	mg/kg OC	9.8	--	150	--
			2,4-Dimethylphenol	ug/kg	58	--	23	--
	15 cm gravel; 48% TOC	400	cPAHs	ug/kg	5,500	5,900	8.4E-11	3.8E-09
			Dioxin/furan TEQ	ng/kg	25	28	0	7.2E-20
			Zinc	mg/kg	820	--	1.1E-08	--
			Anthracene	mg/kg OC	440	--	1.2	--
			Benzo(a)anthracene	mg/kg OC	220	--	8.1E-11	--
			Benzo(a)pyrene	mg/kg OC	198	--	2.1E-18	--
			Benzo(g,h,i)perylene	mg/kg OC	62	--	0	--
			Chrysene	mg/kg OC	220	--	2.6E-11	--
			Dibenzo(a,h)anthracene	mg/kg OC	24	--	0	--
			Fluoranthene	mg/kg OC	320	--	0.0034	--
			Indeno(1,2,3-cd)pyrene	mg/kg OC	68	--	0	--
			Phenanthrene	mg/kg OC	200	--	0.86	--
			Pyrene	mg/kg OC	2,000	--	0.053	--
			Total benzofluoranthenes	mg/kg OC	460	--	0	--
			Total HPAH	mg/kg OC	1,920	--	0.060	--
			BBP	mg/kg OC	9.8	--	0.35	--
			2,4-Dimethylphenol	ug/kg	58	--	19	--

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
26 (cont.)	15 cm gravel; 48% TOC (cont.)	800	cPAHs	ug/kg	5,500	5,900	1.4E-06	1.3E-05
			Dioxin/furan TEQ	ng/kg	25	28	1.6E-17	3.1E-15
			Zinc	mg/kg	820	--	9.3E-04	--
			Anthracene	mg/kg OC	440	--	7.2	--
			Benzo(a)anthracene	mg/kg OC	220	--	1.3E-06	--
			Benzo(a)pyrene	mg/kg OC	198	--	9.7E-13	--
			Benzo(g,h,i)perylene	mg/kg OC	62	--	0	--
			Chrysene	mg/kg OC	220	--	5.4E-07	--
			Dibenzo(a,h)anthracene	mg/kg OC	24	--	0	--
			Fluoranthene	mg/kg OC	320	--	0.51	--
			Indeno(1,2,3-cd)pyrene	mg/kg OC	68	--	0	--
			Phenanthrene	mg/kg OC	200	--	5.7	--
			Pyrene	mg/kg OC	2,000	--	2.3	--
			Total benzofluoranthenes	mg/kg OC	460	--	1.7E-15	--
			Total HPAHs	mg/kg OC	1,920	--	3.0	--
			BBP	mg/kg OC	9.8	--	9.3	--
			2,4-Dimethylphenol	ug/kg	58	--	23	--
	30 cm gravel; 14% TOC	400	cPAHs	ug/kg	5,500	5,900	3.9E-15	5.6E-13
			Dioxin/furan TEQ	ng/kg	25	28	0	0
			Zinc	mg/kg	820	--	7.8E-15	--
			Anthracene	mg/kg OC	440	--	1.2	--
			Benzo(a)anthracene	mg/kg OC	220	--	3.8E-15	--
			Benzo(a)pyrene	mg/kg OC	198	--	0	--

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
26 (cont.)	30 cm gravel; 14% TOC (cont.)	400 (cont.)	Benzo(g,h,i)perylene	mg/kg OC	62	--	0	--
			Chrysene	mg/kg OC	220	--	5.1E-16	--
			Dibenzo(a,h)anthracene	mg/kg OC	24	--	0	--
			Fluoranthene	mg/kg OC	320	--	6.0E-04	--
			Indeno(1,2,3-cd)pyrene	mg/kg OC	68	--	0	--
			Phenanthrene	mg/kg OC	200	--	0.77	--
			Pyrene	mg/kg OC	2,000	--	0.021	--
			Total benzofluoranthenes	mg/kg OC	460	--	0	--
			Total HPAHs	mg/kg OC	1,920	--	0.024	--
			BBP	mg/kg OC	9.8	--	0.19	--
			2,4-Dimethylphenol	ug/kg	58	--	19	--
		800	cPAHs	ug/kg	5,500	5,900	1.4E-08	2.5E-07
			Dioxin/furan TEQ	ng/kg	25	28	0	0
			Zinc	mg/kg	820	--	2.8E-07	--
			Anthracene	mg/kg OC	440	--	8.0	--
			Benzo(a)anthracene	mg/kg OC	220	--	1.4E-08	--
			Benzo(a)pyrene	mg/kg OC	198	--	0	--
			Benzo(g,h,i)perylene	mg/kg OC	62	--	0	--
			Chrysene	mg/kg OC	220	--	3.3E-09	--
			Dibenzo(a,h)anthracene	mg/kg OC	24	--	0	--
			Fluoranthene	mg/kg OC	320	--	0.32	--
			Indeno(1,2,3-cd)pyrene	mg/kg OC	68	--	0	--
			Phenanthrene	mg/kg OC	200	--	6.3	--
			Pyrene	mg/kg OC	2,000	--	2.0	--

RAA	Chemical Isolation Layer Configuration	Seepage Rate (cm/yr)	COC	Unit	RAL		Model-Predicted Sediment Concentration	
					0–10 cm	0–45 cm	0–10 cm	0–45 cm
26 (cont.)	30 cm gravel; 14% TOC (cont.)	800 (cont.)	Total benzofluoranthenes	mg/kg OC	460	--	0	--
			Total HPAHs	mg/kg OC	1,920	--	2.4	--
			BBP	mg/kg OC	9.8	--	8.6	--
			2,4-Dimethylphenol	ug/kg	58	--	23	--

Notes:
--: not applicable
BBP: butyl benzyl phthalate
cm: centimeter
cm/yr: centimeter per year
COC: contaminant of concern
cPAH: carcinogenic polycyclic aromatic hydrocarbon
HPAH: high-molecular-weight polycyclic aromatic hydrocarbon
mg/kg: milligram per kilogram
ng/kg: nanogram per kilogram
OC: organic carbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
TEQ: toxic equivalents quotient
TOC: total organic carbon

Table H.2.3
Model-Predicted COC Concentrations in Year 100 for the Utility Crossing AST Evaluation

RAA	Backfill Thickness (cm)	Seepage Rate (cm/yr)	COC	Unit	RAL	Model-Predicted 0-to 10-cm Sediment Concentration
9K	60	100	Total PCBs	mg/kg OC	12	0.0034
		400	Total PCBs	mg/kg OC	12	0.20
30C	60	100	Total PCBs	mg/kg OC	12	0.0026
			Dioxin/furan TEQ	ng/kg	25	1.6E-07
		400	Total PCBs	mg/kg OC	12	0.15
			Dioxin/furan TEQ	ng/kg	25	0.0018

Notes:
AST: area-specific technology
cm: centimeter
cm/yr: centimeter per year
COC: contaminant of concern
mg/kg: milligram per kilogram
ng/kg: nanogram per kilogram
OC: organic carbon
PCB: polychlorinated biphenyl
RAA: remedial action area
RAL: remedial action level
TEQ: toxic equivalents quotient