APPENDIX J – DETAILED CALCULATIONS AND SENSITIVITY ANALYSES FOR PREDICTIVE EVALUATION OF SITE PERFORMANCE OVER TIME AND RECONTAMINATION POTENTIAL

EAST WATERWAY OPERABLE UNIT FEASIBILITY STUDY

Prepared for

Port of Seattle

Prepared by

Anchor QEA, LLC

720 Olive Way, Suite 1900

Seattle, Washington 98101

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1 INTRODUCTION

This appendix provides the mathematical basis for contaminant concentration predictions for East Waterway (EW) remedial alternatives presented in the Feasibility Study (FS). The purpose of each of the predictive evaluations discussed in this appendix is described in detail in FS Section 5. Remedial technologies for use in the EW are described in FS Section 7, and descriptions of remedial alternatives are provided in FS Section 8.

This appendix provides a summary of input information, methodology, mathematical calculations, and rationale for model assumptions for each of the three predictive evaluations presented in Section 5:

- Site-wide Performance Over Time (referred to as the "box model evaluation") (Section 2 of this appendix, FS Section 5.3)
- Remedial action objective (RAO) 3 Performance Over Time (referred to as the "point mixing model evaluation") (Section 3 of this appendix, FS Section 5.5)
- Recontamination Potential (referred to as the "grid model evaluation") (Section 4 of this appendix, FS Section 5.4)

This appendix also summarizes the sensitivity and bounding analyses conducted to determine the relative influence of input parameters on the results of the predictive evaluations (Sections 2.3, 3.4, and 4.5 of this appendix).

2 SITE-WIDE PERFORMANCE OVER TIME (BOX MODEL EVALUATION)

The box model evaluation was used to predict spatially-weighted average concentrations (SWAC) for the alternatives from years 0 to 40 post-construction for the four human health risk driver contaminants of concern (COCs):

1. Polychlorinated biphenyls (PCBs)
2. Arsenic
3. Carcinogenic polycyclic aromatic hydrocarbons (cPAHs)
4. Dioxins/furans

Predicted SWACs were then used for the screening of alternatives (Appendix L) and for the detailed and comparative evaluation of the retained alternatives (FS Sections 9 and 10).

The box model evaluation was conducted using a Microsoft Excel spreadsheet-based analytical model that calculates site-wide and sub-area SWACs within the EW. The SWAC for each human health risk driver COC is calculated beginning at year 0 (immediately following construction) and at 5-year intervals through year 40. The site-wide SWAC for each COC is determined at each 5-year interval (e.g., 0, 5, 10, 15, etc.) through a series of calculations that take into account remedial technology and sediment mixing assumptions, which vary across the EW, and incoming sediment characteristics. A sensitivity and bounding evaluation was also conducted, based on range of values for input variables, to determine the effect of uncertainty in the input information on the SWAC calculations.

This section provides a description of input parameters used in the evaluation, including ranges used for sensitivity and bounding (Section 2.1), mathematical basis for the calculations (Section 2.2), sensitivity and bounding analyses for the model results (Section 2.3), and a brief summary of where the model results are used within the FS (Section 2.4). Section 5 of this appendix provides additional considerations regarding uncertainties associated with predicted SWAC values using the box model evaluation.

2.1 Input Information

The box model evaluation utilized several types of input information to estimate SWAC values over the 40-year post-construction time period, as follows:

- Upstream and lateral solids loading and net sedimentation rates (NSRs) within the EW
- Chemistry assumptions for incoming solids
- Post-construction surface sediment concentrations, including dredge residuals thickness and concentrations
- Sediment mixing and underpier exchange assumptions
- Bioavailability of hydrophobic organic contaminants
- Remedial technologies for the remedial alternatives

Development of best estimates (base case) values for each of these input parameters are discussed in detail in FS Sections 5.3.1 through 5.3.5, and summarized in the following subsections. There are uncertainties in the selection of the best estimate (base case) values for the input parameters. In order to evaluate the sensitivity of the box model calculations (SWAC values) to these uncertainties, high and low values of these input parameters were also developed. A discussion of the high and low values for these inputs is also provided in the following subsections, and the sensitivity analysis is provided in Section 2.3 herein.

A summary of the best estimate (base case) and high and low values for each of the input variables is provided in Chart 1. Chart 1 also provides a road-map, in the last column of the chart, to the location where detailed discussion and justification for the values of each parameter can be found within the EW FS.

Chart 1

Summary of Base Case and High and Low Range Values of Variables used in the Box Model Evaluation

Variable	Range of Values used in Sensitivity Analysis			Basis for Range of Values	Road Map to Sections in the FS for Detailed Discussion
	Low	Base Case	High		
Site-wide NSR (cm/yr)	0.5	1.2	1.8	**Base case**: Estimated as a site-wide area average by assigning areas either 1.6, 0.5, or 0 cm/yr NSRs based on geochronology core data and vessel operations. **Low**: Estimated with the average of the Pb-210 cores with best-fit lines. **High**: Average of high range of values calculated for Cs-137 data for each core where Cs-137 peaks were found.	• Section 2.1.1 herein • FS Sections 5.1.1 and 5.1.2 • FS Figure 5-1
Variable NSR	Three NSRs assigned to different areas with site-wide average net sedimentation equal to 1.2 cm/yr.			Areas assigned either 1.6, 0.5, or 0 cm/yr NSRs based on geochronology core data, vessel operations, and comparison of bathymetric surveys.	
EW Laterals Chemical Concentrations	Low	Base Case	High	Section 2.1.2.1 and Table 1 herein, FS Section 5.3.1, FS Tables 5-3 and 5-4, and FS Appendix B, Part 4.	
Green River Chemical Concentrations	Low	Base Case	High	Section 2.1.2.1 and Table 1 herein, FS Section 5.3.1, FS Tables 5-3 and 5-4, and FS Appendix B, Part 3B.	
Dredge Residuals Thickness - Dredged Areas / Unremediated Islands (cm)	3.1 / 0.6	5.1 / 1.0	7.2 / 1.4	**Base case**: Core-by-core analysis incorporating multiple dredge passes and assuming 5% loss of dredge material. **Low**: Core-by-core analysis incorporating multiple dredge passes and assuming 3% loss of dredge material. **High**: Core-by-core analysis incorporating multiple dredge passes and assuming 7% loss of dredge material.	• Section 2.1.2.1 herein • FS Appendix B, Part 3A
Dredge Residuals Concentration - Dredged Areas / Unremediated Islands (Total PCBs; µg/kg dw)	540 / 470	760 / 640	1280 / 980	**Base case**: Core-by-core analysis incorporating multiple dredge passes. Cores are area-weighted averaged by Thiessen polygon. **Low**: Median value of the core-by-core analysis. **High**: 95% upper confidence limit on the mean (gamma distribution) of the core-by-core analysis.	• Section 2.1.2.1 herein • FS Appendix B, Part 3A
Mixing Depth due to Propwash in Vessel Operation Areas	1[1]	2	3[1]	Vertical mixing depths were variable across the EW in open-water areas as shown in Figure 5-3. For high and low ranges, only open-water areas with best estimate mixing depths equal to 2 feet were varied as part of the sensitivity analysis. Underpier sediments were assumed to be fully mixed by volume for all cases (sensitivity to underpier mixing was evaluated through range in percent exchange). **Base case**: Approximate site-wide average of estimating propwash mixing depth within areas predicted to have mixing depths greater than 0.5 feet, as shown in Figure 5-3. **Low**: Value chosen to be 1 foot lower than the base case in the 2-foot mixing areas shown in Figure 5-3. **High**: Value chosen to be 1 foot higher than the base case, in the 2-foot mixing areas shown in Figure 5-3. This value is not as large as the largest estimated mixing depth (4.7 feet), as that is a conservatively high value (to assign to the entire EW) based on methods used to estimate propwash mixing depths in the SRI[2].	• Section 2.1.4 herein • FS Section 5.1.5 • FS Figure 5-2 • FS Appendix B, Part 2
Percent of EW Open-water Area that is Vertically Mixed Every 5 Years	30%	50%	90%	10-cm biologically active zone mixing is assumed to be the minimum mixing depth in all areas. **Base case**: Approximate percent of the EW area that is either: 1) subject to frequent propwash mixing based on the area of the EW with geochronology cores with Cs-137 peaks or higher correlation Pb-210 data; 2) contains unrecoverable geochronology cores; 3) contains cores without either Cs-137 peaks or Pb-210 correlations; or 4) in areas where cores were not attempted (areas presumed to mix or that were previous dredged). **Low**: Low bound estimated based on areas where NSRs are 0 or 0.5 cm/yr. Although vessels actively navigate 90% of the EW, propeller scour effects from individual vessels create localized effects, so some sediment could remain undisturbed over time. **High**: Approximate percent of the EW that is, or could be, subject to propwash mixing based on vessel operations in each area as documented in the STER[3] and SRI[2]. Areas 1C and 7 are excluded from propwash mixing due to documented lack of current or future planned vessel operations and all other areas are considered propwash areas.	• Section 2.1.5 herein • FS Section 5.3.3

Chart 1

Summary of Base Case and High and Low Range Values of Variables used in the Box Model Evaluation

Variable	Range of Values used in Sensitivity Analysis – Low	Base Case	High	Basis for Range of Values	Road Map to Sections in the FS for Detailed Discussion
Percent Exchange Between Underpier and Open-water Sediments Every 5 years	5%	25%	50%	**Base case**: Approximate percent of the pier face length subject to significant propwash impact compared to the total length of the pier face. **Low**: Represents minimal exchange of sediment between open-water and underpier areas. **High**: Represents reasonable high underpier exchange estimate. 100% was not chosen because it is likely that some portion of the underpier areas (even in an extreme case) would not mix every 5 years. Approximate percent of the underpier volume mixed based on a 2-foot mixing depth (low end of predicted range for mixing depth). Average depth of sediments in the underpier areas is approximately 2 feet.	• Section 2.1.6 herein • FS Section 5.3.4
Percent Reduction in Bioavailability of Hydrophobic Organic Contaminants in Underpier Sediments Due to In situ Treatment	50%	70%	90%	**Base case**: Represents bioavailability due to in situ treatment in laboratory and field studies in stable sediment (90%) adjusted downward to account for dilution of AC during mixing and exchange of underpier sediment. **Low**: Represents low estimate of bioavailability reduction due to dilution of AC from mixing and exchange of underpier sediment. **High**: Estimate of the percent reduction in bioavailability due to in situ treatment in laboratory and field studies in stable sediment.	• Section 2.1.7 herein • FS Section 7.2.7.1.1

Notes:
1. High and low range of vertical mixing depths applied to open-water areas where best estimate (base case) vertical mixing depth was equal to 2 feet.
2. *Final Supplemental Remedial Investigation Report* (SRI; Windward and Anchor QEA 2014).
3. *Final Sediment Transport Evaluation Report* (STER; Anchor QEA and Coast & Harbor Engineering 2012).

µg/kg – micrograms per kilogram
AC – activated carbon
cm/yr – centimeters per year
Cs-137 – cesium-137
dw – dry weight
EW – East Waterway
FS – Feasibility Study
NSR – net sedimentation rate
Pb-210 – lead-210
PCB – polychlorinated biphenyl

2.1.1 Solids Loads and Net Sedimentation Rate

Representative site-wide average NSR from all solids sources to the EW (upstream and EW lateral inputs) were estimated using site-specific geochronology core data and delineation of vessel operation areas within the EW (see Sections 3.4.2 and 3.3, respectively, of the *Final Supplemental Remedial Investigation Report* (SRI); Windward and Anchor QEA 2014). Additional evaluation of the site average NSR was conducted following approval of the SRI to explicitly include lead-210 (Pb-210) data in the calculation, and to take into account areas of the EW regularly affected by vessel operations where net sedimentation is likely close to 0. These additional evaluations are documented in detail in FS Sections 5.1.1 and 5.1.2 and Figure 5-1. Based on this work, the base case value for site-wide average NSR for the EW was estimated to be 1.2 centimeters per year (cm/yr). For the purposes of the box model evaluation, the representative NSR was assumed to be a single constant value throughout the EW, recognizing that actual sediment accumulation may vary considerably on location basis (both above and below 1.2 cm/yr) due to propwash effects associated with vessel operations within the waterway.

The high range value of site-wide NSR was 1.8 cm/yr, which is the average of the high range of NSRs calculated from cesium-137 (Cs-137) data from recovered geochronology cores (see Table 3-3 in the EW SRI; Windward and Anchor QEA 2014). The low range value for NSR was 0.5 cm/yr, which is the average of the NSRs estimated using Pb-210 data (see Table 3-3 in the EW SRI). In addition to low and high values of site-wide NSRs, the sensitivity analysis for the box model evaluation included a simulation that used variable NSRs within the EW, as shown in Figure 5-1 (as opposed to a single value for the entire site).

The proportion of incoming sediment attributed to upstream solids sources (i.e., the Green River, Lower Duwamish Waterway [LDW] bed sediments, and LDW lateral inputs) and EW lateral sources was estimated using the results of the LDW sediment transport model (QEA 2008), the updated EW hydrodynamic model (Anchor QEA and Coast & Harbor Engineering 2012), and deposition of sediments from EW lateral sources in the EW estimated from particle tracking model (PTM) results (see FS Appendix B). The estimated amount of solids input to the EW (by source), and the amount predicted to deposit within the EW are shown in Table 1.

2.1.2 Chemistry Assumptions

Chemistry assumptions for use in the box model for the four human health risk driver COCs were developed for incoming solids (i.e., upstream sources [the Green River, LDW bed sediments, and LDW lateral sources] and EW lateral sources), for existing conditions for in situ bed sediments, and for post-construction concentrations in remediation areas (i.e., bed replacement values and dredge residuals concentrations, which vary according to the remedial technology used for the alternatives).

2.1.2.1 Incoming Solids

Chemistry assumptions for incoming solids (upstream sources and EW lateral sources) were estimated from available empirical data as described in FS Section 5.3.1 and Appendix B, Parts 3B and 4. The best estimate (base case), high bounding, and low bounding concentrations from all sources to the EW are listed in FS Tables 5-3 and 5-5. The average net incoming concentrations considering both upstream and lateral sources for total PCBs are presented in Chart 2.

Chart 2

Net Incoming Solids Concentrations[1] Considering Upstream and Lateral Sources

Scenario		PCBs Concentration (µg/kg dw)
Current Case (years 0 to 10 post-construction)	Best Estimate	46
	Low Bounding	8.0
	High Bounding	86
Future Case[2] (years 11 to 40 post-construction)	Best Estimate	45
	Low Bounding	7.7
	High Bounding	85

Notes:
1. See FS Table 5-5 for net incoming concentrations for all upstream sources.
2. Future conditions are based on actions to reduce lateral loads such as CSO control where required to meet NPDES permit conditions and source control in storm drain basins. Upstream incoming solids were not modified for the future case because of uncertainty in the timeframe and scope of those controls, and because they are likely to be captured by the low bounding concentration estimate.

µg/kg – micrograms per kilogram
CSO – combined sewer overflow
dw – dry weight
FS – Feasibility Study
LDW – Lower Duwamish Waterway
NPDES – National Pollutant Discharge Elimination System
PCB – polychlorinated biphenyl

2.1.2.2 Dredge Residuals

Generated dredge residuals are contaminated sediments that are resuspended from the seabed during dredging activities and settle back onto the remediated surface or adjacent unremediated surfaces. Methods for estimating chemistry associated with dredge residuals and dredge residuals thickness are discussed in detail in FS Appendix B, Part 3A (Section 2).

Concentrations for the best estimate (base case) dredge residuals were estimated to be 640 micrograms per kilogram (µg/kg) dry weight (dw) for total PCBs, 490 µg toxic equivalent (TEQ)/kg dw for cPAHs, 10 milligrams per kilogram (mg/kg) dw for arsenic, and 17 nanograms (ng) TEQ/kg dw for dioxin/furans. There are two separate thicknesses of dredge residuals used in the box model calculations; one thickness that is applied over areas that are being actively dredged, and another thickness that is applied over adjacent areas where removal is not occurring. Base case assumptions for dredge residuals thickness are estimated to be 5.1 cm for all dredged areas and 1.0 cm in areas adjacent to dredging areas.

High and low ranges of dredge residuals for PCBs used in the sensitivity evaluation were developed by varying both the dredge residuals concentration and dredge residuals thickness. High and low estimates for dredge residuals chemistry (PCBs) and thickness are shown in Chart 1.

2.1.2.3 Post-construction Concentrations

Methods for estimating post-construction (i.e., bed replacement) values associated with each remedial technology are presented in Table 2 and described in detail in FS Appendix B, Part 3A (Sections 2.4 and 3).

Chemical concentrations for existing (in situ) bed sediments used for the no action alternative and designated no action and monitored natural recovery (MNR) areas within remedial alternatives were determined by interpolating existing surface sediment and shallow subsurface sediment data using Thiessen polygons, as discussed in FS Section 2.

2.1.3 Vertical Mixing Depths

Vertical mixing depth estimates in open-water areas for the box model are spatially variable over the EW and were developed based on predicted scour depths in the EW due to propwash. The predicted scour depths are discussed in FS Section 5.1.5 and Appendix B, Part 2. The justification for the range of vertical mixing depths used in the box model evaluation are discussed in FS Section 5.3.3 and illustrated in FS Figure 5-2. The best estimate (base case) vertical mixing depths used in the box model evaluation range from 2 feet in highly energetic propwash areas to 10 cm in areas impacted by bioturbation only (areas with no vessel operations). Underpier areas are assumed to be full-mixed by volume as the average sediment depth is 2 feet.

The high range value for vertical mixing was set to 3 feet in highly energetic propwash areas, and the low range value vertical mixing was set to 1 foot in these areas. These values were chosen based on the range of propwash scour depths calculated in these areas (see FS Figure 5-2 and the SRI [Anchor QEA and Coast & Harbor Engineering 2012]) and to ensure that there was an equal variation about the base case (1 foot higher and 1 foot lower).

2.1.4 Percent of East Waterway Study Area that is Mixed

In addition to vertical mixing assumptions, the percent of the surface area within the EW that is mixed was also included as a variable in the box model because propwash mixing is not expected to cover the entire waterway. The base case value for percent area mixed was set at 50% of the surface area of the EW (both open-water and underpier areas) every 5 years. Justification for selection of 50% area mixing within the EW is provided in FS Section 5.3.3 considering both vessel scour predictions and geochonological data.

The high range value for percent of EW area mixed was set to 90%, which represents the percent of the EW area that is subject to vessel operations and, therefore, has potential for propwash erosion. This includes all vessel operation areas shown in FS Figure 5-1, except for Areas 1C and 7, where no vessel operations are currently occurring or are planned to occur in the future. The low range value for percent of EW area mixed was set to 30%, which represents the percent of the EW area where NSRs were estimated from geochronology cores to be low (0 to 0.5 cm/yr), see FS Figure 5-1. Propwash erosion results in lower NSR estimates, therefore, areas of the EW with lower net sedimentation are most likely to be subject to significant propwash erosion[1].

2.1.5 Percent Exchange

Vessel scour by propwash in open-water and underpier areas results in exchange of sediments between those two areas due to resuspension and deposition of bed sediments. In order to account for this mechanism in the box model evaluation, an exchange of sediments between the open-water and underpier areas was programmed into the model. This physical process was simulated in the model by including a volume exchange calculation in the box model that exchanges 25% of the total volume of sediment located in the underpier areas with the same volume of sediment from the open-water areas within the EW (with each of their associated chemistries). The box model evenly distributes the exchanged underpier sediments throughout the open-water areas; this is a conservative assumption because it is more likely that these sediments settle nearer to piers than the middle of the navigation channel, which would result in locally higher concentrations nearer to outfalls compared to the SWAC value. Justification for selection of 25% exchange within the EW is provided in FS Section 5.3.4.

The high range value for percent of underpier sediments exchanged with open water was set to 50%, which is considered a reasonable high bound and is equivalent to the exchange of 1 foot of sediment across the entire underpier area (see FS Figure 5-3). The low range value for percent of underpier sediments exchanged was set to 5%, which is the approximate volume of underpier sediments adjacent to vessel operational Area 1A-4 (shown in FS Figure 5-1) that has been assigned a NSR of 0 due to impacts from propwash.

2.1.6 Bioavailability of Hydrophobic Organic Contaminants

The percent reduction in bioavailability of hydrophobic organic contaminants (including total PCBs) in underpier sediments due to in situ treatment was included as a parameter in the box model evaluation for remedial alternatives that included in situ treatment. The best

[1] In the SRI, the EW was determined to be net depositional (site-wide average) and that near-bed current velocities were not large enough to cause erosion of bed sediments. Therefore, areas within the EW found to have lower or zero net sedimentation are assumed to be subject to erosion by propwash (see FS Section 5.1).

estimate value for reduction in bioavailability (70%) was determined through review of literature and pilot study results and consideration of stability of the material, and is discussed in FS Section 7.2.7.1.1.

High and low values for this parameter were used to examine the sensitivity of the box model calculations to choice of bioavailability. The high range value for reduction in bioavailability was based on laboratory and field studies, and assumes that sediments will be largely stable (90%). The low range value for bioavailability was estimated assuming that effectiveness is further diminished by loss of stability through scour and transport mechanisms in the EW, which lowers activated carbon (i.e., in situ treatment material) concentrations in sediments to less effective levels (50%).

2.1.7 Remedial Technology Assignments

The area of each remedial technology for the screening alternatives is presented in Table 3 herein and depicted in FS Appendix L, Figures 2-1 through 2-16. Table 2 herein provides the post-construction concentrations associated with each remedial technology and screening alternative.

Each remedial technology is represented in the box model by a vertical bed layer model, which consisted of post-construction surface concentrations, dredge residuals layer, enhanced natural recovery (ENR) layer, backfill layer, residuals management cover (RMC) layer, and/or cap material layer, depending on remedial technology. The vertical layers associated with each remedial technology are summarized in Chart 3 and depicted in Figures 1a through 1j.

Chart 3
Remedial Technologies and Associated Actions for Box Model Evaluation

Technology	Model Components (see Figures 1a – 1h herein)			
	Removal	Placement Material	Dredge Residuals Layer	Vertical Sediment Bed Layer Figure (s)
Removal	X	Residuals management cover	X	1a and 1b
Removal and backfill to existing grade	X	Backfill	X	1c
No action (open-water interior unremediated islands)		Residuals management cover	X	1d
No action (Junction Reach and Northern end of EW)		None		1e
MNR		None	X	1f
ENR		ENR sand	X	1g
Partial removal and cap	X	Multi-layer cap with armor	X	1h and 1i
ENR-nav		ENR sand	X	1j
In situ treatment (underpier)		In situ treatment material	X[a]	None – underpier sediment is modeled as a single volume of material

Notes:
a. In situ treatment was placed on a residuals layer in areas that included diver-assisted hydraulic dredging prior to placement of in situ treatment.
ENR – enhanced natural recovery
MNR – monitored natural recovery
EW – East Waterway

2.2 Site-wide SWAC Calculations

The box model evaluation is used to calculate site-wide surface sediment SWAC over time for the four human health risk COCs for the screening alternatives based on the model inputs described above.

This section summarizes the specific mathematical calculations that were conducted as part of the box model evaluation to calculate site-wide SWAC values for all screening alternatives at year 0, directly following construction, and years 5 through 40, post-construction. Justification for the methodology for calculating site-wide SWAC values is discussed in FS Section 5.3.

2.2.1 Definition of East Waterway Sub-areas

The EW is divided up into sub-areas that represent remedial technologies applied within the EW for each alternative. These remedial technology sub-areas are further sub-divided based on vertical mixing depth areas (see FS Figure 5-2). This results in definition of each sub-area within the EW that has a unique remedial technology and vertical mixing depth. Figure 2 shows an example map to illustrate what these sub-areas look like, developed for Alternative 1A(12). All underpier areas are treated as one sub-area for the purpose of these calculations.

2.2.2 Total Incoming Solids Chemistry

A value of 1.2 cm was used for the current condition annual NSR for the EW. The NSR for the future condition was adjusted downward to 1.198 cm to account for the predicted reduction of input from additional source control actions that are expected to take place in the next 10 years that will reduce loads from EW storm drains (SDs) and combined sewer overflows (CSOs).

The average incoming solids concentrations were calculated by calculating the weighted average by mass of the five deposited solids loads to the EW from each of the source locations, which are as follows:

1. Green River
2. LDW bed sediments
3. LDW lateral inputs
4. EW SDs
5. EW CSOs

Equation 1 was used to find the average incoming solids concentrations to the EW from the five source locations.

$$Average\ Incoming\ Solids\ Concentration = \frac{\sum_{i=1}^{5}[Input_i Load * Input_i Concentration]}{\sum_{i=1}^{5} Input_i Load} \qquad (1)$$

where:

$Input_i$ Load	=	deposited sediment load from each of the five input locations listed above
$Input_i$ Concentration	=	chemical concentration for each of the COCs associated with the identified solids loads from the five input locations above

Values for average incoming sediment concentrations used for the box model evaluation are provided in FS Section 5, Table 5-5.

2.2.3 Year 0 SWAC

Year 0 SWAC concentrations were calculated based on delineation of remedial technologies and corresponding existing (in situ) sediment chemistry or bed replacement chemistry values for each alternative. Equation 2 was used to calculate year 0 post-construction SWAC values.

$$SWAC_0 = \frac{\sum_{m=1}^{a}[C_{m0}A_m]}{\sum_{m=1}^{a}A_m} \quad (2)$$

where:

$SWAC_0$	=	SWAC at year 0
a	=	Number of unique sub-areas (combinations of remedial technologies and vertical mixing depths, including underpier areas)
A_m	=	Area of each individual sub-area
C_{m0}	=	Surface concentration of year 0 of each individual sub-area

2.2.4 Concentrations of Vertically Mixed Open-water Sub-areas

At year 0, each open-water sub-area is characterized by a vertical bed layer model (thickness and concentration of sediment layers) based on remedial technology as shown in Figures 1a through 1j. At year 5, an additional sediment layer representing deposition of incoming solids is included on top of the year 0 sediment layers. Following deposition, the individual sediment layers shown in Figures 1a through 1j are mixed vertically over the vertical mixing depth for 50% of each sub-area. The other 50% of each sub-area is vertically mixed based on the bioturbation depth (10 cm). This simulates that only 50% of the open-water area of the EW is mixed by propwash within the 5-year timeframe.

The general formulas used to calculate the vertically mixed surface sediment concentration for each sub-area at year 5 post-remediation are presented in Equations 3 and 4. These general formulas are applicable to all open-water remedial technologies, consistent with vertical bed layer models and vertical mixing processes shown in Figures 1a through 1j.

$$C_{5i(a)} = \left[\frac{(C_{depc} \times T_{ydc}) + (C_{sc(a)} \times T_{sc(a)}) + \left(C_{br(a)} \times T_{br(a)}\right) + (C_{r(a)} \times T_{r(a)})}{T_{mix(a)}} \right] \tag{3}$$

$$T_{br(a)} = T_{mix(a)} - T_{ydc} - T_{sc(a)} \tag{4}$$

where:

$C_{5i(a)}$	=	vertically mixed sediment concentration for sub-area "a" at year 5 prior to exchange (called "intermediate value" in Figures 1a through 1j)
C_{depc}	=	concentration of net deposition sediments (current conditions)
T_{ydc}	=	thickness of net deposition sediments over 5-year timeframe (current conditions)
$C_{sc(a)}$	=	concentration of sand cover layer for sub-area "a"
$T_{sc(a)}$	=	thickness of sand cover layer for sub-area "a"
$C_{br(a)}$	=	concentration of bed replacement layer sediments for sub-area "a"
$T_{br(a)}$[2]	=	thickness of bed replacement layer sediments captured by the vertical mixing depth ($T_{mix(a)}$) for sub-area "a"
$T_{mix(a)}$	=	mixing depth for sub-area "a" (mixing by propwash)

Once the initial vertical mixing of each sub-area is conducted (either to the full mixing depth or the bioturbation depth), exchange with underpier sediments is incorporated into the sub-area sediment concentrations. The exchange calculations between open-water and underpier sediments simulates mixing of bed sediments between the underpier and open-water areas

[2] This variable is not defined in the vertical bed models shown in Figures 1a through 1j.

due to re-suspension from the bed by propwash[3]. This calculation is performed for each sub-area, as shown in Equations 5 and 6 and illustrated in Figures 1a through 1j.

$$C_{5f(a)} = \left[\frac{(C_{5i(a)} \times T_{5i(a)}) + (C_{5ex} \times T_{5ex})}{T_{mix(a)}} \right] \tag{5}$$

$$T_{5i(a)} = T_{mix(a)} - T_{5ex} \tag{6}$$

where:

$C_{5f(a)}$ = vertically mixed sediment concentration for sub-area "a" at year 5 following exchange (called "final value" in Figures 1a through 1j)

$T_{5i(a)}$[4] = thickness of vertically mixed sediment layer prior to exchange at year 5 captured by the vertical mixing depth ($T_{mix(a)}$) for sub-area "a"

C_{5ex} = concentration of under pier sediments following mixing at year 5, but prior to exchange with open-water sediments (see Section 2.3.5)

T_{5ex} = thickness of volume of under pier sediments exchanged at year 5; this is estimated as the volume of underpier sediments to be exchanged (25% of total volume) spread evenly over the entire surface area of the open-water areas

$T_{mix(a)}$ = mixing depth for sub-area "a" (mixing by propwash)

The general formulas for year 5 (Equations 3 through 6) are conceptually the same for years 10 through 40 (Equations 7 through 10); however, there are fewer distinct sediment layers present following the first vertical mixing event in year 5. The general formulas used to calculate the vertically mixed surface sediment concentration for each open-water sub-area for years 10 through 40 prior to exchange are presented in Equations 7 and 8 and illustrated in Figures 1a through 1j.

$$C_{Ni(a)} = \left[\frac{(C_{depc} \times T_{ydc}) + (C_{(N-5)f(a)} \times T_{(N-5)f(a)})}{T_{mix(a)}} \right] \tag{7}$$

[3] The rationale for 25% exchange estimate between open-water and underpier areas is provided in FS Section 5.3.4.

[4] This variable is not defined in the vertical bed models shown in Figures 1a through 1j.

$$T_{(N-5)f(a)} = T_{mix(a)} - T_{ydc} \tag{8}$$

where:

$C_{Ni(a)}$	=	vertically mixed sediment concentration for sub-area "a" at year N prior to exchange (called "intermediate value" in Figures 1a through 1j)
$C_{(N-5)f(a)}$	=	final vertically mixed concentration of sediments for prior 5-year interval (year=N-5) for sub-area "a" after exchange taken into account (called "final value" in Figures 1a through 1j)
C_{depc}	=	concentration of net deposition sediments (current conditions for year 10, future conditions for years greater than 10)
T_{ydc}	=	thickness of net deposition sediments over 5-year time period (current conditions for year 10, future conditions for years greater than 10)
$T_{(N-5)f(a)}$[5]	=	thickness of the vertically mixed layer from prior 5-year interval (year=N-5) captured by the vertical mixing depth ($T_{mix(a)}$) for sub-area "a"
$T_{mix(a)}$	=	mixing depth for sub-area "a" (mixing by propwash)

For years 10 through 40 (as with year 5), once the initial vertical mixing of each sub-area is conducted (either to the full mixing depth or the bioturbation depth), exchange with underpier sediments is incorporated into the sub-area sediment concentrations. This is done mathematically for each sub-area, as shown in Equations 9 and 10 and illustrated in Figures 1a through 1j.

$$C_{Nf(a)} = \left[\frac{(C_{Ni(a)} \times T_{Ni(a)}) + (C_{Nex} \times T_{Nex})}{T_{mix(a)}} \right] \tag{9}$$

$$T_{Ni(a)} = T_{mix(a)} - T_{Nex} \tag{10}$$

where:

$C_{Nf(a)}$	=	vertically mixed sediment concentration for sub-area "a" at year N following exchange (called "final value" in Figures 1a through 1j)

[5] This variable is not defined in the vertical bed models shown in Figures 1a through 1j.

$T_{Ni(a)}$[6] = thickness of vertically mixed sediment layer prior to exchange at year N captured by the vertical mixing depth ($T_{mix(a)}$) for sub-area "a"

C_{Nex} = concentration of underpier sediments following mixing at year N, but prior to exchange with open-water sediments (see Section 2.3.5)

T_{Nex} = thickness of volume of underpier sediments exchanged at year N; this is estimated as the volume of underpier sediments to be exchanged (25% of total volume) spread evenly over the entire surface area of the open-water areas

$T_{mix(a)}$ = mixing depth for sub-area "a" (mixing by propwash)

2.2.5 Concentrations of Vertically Mixed Underpier Areas

The underpier areas are represented as a single area within the box model. At year 0, the surface concentration of the underpier area is calculated as a SWAC based on the area and concentration for each technology sub-area (Table 2; Equation 1). For years 5 through 40, an additional sediment volume representing deposition of incoming solids over the previous 5-year time period is added to the in situ underpier sediment volume; and the entire volume of material is mixed to calculate a volume-weighted average concentration. The rationale for assumption of complete vertical mixing of underpier sediments is discussed in FS Section 5.3.4.

Equations 11 through 13 show the calculation of underpier sediment concentrations at years 5 to 40 in the box model (prior to exchange with open-water areas).

$$C_{ex\_N} = C_{UP\_Ni} = \left[\frac{(C_{UP(N-5)f} \times V_{UP(N-5)f}) + (C_{depc} \times V_{depc})}{V_{UP\_Ni}} \right] \tag{11}$$

$$V_{UP\_Ni} = V_{UP(N-5)f} + (SA_{UP} \times T_{ydc}) \tag{12}$$

$$V_{depc} = SA_{UP} \times T_{ydc} \tag{13}$$

where:

C_{ex_N}, C_{UP_Ni} = concentration of underpier sediments at year N prior to exchange with open-water areas ("intermediate" concentration); this is the

[6] This variable is not defined in the vertical bed models shown in Figures 1a through 1j.

		concentration of underpier sediments exchanged with open-water areas (C_{ex} in Figures 1a through 1j)
$C_{UP\_(N-5)f}$	=	final concentration of underpier sediments of prior 5-year interval (where N is current year) after exchange with open-water areas ("final" concentration)
$V_{UP(N-5)f}$	=	total volume of underpier sediments of prior 5-year interval (where N is current year) after exchange with open-water areas
V_{UP_Ni}	=	total volume of underpier sediments at year N (including volume of deposited sediments) prior to exchange with open-water areas
C_{depc}	=	concentration of net deposition sediments
T_{ydc}	=	thickness of net deposition sediments
SA_{UP}	=	surface area of underpier areas where sediment is deposited over the armor rock (see FS Section 2.6)
V_{depc}	=	volume of deposited sediments in underpier areas calculated using Equation 13

For years 5 through 40, once the intermediate concentration of underpier sediments is calculated, exchange with open-water sediments is incorporated into the underpier sediment concentrations. First, 25% of the underpier sediment volume (V_{UP_Ni}) with a concentration equal to C_{ex_N} (concentration of underpier sediments prior to exchange) is evenly deposited over each open-water sub-area. Then, the exchanged underpier sediment is mixed vertically within each open-water sub-area as discussed in Section 2.3.4 to calculate final post-exchange concentrations in each open-water sub-area. The SWAC of the open-water sub-areas (using these post-exchange concentrations) is then calculated. Finally, a volume of open-water sediments equal to 25% of the underpier sediment volume with a concentration equal to the pre-exchange SWAC of the open-water areas is added to the underpier sediments to complete the exchange. The final post-exchange concentration of the underpier sediments is calculated by averaging concentrations of the initially mixed underpier sediments with the exchanged sediment from the open-water areas (volume-weighted average). This is shown mathematically in Equation 14.

$$C_{UP\_Nf} = \left[\frac{(C_{UP\_Ni} \times V_{UP\_Ni}) + (C_{SWAC\_OW\_Nf} \times V_{ex})}{V_{UP\_Ni} + V_{ex}} \right] \tag{14}$$

where:

C_{UP_Nf} = concentration of underpier sediments at year N following to exchange with open-water areas ("final" concentration)

C_{UP_Ni} = concentration of underpier sediments at year N prior to exchange with open-water ("intermediate" concentration)

$C_{SWAC\_OW\_Nf}$ = SWAC concentration of open-water sediments at year N after exchange with underpier sediments

V_{UP_Ni} = total volume of underpier sediments at year N (including volume of deposited sediments) prior to exchange with open-water areas

V_{ex} = volume of open-water sediment exchanged with underpier areas; 25% of V_{UP_Ni}

2.2.6 Site-wide SWAC (Years 5 to 40)

For each 5-year interval post-construction from years 5 to 40, site-wide SWACs are calculated using the post-exchange fully-mixed surface sediment concentrations for each open-water sub-area and the underpier area using Equation 15.

$$SWAC_{\mathrm{N}} = \frac{\sum_{m=1}^{\mathrm{a}} [C_{m\mathrm{N}} A_m]}{\sum_{m=1}^{\mathrm{a}} A_m} \tag{15}$$

where:

$SWAC_N$ = site-wide EW SWAC for year N, where N is from 5 to 40 years

a = number of unique sub-areas (combinations of remedial technologies and vertical mixing depths, including underpier areas)

A_m = area of each individual sub-area

C_{mN} = surface concentration at year N of each individual sub-area following deposition of incoming solids, vertical mixing, and exchange with underpier

2.3 Sensitivity and Bounding Evaluation

The effects of variability and uncertainty in the physical processes and chemical concentrations in the EW on estimates of site-wide SWACs were evaluated with a sensitivity and bounding analysis. The sensitivity evaluation was completed to examine the relative impact of individual variables on the predicted site-wide SWACs. The bounding evaluation was used to examine the potential range in predicted SWACs based on combinations of specific input variables that were found to significantly impact the SWACs in the sensitivity evaluation.

The sensitivity and bounding evaluations were conducted on Alternatives 1A(12) and 2B(12) (see FS Appendix L, Figures 2-1 and 2-5) using a range of input variable assumptions (see Section 2.3.1 below for more detail). The sensitivity and bounding calculations were conducted using two remedial alternatives so that the analysis could be applied to different remedial technology combinations. Alternative 1A(12) was selected because it relies on natural recovery more than the other alternatives. Alternative 2B(12) was selected because it is representative of the majority of the remedial alternatives that rely more heavily on removal.

Sensitivity and bounding analyses were conducted for total PCBs only. Total PCBs is the COC that contributes the most to site risk for RAOs 1 (human health seafood consumption), 3 (benthic invertebrates), and 4 (ecological risk), and is distributed throughout the waterway. For this modeling analysis, PCBs effectively demonstrate the trends that can be expected for other COCs.

2.3.1 Variables Used in Evaluation

The sensitivity of the SWAC values calculated using the box model evaluation were analyzed for the following input variables to the box model:

- Value of the average NSR for the EW (single value applied across the site)
- Use of variable NSR in the EW
- Vertical mixing depth in the highly energetic propwash mixing areas
- Percent of the EW Study Area that was allowed to fully mix (vertically)
- Percent of underpier sediment volume that is exchanged with open-water areas
- Bioavailability of hydrophobic organic contaminants (including total PCBs) in underpier sediments due to in situ treatment

- Dredge residuals layer thickness and concentrations and replacement values
- Green River solids and chemistry[7]
- EW lateral solids and chemistry

The range of values for each variable used in the sensitivity and bounding analysis are discussed in Section 2.1 above and summarized in Chart 1.

2.3.2 Sensitivity Analysis

A list of sensitivity scenarios is provided in Table 4; 18 different scenarios for Alternative 1A(12) and 20 different scenarios for Alternative 2B(12) were evaluated for total PCBs. Alternative 1A(12) only has 18 scenarios because it does not have underpier in situ treatment, and therefore does not have sensitivity parameters for bioavailability. Table 2 herein provides initial surface sediment chemistry for total PCBs by remedial alternative (for the best-estimate dredging residuals and replacement value assumptions), and FS Table 5-3 provides chemistry assumptions for incoming solids.

The total PCB SWAC values over time calculated using the box model for each of the sensitivity scenarios listed in Table 4 were compared to each other numerically and graphically (see Table 5 and Figures 3a through 4b). Figures 3a and 4a plot the estimated SWAC values from year 0 to year 40 for each of the sensitivity analysis scenarios for Alternatives 1A(12) and 2B(12), respectively. Figures 3b and 4b show the comparative percent change in SWAC value for each sensitivity scenario compared to the base case scenario for Alternatives 1A(12) and 2B(12), respectively at years 10 and 30 post-construction. The comparative changes shown in Figures 3b and 4b were calculated by normalizing the SWAC values calculated for each sensitivity scenario at years 10 and 30 post-construction by the SWAC values calculated for the base case scenario at those same years.

2.3.2.1 Alternative 1A(12)

For Alternative 1A(12), the range in inputs for underpier exchange, NSR, and Green River concentration had a relatively high degree of sensitivity (i.e., resulted in greater than 10%

[7] For upstream chemistry the LDW lateral sources and LDW bed sediments inputs are not changed for the sensitivity analysis.

change in SWAC), and the other parameters (residuals thickness, residuals concentration, mixing depth, area mixed, and concentrations in lateral load) showed a low degree of sensitivity (Figures 3a and 3b).

Underpier exchange was the most sensitive parameter 0 to 10 years following construction, but was not a very sensitive parameter in the long-term. The model results predict that more underpier exchange would result in a higher temporary increase in site-wide SWAC following construction, due to the distribution of higher concentration underpier sediments into the larger, mostly remediated open-water areas. Less underpier exchange reduces the site-wide SWAC because the higher concentration sediments in the underpier remain localized.

The two parameters that are the most sensitive in the long-term are range in inputs for NSR and the concentrations of Green River solids. These two parameters are also the second and third most sensitive parameters 0 to 10 years following construction (after underpier exchange), and are therefore the most influential parameters affecting the box model results. Moreover, the two parameters are related because 99% of the sediment deposited in the EW originates from the Green River upstream of the LDW (Table 1).

A higher NSR reduces the site-wide SWAC by reducing the time needed for the site to equilibrate to net incoming concentrations (i.e., increases the rate of natural recovery). A lower NSR increases the site-wide SWAC by increasing the time needed for the site to equilibrate to net incoming concentrations (i.e., decreases the rate of natural recovery). Use of a variable NSR within the EW (based on FS Figure 5-1) did not have any appreciable effect on the SWAC predictions compared to best estimate calculations for any years (see Figure 3a).

In the very long term (i.e., 30 years post-construction and beyond), Green River chemistry is the primary controlling parameter, because it is the primary determinant of the concentration the site will equilibrate to (i.e., the EW net incoming sediment concentrations). In the long-term, higher Green River concentrations will result in higher site-wide SWACs, and lower Green River concentrations will result in lower site-wide SWACs.

2.3.2.2 Alternative 2B(12)

Compared to Alternative 1A(12), Alternative 2B(12) relies less on natural recovery and more on in situ treatment (Alternative 1A(12) uses MNR in underpier areas, and

Alternative 2B(12) used in situ treatment in underpier areas). In addition, Alternative 2B(12) relies on more removal (Alternative 1A(12) uses some ENR-nav in the navigation channel, and Alternative 2B(12) used removal). As a result, Alternatives 2B(12) is less sensitive to the range in inputs for NSR and underpier exchange than Alternative 1A(12), and more sensitive to the range in inputs for Green River concentrations. Alternative 2B(12) also has a high degree of sensitivity to the range in inputs for percent reduction in bioavailability due to in situ treatment. Consistent with Alternative 1A(12), the impact of the other parameters (i.e., residuals thickness, residuals concentration, mixing depth, area mixed, and concentrations in lateral load) showed a low degree of sensitivity (Figure 4a and 4b).

Percent reduction in bioavailability due to in situ treatment was the most sensitive parameter 0 to 10 years following construction, but was less sensitive in the long term. If in situ treatment is more effective at reducing bioavailability, then site-wide SWACs are predicted to be effectively lower, and if in situ treatment is less effective at reducing bioavailability, then site-wide SWACs are predicted to be higher. FS Section 7.2.7.1 describes the in situ treatment effectiveness estimates based on relevant case studies and guidance.

Similar to Alternative 1A(12), Green River chemistry is the primary controlling parameter in the long term, because it is the primary determinant of the concentration the site will equilibrate to. The effect of the range in inputs for Green River chemistry is higher for Alternative 2B(12) compared to Alternative 1A(12) because site-wide SWACs are lower following construction for Alternative 2B(12) (largely due to the change in remediation technology in underpier areas), and therefore it equilibrates more rapidly to net incoming sediment concentrations.

For Alternative 2B(12), the greatest effects to predicted SWAC values are associated with the Green River chemistry (up to 45%) and NSR (up to 15%). The range in inputs for all other variables result in less than 10% change from the base case SWAC values. The predicted SWAC values for Alternative 2B(12) are not as sensitive to the range in inputs for underpier exchange as Alternative 1A(12) because Alternative 2B(12) has active remedial technology in underpier sediments, which results in a lower initial concentration of underpier sediments for Alternative 2B(12).

Residual inputs have more effect on SWAC predictions for Alternative 2B(12); this is because of the combined effect of lower year 0 SWAC (related to active remediation under piers) and more removal in open-water areas. With lower year 0 SWAC and more removal, the site is more influenced by the higher concentrations of residuals when vertical mixing takes place. Also because of the lower year 0 SWAC in Alternative 2B(12), the NSR inputs have less of an influence compared to Alternative 1A(12). As with Alternative 1A(12), use of a variable NSR within the EW (based on FS Figure 5-1) did not have any appreciable impact on the SWAC calculations for any years (see Figure 4a).

2.3.2.3 Summary

Using the combined results for both Alternative 1A(12) and Alternative 2A(12), a summary of the sensitivity analysis by parameter is provided below:

- The range in inputs for Green River chemistry can change predicted SWAC values by up to 25% through year 10 post-construction, and up to 45% by year 30 post-construction. Green River chemistry has greater effect on alternatives with more active remediation and less reliance on natural recovery.
- The range in inputs for NSR can change predicted SWAC values by up to 15% through year 10 post-construction, and up to 35% by year 30 post-construction. NSR has a greater effect on alternatives with more reliance on natural recovery.
- The range in inputs for underpier exchange can change predicted SWAC values by up to 20% at year 10, but its influence drops off to below 10% by year 30. Underpier exchange has more effect on alternatives with MNR in the underpier area.
- The range in inputs for the percent reduction in bioavailability due to in situ treatment can change predicted SWAC values by up to 30% at year 10, but its influence is reduced to up to 20% by year 30. This parameter only effects alternatives that employ in situ treatment.
- The range in inputs for all other parameters effect predicted SWAC values by 10% or less.

2.3.3 Bounding Analysis

The results of the sensitivity analysis were used to develop scenarios (combinations of input parameter values) that result in the lowest and highest SWAC predictions for Alternatives 1A(12) and 2B(12). This bounding analysis was done to quantify the maximum uncertainty in predicted SWAC values from the box model evaluation for all remedial alternatives. The lowest and highest bounding scenarios are determined using results of the sensitivity analysis for Alternatives 1A(12) and 2B(12) that showed which parameters caused the SWAC to increase or decrease (Figures 3b and 4b).

For Alternative 1A(12), using Figure 3b, the following conclusions were made to establish the highest and lowest bounds:

- **NSR and Vertical Mixing Depth[8]:** Decreasing the value of these parameters result in a higher predicted SWAC at years 10 and 30. Therefore the low range values were used for the highest bound scenario and the high range values were used for the lowest bound scenario.
- **Residual Thickness, Residual Concentration, Lateral Concentrations, and Green River Concentrations:** Decreasing the value of these parameters results in a lower predicted SWAC at years 10 and 30. Therefore, the low range values were used for the lowest bound scenario and the high range values were used for the highest bound scenario.
- **Area Mixed:** The effect on the SWAC from this parameter is different at years 10 and 30. Because the box model evaluation was developed to look at effectiveness over the long term, the effect at year 30 was used to determine bounding scenarios. At year 30, decreasing the value of this parameter decreases the predicted SWAC value. Therefore, the low range value was used for the lowest bound scenario and the high range value was used for the highest bound scenario.
- **Underpier Exchange:** The effect on the SWAC from this parameter is different at years 10 and 30. At year 30, both decreasing and increasing this parameter results in a lower predicted SWAC value. At year 5, decreasing the value of this parameter reduces the predicted SWAC, and increasing the value increases the predicted SWAC, so the effect from year 5 was used to determine bounding scenarios. The low input value was used for the lowest bound scenario and the high input value was used for the highest bound scenario.

[8] The shallower mixing depth results in a higher concentration post-construction because of reduced dilution of dredge residuals and underpier exchange material with the cleaner underlying sediments.

Alternative 2B(12) followed the same general patterns as Alternative 1A(12), and used the same input parameters for bounding. For the reduction in bioavailability parameter[9], the higher reduction percent resulted in a lower predicted SWAC value. Therefore, the higher reduction percent was used for the lowest bound scenario, and the lower reduction percent was used for the highest bound scenario.

A summary of the input variables associated with the lowest and highest bounding scenarios are provided in Table 4.

The lowest and highest bound scenarios represent conditions where all of the input parameters that would influence either a high or low SWAC would occur at the same time; which has a very low probability of occurrence. As shown in Figures 3b and 4b, and discussed earlier, the NSR and Green River chemistry have the greatest input on the predicted SWAC calculations. Therefore, these input parameters will have the greatest impact on the spread between the lowest and highest bounding scenarios. To illustrate the impact of NSR and Green River chemistry on the uncertainty of the SWAC predictions, four additional bounding scenarios were conducted; two scenarios that retained the NSR and Green River chemistry at base case values and varied all other input parameters, and two scenarios and varied only the Green River chemistry:

- Additional Low
- Additional High
- Green Low
- Green High

The inputs for these four additional scenarios are also summarized in Table 4.

The SWAC values predicted using the bounding and base case scenarios are provided in Table 6 and shown graphically in Figure 5a for Alternative 1A(12) and Figure 5b for Alternative 2B(12). The range of predicted SWAC values shown in Figures 5a and 5b for the highest and lowest bounding scenarios suggest that SWAC values for the EW predicted by the box model could vary by up to +125% and -75% at year 10, and by up to +110% and -80% at year 30 due primarily to the significant influence of Green River chemistry and NSR.

[9] This parameter is not applicable to Alternative 1A(12) because in situ treatment is not one of the technologies used.

Looking at the additional high and low bounding scenarios, which hold the Green River chemistry and NSR at base case values while varying all other parameters, the SWAC values predicted by the box model vary by +50% and -40% at year 10 and by up to +20% and -25% at year 30. Considering only the Green River chemistry effects, the SWAC values predicted by the box model vary by +25% and -25% at year 10, and by up to +40% and -40% at year 30.

3 RAO 3 PERFORMANCE OVER TIME (POINT MIXING MODEL EVALUATION)

The box model evaluation described in Section 2 above was used to estimate SWACs for alternatives to assess achievement of RAOs 1, 2, and 4, which are evaluated based on area-average concentrations. RAO 3 however, while evaluated for the site as a whole, is based on individual point locations as opposed to area averages. Therefore, an additional modeling calculation, referred to as the point mixing model evaluation, was conducted to assist in achieving RAO 3. The point mixing model evaluation was conducted on a subset of seven risk-driver COCs for RAO 3. The seven COCs were selected to be representative of the 29 Washington State Sediment Management Standards (SMS) contaminants identified as benthic invertebrate community COCs in the ERA:

1. PCBs
2. Arsenic
3. Mercury
4. High-molecular-weight polycyclic aromatic hydrocarbons (HPAHs)
5. Low-molecular-weight polycyclic aromatic hydrocarbons (LPAHs)
6. Bis(2-ethylhexyl)phthalate (BEHP)
7. 1,4-dichlorobenzene

The point mixing model was only applied where MNR is used as a remedial technology (Alternative 1A(12) only) because all other surface sediment stations will meet RAO 3 preliminary remediation goals (PRGs) following construction, either through active remediation or because they are currently below RAO 3 PRGs. The point mixing model predicts surface sediment concentrations for years 0 through 40 post-construction for the 18 existing surface sediment sampling station locations in proposed MNR areas that exceed the RAO 3 PRGs.

The calculations were conducted for each point location using similar methodology as the box model evaluation described in Section 2; where deposition of incoming solids and vertical mixing assumptions were applied to each point location. Exchange between underpier and open-water areas was not included in these calculations, to provide a conservative estimate of natural recovery in these locations. This assumption tends to bias the predicted sediment concentrations high because the calculations do not account for cleaner sediment from open-water areas accumulating in the underpier locations.

3.1 Input Variables

The variables used as input for the point mixing model are outlined in Chart 4 and discussed in more detail below.

Chart 4
Input Variables for the Point Mixing Model

Input or Variable	Variable or Constant for Analysis	Location of Details
Current representative annual NSR at each MNR point (upstream sources)	Constant over the EW and time.	Section 3.3 and Table 7 herein
Future annual sedimentation rate at MNR point (upstream sources)	Constant over the EW and time.	Section 3.3 and Table 7 herein
Current annual sedimentation from EW laterals	Variable by MNR point (based on PTM output), constant over time.	FS Appendix B, Part 1
Future annual sedimentation from EW laterals	Variable by MNR point (based on PTM output), constant over time.	FS Appendix B, Part 1
Chemistry of surface sediment at year 0	Variable by MNR point based on SRI[1] data.	Table 7 herein
Chemistry of current incoming solids for upstream and EW laterals	Chemistry per point varies, but chemistry used at each point is constant for years 1 to 10.	FS Table 5-3
Chemistry of future incoming solids for upstream and EW laterals	Chemistry per point varies, but chemistry used at each point is constant for years 11 to 40, based on future source control.	FS Table 5-3
Vertical mixing depth assumptions	Variable by point (based on estimated propwash depths, see FS Figure 5-3), constant over time.	Section 3.3 herein

Notes:
1. *Final Supplemental Remedial Investigation Report* (SRI; Windward and Anchor QEA 2014).
EW – East Waterway
FS – Feasibility Study
MNR – monitored natural recovery
NSR – net sedimentation rate
PTM – particle tracking model

The point mixing model was used to predict the surface concentrations for 18 points (15 located in underpier areas and three in under-bridge areas) for the seven risk driver COCs for RAO 3, based on anticipated solids deposition and vertical mixing assumptions. The current surface concentrations for each of the 18 sediment locations were derived from sampling conducted between 2001 and 2009, as shown in Figure 6. These calculations used results from the PTM (FS Appendix B) to establish the deposition from lateral sources at each individual surface point. This is different than the box model evaluation, which assumed that depositing sediments from both upstream and EW lateral sources settled evenly through the EW.

Table 7 lists the MNR points by station name, their locations, the specific deposition rates derived from the PTM results at each MNR point location, and the chemistries used for the calculations. The current surface concentrations were assumed to be the measured concentrations from the EW SRI surface sediment samples collected at each of the 18 locations (Windward and Anchor QEA 2014). The NSR at each point is based on the deposition patterns for the area around the sample location from the PTM (FS Appendix B). As the amount of sediment from the different sources varies by point location, the incoming chemistry concentration is also varied based on the source's chemistry. See Section 3.3 for a calculation of incoming solids concentrations.

The vertical mixing depth assumptions were the same as used in the box model evaluation (FS Figure 5-2). Underpier areas were assumed to be fully mixed by volume in the box model evaluation. Volumetric mixing is not applicable to this evaluation, which focuses on single point locations (as opposed to areas). Therefore, the volumetric mixing of underpier areas used in the box model evaluation had to be changed to an approximate equivalent mixing depth in underpier areas; as was done in the open-water areas for the box model evaluation. Based on vertical mixing assumptions in the EW shown in Figure 5-2, the majority of the underpier areas are adjacent to open-water areas assigned a 2-foot mixing depth. The typical thickness of underpier sediments in the EW is about 2 feet (see FS Section 2.6) based on probing data. Therefore, the mixing depth in underpier areas (15 of the 18 points) was set to 2 feet. Mixing depth in under-bridge areas (3 of the 18 points: EW09-SS-010, EW09-SS-012, and EW-128) was set to 10 cm for bioturbation mixing because there are no vessel operations next to under-bridge areas.

3.2 Calculations

Surface sediment concentrations over time at each of the 18 MNR points were calculated using similar methodology as used for the box model evaluation discussed in Section 2, including vertical bed model for MNR areas (see Figure 1f), vertical mixing assumptions, incoming solids chemistry, and site-wide NSR.

Current surface concentrations and mixing assumptions at each point, solids deposition and chemistry from upstream sources, and solids deposition and chemistry from EW lateral sources were used to predict surface concentrations at each of the 18 MNR points as a function of time post-construction (0 to 40 years) in 5-year intervals. The predicted surface concentrations were compared to PRG (remedial action level [RAL]/sediment quality standards [SQS]) and cleanup screening level (CSL) values for each COC evaluated.

Current surface concentrations at each point are provided in Table 7. Points in underpier areas used a mixing depth of 2 feet, which is the thickness of underpier sediments based on probing data. This is consistent with the box model assumption that underpier sediments are fully mixed by volume over a 5-year period. Points located in under-bridge areas used a mixing depth of 10 cm.

Solids deposition from upstream sources only (i.e., the Green River, LDW bed sediment and LDW lateral sources) were assumed to be constant throughout the EW, and therefore constant at each point location. The value of total annual upstream deposition from all sources was kept constant for each point for current and future conditions and was set to the value used in the recontamination evaluation (grid model evaluation) discussed in FS Section 4 (1.175 cm/yr). A discussion of how this was calculated is provided in Section 4.3, Step 3 in this appendix.

The solids deposition at each point location from EW lateral sources was taken directly from the results of the PTM. The deposition predicted by the PTM for each EW lateral source (see FS Appendix B, Part 1) was extracted from the 50-foot-by-50-foot grid cell where each point is located (see Figure 6). The total deposition from EW lateral sources extracted at each point location was divided into six different source categories (see Figure 2 in FS Appendix B, Part 1) to allow for different chemistry assumptions:

1. Hinds CSO
2. Lander CSO
3. Hanford #2 CSO
4. Nearshore SDs (see Table 1 in FS Appendix B, Part 1: 33 input locations including outfalls for the Port of Seattle, the City of Seattle, and private outfalls)
5. S. Lander St SD
6. Non-nearshore SDs (see Table 1 in FS Appendix B, Part 1: seven input locations including outfalls for S Hinds St SD and U.S. Coast Guard SD)

The chemistry assumptions for EW lateral sources for this evaluation are different than the box model evaluation (Section 2), which assumed a single chemistry assumption for all stormwater and a single chemistry assumption for all CSO discharges, since that evaluation focused on site-wide average calculations. For this evaluation, EW lateral sources were further divided into the six source categories listed above to add additional resolution to the point mixing model calculations. FS Table 5-3 provides chemistry assumptions for each of the seven COCs evaluated as part of this analysis, for the six source categories listed above. The data and development of these chemistry assumptions for EW laterals are described in FS Appendix B, Part 4. FS Table 5-3 also provides chemistry assumptions for these same COCs for upstream sources. Green River chemistry was developed based on methods outlined in the EW FS Appendix B, Part 3, and chemistry for LDW bed and LDW lateral solids was taken from the LDW FS (AECOM 2012).

The total concentration of solids deposited at each point location was calculated as a weighted average on deposited loads to each point from the various input locations. Equation 16 was used to find the input concentration to the EW at each point location.

$$Incoming\ Solids\ Concentration = \frac{\sum_{i=1}^{9} Input_i Solids * Input_i Concentration}{\sum_{i=1}^{9} Input_i Solids} \qquad (16)$$

where:

$Input_i$ Solids	=	solids deposited from each of the three upstream sources and six categories of EW lateral sources discussed above
$Input_i$ Concentration	=	chemistry for each of the COCs based on solids source (Table 11a and 11b)

The surface concentrations were calculated differently for years 0, 5, and 15. Year 10 used the same equation used to calculate year 5. Year 15 represents the first year that future source control scenarios for EW Laterals were assumed to be fully operational and therefore used in the calculations. Years 20 and onward used the same equation for the concentration of year 15.

Year 0 surface concentration was equal to the existing measured surface concentration at each point.

The years 5 and 10 surface concentrations were calculated using Equation 17.

$$C_n = \frac{5T_c * C_{eqc} + (T_{mix} - 5T_c) * C_{n-5}}{T_{mix}} \tag{17}$$

where:

C_n	=	concentration of surface sediments for year (n)
C_{eqc}	=	chemistry of incoming sediments (current conditions)
T_c	=	annual thickness of deposition sediments (current conditions)
T_{mix}	=	mixing depth

The years 15 and onward surface concentrations were calculated using Equation 18.

$$C_n = \frac{5T_f * C_{eqf} + (T_{mix} - 5T_f) * C_{n-5}}{T_{mix}} \tag{18}$$

where:

C_{eqf}	=	chemistry of incoming sediments (future conditions)
T_f	=	annual thickness of deposition sediments (future conditions)

Table 10 provides a summary of estimated concentrations for each MNR point location.

3.3 Sensitivity Evaluation

There was no separate sensitivity evaluation conducted for the point mixing model approach because the box model sensitivity evaluation described in Section 2.4 was considered to be representative of how the surface sediment concentrations for the 18 MNR points could vary for the given input variables. The calculations carried out in the box model are very similar to those of the point mixing model, with two exceptions: 1) the box model encompasses the entire EW Operable Unit as opposed to discrete points within the EW; and 2) exchange between underpier and open-water areas was not included in the point mixing model. For discussion of how the expected variation in calculated surface sediment concentrations at proposed MNR points effects evaluation of RAO 3 compliance within the context of the FS, refer to FS Section 9.

3.4 Results of Calculations

Surface sediment point concentrations and spatial distributions of the point exceedances over time and for the seven key risk driver COCs are provided in Figures 7a and 7b for the 18 MNR points. Figure 7a calls out the points and years that are predicted to exceed the PRG (RAL/SQS), and Figure 7b calls out the points and years that are predicted to exceed the CSL.

FS Table 9-2a outlines how many points are predicted to exceed the CSL and PRG (RAL/SQS) values for the seven COCs over the 40-year period. RAO 3 will be evaluated based on these results in combination with surface and shallow surface sediment concentrations of the approximately 300 additional points that will be remediated using technologies other than MNR or that under current conditions are below RALs. This evaluation is provided in FS Section 9.

4 RECONTAMINATION POTENTIAL EVALUATION (GRID MODEL EVALUATION)

The grid model evaluation was used to identify discrete areas within the EW where recontamination from EW lateral deposition could be a concern post-construction. The spatial distribution of surface concentrations throughout the EW due to deposited solids from upstream and lateral inputs was estimated for years 0 through 40 post-construction. The predicted percentage of EW surface area exceeding RALs at any time over that 40-year time period was used to identify areas where potential recontamination from incoming sediments could occur, inform future source control efforts, and target general areas where post-construction monitoring may be needed. This evaluation, referred to as the grid model evaluation, is different than the box model evaluation because it uses the spatial distribution of EW lateral solids deposition predicted by the PTM as input rather than a cumulative site-wide value. This evaluation was completed from years 0 to 40 post-construction for nine key risk driver COCs: PCBs, cPAHs, dioxins/furans, arsenic, mercury, HPAHs, LPAHs, BEHP, and 1,4-dichlorobenzene (see FS Section 5.4.2 for more detail on selection of COCs for this analysis).

The evaluation of recontamination potential is challenging in the EW due to the influence of anthropogenic activity, such as propwash, which can resuspend recently deposited finer sediments or mix them into the underlying sediments. The effects of propwash on the spatial distribution of EW lateral solids deposition was not taken into account with the PTM because of the difficulty in accurately quantifying the location, mass, and frequency of solids resuspended by vessel activity[10]. Therefore, the recontamination evaluation focused on identifying areas of concern using RALs as metrics without attempting to quantify surface concentrations in the long term with certainty.

Several assumptions were made to simplify the calculations while still meeting the objective of the evaluation, as discussed in Section 4.3. However, there are two primary assumptions that were developed to focus the evaluation on recontamination potential due to incoming solids. The first is that the initial surface concentrations within the EW (at year 0) were

[10] Not accounting for propwash tends to overestimate the predicted concentrations near outfalls, because post-construction propwash will mix and redistribute higher concentration sediments with surrounding lower concentration sediments.

assumed to be zero. This focuses the results of the evaluation on recontamination from incoming sediment sources only and removes the influence of underlying sediment concentrations. The second is that vertical mixing depths were assumed to be constant throughout the EW and thus set to the bioturbation mixing depth assumed for the EW (10 cm). This limits the amount of dilution of incoming sediment sources that could occur due to deeper vertical mixing, which may be sporadic or not occur at any particular location. Ultimately this recontamination evaluation is just an estimate of what might happen in the future, and therefore, monitoring post-construction will be the best method to evaluate recontamination from incoming sediment sources.

4.1 Input Variables

The inputs required for the recontamination potential evaluation are outlined in Chart 5.

Chart 5
Input Variables for the Grid Model

Input or Variable	Variable or Constant for Analysis	Location of Details
Initial surface sediment concentrations (at Time 0 post-construction)	Constant over the EW	Set to 0 for all COCs
Annual upstream NSR	Constant over the EW and over time	FS Section 5.4.3 and Table 5-10
Chemistry assumptions for upstream solids sources	Constant over time	FS Table 5-3
Chemistry assumptions for EW lateral solids sources (current conditions)	Constant for years 1 through 10 post-construction	FS Table 5-3
Chemistry assumptions for EW lateral solids sources (future conditions)	Constant for years 11 through 40 post-construction	FS Table 5-3
Annual deposition rates from EW lateral sources predicted by PTM (current conditions)	Variable over the EW, constant for years 1 through 10 post-construction	FS Appendix B, Part 1 Figures 6 through 8
Annual deposition rates from EW lateral sources predicted by PTM (future conditions)	Variable over the EW, constant for years 11 through 40 post-construction	FS Appendix B, Part 1 Figures 9 through 11

Notes:
COC – contaminant of concern
EW – East Waterway
FS – Feasibility Study
NSR – net sedimentation rate
PTM – particle tracking model

The total annual upstream NSR from all sources (upstream and EW lateral inputs) was set to 1.2 cm/yr based on the evaluation of NSR from geochronological cores in the EW (see FS Section 5.1.2). The portion of the net sedimentation attributed to upstream sources was calculated as the difference between the NSR assumed for the EW from all sources and annual deposition from EW lateral inputs predicted by the PTM (see Step 3 in Section 4.3). Chemistry assumptions for both the upstream solids and lateral inputs for current and future conditions are shown in FS Table 5-3.

4.2 Calculations

The following equations and assumptions were used to complete the recontamination potential evaluation for the EW to identify areas within the EW where recontamination could be a concern post-construction.

Step 1: Assign Surface Concentrations in the East Waterway at Time 0

The surface concentrations throughout the EW at Time 0 (post-construction) for each COC were assumed to be 0. This assumption was made to focus the evaluation on recontamination potential due to incoming solids.

Step 2: Calculate East Waterway Lateral Solids Deposition

The output of the PTM is the initial deposited location of each sediment parcel input into the model. Each parcel of sediment in the PTM represents 0.5 kg of sediment and is assigned an appropriate sediment size or fall velocity based on the particle size distribution in the input solids load. The PTM refers to sediment parcels as particles. Equation 19 was used to develop deposition rates due to EW lateral inputs in equally sized grid cells throughout the EW for the period of the simulation.

$$EW\ Lateral\ Deposition = \frac{\frac{NP * (kilograms\ per\ particle)}{\rho}}{(area\ of\ cell)} \tag{19}$$

where:

NP = number of particles in each 50-square-foot cell (2,500 ft^2 or 232 m^2)

ρ = density of the deposited sediment (estimated to be 1.5 g/cm^3 or 1,500 kg/m^3)[11]

Based on Equation 19, the deposition of one particle in a cell is represented by Equation 20.

$$EW\ Lateral\ Deposition = \frac{\frac{1[particle]*(0.5\,[\frac{kilogram}{particle}])}{1500[\frac{kilogram}{m^3}]}}{232[m^2]} = 0.0000014\ m \qquad (20)$$

This deposition is based on the simulation period, which was 28 days. Therefore, the deposition over the simulation time of 28 days was extrapolated (multiplied by a factor of 13.04) to provide predictions for annual deposition rates. A single particle in a cell would represent an annual deposition of 0.000019 meter or 0.002 centimeter spread evenly across the cell.

The EW lateral inputs were divided into six categories based on chemistry assumptions (Step 4), as was done for the point mixing evaluation. See Section 3.3 of this appendix for more information.

Step 3: Determine Upstream Solids Deposition

The method used to estimate the contribution of upstream solids sources (for current conditions) to the average NSR is different from what was used in the box model evaluation. Instead of using the entire EW surface area to estimate an average deposition rate in cm/yr from upstream and EW lateral inputs, the smaller surface area where the PTM predicts deposition from EW lateral inputs was used (the shaded areas shown in Figures 7 through 12 in FS Appendix B, Part 1). This results in a slightly larger contribution from EW lateral inputs (in cm/yr over that smaller area) in those locations compared to how it was depicted in the box model evaluation, where deposition from EW lateral inputs were spread evenly throughout the entire EW area. The contribution from upstream sources for current conditions in those locations is calculated as shown in Equation 21, by subtracting the

[11] Based on site-specific SEDflume data in the EW.

contribution from EW lateral sources (all six categories combined) from the assumed representative NSR measured by geochronological cores (1.2 cm/yr[12]).

$$Annual\ Upstream\ Sed\ Rate = Annual\ Sed\ Rate - Annual\ EW\ Lateral\ Sed\ Rate \quad (21)$$

where:

Sed Rate = sedimentation rate (or deposition rate)

The specific values for the calculation and a summary of the calculations are outlined in Table 10. The NSR for upstream is estimated to be 1.175 cm/yr for the current base case condition. This upstream deposition is used for both current and future conditions.

Step 4: Assign Concentrations to Upstream and East Waterway Lateral Solids

Different chemistry values are assumed for the six different categories of lateral inputs, and three different chemistry values are included for the upstream portion (i.e., the Green River, LDW bed sediment, and LDW lateral inputs). The chemical concentrations for the EW lateral inputs are discussed in further detail in Part 4 of FS Appendix B, and the upstream chemical concentrations were based on results from the LDW FS (AECOM 2012). Inputs used for the recontamination potential evaluation are outlined in FS Table 5-3 for current and future conditions, respectively.

Step 5: Calculate Lateral input derived Surface Concentrations at 5-year time steps

To calculate the surface concentration, the top 10 cm of the bed is combined including the annual EW lateral deposition, upstream deposition, and in situ sediment. For this analysis all surface concentrations were set to zero at end of construction (year 0).

For each following year, the preceding year is used as the base, with an annual deposition added from upstream and EW lateral inputs. The surface concentration is calculated by mixing the top 10 cm using Equation 22.

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[12] This value represents the average of the net sedimentation rate calculated from evaluation of geochronological cores as described in FS Section 5.1.3.

$$Year_n\ Surface\ Concentration = \frac{(Lat_t)*(Lat_C)+(Up_t)*(Up_C)+\left(10\ cm-(Lat_t+Up_t)\right)*Year_{n-1\_C}}{10\ cm} \quad (22)$$

where:

cm	=	centimeters
Lat_t	=	lateral deposition thickness
Lat_C	=	lateral concentration
Up_t	=	upstream deposition thickness
Up_C	=	upstream concentration
$Year_{n-1\_C}$	=	previous year's surface concentration

Current conditions for lateral inputs were used for years 1 through 10, and future conditions were used for years 11 through 30.

4.3 Results

The results of the recontamination evaluation for all nine COCs are shown in FS Figure 9-7, which are used to highlight areas with elevated potential for recontamination based on results for years 0 to 10 post-remediation. The results of this evaluation are discussed in FS Section 9.

4.4 Bounding Evaluation

The predicted range in annual solids deposition due to EW lateral solids (see FS Appendix B, Part 1) and range of potential chemistry for EW lateral solids (see FS Appendix B, Part 5) were used to develop bounding scenarios for the recontamination potential evaluation. Scenarios are outlined in Table 11 and combine higher predicted solids deposition with higher chemistry assumptions, and lower predicted solids deposition with lower chemistry assumptions to provide bounding runs. The purpose of the bounding runs was to determine changes to the spatial area identified as having an elevated potential for recontamination (Section 4.4) based on potential range of EW solids deposition (FS Appendix B, Part 1) and chemistry values (FS Table 5-3). The bounding evaluation was completed for three representative COCs based on the results of the base case runs as follows:

- One COC where surface concentrations are predicted to be below RAL for all years (PCBs)
- One COC where surface concentrations are predicted to be above RAL initially, and then fall below RAL after year 10 (dioxins/furans)
- One COC where surface concentrations are predicted to be above RAL for all years (BEHP)

The results of the bounding evaluation are shown in Figures 8a and 8b for PCBs, Figures 9a and 9b for dioxins/furans, and Figures 10a and 10b for BEHP.

In Figure 8a, the cells that have a concentration for PCB (Scenarios 1 and 2 of Table 11) that exceed the RAL for years 0 through 10 are highlighted. Figure 8b highlights the cells that have a concentration for PCB that exceed the RAL for years 11 to 40. In the case of PCB scenarios, only the higher bounding scenario (higher deposition and higher chemical concentrations) led to exceedances in a few discrete locations close to outfalls.

Figure 9a shows predicted dioxins/furans exceedances for years 0 to 10, and Figure 9b shows predicted exceedances for years 11 to 40 (Scenarios 3 and 4 of Table 11). In the lower bound scenario (lower deposition and lower chemical concentrations) for years 0 to 10, there was only one discrete area in the EW that exceeded the RAL of 25 ng TEQ/kg dw, and there were no exceedances for the future condition years. In the higher bound scenario for dioxins/furans, there are a few more discrete areas close to outfalls that have RALs exceedances for dioxins/furans.

Figure 10a shows predicted BEHP exceedances for years 0 to 10, and Figure 10b shows predicted exceedances for years 11 to 40 (Scenarios 5 and 6 of Table 11). The lower bound scenario for years 0 to 10 shows discrete locations (less than ten) that show exceedances for both current and future conditions years. In the higher bound scenario, the area of exceedance extends beyond the few discrete locations next to outfalls shown in the lower bounding run, but still represents a small fraction of the EW.

The results of the bounding evaluation show the following trends:

- All COCs had less areas of concern for the low bounding runs. PCB had no areas of concern for the low bounding run.
- All COCs had additional areas of concern based on the high bounding run. However, these areas represent a small portion of the EW area and do not extend far from source outfalls.
- Dioxins/furans had a small reduction in areas of concern once proposed future source control actions were accounted for. PCB and BEHP did not have any reduction in predicted areas of concern due to proposed source control actions.

5 ADDITIONAL CONSIDERATIONS

Results from the sediment transport evaluation (STE) completed for the EW and the updated Physical Processes conceptual site model (CSM) developed as part of the EW SRI (Windward and Anchor QEA 2014) and the EW FS are being used as input to the evaluation of site performance over time and recontamination potential within the EW, post-remediation. The effects on predictions of hydrodynamics and sediment transport due to uncertainty in data collection methods, hydrodynamic and PTM inputs, and specific model parameters were investigated as part of the STE and a description of those analyses are provided in the STER (Anchor QEA and Coast & Harbor Engineering 2012).

Specific discussion of uncertainties associated with prediction of site performance over time and recommendation potential based on the chosen values for input variables are discussed in the previous sections of this appendix summarized below:

- Site performance over time, predicted SWAC values (box model evaluation); see Sections 2.4.2 and 2.4.3
- Site performance over time, proposed MNR areas (point mixing model evaluation); see Section 3.4
- Recontamination potential (grid model evaluation); see Section 4.5

This section provides discussion of other considerations that could introduce uncertainty into the evaluation of site performance over time and/or recontamination potential. Much of this information has already been provided in the STER (Anchor QEA and Coast & Harbor Engineering 2012) or EW SRI (Windward and Anchor QEA 2014); however, it is re-summarized here for the reader's benefit. These considerations have been separated into three general categories as described below:

- Considerations related to estimates of input data (i.e., NSR and vertical mixing) taken from the STE and updated Physical Processes CSM are discussed in Section 5.1.
- Considerations associated with calculation methodology developed to estimate SWAC values over time (box model evaluation) and surface concentrations over time in proposed MNR areas (point mixing model evaluation) are discussed in Section 5.2.
- Considerations associated with methodology developed to evaluate recontamination potential due to deposition of EW lateral sediments are discussed in Section 5.3.

5.1 Considerations Associated with Input Data from Sediment Transport Evaluation

This section discusses other considerations that could introduce uncertainties in the evaluations of site performance over time and recontamination potential in the EW FS associated specifically with measurements or calculations of the input data used. The information provided in this section is a summary of more detailed discussions published previously in the STER (Anchor QEA and Coast & Harbor Engineering 2012) and EW SRI (Windward and Anchor QEA 2014).

5.1.1 Representative Net Sedimentation Rate

A representative NSR of 1.2 cm/yr was assumed for the entire EW for the purposes of the FS modeling (see FS Section 5.1.2). This value is the site-wide area average value of net sedimentation calculated from evaluation of NSRs interpreted from geochronological cores for Cs-137 and Pb-210 collected in the EW as part of the STE (see FS Figure 5-1). There is uncertainty in this assumed value of NSR that can be applied for EW as a whole due to variation of estimates of estimated NSRs throughout the EW from the empirical evaluation conducted as part of the STER (0 to 4.2 cm/yr; Anchor QEA and Coast & Harbor Engineering 2012). There is additional uncertainty associated with extrapolating NSRs measured at discrete geochronological core locations to the entire EW area due to influence of vessel operations in the EW on NSRs (e.g., resuspension and re-distribution of EW bed sediments by propwash).

5.1.2 Propwash Impacts to Deposition Patterns

Patterns of solids deposition within the EW from EW Lateral sources based on PTM (see FS Appendix B, Part 1) represent the initial deposition patterns and do not take into account re-suspension or re-distribution of these sediments due to influence of vessel operations in the EW. Deposition patterns shown in Appendix B, Part 1 would likely be more spread out than shown, but would result in lower surface sediment chemical concentrations due to the deposited material being spread out over a larger area. Therefore, the areas identified as having increased potential for recontamination post-construction are approximate. This will be considered when developing the proposed monitoring plan during design.

5.1.3 Upstream Solids Inputs

Uncertainty exists in the chemistry estimates and solids loadings input from upstream sources (Green River, LDW bed sediments, and LDW laterals). This uncertainty will exist well into the future based on the variable nature of these sources. However, a range of concentrations were developed (in Section 5) to evaluate the uncertainty in upstream values. Specifically, the input (e.g., Base Case) values were bracketed by lower- and upper-bound values.

In general, the value representing a mid-range of the various lines of evidence was considered for the input value, and then values representing upper and lower bounds were selected for the high and low sensitivity input values, respectively. One goal of including a range in the input values is to account for uncertainty in all the datasets representing upstream inputs and show how these data ranges affect the long term predictions for the remedial alternatives.

The high end of the range (high chemistry and high solids) is intended to capture variability in the source concentrations, typical seasonal high flows, and the less frequent high flow events (e.g., 100-year flood) that is considered likely to overestimate contaminant concentrations. The low end of the range (low chemistry and low solids) represents a non-conservative set of assumptions that is considered likely to underestimate contaminant concentrations.

The incoming solids from upstream to the EW were based on the outgoing solids estimated from the LDW Sediment Transport Modeling Report (STM; Windward and QEA 2008), which, like all models, has uncertainty. The upstream load from the LDW STM was used to partition the upstream load between the three contributing sources (Green River, LDW bed, and LDW laterals). There is some uncertainty that the distribution of inputs upstream of the EW/WW split matches the distribution entering the EW.

Chemistry assumptions for LDW bed and LDW lateral sediment sources were taken from values provided in the LDW FS (AECOM 2012). LDW bed and lateral sediment inputs were not varied for the sensitivity analysis because the mass of sediment that enters the EW from these sources are small compared to other upstream inputs (i.e., Green River) and do not have a large effect on long-term SWACs for the alternatives. Chemistry assumptions for Green River input (as described in FS Appendix B, Part 3B) considered the same datasets for use in the LDW (AECOM 2012), but selected different concentrations of certain parameters due to a lower percentage of coarse-grained sediment entering the EW from upstream. These datasets are considered reasonable lines of evidence for developing incoming concentrations to the EW from upstream, although each type of data collection tends to bias the results toward lower or higher values (e.g., low percent fines versus high percent fines; single collection events instead of seasonal collection events; potential influence of sources).

5.1.4 East Waterway Lateral Solids Inputs

The uncertainties in the incoming solids input from EW laterals include particle size distributions, stormwater and CSO flows, and total suspended solids concentrations. Appendix F of the EW STER (Anchor QEA and Coast & Harbor Engineering 2012) provides detailed information on how this information was developed for use in the PTM.

There is additional uncertainty associated with the use of shorter-term PTM simulations performed to provide information used to evaluate long-term deposition in the EW from lateral sources. This involved using a representative tidal condition and temporally-constant mean annual average riverine inflow (for the hydrodynamic model used as input to the PTM) and annual average sediment source input rates. This information, while not representative of any particular storm event, provided average initial deposition rates and patterns from EW lateral solids inputs into the EW.

Uncertainties in chemistry assumptions include assignments of the same chemistry values to different outfalls, future concentrations following additional source control actions, as well as chemistry associated with the specific particle sizes that will settle onto EW bed sediments. For example, the same chemistry value was assigned to all nearshore storm drain basins in the point mixing model and grid model evaluations for the reasons listed in FS Appendix B, Part 4 (e.g., consideration of number of samples for a given basin). In addition, the source tracing dataset for SDs included catch basins that are related to a smaller area within the basin and may not be representative of what ultimately is discharged through the outfall. Collectively, these assumptions may lead to over or underestimation of contaminant concentrations for an individual basin.

5.1.5 Vertical Mixing Assumptions

5.1.5.1 Delineation of Vessel Operational Areas

The EW was divided into areas in which vessel operations activities and vessel types were similar as part of the EW STE. These vessel operational areas were used in the FS to calculate scour depths and develop vertical mixing depth assumptions in the EW. Fourteen separate areas and sub-areas were identified. The areas and operations were developed through interviews and personal conversations with individuals that work within the EW including pilots, operations managers, U.S. Coast Guard officials, Port planners, and others (see Section 5.1.2 of the STER; Anchor QEA and Coast & Harbor Engineering 2012). Therefore, uncertainty in the delineation of vessel operational areas is primarily dependent on the reliability of this information for specific areas and changes over time. This uncertainty is taken into account by using conservative operational criteria for the propwash simulations (conducted as part of the STE) based on an understanding of vessel operations. However, there is still some uncertainty in the definitions of specific vessel operation parameters for each scenario (e.g., percent power used for bow thrusters and actual tug operations). Additional uncertainties exist in the location of transitions between operational areas.

5.1.5.2 Prediction of Scour Depths

Scenarios used to estimate scour depths in the EW have been chosen to represent extreme conditions, as defined in Section 5.1.2 of the STER (Anchor QEA and Coast & Harbor Engineering 2012), within each of the defined vessel operational areas in the EW (see Section 5.1.5.1 above). These scenarios are anticipated to drive sediment mobilization in the EW (due to propwash) to a larger extent than a single emergency maneuver or event. The scour depths were predicted by propwash modeling is outlined in FS Appendix B, Part 2.

Uncertainty in estimates of scour depth, as with the delineation of operational areas, are primarily associated with uncertainty in information gathered about vessel operations during the STE. Additional uncertainty is associated with estimates of critical shear stress of surface sediments in the EW. The uncertainties in estimates of critical shear stress, as evaluated from

SEDflume data as part of the STE, include collection effects on sediment properties, experimental error during testing, methodology used to estimate critical shear stress, and spatial variability in erosion properties. While spatial variability in critical shear stress in the EW based on SEDflume data does exist, the representative range in critical shear stress for surface sediments was estimated to be about 0.20 to 0.37 Pa.

Additional uncertainty in prediction of scour depths in the EW can be attributed to the methodology and equations used to complete the calculations (FS Appendix B, Part 2). The equations used in the described methodology have constants that were developed through empirical methods that may not be completely representative of vessel operations and conditions within the EW. Uncertainties in calculation of scour depths were taken into account through use of conservative assumptions, including shallower water depths (operations at mean lower low water) and relatively high power assumptions for vessel operations.

5.1.6 Bed Replacement Values

Post-construction sediment bed replacement values are used as input for modeling for post-construction starting conditions. These values are predictions that represent the initial (or end of construction - Time 0) bed sediment contaminant concentrations following completion of remedial activities involving dredging and placement of RMC, capping, or ENR material. Bed replacement values affect the short term surface concentrations but other variables contribute to the long term predictions of surface concentrations in the EW. Evidence from other sediment sites has shown that contaminant concentrations in the sediment bed after completing a remedial action cannot be assumed to be zero (NRC 2008; EPA 2005), as a result of resettling of contaminated sediments suspended during remedial activities, material being used for RMC following dredging may contain low concentrations of key risk driver COCs, and propwash from large ships in the EW will mix dredge residuals, RMC, and existing sediments around the site. The degree of residual contamination is dependent on the type of remedial activity, specific design elements, construction methods; best management practices (BMPs), engineering controls, contingency measures, and other variables, the effects of which cannot be accurately predicted through modeling.

In the EW, replacement values were developed for 1) remediated areas and 2) interior unremediated areas. FS Appendix B, Part 3A describes the input, low, and high replacement values. This range is intended to capture the uncertainty associated with any of the variables that contribute to the actual post-construction surface sediment concentration.

The most important variables that affect the post-construction surface sediment concentration estimated for the EW are the dredge residuals concentrations and thickness. Thickness of dredge cut, type of dredge equipment, and use of BMPs will affect the dredge residuals thickness. The concentration of sediment being dredged (especially the last pass for dredging areas where multiple passes are required) also varies throughout the EW and will influence dredge residuals concentrations. As described in FS Appendix B, Part 5, variables that affect the dredge residuals thickness, concentration, and distribution include hydrodynamic and operational conditions within the EW during dredging and placement of RMC, including water depth, anticipated duration it would take to place clean material over the entire open-water remediation area (which could require a full construction season due to the extensive size of the anticipated remediation area), and frequency of ongoing vessel traffic in the EW that causes sediment resuspension and sediment bed mixing.

In addition, actual undredged sediment concentrations in remediated and interior unremediated areas following construction affect the post-construction sediment concentration. In areas where limited or no dredge residuals have been deposited and sediment with low concentrations is exposed, the post-construction concentrations may be closer to the low replacement value shown in FS Appendix B, Part 3A. Alternately, where a thicker layer of dredge residuals have deposited, dredge residuals concentrations are higher, or mixing from propwash or placement of RMC spreads contaminated sediment, post-construction concentrations may result in concentrations closer to the high estimate shown in FS Appendix B, Part 3A.

5.2 Considerations Associated with Calculation Methodology for SWAC Values (Box Model Evaluation and Point Mixing Model Evaluation)

In addition to uncertainty in input data, additional uncertainty in predicted SWAC values from the box and point mixing models can be attributed to the methodology developed for those calculations (i.e., vertical mixing assumptions, time frame assumed for mixing to occur, etc.). In order to account for this uncertainty, bounding and sensitivity evaluations were conducted as described in Sections 2.3 and 2.4 of this appendix. Additional considerations that could introduce uncertainty in predictions of SWAC values using the box model evaluation or point mixing model evaluation are discussed in the following sections.

5.2.1 Post-construction (Year 0) Sediment Concentrations

The post-construction (year 0) sediment concentrations estimated for each remedial technology have not taken into account that construction will take place over multiple in-water construction seasons. Instead, the model assumes that all remediation is completed at one time; bed disturbance and deposition that occurs between construction seasons is not taken into account in the estimates of year 0 sediment concentrations.

5.2.2 Vertical Bed Mixing Model and Mixing Depth Assumptions

The vertical bed mixing models (shown in Figures 1a through 1j) are idealized models used to represent the sediment bed post-construction (year 0) for each remedial alternative, as well as sediment deposition and vertical mixing for years following year 0. It is understood that existing bottom sediments, placed sediment, and natural sedimentation within the EW will not resemble even constant layers of sediment as shown in Figures 1a through 1j. This simplification was used to facilitate calculations of long term surface concentrations within the EW.

Vertical mixing assumptions were developed based on calculations of scour depth within the EW, which varied from 0.5 to almost 5 feet depending on location and vessel use (see FS Figure 5-2). However, the range of predicted scour depths was simplified in the evaluation of site performance over time by dividing the EW into areas which were assigned one of four mixing depths: 10 cm (bioturbation), 0.5 feet, 1 foot, and a maximum mixing depth of 2 feet (see Section 2.2.4).

5.2.3 Exchange between Open-water and Underpier Areas

An exchange of sediment between open-water and underpier areas is expected to occur in the EW due to resuspension and distribution of sediments due to impacts from vessel operations, including use of bow thrusters and other propwash scenarios. It is not possible to calculate this exchange rate with any precision due to the variability in vessel operations and underpier sediment characteristics. Therefore, the physical process was simulated in the model through a mass-balance exchange of sediment between open-water and underpier areas.

5.2.4 Timeframe for Complete Mixing in the East Waterway

The timeframe for the EW to completely mix both spatially and vertically to the estimated mixing depths is difficult to predict due to spatial and temporal variability in vessel operations and spatial variability of sediment conditions within the EW. Therefore, the timeframe assumed for complete mixing (i.e., sediments in all open-water areas in the EW are mixed between 10 cm and 2 feet below mudline depending on location) to occur was assumed to be 5 years. Since this timeframe is difficult to predict using available empirical data (due to complexity of vessel operations in the EW), the uncertainty associated with the timeframe of mixing in the EW was parameterized in the sensitivity analysis using two other related variables: vertical mixing depth and percent of the EW area that was fully mixed in the assumed 5-year timeframe.

5.3 Considerations Associated with the Methodology for Recontamination Evaluation (Grid Model Evaluation)

Considerations associated with the methodology used to evaluate recontamination potential that could introduce uncertainty in the evaluation include assumptions for surface concentrations at year 0 post-remediation and vertical mixing assumptions. Year 0 surface sediment concentrations were all set to zero to focus the evaluation on impacts of sediment deposition on recontamination potential. This will result in lower surface concentrations for a short duration following remediation. However, by Year 10 post-remediation, surface sediment within the top 10 cm will consist almost entirely of deposited sediment from upstream and EW lateral sources based on the representative NSR for the EW used in the FS (1.2 cm/yr). This is because vertical mixing due to vessel operations was not considered as part of the recontamination evaluation; and mixing depths in the EW were all set to the bioturbation mixing depth of 10 cm. The deposition patterns predicted by the PTM for EW laterals do not take into account impacts of re-suspension due to vessel operations. Therefore, deposition patterns predicted by the PTM (used as input for the grid model evaluation) would likely be more spread out and would have lower calculated surface sediment chemical concentrations due to the deposited material being spread out over a larger area. Therefore, the areas identified as having increased potential for recontamination post-restoration are approximate. This will be considered when developing the proposed monitoring plan during design.

6 REFERENCES

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QEA (Quantitative Environmental Analysis), 2008. Lower Duwamish Waterway Sediment Transport Modeling (STM) Report, Final. Prepared for USEPA, Region 10, and the Washington State Department of Ecology. Quantitative Environmental Analysis, Montvale, NJ. October.

Windward and Anchor QEA, 2014. Supplemental Remedial Investigation. East Waterway Operable Unit Supplemental Remedial Investigation/Feasibility Study. Final. January 2014.

TABLES

Table 1
Summary of Solids Inputs to the East Waterway

Current Conditions

Input	Source	Total Annual Incoming Sediment (kg)[1]	Cumulative Total Annual Incoming Sediment (kg)[2]	Annual Incoming Sediment by Size (kg)[3] A (0.005 mm)	B (0.02 mm)	C (0.13 mm)	D (0.54 mm)	Total Annual Deposited Sediment (kg)[4]	% Total Deposited Sediment[4]
Upstream	Green River	32,159,000 to 53,598,000[5]	32,415,000 to 53,998,000[5]	29,013,000 to 48,355,000	3,145,000 to 5,242,000	199 to 332	29 to 49	15,116,510	99%
	LDW Lateral	178,000 to 296,000[5]		161,000 to 267,000	17,000 to 29,000	1.1 to 1.8	0.1 to 0.3	83,803	0.55%
	LDW Bed	78,000 to 131,000[5]		70,000 to 118,000	7,600 to 12,800	0.5 to 0.8	0.07 to 0.12	36,569	0.24%
EW Laterals	Hinds CSO	326	37,471	137	133	55	0	176	0.00%
	Lander CSO	12,957		5,442	5,312	2,203	0	8,000	0.05%
	Hanford #2 CSO	24,188		10,159	9,917	4,112	0	13,642	0.09%
	Nearshore SD[6]	33,357	75,623	5,137	7,706	8,706	11,809	27,682	0.18%
	S Lander St SD	31,940		4,919	7,378	8,337	11,307	27,089	0.18%
	Non-nearshore SD[7]	10,326		1,590	2,385	2,695	3,655	8,040	0.05%

Future Source Control Conditions (Values are the same as current conditions [grey text] except where noted [bold black text])

Input	Source	Total Annual Incoming Sediment (kg)[1]	Cumulative Total Annual Incoming Sediment (kg)[2]	Annual Incoming Sediment by Size (kg)[3] A (0.005 mm)	B (0.02 mm)	C (0.13 mm)	D (0.54 mm)	Total Annual Deposited Sediment (kg)[4]	% Total Deposited Sediment[4]
Upstream	Green River	32,159,000 to 53,598,000[5]	32,415,000 to 53,998,000[5]	29,013,000 to 48,355,000	3,145,000 to 5,242,000	199 to 332	29 to 49	15,116,510	99%
	LDW Lateral	178,000 to 296,000[5]		161,000 to 267,000	17,000 to 29,000	1.1 to 1.8	0.1 to 0.3	83,803	0.55%
	LDW Bed	78,000 to 131,000[5]		70,000 to 118,000	7,600 to 12,800	0.5 to 0.8	0.07 to 0.12	36,569	0.24%
EW Laterals	Hinds CSO	**207**	**16,744**	**87**	**85**	**35**	**0**	**111**	0.00%
	Lander CSO	**195**		**82**	**80**	**33**	**0**	**124**	0.00%
	Hanford #2 CSO	**16,342**		**16,154**	**133**	**55**	**0**	**2,919**	0.02%
	Nearshore SD[6]	**15,594**	**57,860**	**4,115**	**3,819**	**3,251**	**4,409**	**11,206**	0.07%
	S Lander St SD	31,940		4,919	7,378	8,337	11,307	27,089	0.18%
	Non-nearshore SD[7]	10,326		1,590	2,385	2,695	3,655	7,987	0.05%

Notes:
1. Categories of solids sources used for recontamination potential evaluation and Point Mixing Model.
2. Categories of solids sources used for evaluation of site performance over time (SWACs).
3. Upstream annual incoming sediment by size was based on suspended sediment size classes predicted to leave the model domain boundary upstream of the EW and WW split, and averaged over 30 years predicted by the LDW Sediment Transport Model (AECOM 2012).
4. Deposition values based on Base Case PTM Model runs for EW Laterals (see Appendix B, Part 1 of the FS) and average net sedimentation rate for the EW from geochronology cores (see Section 5.1.2 of the FS).
5. Range in values based on range in the estimated split in flow between the EW and WW, 50% to 30% to EW from LDW.
6. Nearshore SDs include SW Florida St SD (B-21), B-25, all Port SDs, and all private SDs along waterfront (A-6, B-40, B-41, B-42, B-43).
7. Non-nearshore SDs include S Hinds St SD, SW Spokane St EOF/SD (B-5), SW Spokane St SD (B-4), S Spokane St SD (B-36), and all bridges (BR-2, BR-4, BR-34, BR-39).

CSO – Combined Sewer Overflow; EW – East Waterway; FS – Feasibility Study; kg – kilogram; LDW – Lower Duwamish Waterway; mm – millimeter; PTM – particle tracking model; SD – Storm Drain; SWAC – spatially-weighted average concentration; WW – West Waterway

Table 2

Alternative-specific Post-construction Concentrations by Technology Application Area

Technology[1]	Total PCBs (µg/kg considering bioavailability)[5]															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Removal to the Extent Practicable and Backfill[2]	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Removal and Backfill to Existing Contours[3]	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Partial Removal and Cap	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Partial Removal and ENR-nav[4]	35	35	35													
ENR-sill[2]	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
ENR-nav[4]	8	8	8													
MNR	1268			1268												
Interior Unremediated Island[2]	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Exterior Unremediated Island	54	54	54	54	54	54	54	54	54	54	27	20	27	20	27	20
Underpier																
Hydraulic Dredging Followed by In situ Treatment			411				411		411		173	165	411	411	411	0
Hydraulic Dredging						1,371				596						550
In situ Treatment		179	135		179	135	135	179	135				130	124	130	
MNR	596			596												
No Action	81	81	81	81	81	81	81	81	81	81	40	23	40	23	40	23

Technology	Total cPAHs TEQ (µg/kg considering bioavailability)[5]															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Removal to the Extent Practicable and Backfill[2]	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Removal and Backfill to Existing Contours[3]	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Partial Removal and Cap	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Partial Removal and ENR-nav[4]	28	28	28													
ENR-sill[2]	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
ENR-nav[4]	13	13	13													
MNR	582			582												
Interior Unremediated Island[2]	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Exterior Unremediated Island	164	164	164	164	164	164	164	164	164	164	170	186	170	186	170	186
Underpier																
Hydraulic Dredging Followed by In situ Treatment			423				423		423		196	187	423	423	423	
Hydraulic Dredging						1,409				596						622
In situ Treatment		179	132		179	132	132	179	132				155	147	155	
MNR	596			596												
No Action	540	540	540	540	540	540	540	540	540	540	106	121	106	121	106	121

Table 2

Alternative-specific Post-construction Concentrations by Technology Application Area

Technology[1]	Total Dioxins/Furans TEQ (ng/kg considering bioavailability)[5]															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Removal to the Extent Practicable and Backfill[2]	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Removal and Backfill to Existing Contours[3]	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Partial Removal and Cap	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Partial Removal and ENR-nav[4]	2.8	2.8	2.8													
ENR-sill[2]	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
ENR-nav[4]	2.2	2.2	2.2													
MNR	17			17												
Interior Unremediated Island[2]	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Exterior Unremediated Island	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.9	8.7	7.9	8.7	7.9	8.7
Underpier																
Hydraulic Dredging Followed by In situ Treatment			4.8				4.8		4.8		4.9	4.9	4.8	4.8	4.8	
Hydraulic Dredging						16				17						16
In situ Treatment		5.0	5.0		5.0	5.0	5.0	5.0	5.0				5.0	4.9	5.0	
MNR	17			17												
No Action	12	12	12	12	12	12	12	12	12	12	12	10	12	10	12	10

Technology[1]	Arsenic (mg/kg)[5]															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Removal to the Extent Practicable and Backfill[2]	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Removal and Backfill to Existing Contours[3]	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Partial Removal and Cap	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Partial Removal and ENR-nav[4]	4.2	4.2	4.2													
ENR-sill[2]	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
ENR-nav[4]	4.0	4.0	4.0													
MNR	14.8			14.8												
Interior Unremediated Island[2]	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Exterior Unremediated Island	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.3	5.0	5.3	5.0	5.3
Underpier																
Hydraulic Dredging Followed by In situ Treatment			13				13		13		8.4	8.2	13	13	13	
Hydraulic Dredging						20				12						11
In situ Treatment		11	9.5		11	9.5	9.5	11	9.5				10	9.3	10	
MNR	12			12												
No Action	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	4.6	4.5	4.6	4.5	4.6	4.5

Table 2

Alternative-specific Post-construction Concentrations by Technology Application Area

Notes:

1. Residuals thickness varies by alternative; see FS Appendix L and FS Section 8 for this information.
2. Includes 9 inches of sand cover in ENR sill areas in calculations.
3. Includes 4 feet of sand cover in calculations.
4. Includes 1.5 feet of sand cover in ENR-nav areas in calculations.
5. Post-construction concentrations are calculated in the top 10 centimeters of bed sediments.

µg/kg – microgram per kilogram
cPAH – carcinogenic polycyclic aromatic hydrocarbon
ENR – enhanced natural recovery
mg – milligram
MNR – monitored natural recovery
ng – nanogram
PCB – polychlorinated biphenyl
TEQ – toxic equivalent

Table 3

Sub-area Input Values by Remedial Alternative for SWAC Calculations (Box Model Evaluation)

(Total Area of EW for all Remedial Alternatives is 157.4 acres)

Technology[1]	Areas (acres)															
	Alternative															
	1A(12)	1B(12)	1C+(12)	2A(12)	2B(12)	2C(12)	2C+(12)	3B(12)	3C+(12)	3D(12)	3E(7.5)	3E(5.0)	2C+(7.5)	2C+(5.0)	3C+(7.5)	3D(5.0)
Open-water																
Removal[2]	73.2	73.2	73.2	87.9	87.9	87.9	87.9	92.3	92.3	92.3	102.1	109.6	97.7	105.2	102.2	109.6
Removal to the Extent Practicable and Backfill[2]	3.3	3.3	3.3	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Removal and Backfill to Existing Contours[3]	0.7	0.7	0.7	0.7	0.7	0.7	0.7	3.5	3.5	3.5	3.8	3.8	0.8	0.8	3.8	3.8
Partial Removal and Cap	12.8	12.8	12.8	12.8	12.8	12.8	12.8	7.3	7.3	7.3	7.3	7.3	12.8	12.8	7.3	7.3
Partial Removal and ENR-nav[4]	7.4	7.4	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENR-sill[2]	2.4	2.9	2.9	2.4	2.9	2.9	2.9	1.2	1.2	1.2	1.3	1.3	3.2	3.2	1.3	1.3
ENR-nav[4]	8.7	8.7	8.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MNR	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action-Interior Unremediated Island[2]	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	15.1	9.2	15.1	9.2	15.1	9.2
No Action-Exterior Unremediated Island	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	14.8	8.5	6.9	8.5	6.9	8.5	6.9
Underpier																
Hydraulic Dredging Followed by In situ Treatment	0.0	0.0	1.9	0.0	0.0	0.0	1.9	0.0	1.9	0.0	12.7	13.4	1.9	1.9	1.9	0.0
Hydraulic Dredging	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	12.1	0.0	0.0	0.0	0.0	0.0	13.4
In situ Treatment	0.0	12.1	10.1	0.0	12.1	10.1	10.1	12.1	10.1	0.0	0.0	0.0	10.7	11.5	10.7	0.0
MNR	12.1	0.0	0.0	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
No Action-Underpier Unremediated	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.8	1.1	1.9	1.1	1.8	1.1

Notes:
1. Residuals thickness varies by alternative; see FS Appendix L and FS Section 8 for this information.
2. Includes 9 inches of sand cover in ENR-sill areas in calculations.
3. Includes 4 feet of sand cover in calculations.
4. Includes 1.5 feet of sand cover in ENR-nav areas in calculations.
ENR – enhanced natural recovery
EW – East Waterway
MNR – monitored natural recovery
SWAC – spatially-weighted average concentration

Table 4

Sensitivity and Bounding Scenarios for SWAC Calculations (Box Model Evaluation)

Sensitivity Analysis-Review Influence of Each Parameter (Alternatives 1A(12) and 2B(12))

Scenario	Scenario Name	1: Net Sedimentation Rate	2: Residuals Thickness[2]	3: Residuals Concentration	4: Mixing Depth	5: Area Mixed	6: Underpier Exchange	7: Lateral Concentrations[3]	8: Green River Concentrations[3]	9: Bioavailability[4]
1[1]	Base Case	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
2	1: Net Sedimentation Rate-Low	0.5 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
3	1: Net Sedimentation Rate-High	1.8 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
4	1a: Variable NSR	0 cm/0.5 cm/1.6 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
5	2: Residuals Thickness-Low	1.2 cm	3.1 cm; 0.6 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
6	2: Residuals Thickness-High	1.2 cm	7.2 cm; 1.4 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
7	3: Residuals Concentration-Low	1.2 cm	5.1 cm; 1.0 cm	470 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
8	3: Residuals Concentration-High	1.2 cm	5.1 cm; 1.0 cm	980 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
9	4: Mixing Depth-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	1 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
10	4: Mixing Depth-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	3 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
11	5: Area Mixed-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	30%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
12	5: Area Mixed-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	90%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
13	6: Underpier Exchange-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	5%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
14	6: Underpier Exchange-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	50%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
15	7: Lateral Concentrations-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.36 µg/kg; 44.44 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
16	7: Lateral Concentrations-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	48.54 µg/kg; 45.52 µg/kg	45.99 µg/kg; 44.72 µg/kg	70%
17	8: Green Concentrations-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	9.58 µg/kg; 8.44 µg/kg	70%
18	8: Green Concentrations-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	83.38 µg/kg; 82.31 µg/kg	70%
19	9: Bioavailability-Low	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	50%
20	9: Bioavailability-High	1.2 cm	5.1 cm; 1.0 cm	640 µg/kg	2 feet	50%	25%	45.99 µg/kg; 44.72 µg/kg	45.99 µg/kg; 44.72 µg/kg	90%

Notes:

1. Scenario 1 used as base case for conducting all evaluations (box model, point-by-point mixing model, and grid model).
2. See Appendix B, Part 3A.
3. See Appendix B, Part 4.
4. Underpier bioavailability for underpier areas. Only valid for Alternative 2B(12); Alternative 1A(12) stays constant.

Shaded boxes indicate that the parameter changed compared to the Sensitivity Analysis, Scenario 1.

µg/kg – microgram per kilogram; cm – centimeters; NSR – net sedimentation rate; SWAC – spatially-weighted average concentration

Table 4
Sensitivity and Bounding Scenarios for SWAC Calculations (Box Model Evaluation)

Bounding Scenarios (Alternatives 1A(12) and 2B(12))

Scenario	1: Net Sedimentation Rate	2: Residuals Thickness	3: Residuals Concentration	4: Mixing Depth	5: Area Mixed	6: Underpier Exchange	7: Lateral Concentrations	8: Green River Concentrations	9: Bioavailability[1]
Lowest Bound	High	Low	Low	High	Low	Low	Low	Low	High
Highest Bound	Low	High	High	Low	High	High	High	High	Low
Additional Low	Base	Low	Low	High	Low	Low	Low	Base[2]	High
Additional High	Base	High	High	Low	High	High	High	Base[2]	Low
Green River Low	Base	Base	Base	Base	Base	Base	Base	Low	Base
Green River High	Base	Base	Base	Base	Base	Base	Base	High	Base

Notes:
1. Bioavailability is only applied to sensitivity and bounding runs for Alternative 2B(12); Alternative 1A(12) stays constant.
2. NSR and Green River concentrations left as base case to illustrate the impact these parameters have on the SWAC predictions (see Section 2.3.3).

Table 5

Site-wide Total PCB SWAC (µg/kg dw) Results for Box Model Sensitivity Scenarios[1]

Alternative 1A(12)		Years Post-construction								
Scenario	**Scenario Name**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1	Base Case	76	131	126	114	103	95	87	82	77
2	1: Net Sedimentation Rate-Low	76	123	143	142	135	127	119	112	106
3	1: Net Sedimentation Rate-High	76	125	111	97	88	81	75	71	67
4	1a: Variable NSR	76	127	122	113	104	97	91	86	82
5	2: Residuals Thickness-Low	76	127	122	110	100	91	84	79	74
6	2: Residuals Thickness-High	76	136	130	118	107	98	91	85	80
7	3: Residuals Concentration-Low	76	128	123	111	101	92	85	80	75
8	3: Residuals Concentration-High	76	138	132	120	109	100	92	86	81
9	4: Mixing Depth-Low	76	131	127	116	105	95	88	81	76
10	4: Mixing Depth-High	76	130	124	112	101	93	86	80	76
11	5: Area Mixed-Low	76	137	132	118	105	95	87	81	76
12	5: Area Mixed-High	76	119	114	107	100	94	89	84	80
13	6: Underpier Exchange-Low	76	98	97	93	89	86	83	80	77
14	6: Underpier Exchange-High	76	173	143	117	101	90	82	77	73
15	7: Lateral Concentrations-Low	76	131	126	114	103	94	87	82	77
16	7: Lateral Concentrations-High	76	132	127	115	104	95	88	83	78
17	8: Green Concentrations-Low	76	118	108	94	81	70	62	55	50
18	8: Green Concentrations-High	76	144	144	136	127	119	114	109	106

Alternative 2B(12)		Years Post-construction								
Scenario	**Scenario Name**	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**
1	Base Case	42	72	71	68	65	63	60	59	57
2	1: Net Sedimentation Rate-Low	42	67	74	75	74	72	70	68	67
3	1: Net Sedimentation Rate-High	42	71	68	64	61	58	56	55	53
4	1a: Variable NSR	42	69	69	66	63	61	59	58	56
5	2: Residuals Thickness-Low	42	67	67	64	61	59	57	55	54
6	2: Residuals Thickness-High	42	77	76	73	70	67	64	62	60
7	3: Residuals Concentration-Low	42	68	68	65	62	60	58	56	55
8	3: Residuals Concentration-High	42	79	78	75	71	68	66	64	62
9	4: Mixing Depth-Low	42	70	70	67	64	61	58	56	55
10	4: Mixing Depth-High	42	67	67	64	61	59	57	56	54
11	5: Area Mixed-Low	42	71	71	68	65	62	59	58	56
12	5: Area Mixed-High	42	72	71	69	67	64	62	61	59
13	6: Underpier Exchange-Low	42	62	63	62	60	59	58	57	56
14	6: Underpier Exchange-High	42	84	77	70	66	63	60	58	57
15	7: Lateral Concentrations-Low	42	71	71	68	65	62	60	58	57
16	7: Lateral Concentrations-High	42	72	73	69	66	63	61	59	58
17	8: Green Concentrations-Low	42	59	54	48	43	39	35	32	30
18	8: Green Concentrations-High	42	84	89	89	88	87	86	86	85
19	9: Bioavailability-Low	51	90	89	83	78	73	69	66	64
20	9: Bioavailability-High	32	53	54	54	53	52	52	51	50

Notes:
1. All sensitivity runs were conducted using total PCBs, sensitivity scenarios are listed in Table 4.
µg/kg – microgram per kilogram
dw – dry weight
NSR – net sedimentation rate
PCB – polychlorinated biphenyl
SWAC – spatially-weighted average concentration

Table 6
Site-wide Total PCB SWAC (µg/kg dw) Results for Box Model Bounding Scenarios[1]

Alternative 1A(12)	Years Post-construction								
	0	5	10	15	20	25	30	35	40
Base Case	76	131	126	114	103	95	87	82	77
Lowest Bound	76	68	60	54	49	44	41	38	36
Highest Bound	76	196	212	202	192	183	175	168	161
Reasonable Low	76	94	93	90	86	83	80	77	75
Reasonable High	76	162	144	126	111	99	90	83	76
Green Low	76	118	108	94	81	70	62	55	50
Green High	76	144	144	136	127	119	114	109	106

Alternative 2B(12)	Years Post-construction								
	0	5	10	15	20	25	30	35	40
Base Case	42	72	71	68	65	63	60	59	57
Lowest Bound	32	21	19	17	16	15	14	14	13
Highest Bound	51	154	160	149	137	127	118	109	101
Reasonable Low	32	43	45	45	45	45	45	45	45
Reasonable High	51	116	105	95	86	79	73	69	65
Green Low	42	59	54	48	43	39	35	32	30
Green High	42	84	89	89	88	87	86	86	85

Note:
1. All bounding runs were conducted using total PCBs, bounding scenarios are listed in Table 4.
µg/kg – microgram per kilogram
dw – dry weight
PCB – polychlorinated biphenyl
SWAC – spatially-weighted average concentration

Table 7

Point Mixing Model Solids Inputs and Chemistry Assumptions for Calculations

	Location[1]		PTM-derived Annual Deposition		Arsenic (mg/kg dw)			Mercury (mg/kg dw)			Total HPAHs (µg/kg dw)			Total LPAHs (µg/kg dw)		
Point	**X Latitude**	**Y Longitude**	**Current (cm)**	**Future[2] (cm)**	**Current Surface**	**Current Incoming**	**Future Incoming**	**Current Surface**	**Current Incoming**	**Future Incoming**	**Current Surface**	**Current Incoming**	**Future Incoming**	**Current Surface**	**Current Incoming**	**Future Incoming**
EW09-SS-010	1267383	212101	**1.356**	**1.347**	8.4	9.2	9.2	0.11	0.11	0.11	3040	2343	1940	370	354	300
EW09-SS-012	1267207	212224	**1.199**	**1.199**	6.0	9.0	9.0	0.02	0.10	0.10	2680	1338	1338	360	138	138
EW09-SS-027	1267850	213108	**1.212**	**1.204**	12.1	9.1	9.1	0.40	0.10	0.10	3270	1383	1357	500	147	142
EW09-SS-038	1267846	214050	**1.197**	**1.197**	9.1	9.0	9.0	0.46	0.10	0.10	4240	1331	1331	340	137	137
EW09-SS-100	1267016	214210	**1.210**	**1.199**	6.8	9.1	9.0	0.29	0.10	0.10	2220	1376	1338	350	146	138
EW09-SS-101	1267840	214257	**1.197**	**1.197**	7.5	9.0	9.0	0.47	0.10	0.10	3180	1331	1331	630	137	137
EW09-SS-110	1268243	215019	**1.197**	**1.197**	9.2	9.0	9.0	0.48	0.10	0.10	2120	1331	1331	310	137	137
EW09-SS-114	1267035	215406	**1.197**	**1.197**	22.7	9.0	9.0	0.32	0.10	0.10	1700	1331	1331	250	137	137
EW09-SS-126	1267067	217295	**1.208**	**1.201**	6.4	9.1	9.1	0.17	0.10	0.10	1080	1370	1344	82	145	139
EW09-SS-211	1267130	218822	**1.197**	**1.197**	3.6	9.0	9.0	0.17	0.10	0.10	1940	1331	1331	280	137	137
EW09-SS-219	1267959	219386	**1.197**	**1.197**	3.1	9.0	9.0	0.16	0.10	0.10	1370	1331	1331	400	137	137
EW-109	1267155	218459	**1.197**	**1.197**	9.0	9.0	9.0	0.16	0.10	0.10	6200	1331	1331	1230	137	137
EW-128	1267088	212098	**1.201**	**1.204**	20.0	9.1	9.1	0.31	0.10	0.10	6100	1344	1363	940	139	145
EW-132	1267138	218690	**1.197**	**1.197**	8.0	9.0	9.0	0.19	0.10	0.10	2970	1331	1331	400	137	137
EW-135	1267878	215761	**1.223**	**1.208**	12.0	9.0	9.0	0.47	0.10	0.10	6500	1547	1399	1180	179	150
EW-136	1268185	215025	**1.212**	**1.201**	10.0	9.0	9.0	0.49	0.10	0.10	7600	1431	1354	1700	156	141
EW-138	1267049	213522	**1.197**	**1.197**	10.0	9.0	9.0	0.50	0.10	0.10	6500	1331	1331	750	137	137
LSO-01	1267897.4	215773.5	**1.223**	**1.208**	7.3	9.0	9.0	0.27	0.10	0.10	3910	1547	1399	930	179	150

Table 7

Point Mixing Model Solids Inputs and Chemistry Assumptions for Calculations

Point[1]	Yearly Deposition Current (cm)	Yearly Deposition Future[2] (cm)	BEHP (µg/kg dw) Current Surface	BEHP (µg/kg dw) Current Incoming	BEHP (µg/kg dw) Future Incoming	1,4-DCB (µg/kg dw) Current Surface	1,4-DCB (µg/kg dw) Current Incoming	1,4-DCB (µg/kg dw) Future Incoming	Total PCBs (µg/kg dw) Current Surface	Total PCBs (µg/kg dw) Current Incoming	Total PCBs (µg/kg dw) Future Incoming
EW09-SS-010	**1.356**	**1.347**	520	2357	1700	10.0	17.7	17.0	1130	73.0	61.6
EW09-SS-012	**1.199**	**1.199**	36	172	172	5.8	1.7	1.7	78	44.5	44.5
EW09-SS-027	**1.212**	**1.204**	310	260	210	6.0	2.5	2.0	160	45.7	45.0
EW09-SS-038	**1.197**	**1.197**	340	159	159	460.0	1.6	1.6	1600	44.3	44.3
EW09-SS-100	**1.210**	**1.199**	320	248	172	24.0	2.4	1.7	160	45.6	44.5
EW09-SS-101	**1.197**	**1.197**	1000	159	159	4200.0	1.6	1.6	310	44.3	44.3
EW09-SS-110	**1.197**	**1.197**	180	159	159	17.0	1.6	1.6	140	44.3	44.3
EW09-SS-114	**1.197**	**1.197**	230	159	159	10.0	1.6	1.6	220	44.3	44.3
EW09-SS-126	**1.208**	**1.201**	120	235	185	28.0	2.3	1.8	880	45.4	44.7
EW09-SS-211	**1.197**	**1.197**	830	159	159	10.0	1.6	1.6	180	44.3	44.3
EW09-SS-219	**1.197**	**1.197**	56	159	159	6.1	1.6	1.6	20	44.3	44.3
EW-109	**1.197**	**1.197**	220	159	159	31.0	1.6	1.6	1900	44.3	44.3
EW-128	**1.201**	**1.204**	770	185	237	2.0	1.8	2.3	2400	44.7	45.2
EW-132	**1.197**	**1.197**	300	159	159	1.4	1.6	1.6	330	44.3	44.3
EW-135	**1.223**	**1.208**	1400	363	270	2.0	4.9	2.6	740	45.4	45.0
EW-136	**1.212**	**1.201**	500	255	196	1.9	3.9	1.9	370	44.7	44.5
EW-138	**1.197**	**1.197**	760	159	159	1.8	1.6	1.6	590	44.3	44.3
LSO-01	**1.223**	**1.208**	37000	363	270	20.0	4.9	2.6	340	45.4	45.0

Notes:
1. Locations of points are shown on Figure 5.
2. Future deposition is based on expected future source control conditions for EW Laterals.
µg/kg – microgram per kilogram
BEHP – bis(2-ethylhexyl) phthalate
cm – centimeters
DCB – dichlorobenzene
dw – dry weight
EW – East Waterway
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
mg/kg – milligram per kilogram
PCB – polychlorinated biphenyl
PTM – particle tracking model

Table 8

Concentrations at Point Locations - Years 0 to 40 Post-construction

PCB (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[2]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	70.6	25.8	11.4	6.3	4.7	4.1	3.9	3.9	3.9
EW09-SS-012	10	**1.199**	**1.199**	4.9	3.6	3.1	2.9	2.8	2.8	2.8	2.8	2.8
EW09-SS-027	60.96	**1.212**	**1.204**	10.0	9.3	8.7	8.1	7.6	7.1	6.7	6.3	5.9
EW09-SS-038	60.96	**1.197**	**1.197**	100.0	90.5	81.8	74.1	67.1	60.8	55.1	49.9	45.3
EW09-SS-100	60.96	**1.210**	**1.199**	10.0	9.3	8.7	8.1	7.6	7.1	6.7	6.3	5.9
EW09-SS-101	60.96	**1.197**	**1.197**	19.4	17.7	16.3	14.9	13.8	12.7	11.7	10.8	10.0
EW09-SS-110	60.96	**1.197**	**1.197**	8.8	8.2	7.6	7.2	6.7	6.3	6.0	5.7	5.4
EW09-SS-114	60.96	**1.197**	**1.197**	13.8	12.7	11.7	10.8	10.0	9.3	8.7	8.1	7.6
EW09-SS-126	60.96	**1.208**	**1.201**	55.0	49.8	45.2	41.0	37.2	33.8	30.8	28.0	25.5
EW09-SS-211	60.96	**1.197**	**1.197**	11.3	10.4	9.7	9.0	8.4	7.8	7.3	6.9	6.5
EW09-SS-219	60.96	**1.197**	**1.197**	1.3	1.4	1.5	1.7	1.8	1.9	2.0	2.0	2.1
EW-109	60.96	**1.197**	**1.197**	118.8	107.4	97.1	87.8	79.5	72.0	65.2	59.0	53.5
EW-128	10	**1.201**	**1.204**	150.0	61.6	26.3	12.2	6.5	4.3	3.4	3.1	2.9
EW-132	60.96	**1.197**	**1.197**	20.6	18.9	17.3	15.9	14.6	13.4	12.4	11.4	10.6
EW-135	60.96	**1.223**	**1.208**	46.3	41.9	38.0	34.5	31.4	28.5	26.0	23.7	21.6
EW-136	60.96	**1.212**	**1.201**	23.1	21.1	19.3	17.7	16.2	14.9	13.7	12.6	11.6
EW-138	60.96	**1.197**	**1.197**	36.9	33.5	30.5	27.8	25.3	23.1	21.1	19.3	17.7
LSO-01	60.96	**1.223**	**1.208**	21.3	19.4	17.7	16.3	14.9	13.7	12.6	11.7	10.8

Mercury (mg/kg)				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
EW09-SS-012	10	**1.199**	**1.199**	0.02	0.07	0.09	0.10	0.10	0.10	0.10	0.10	0.10
EW09-SS-027	60.96	**1.212**	**1.204**	0.4	0.37	0.34	0.32	0.30	0.28	0.26	0.25	0.23
EW09-SS-038	60.96	**1.197**	**1.197**	0.46	0.42	0.39	0.36	0.34	0.32	0.29	0.28	0.26
EW09-SS-100	60.96	**1.210**	**1.199**	0.29	0.27	0.25	0.24	0.23	0.21	0.20	0.19	0.18
EW09-SS-101	60.96	**1.197**	**1.197**	0.47	0.43	0.40	0.37	0.35	0.32	0.30	0.28	0.26
EW09-SS-110	60.96	**1.197**	**1.197**	0.48	0.44	0.41	0.38	0.35	0.33	0.31	0.29	0.27
EW09-SS-114	60.96	**1.197**	**1.197**	0.32	0.30	0.28	0.26	0.25	0.23	0.22	0.21	0.20
EW09-SS-126	60.96	**1.208**	**1.201**	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13
EW09-SS-211	60.96	**1.197**	**1.197**	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14	0.13
EW09-SS-219	60.96	**1.197**	**1.197**	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13
EW-109	60.96	**1.197**	**1.197**	0.16	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.13
EW-128	10	**1.201**	**1.204**	0.31	0.19	0.14	0.12	0.11	0.10	0.10	0.10	0.10
EW-132	60.96	**1.197**	**1.197**	0.19	0.18	0.17	0.17	0.16	0.15	0.15	0.14	0.14
EW-135	60.96	**1.223**	**1.208**	0.47	0.43	0.40	0.37	0.34	0.32	0.30	0.28	0.26
EW-136	60.96	**1.212**	**1.201**	0.49	0.45	0.42	0.39	0.36	0.33	0.31	0.29	0.27
EW-138	60.96	**1.197**	**1.197**	0.5	0.46	0.43	0.39	0.37	0.34	0.32	0.30	0.28
LSO-01	60.96	**1.223**	**1.208**	0.274	0.26	0.24	0.23	0.22	0.20	0.19	0.19	0.18

Table 8

Concentrations at Point Locations - Years 0 to 40 Post-construction

BEHP (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	32.5	110.4	135.4	115.8	109.3	107.2	106.6	106.3	106.3
EW09-SS-012	10	**1.199**	**1.199**	2.3	7.4	9.4	10.2	10.5	10.7	10.7	10.7	10.8
EW09-SS-027	60.96	**1.212**	**1.204**	19.4	19.1	18.8	18.2	17.7	17.3	16.9	16.5	16.2
EW09-SS-038	60.96	**1.197**	**1.197**	21.3	20.1	19.1	18.2	17.4	16.7	16.0	15.4	14.9
EW09-SS-100	60.96	**1.210**	**1.199**	20.0	19.6	19.1	18.3	17.6	16.9	16.3	15.8	15.3
EW09-SS-101	60.96	**1.197**	**1.197**	62.5	57.3	52.7	48.5	44.7	41.3	38.2	35.5	32.9
EW09-SS-110	60.96	**1.197**	**1.197**	11.3	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5
EW09-SS-114	60.96	**1.197**	**1.197**	14.4	13.9	13.6	13.2	12.9	12.6	12.3	12.1	11.9
EW09-SS-126	60.96	**1.208**	**1.201**	7.5	8.2	8.9	9.1	9.4	9.6	9.8	9.9	10.1
EW09-SS-211	60.96	**1.197**	**1.197**	51.9	47.8	44.0	40.7	37.7	35.0	32.5	30.3	28.3
EW09-SS-219	60.96	**1.197**	**1.197**	3.5	4.1	4.7	5.2	5.7	6.1	6.5	6.8	7.1
EW-109	60.96	**1.197**	**1.197**	13.8	13.4	13.0	12.7	12.5	12.2	12.0	11.8	11.6
EW-128	10	**1.201**	**1.204**	48.1	26.2	17.4	15.8	15.2	15.0	14.9	14.8	14.8
EW-132	60.96	**1.197**	**1.197**	18.8	17.9	17.1	16.4	15.8	15.2	14.7	14.2	13.8
EW-135	60.96	**1.223**	**1.208**	87.5	81.0	75.1	69.4	64.2	59.5	55.3	51.4	48.0
EW-136	60.96	**1.212**	**1.201**	31.3	29.7	28.4	26.8	25.3	24.1	22.9	21.8	20.9
EW-138	60.96	**1.197**	**1.197**	47.5	43.8	40.5	37.5	34.8	32.4	30.2	28.2	26.4
LSO-01	60.96	**1.223**	**1.208**	2313	2083	1876	1692	1526	1376	1242	1120	1011

1,4-DCB (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	0.63	0.95	1.06	1.06	1.06	1.06	1.06	1.06	1.06
EW09-SS-012	10	**1.199**	**1.199**	0.36	0.21	0.15	0.12	0.11	0.11	0.11	0.11	0.11
EW09-SS-027	60.96	**1.212**	**1.204**	0.38	0.35	0.33	0.31	0.29	0.28	0.26	0.25	0.24
EW09-SS-038	60.96	**1.197**	**1.197**	28.75	25.94	23.40	21.11	19.05	17.19	15.51	14.00	12.63
EW09-SS-100	60.96	**1.210**	**1.199**	1.50	1.37	1.25	1.13	1.03	0.94	0.86	0.78	0.72
EW09-SS-101	60.96	**1.197**	**1.197**	263	237	214	193	174	157	141	127	115
EW09-SS-110	60.96	**1.197**	**1.197**	1.06	0.97	0.88	0.81	0.74	0.67	0.62	0.57	0.52
EW09-SS-114	60.96	**1.197**	**1.197**	0.63	0.57	0.53	0.48	0.45	0.41	0.38	0.35	0.33
EW09-SS-126	60.96	**1.208**	**1.201**	1.75	1.59	1.45	1.32	1.20	1.09	0.99	0.91	0.83
EW09-SS-211	60.96	**1.197**	**1.197**	0.63	0.57	0.53	0.48	0.45	0.41	0.38	0.35	0.33
EW09-SS-219	60.96	**1.197**	**1.197**	0.38	0.35	0.33	0.31	0.29	0.27	0.25	0.24	0.22
EW-109	60.96	**1.197**	**1.197**	1.94	1.76	1.59	1.45	1.31	1.20	1.09	0.99	0.90
EW-128	10	**1.201**	**1.204**	0.13	0.12	0.12	0.13	0.14	0.14	0.15	0.15	0.15
EW-132	60.96	**1.197**	**1.197**	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
EW-135	60.96	**1.223**	**1.208**	0.13	0.14	0.16	0.16	0.16	0.16	0.16	0.16	0.16
EW-136	60.96	**1.212**	**1.201**	0.12	0.13	0.14	0.14	0.14	0.14	0.13	0.13	0.13
EW-138	60.96	**1.197**	**1.197**	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.10
LSO-01	60.96	**1.223**	**1.208**	1.25	1.16	1.07	0.98	0.90	0.83	0.76	0.70	0.65

Table 8

Concentrations at Point Locations - Years 0 to 40 Post-construction

Arsenic (mg/kg)				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	8.4	8.9	9.1	9.1	9.1	9.2	9.2	9.2	9.2
EW09-SS-012	10	**1.199**	**1.199**	6.0	7.8	8.6	8.9	9.0	9.0	9.0	9.0	9.0
EW09-SS-027	60.96	**1.212**	**1.204**	12.1	11.8	11.5	11.3	11.1	10.9	10.7	10.5	10.4
EW09-SS-038	60.96	**1.197**	**1.197**	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1	9.1
EW09-SS-100	60.96	**1.210**	**1.199**	6.8	7.0	7.2	7.4	7.6	7.7	7.8	8.0	8.1
EW09-SS-101	60.96	**1.197**	**1.197**	7.5	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4
EW09-SS-110	60.96	**1.197**	**1.197**	9.2	9.2	9.2	9.2	9.1	9.1	9.1	9.1	9.1
EW09-SS-114	60.96	**1.197**	**1.197**	22.7	21.4	20.2	19.1	18.1	17.2	16.4	15.7	15.0
EW09-SS-126	60.96	**1.208**	**1.201**	6.4	6.7	6.9	7.1	7.3	7.5	7.6	7.8	7.9
EW09-SS-211	60.96	**1.197**	**1.197**	3.6	4.1	4.6	5.1	5.4	5.8	6.1	6.4	6.7
EW09-SS-219	60.96	**1.197**	**1.197**	3.1	3.7	4.2	4.7	5.1	5.5	5.8	6.2	6.4
EW-109	60.96	**1.197**	**1.197**	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
EW-128	10	**1.201**	**1.204**	20.0	13.4	10.8	9.7	9.3	9.2	9.1	9.1	9.1
EW-132	60.96	**1.197**	**1.197**	8.0	8.1	8.2	8.3	8.4	8.4	8.5	8.5	8.6
EW-135	60.96	**1.223**	**1.208**	12.0	11.7	11.4	11.2	11.0	10.8	10.6	10.5	10.3
EW-136	60.96	**1.212**	**1.201**	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.5	9.5
EW-138	60.96	**1.197**	**1.197**	10.0	9.9	9.8	9.7	9.7	9.6	9.6	9.5	9.5
LSO-01	60.96	**1.223**	**1.208**	7.3	7.5	7.6	7.8	7.9	8.0	8.1	8.2	8.3

HPAH (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	190	160	151	131	124	122	122	121	121
EW09-SS-012	10	**1.199**	**1.199**	168	117	97	89	86	84	84	84	84
EW09-SS-027	60.96	**1.212**	**1.204**	204	193	182	172	164	156	149	143	137
EW09-SS-038	60.96	**1.197**	**1.197**	265	247	231	217	203	192	181	171	163
EW09-SS-100	60.96	**1.210**	**1.199**	139	134	129	124	120	117	113	111	108
EW09-SS-101	60.96	**1.197**	**1.197**	199	187	177	168	160	152	145	139	134
EW09-SS-110	60.96	**1.197**	**1.197**	133	128	123	119	116	113	110	107	105
EW09-SS-114	60.96	**1.197**	**1.197**	106	104	102	100	98	97	96	94	93
EW09-SS-126	60.96	**1.208**	**1.201**	68	69	71	72	73	74	75	76	77
EW09-SS-211	60.96	**1.197**	**1.197**	121	118	114	111	108	106	104	102	100
EW09-SS-219	60.96	**1.197**	**1.197**	86	85	85	85	85	85	85	84	84
EW-109	60.96	**1.197**	**1.197**	388	358	331	306	284	265	247	231	216
EW-128	10	**1.201**	**1.204**	381	203	131	104	93	88	86	86	85
EW-132	60.96	**1.197**	**1.197**	186	176	167	158	151	144	138	133	128
EW-135	60.96	**1.223**	**1.208**	406	375	347	321	298	277	259	242	226
EW-136	60.96	**1.212**	**1.201**	475	437	402	371	343	317	294	274	255
EW-138	60.96	**1.197**	**1.197**	406	375	346	320	297	276	257	240	225
LSO-01	60.96	**1.223**	**1.208**	244	230	216	203	192	182	172	164	156

Table 8

Concentrations at Point Locations - Years 0 to 40 Post-construction

LPAH (mg/kg OC)[1]				Years Post-construction								
	Mixing Depth	1-year Deposition (cm)		Current Conditions			Future Conditions					
Point	(cm)	Current	Future[1]	0	5	10	15	20	25	30	35	40
EW09-SS-010	10	**1.356**	**1.347**	23.1	22.5	22.2	19.9	19.1	18.8	18.8	18.7	18.7
EW09-SS-012	10	**1.199**	**1.199**	22.5	14.2	10.9	9.5	9.0	8.8	8.7	8.6	8.6
EW09-SS-027	60.96	**1.212**	**1.204**	31.3	29.1	27.1	25.3	23.7	22.2	20.9	19.7	18.6
EW09-SS-038	60.96	**1.197**	**1.197**	21.3	20.0	18.9	17.9	16.9	16.1	15.4	14.7	14.1
EW09-SS-100	60.96	**1.210**	**1.199**	21.9	20.6	19.5	18.4	17.4	16.6	15.8	15.1	14.5
EW09-SS-101	60.96	**1.197**	**1.197**	39.4	36.3	33.6	31.2	28.9	26.9	25.1	23.5	22.0
EW09-SS-110	60.96	**1.197**	**1.197**	19.4	18.3	17.4	16.5	15.7	15.0	14.4	13.8	13.3
EW09-SS-114	60.96	**1.197**	**1.197**	15.6	14.9	14.3	13.7	13.2	12.8	12.4	12.0	11.6
EW09-SS-126	60.96	**1.208**	**1.201**	5.1	5.5	5.9	6.1	6.4	6.6	6.8	7.0	7.2
EW09-SS-211	60.96	**1.197**	**1.197**	17.5	16.6	15.8	15.1	14.5	13.9	13.4	12.9	12.5
EW09-SS-219	60.96	**1.197**	**1.197**	25.0	23.4	21.9	20.6	19.4	18.4	17.4	16.5	15.7
EW-109	60.96	**1.197**	**1.197**	76.9	70.2	64.1	58.7	53.7	49.3	45.3	41.7	38.4
EW-128	10	**1.201**	**1.204**	58.8	28.7	16.7	12.1	10.3	9.5	9.2	9.1	9.1
EW-132	60.96	**1.197**	**1.197**	25.0	23.4	21.9	20.6	19.4	18.4	17.4	16.5	15.7
EW-135	60.96	**1.223**	**1.208**	73.8	67.5	61.8	56.6	51.9	47.7	43.9	40.5	37.4
EW-136	60.96	**1.212**	**1.201**	106.3	96.7	88.0	80.2	73.2	66.9	61.1	56.0	51.3
EW-138	60.96	**1.197**	**1.197**	46.9	43.1	39.7	36.7	33.9	31.4	29.2	27.1	25.3
LSO-01	60.96	**1.223**	**1.208**	58.1	53.4	49.2	45.2	41.7	38.5	35.6	33.0	30.7

Notes:
1. TOC assumed to be 1.6% for the EW.
2. Future deposition is based on expected future source control conditions for EW Laterals.
BEHP – bis(2-ethylhexyl) phthalate
cm – centimeters
DCB – dichlorobenzene
EW – East Waterway
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
mg/kg – milligram per kilogram
OC – organic carbon
PCB – polychlorinated biphenyl

Table 9a

Chemistry Assumptions for Solids Inputs to the EW for Recontamination Potential Evaluation – Current Conditions

Input Location	Contaminant of Concern								
	Arsenic (mg/kg dw)	Mercury (mg/kg dw)	Total HPAHs (µg/kg dw)	Total LPAHs (µg/kg dw)	Total cPAHs (µg TEQ/kg dw)	BEHP (µg/kg dw)	1,4-DCB (µg/kg dw)	Total PCBs (µg/kg dw)	Dioxin/Furan TEQ (ng TEQ/kg dw)
Hinds CSO									
mean[1]	5	1.71	4,000	870	680	6,700	820	260	16
median[2]	6	0.36	2,900	640	430	3,000	260	240	7.6
90th percentile[3]	9	2.57	10,000	1,900	1,500	23,000	2,000	630	37
Lander CSO									
mean[1]	2	0.21	1,800	280	250	1,000	320	11	1.8
median[2]	2	0.25	2,200	220	300	800	230	11	1.8
90th percentile[3]	2	0.26	2,700	500	380	1,700	560	18	2.6
Hanford #2 CSO									
mean[1]	6	2.00	3,900	880	670	7,700	990	270	30
median[2]	6	0.72	3,100	670	540	3,300	320	250	30
90th percentile[3]	9	2.94	6,200	1,600	930	27,000	2,300	510	44
Nearshore SDs[4]									
mean[1]	10	0.09	5,500	1,000	820	8,300	75	160	15
median[2]	10	0.08	4,400	740	550	6,200	17	39	7.9
90th percentile[3]	15	0.14	14,000	1,900	2,100	19,000	180	440	32
S Lander St SD									
mean[1]	9	0.15	14,000	2,600	2,100	12,000	110	120	68
median[2]	10	0.13	5,500	810	670	9,300	90	53	68
90th percentile[3]	20	0.29	17,000	3,400	2,400	21,000	200	280	93
Non-nearshore SDs[5]									
mean[1]	10	0.19	10,000	2,000	1,400	19,000	140	290	68
median[2]	7	0.12	4,000	680	450	9,400	90	58	68
90th percentile[3]	20	0.32	11,000	3,400	1,700	24,000	280	460	93
LDW Laterals[6]									
base	13	0.14	3,900	880	1,400	15,475	990	300	20
low bounding	9	n/a	n/a	n/a	500	n/a	n/a	100	10
high bounding	30	n/a	n/a	n/a	3,400	n/a	n/a	1,000	40
LDW Bed[6]									
base	16	0.53	3,800	700	390	590	23	350	26
Green River									
base	9	0.10	1,300	130	135	120	1.20	42	6
low bounding	7	0.06	160	17	40	75	0.84	5	2
high bounding	10	0.20	1,900	230	270	210	1.30	80	8

Notes:
1. Mean chemistry values are used for Base Case scenarios.
2. Median chemistry values are used for Low Bounding Case scenarios.
3. 90th percentile chemistry values are used for High Bounding Case scenarios.
4. Nearshore SDs include SW Florida St SD (B-21), B-25, all Port SDs, and all private SDs along the waterfront (A-6, B-40, B-41, B-42, and B-43).
5. Non-nearshore SDs include S Hinds St SD, SW Spokane St EOF/SD (B-5), SW Spokane St SD (B-4), S Spokane St SD (B-36), and all bridges (BR-2, BR-4, BR-34, and BR-39).
6. Values for LDW Bed and Laterals are taken from the LDW FS (AECOM 2012).

See EW FS Appendix B, Part 4 for details on EW lateral chemistry analysis, and EW FS Appendix B, Part 3 for Green River chemistry.

µg/kg – microgram per kilogram; BEHP – bis(2-ethylhexyl) phthalate; cPAH – carcinogenic polycyclic aromatic hydrocarbon; CSO – combined sewer overflow; DCB – dichlorobenzene; dw – dry weight; EOF – emergency overflow; EW – East Waterway; FS – Feasibility Study; HPAH- – high-molecular-weight polycyclic aromatic hydrocarbon; LDW – Lower Duwamish Waterway; LPAH – low-molecular-weight polycyclic aromatic hydrocarbon; mg/kg – milligram per kilogram; ng – nanogram; PCB – polychlorinated biphenyl; SD – storm drain; TEQ – toxicity equivalent

Table 9b

Chemistry Assumptions for Solids Inputs to the EW for Recontamination Potential Evaluation – Future Source Control Conditions

Input Location	Contaminant of Concern								
	Arsenic (mg/kg dw)	Mercury (mg/kg dw)	Total HPAHs (µg/kg dw)	Total LPAHs (µg/kg dw)	Total cPAHs (µg TEQ/kg dw)	BEHP (µg/kg dw)	1,4-DCB (µg/kg dw)	Total PCBs (µg/kg dw)	Dioxin/Furan TEQ (ng TEQ/kg dw)
Hinds CSO (same as current conditions)									
mean[1]	5	1.71	4,000	870	680	6,700	820	260	16
median[2]	6	0.36	2,900	640	430	3,000	260	240	7.6
90th percentile[3]	9	2.57	10,000	1,900	1,500	23,000	2,000	630	37
Lander CSO (same as current conditions)									
mean[1]	2	0.21	1,800	280	250	1,000	320	11	1.8
median[2]	2	0.25	2,200	220	300	800	230	11	1.8
90th percentile[3]	2	0.26	2,700	500	380	1,700	560	18	2.6
Hanford #2 CSO (same as current conditions)									
mean[1]	6	2.00	3,900	880	670	7,700	990	270	30
median[2]	6	0.72	3,100	670	540	3,300	320	250	30
90th percentile[3]	9	2.94	6,200	1,600	930	27,000	2,300	510	44
Nearshore SDs (same as current conditions)									
mean[1]	10	0.09	5,500	1,000	820	8,300	75	160	15
median[2]	10	0.08	4,400	740	550	6,200	17	39	7.9
90th percentile[3]	15	0.14	14,000	1,900	2,100	19,000	180	440	32
S Lander St SD (values in BOLD are different than current conditions, all other values same as current conditions)									
mean[1]	9	0.15	**8,600**	**1,600**	2,100	12,000	110	120	**22**
median[2]	10	0.13	5,500	810	670	9,300	90	53	**12**
90th percentile[3]	20	0.29	17,000	3,400	2,400	21,000	200	280	**37**
Non-nearshore SDs (values in BOLD are different than current conditions, all other values same as current conditions)									
mean[1]	**10**	0.16	**6,800**	**1,600**	**930**	**14,000**	140	**200**	**22**
median[2]	**7**	0.12	4,000	680	450	9,400	90	58	**12**
90th percentile[3]	**20**	0.32	11,000	3,400	**1,600**	24,000	**260**	460	**37**
LDW Laterals[6] (same as current conditions)									
base	13	0.14	3,900	880	1,400	15,475	990	300	20
low bounding	9	n/a	n/a	n/a	500	n/a	n/a	100	10
high bounding	30	n/a	n/a	n/a	3,400	n/a	n/a	1,000	40
LDW Bed[6] (same as current conditions)									
base	16	0.53	3,800	700	390	590	23	350	26
Green River (same as current conditions)									
base	9	0.10	1,300	130	135	120	1.20	42	6
low bounding	7	0.06	160	17	40	75	0.84	5	2
high bounding	10	0.20	1,900	230	270	210	1.30	80	8

Notes:
1. Mean chemistry values are used for Base Case scenarios.
2. Median chemistry values are used for Low Bounding Case scenarios.
3. 90th percentile chemistry values are used for High Bounding Case scenarios.
4. Nearshore SDs include SW Florida St SD (B-21), B-25, all Port SDs, and all private SDs along the waterfront (A-6, B-40, B-41, B-42, and B-43).
5. Non-nearshore SDs include S Hinds St SD, SW Spokane St EOF/SD (B-5), SW Spokane St SD (B-4), S Spokane St SD (B-36), and all bridges (BR-2, BR-4, BR-34, and BR-39).
6. Values for LDW Bed and Laterals are taken from the LDW FS (AECOM 2012).

Values are the same as current conditions (grey text) except where noted (**bold black text**).

See EW FS Appendix B, Part 4 for details on EW lateral chemistry analysis, and EW FS Appendix B, Part 3 for Green River chemistry.

µg/kg – microgram per kilogram; BEHP – bis(2-ethylhexyl) phthalate; cPAH – carcinogenic polycyclic aromatic hydrocarbon; CSO – combined sewer overflow; DCB – dichlorobenzene; dw – dry weight; EOF – emergency overflow; EW – East Waterway; FS – Feasibility Study; HPAH – high-molecular-weight polycyclic aromatic hydrocarbon; LDW – Lower Duwamish Waterway; LPAH – ow-molecular-weight polycyclic aromatic hydrocarbon; mg/kg – milligram per kilogram; ng – nanogram; PCB – polychlorinated biphenyl; SD – storm drain; TEQ – toxicity equivalent

Table 10

Calculation of Net Sedimentation Rates Used for Recontamination Potential Evaluation

PTM Model Simulation: Base Case Current Conditions			**PTM Model Simulation: Lower Bound Current Conditions**			**PTM Model Simulation: Upper Bound Current Conditions**		
Calculate total area in EW where PTM model predicts deposition of solids from EW laterals to occur over simulation period:								
Cells with Deposition	949		Cells with Deposition	710		Cells with Deposition	1086	
Area per cell	232	m^2	Area per cell	232	m^2	Area per cell	232	m^2
Total Area of Footprint:	220,525	m^2	Total Area of Footprint:	164,987	m^2	Total Area of Footprint:	252,361	m^2
Calculate the total mass and volume of the deposition of solids from EW lateral sources within the deposition footprint over an annual basis:								
Total Mass (kg)	84,630	per yr	Total Mass (kg)	45,475	per yr	Total Mass (kg)	114,117	per yr
Total Mass (g)	84,629,860	per yr	Total Mass (g)	45,474,710	per yr	Total Mass (g)	114,116,740	per yr
Density	1.5	g/cm^3	Density	1.5	g/cm^3	Density	1.5	g/cm^3
Volume of Solids Deposited	56,419,906	cm^3	Volume of Solids Deposited	30,316,473	cm^3	Volume of Solids Deposited	76,077,826	cm^3
Calculate the net sedimentation rate (cm/yr) of EW lateral sources in the deposition footprint (volume divided by area):								
NSR (laterals)	0.026	cm/yr		0.018	cm/yr		0.030	cm/yr
Total NSR (from upstream and EW lateral sources) taken from evaluation of geochronology core, see Section 5.1.2 in EW FS):								
NSR (Total)	1.20	cm/yr		1.20	cm/yr		1.20	cm/yr
Estimate the NSR due to upstream sources (Green River and LDW laterals) within the deposition footprint as the difference between the EW laterals NSR and the total NSR from geochronology cores:								
NSR (upstream contribution)	**1.175**	**cm/yr**	**NSR (upstream contribution)**	**1.18**	**cm/yr**	**NSR (upstream contribution)**	**1.17**	**cm/yr**

Notes:
cm – centimeters
cm^3 – cubic centimeters
EW – East Waterway
FS – Feasibility Study
g – gram
kg – kilogram
LDW – Lower Duwamish Waterway
m^2 – square meters
NSR – net sedimentation rate
PTM – particle tracking model
yr – year

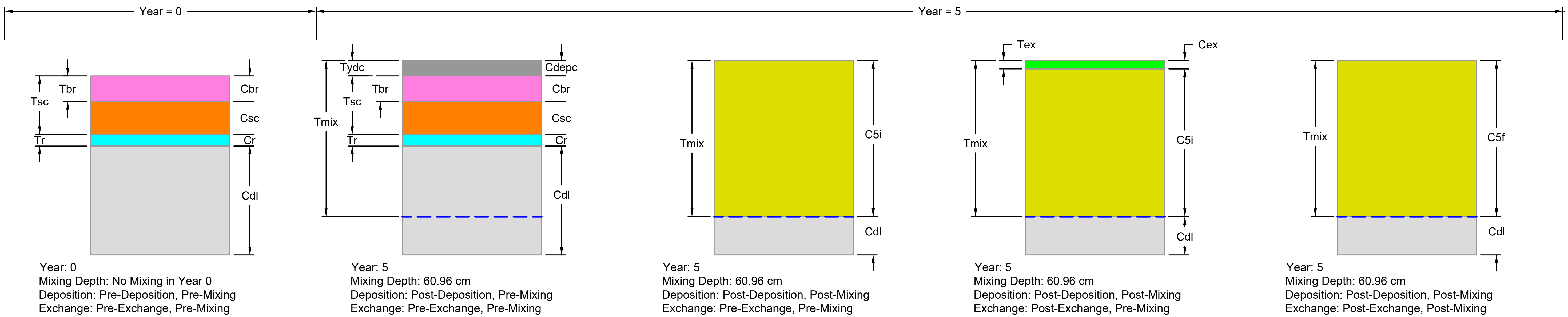
Table 11
Bounding Scenarios for Recontamination Potential Evaluation

Scenario	COC	EW Lateral Deposition[1]	EW Lateral Chemistry[2]	Upstream Deposition[3]	Upstream Chemistry[4]
1a	PCBs	High bound	High bound	1.175 cm/yr (Base)	Base/Mean
1b	PCBs	Low bound	Low bound		
2a	Dioxins/Furans	High bound	High bound		
2b	Dioxins/Furans	Low bound	Low bound		
3a	BEHP	High bound	High bound		
3b	BEHP	Low bound	Low bound		

Notes:
1. EW Lateral Deposition details can be found in Section 4.2 of Appendix J, and Figures 7 to 12 of FS Appendix B.
2. EW Lateral Chemistry details can be found in Section 4.2 and Tables 9a and 9b of Appendix J.
3. Upstream Deposition details can be found in Section 4.2 and Table 10 of Appendix J.
4. Upstream Chemistry details can be found in Section 4.2 and Tables 9a and 9b of Appendix J.

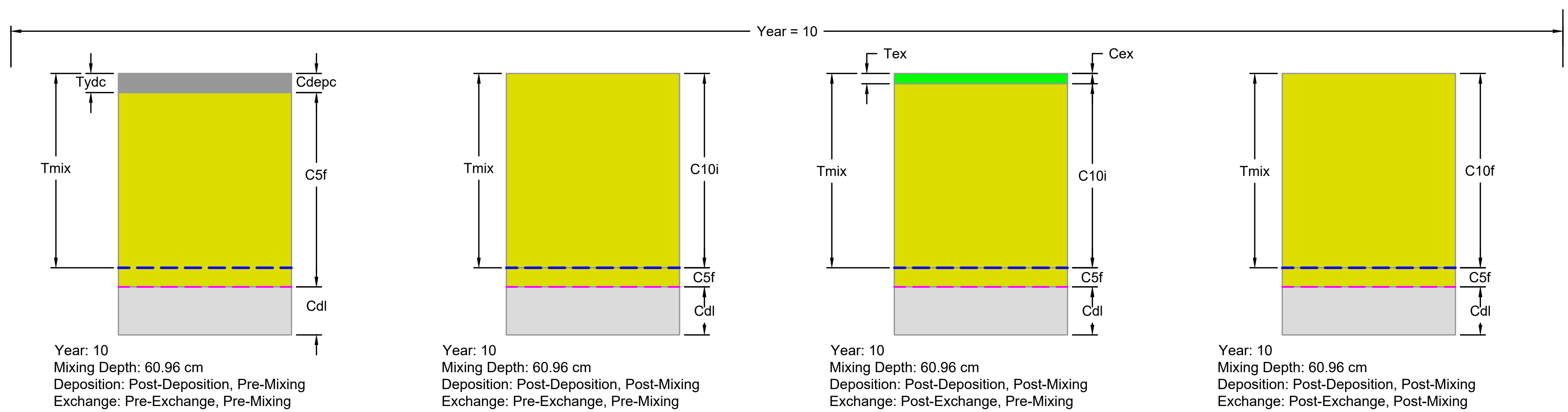
BEHP – bis(2-ethylhexyl)phthalate
cm/yr – centimeters per year
COC – contaminant of concern
EW – East Waterway
FS – Feasibility Study
PCB – polychlorinated biphenyl

FIGURES



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.



LEGEND

- Bed Replacement Layer
- Residuals Management Cover (RMC) Layer
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Csc	Conc. of Residuals Management Cover (RMC)
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Residuals Management Cover (RMC, 9 in = 23 cm)
Tr	Depth of Dredge Residual Sediment (5.1 cm minus 10% loss during placement for the base case)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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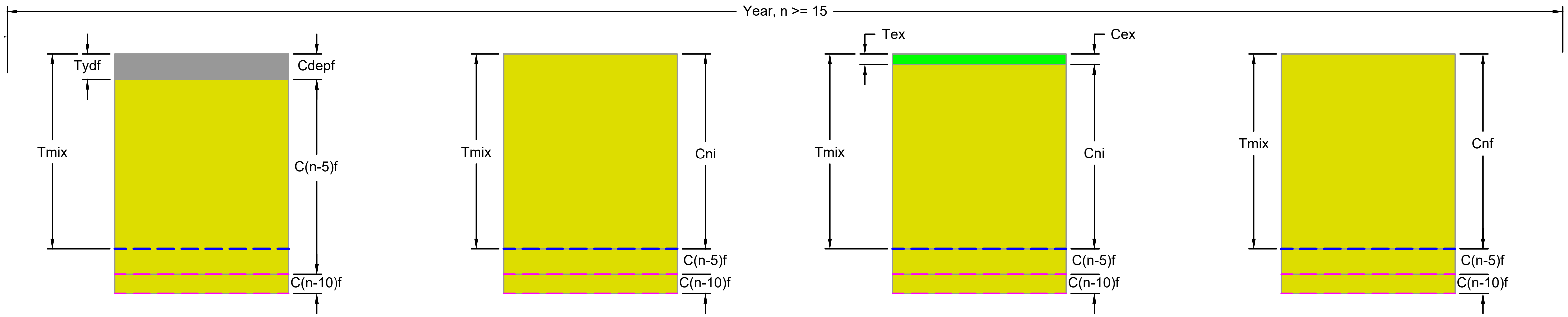
Figure 1a
Box Model: Removal Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



Year: n >=15
Mixing Depth: 60.96 cm
Deposition: Post-Deposition, Pre-Mixing
Exchange: Pre-Exchange, Pre-Mixing

Year: n >=15
Mixing Depth: 60.96 cm
Deposition: Post-Deposition, Post-Mixing
Exchange: Pre-Exchange, Pre-Mixing

Year: n >=15
Mixing Depth: 60.96 cm
Deposition: Post-Deposition, Post-Mixing
Exchange: Post-Exchange, Pre-Mixing

Year: n >=15
Mixing Depth: 60.96 cm
Deposition: Post-Deposition, Post-Mixing
Exchange: Post-Exchange, Post-Mixing

NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See other Figures for years 0 through 10; applies to Figures 1a, 1c, 1d, 1e, and 1j.

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Residuals Management Cover (RMC, 9 in = 23 cm)
Tr	Depth of Dredge Residual Sediment (5.1 cm minus 10% loss during placement for the base case)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

LEGEND

- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cdepf	Conc. of Depositional Sediment (Future Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tydf	Depth of Depositional Sediment (Future Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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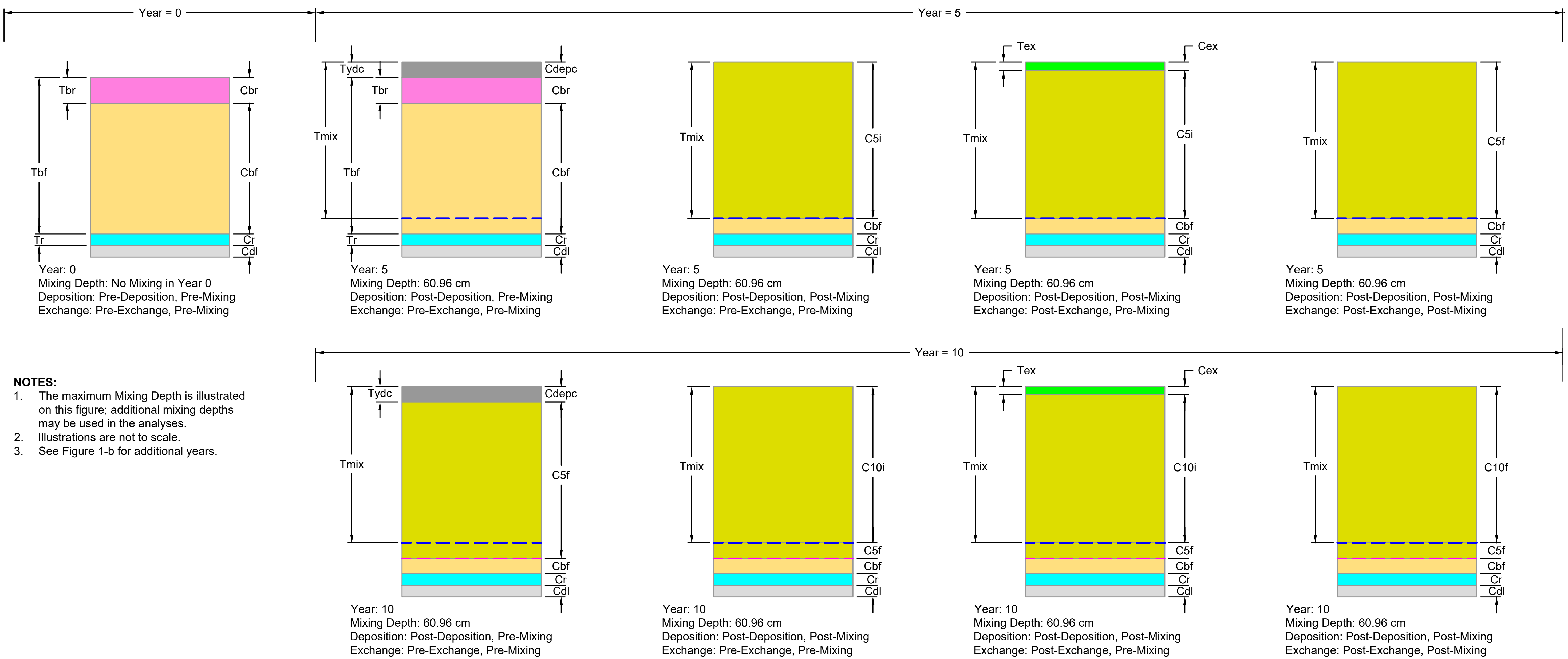
Figure 1b
Box Model: Select Remedies Beyond Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.

LEGEND

- Bed Replacement Layer
- Placement Layer
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Cbf	Conc. of Placement Layer
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tbf	Depth of Backfill (Location Specific but Greater Than 61 cm Mixing Depth)
Tr	Depth of Dredge Residual Sediment (5.1 cm minus 10% loss during placement for the base case)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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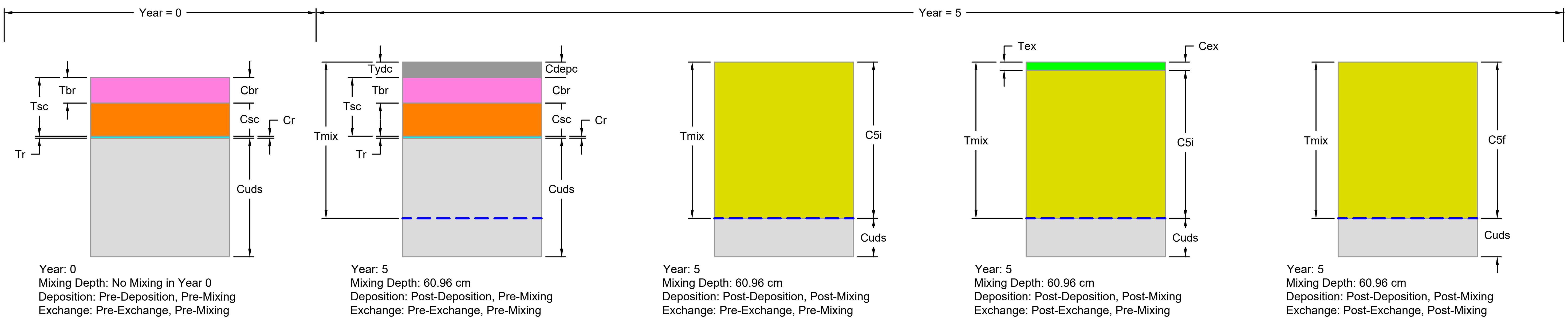
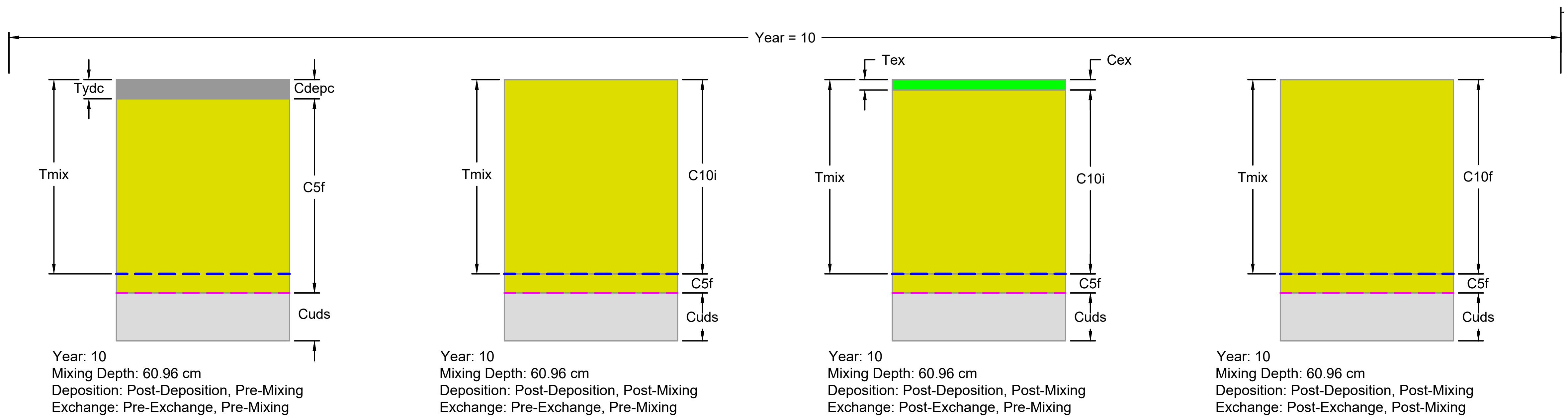
Figure 1c
Box Model: Removal and Fill to Existing Contours Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.



LEGEND
- Bed Replacement Layer
- Residuals Management Cover (RMC) Layer
- Dredge Residuals Layer
- In-Situ (Undisturbed) Sediment
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

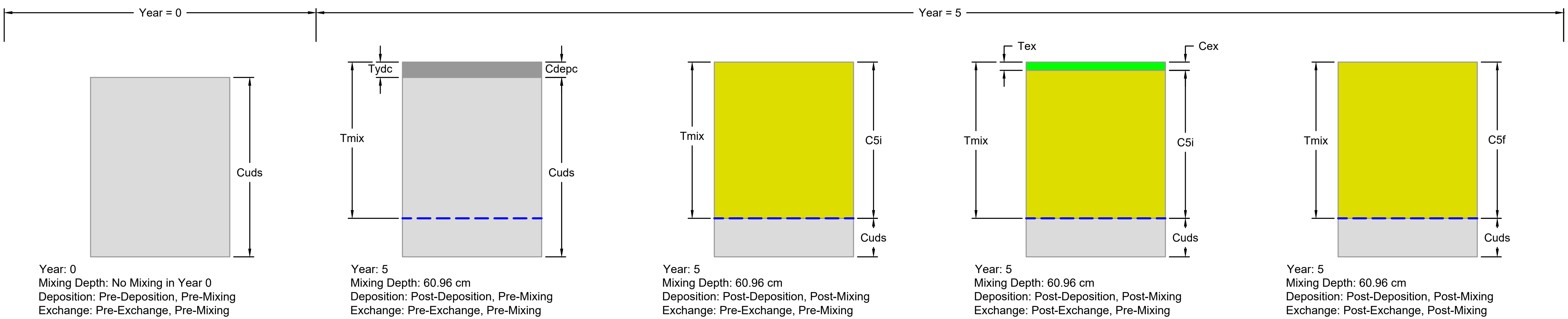
CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Csc	Conc. of Residuals Management Cover (RMC)
Cr	Conc. of Dredge Residual Sediment
Cuds	Conc. of In-Situ Undisturbed Sediment
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

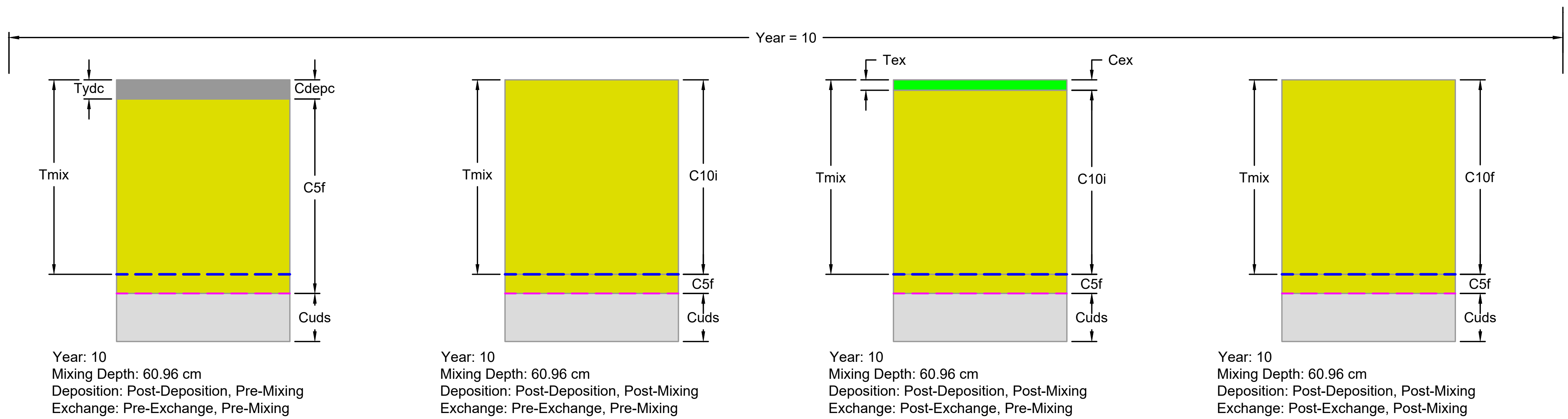
DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Residuals Management Cover (RMC, 9 in = 23 cm)
Tr	Depth of Dredge Residual Sediment (5.1 cm minus 10% loss during placement for the base case)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

Figure 1d
Box Model: No Action (Open Water; Internal Unremediated Islands) Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.



LEGEND

- In-Situ (Undisturbed) Sediment
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cuds	Conc. of In-Situ Undisturbed Sediment
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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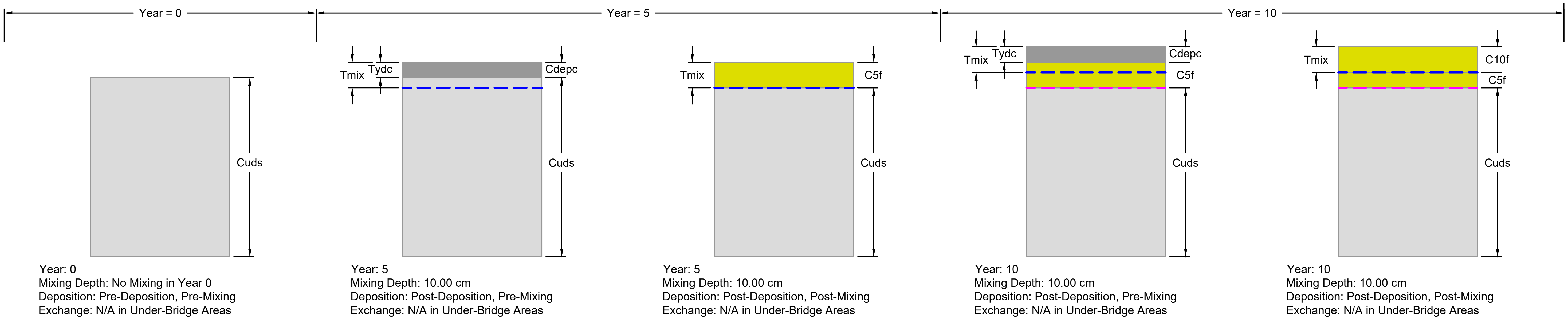
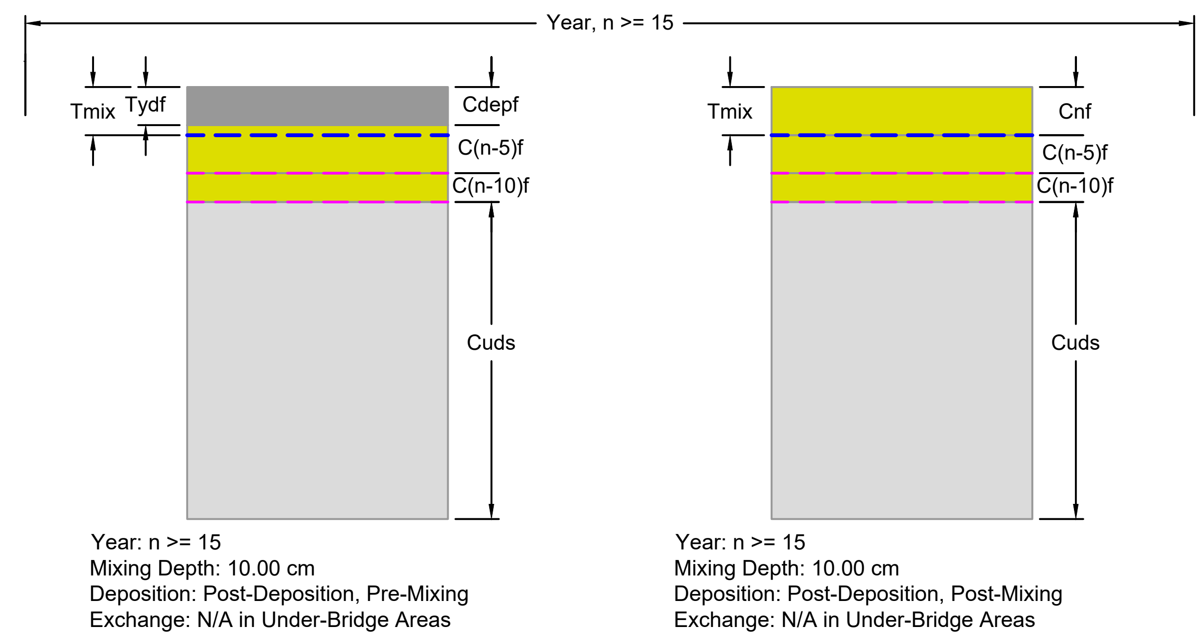
Figure 1e
Box Model: No Action (External Unremediated Areas) Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.



LEGEND

- In-Situ (Undisturbed) Sediment
- Depositional Sediment Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cuds	Conc. of In-Situ Undisturbed Sediment
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cdepf	Conc. of Depositional Sediment (Future Conditions)
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tydf	Depth of Depositional Sediment (Future Conditions, 1.2 cm/ year for the base case)
Tmix	Vertical Depth of Mixing (10 cm)

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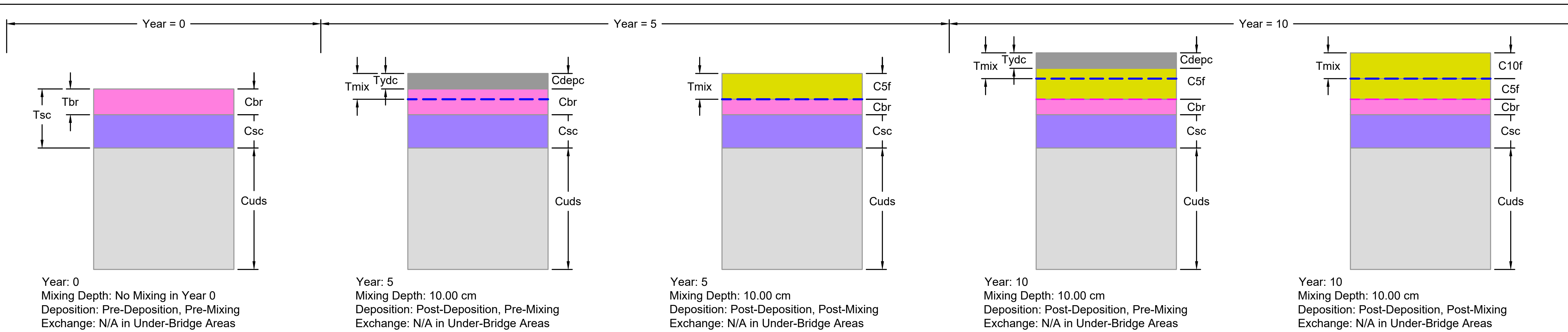
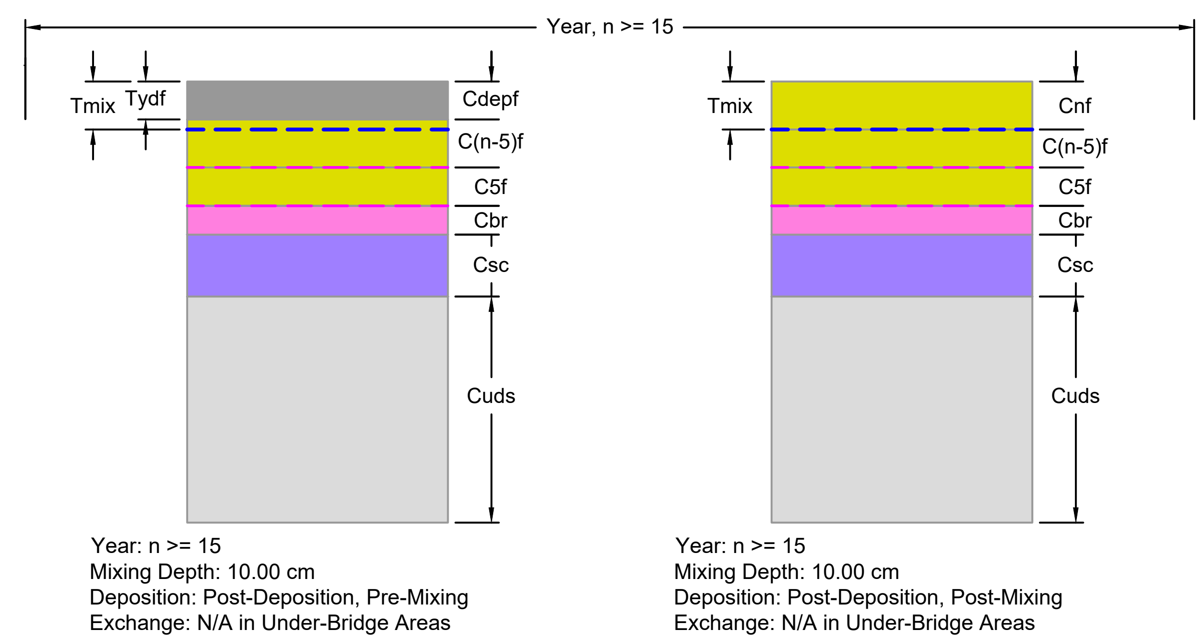
Figure 1f
Box Model: Monitored Natural Recovery (MNR) in the Sill Reach All Years
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.



LEGEND
- Bed Replacement Layer
- Enhanced Natural Recovery (ENR) Layer
- In-Situ (Undisturbed) Sediment
- Depositional Sediment Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Csc	Conc. of Enhanced Natural Recovery (ENR) Layer
Cuds	Conc. of In-Situ Undisturbed Sediment
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cdepf	Conc. of Depositional Sediment (Future Conditions)
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Enhanced Natural Recovery (ENR) Layer (9 in = 23 cm)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tydf	Depth of Depositional Sediment (Future Conditions, 1.2 cm/ year for the base case)
Tmix	Vertical Depth of Mixing (10 cm)

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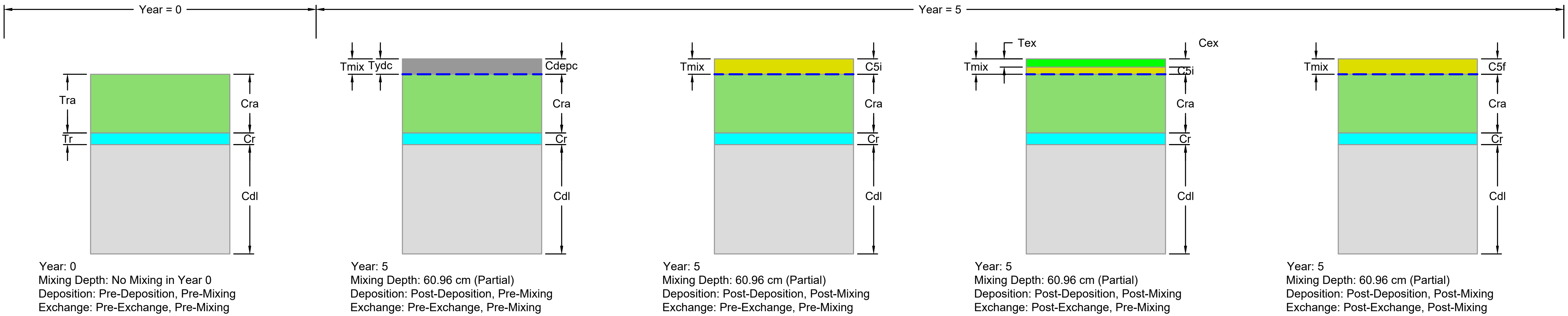
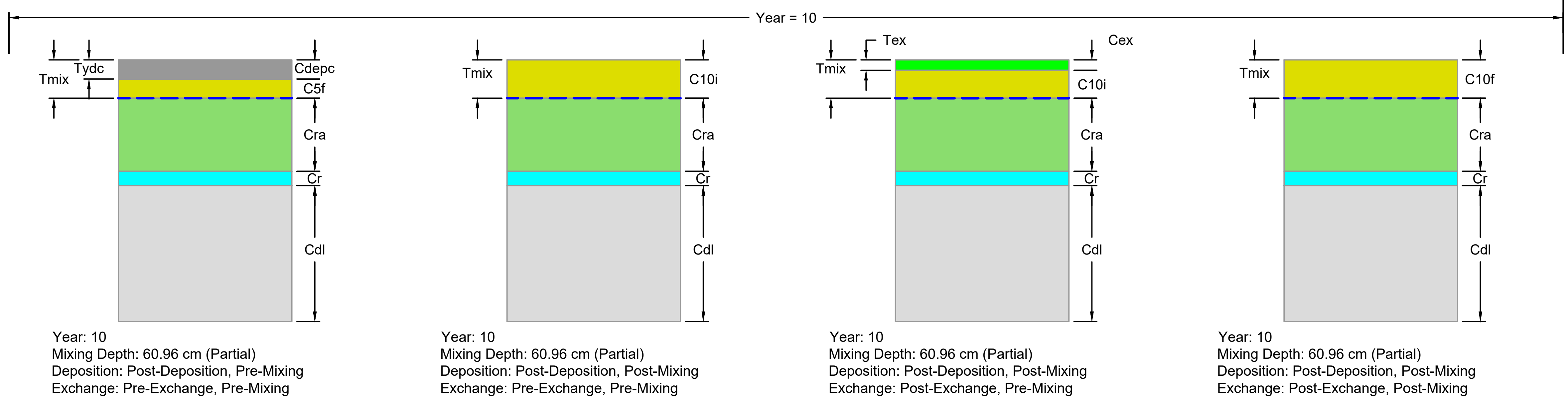
Figure 1g
Box Model: Enhanced Natural Recovery in the Sill Reach (ENR-sill) All Years
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. Mixing depth is limited to the top of the Cap Placement Layer.
4. See Figure 1i for additional years.



LEGEND

- Cap Placement Layer (Including Armor Rock)
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

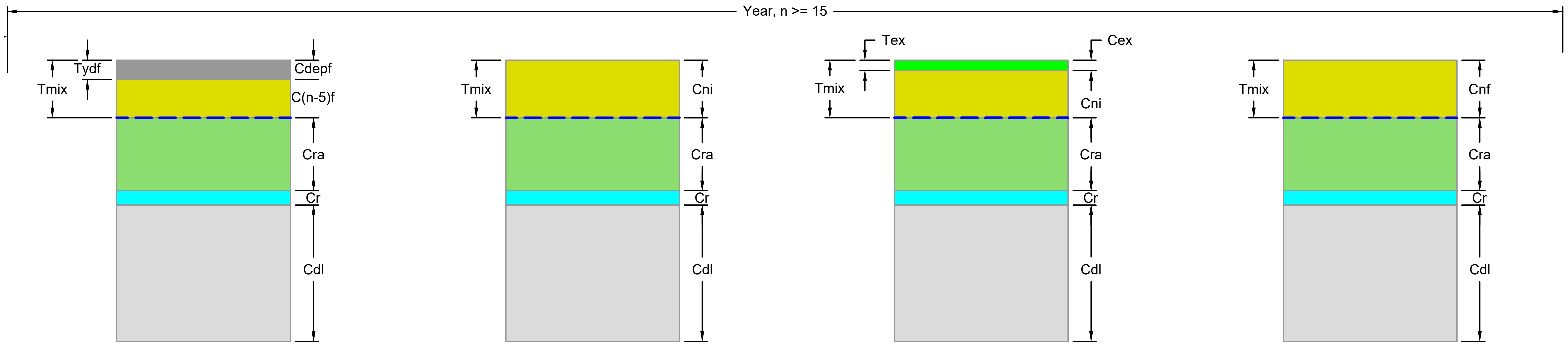
CONCENTRATION VARIABLES

Cra	Conc. of Cap Placements (Including Armor Rock)
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tra	Depth of Cap Placements (Including Armor Rock, depth n/a - armored)
Tr	Depth of Dredge Residual Sediment (depth n/a - isolated in armored cap)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (up to 10 cm to 61 cm depending on the location; maximum depth of mixing down to the cap armor)

Figure 1h
Box Model: Partial Removal and Cap Through Year 10
Feasibility Study - Appendix J
East Waterway Study Area



Year: n>=15
Mixing Depth: 60.96 cm (Partial)
Deposition: Post-Deposition, Pre-Mixing
Exchange: Pre-Exchange, Pre-Mixing

Year: n>=15
Mixing Depth: 60.96 cm (Partial)
Deposition: Post-Deposition, Post-Mixing
Exchange: Pre-Exchange, Pre-Mixing

Year: n>=15
Mixing Depth: 60.96 cm (Partial)
Deposition: Post-Deposition, Post-Mixing
Exchange: Post-Exchange, Pre-Mixing

Year: n>=15
Mixing Depth: 60.96 cm (Partial)
Deposition: Post-Deposition, Post-Mixing
Exchange: Post-Exchange, Post-Mixing

NOTES:
1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. Mixing depth is limited to the top of the Cap Placement Layer.
4. See Figure 1h for years 0 through 10.

LEGEND

Cap Placement Layer (Including Armor Rock)
Dredge Residuals Layer
In-Situ Sediment Below Dredge Neatline
Depositional Sediment Layer
Exchanged Under-Pier Depositional Layer
Homogeneous Mixed Sediment Layer
Vertical Limit of Mix Depth
Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cra	Conc. of Cap Placements (Including Armor Rock)
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepf	Conc. of Depositional Sediment (Future Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tra	Depth of Cap Placements (Including Armor Rock, depth n/a - armored)
Tr	Depth of Dredge Residual Sediment (depth n/a - isolated in armored cap)
Tydf	Depth of Depositional Sediment (Future Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (up to 10 cm to 61 cm depending on the location; maximum depth of mixing down to the cap armor)

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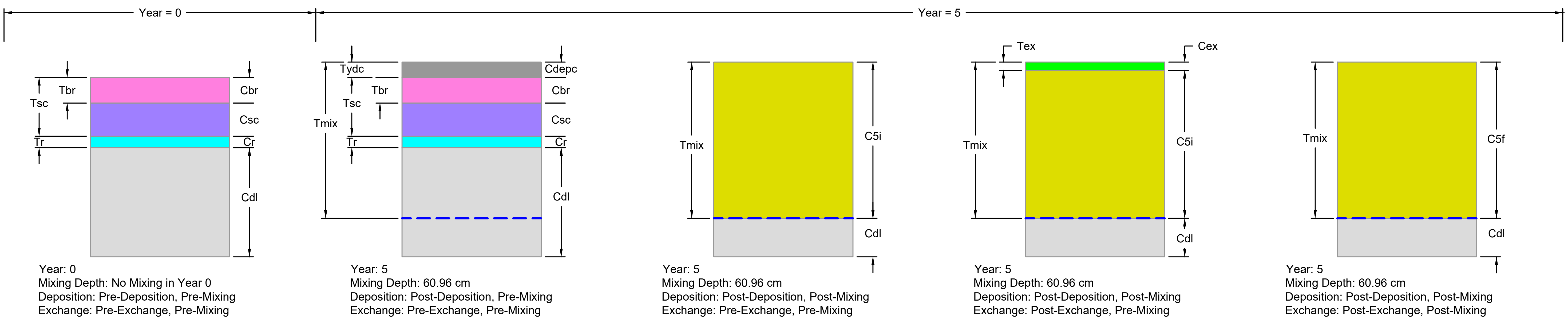
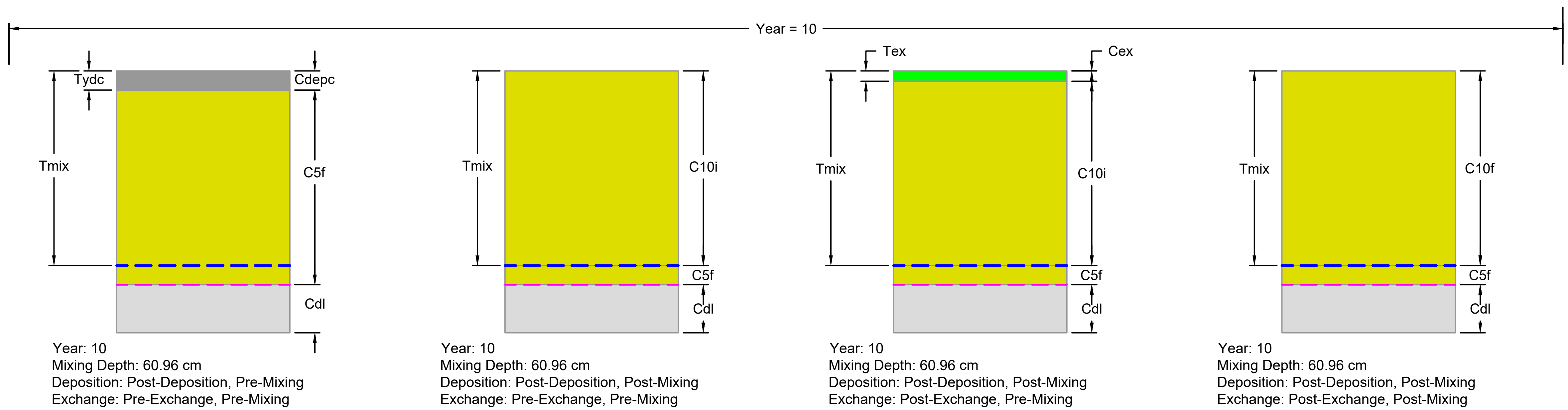
Figure 1i
Box Model: Partial Removal and Cap Beyond Year 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:

1. The maximum Mixing Depth is illustrated on this figure; additional mixing depths may be used in the analyses.
2. Illustrations are not to scale.
3. See Figure 1-b for additional years.



LEGEND

- Bed Replacement Layer
- Enhanced Natural Recovery (ENR) Layer
- Dredge Residuals Layer
- In-Situ Sediment Below Dredge Neatline
- Depositional Sediment Layer
- Exchanged Under-Pier Depositional Layer
- Homogeneous Mixed Sediment Layer
- Vertical Limit of Mix Depth
- Vertical Limit of Previous Mix Depth

CONCENTRATION VARIABLES

Cbr	Conc. of Bed Replacement Layer
Csc	Conc. of Enhanced Natural Recovery (ENR) Layer
Cr	Conc. of Dredge Residual Sediment
Cdl	Conc. of In-Situ Sediment Below Dredge Neatline
Cdepc	Conc. of Depositional Sediment (Current Conditions)
Cex	Conc. of Exchanged Sediment (Under-Pier / Open-Water)
Cni	Conc. of Mixed Sediments at Year n, Intermediate Value
Cnf	Conc. of Mixed Sediments at Year n, Final Value

DEPTH VARIABLES

Tbr	Depth of Bed Replacement Layer (10 cm)
Tsc	Depth of Enhanced Natural Recovery (ENR) Layer (18 in = 46 cm)
Tr	Depth of Dredge Residual Sediment (in ENR-nav areas, 1.0 cm minus 10% loss during placement for the base case; in partial removal and ENR-nav areas, 5.1 cm minus 10% loss during placement for the basecase)
Tydc	Depth of Depositional Sediment (Current Conditions, 1.2 cm/ year for the base case)
Tex	Depth of Exchanged Sediment (Under-Pier / Open-Water, 0.4 cm to 2 cm per year depending on the alternative)
Tmix	Vertical Depth of Mixing (10 cm to 61 cm depending on the location; 61 cm shown in this example)

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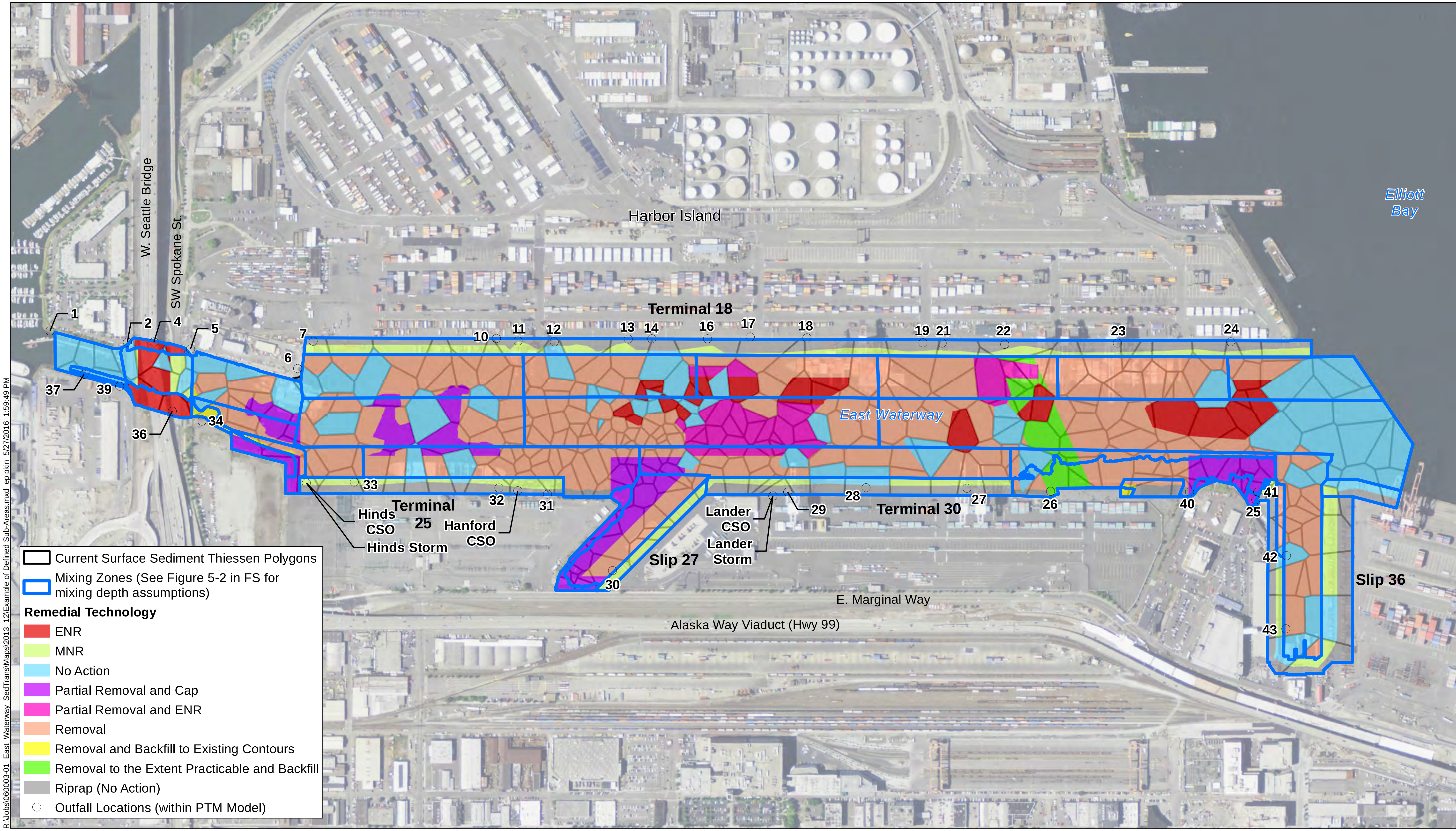
Figure 1j

Box Model: Enhanced Natural Recovery Navigation (ENR-nav) All Years

Feasibility Study - Appendix J

East Waterway Study Area



R:\Jobs\060003-01_East_Waterway_SedTrans\Maps\2013_12\Example of Defined Sub-Areas.mxd epipkin 5/27/2016 1:59:49 PM

NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Remedial technology sub-areas shown are for Alternative 3 (see Map 9-2 in Section 8 of the FS).
4. Current surface sediment thiessen polygons presented are for

0 500 1,000
Scale in Feet

Figure 2
Example of Development of Box-model Sub-areas based on Alternative 1A(12)
Feasibility Study - Appendix J
East Waterway Study Area

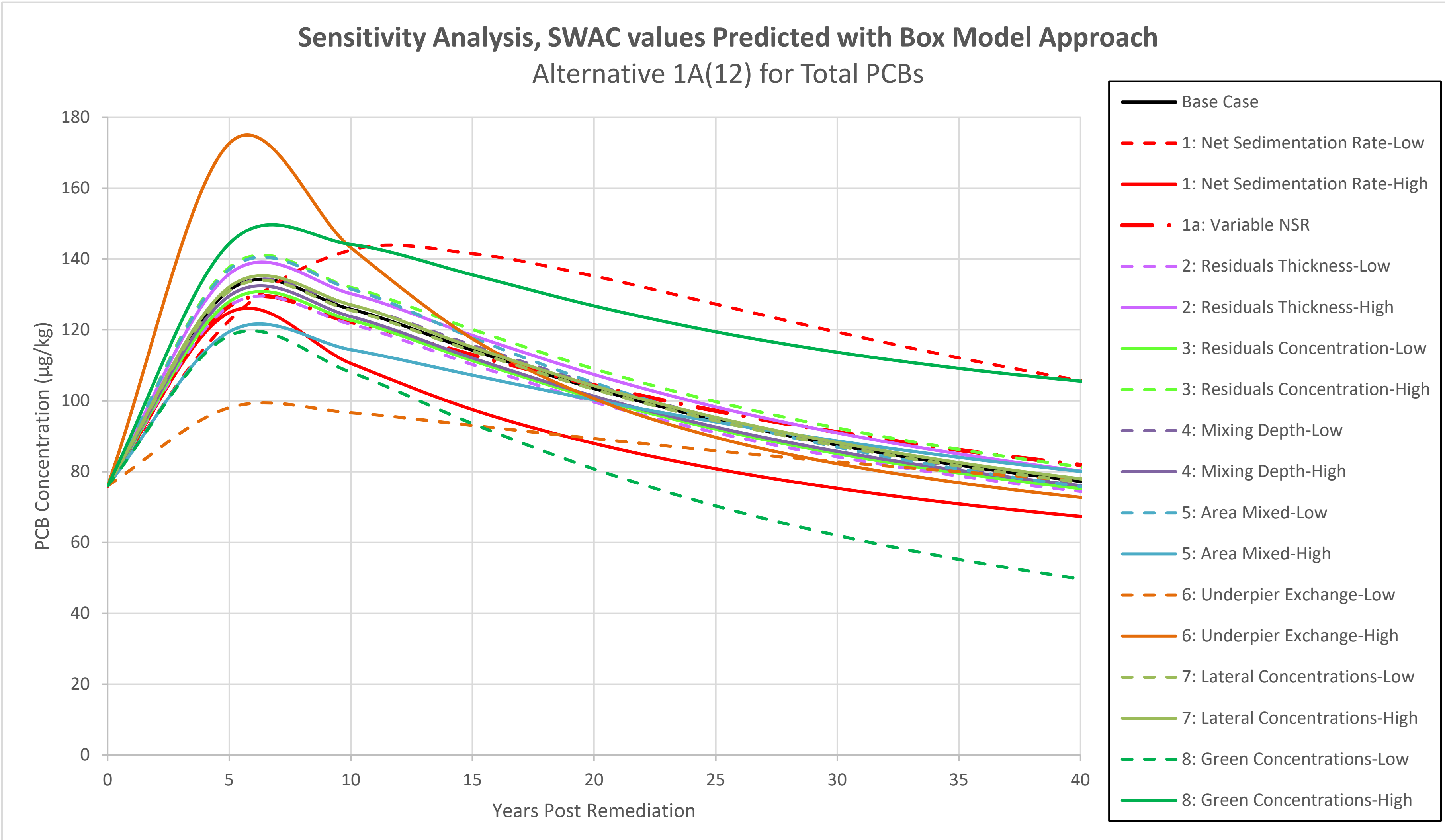


Figure 3a
Sensitivity Analysis, SWAC Values Predicted with Box Model Approach, Alternative 1A(12)
Feasibility Study - Appendix J
East Waterway Study Area

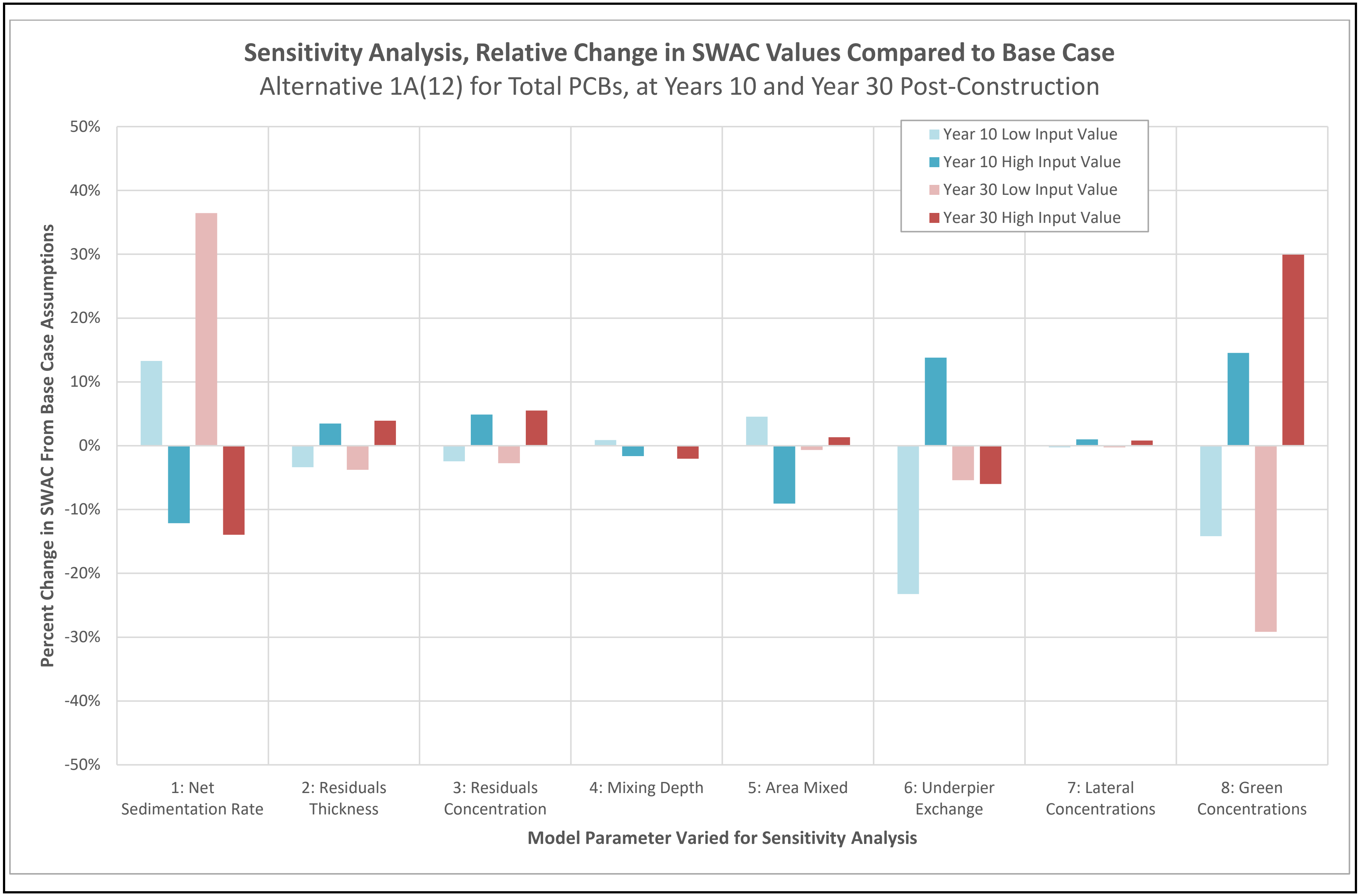


Figure 3b
Sensitivity Analysis, Relative Change in SWAC Values Compared to Base Case, Alternative 1A(12)
Feasibility Study - Appendix J
East Waterway Study Area

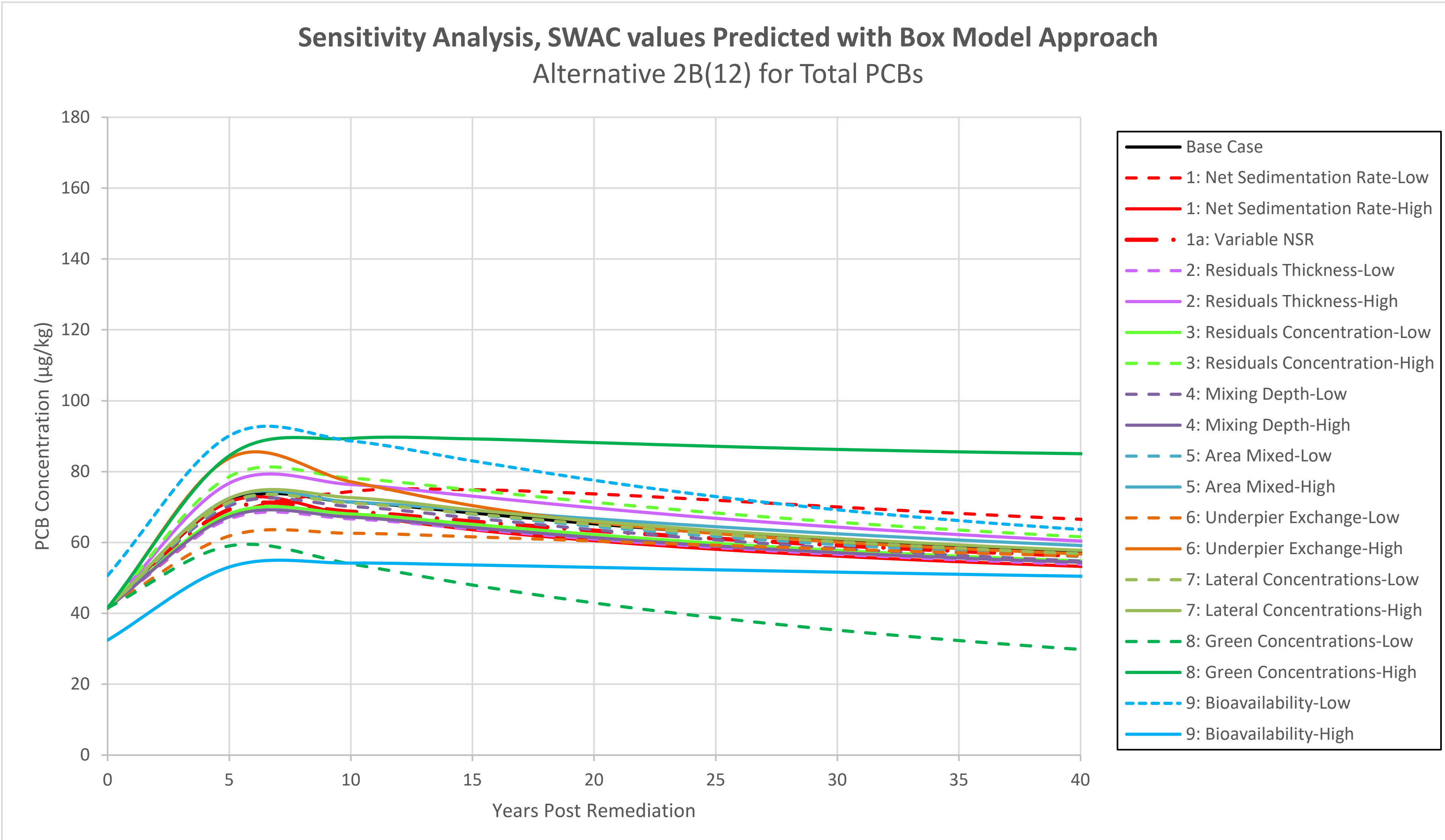


Figure 4a
Sensitivity Analysis, SWAC Values Predicted with Box Model Approach, Alternative 2B(12)
Feasibility Study - Appendix J
East Waterway Study Area

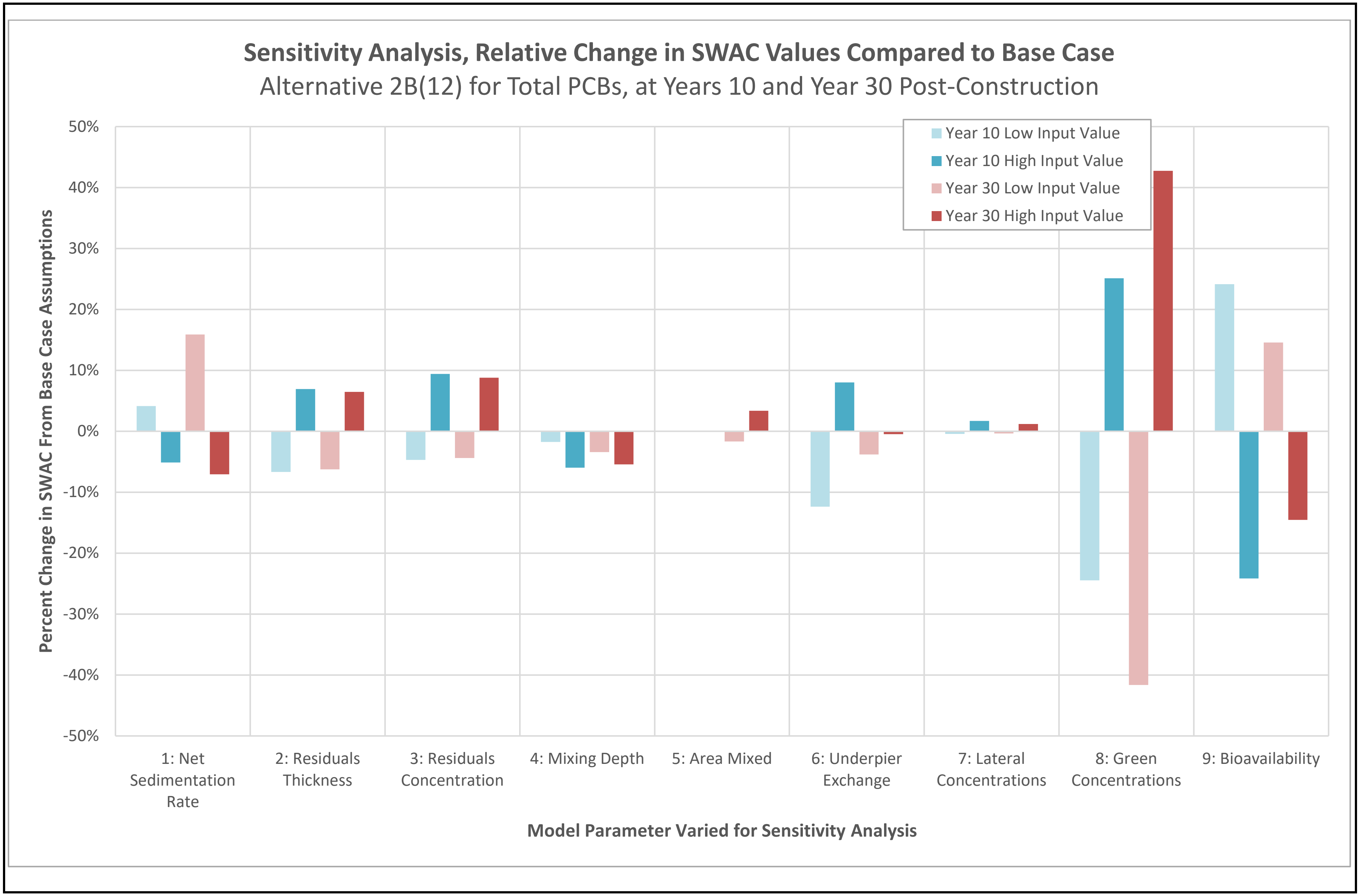


Figure 4b
Sensitivity Analysis, Relative Change in SWAC Values Compared to Base Case, Alternative 2B(12)
Feasibility Study - Appendix J
East Waterway Study Area

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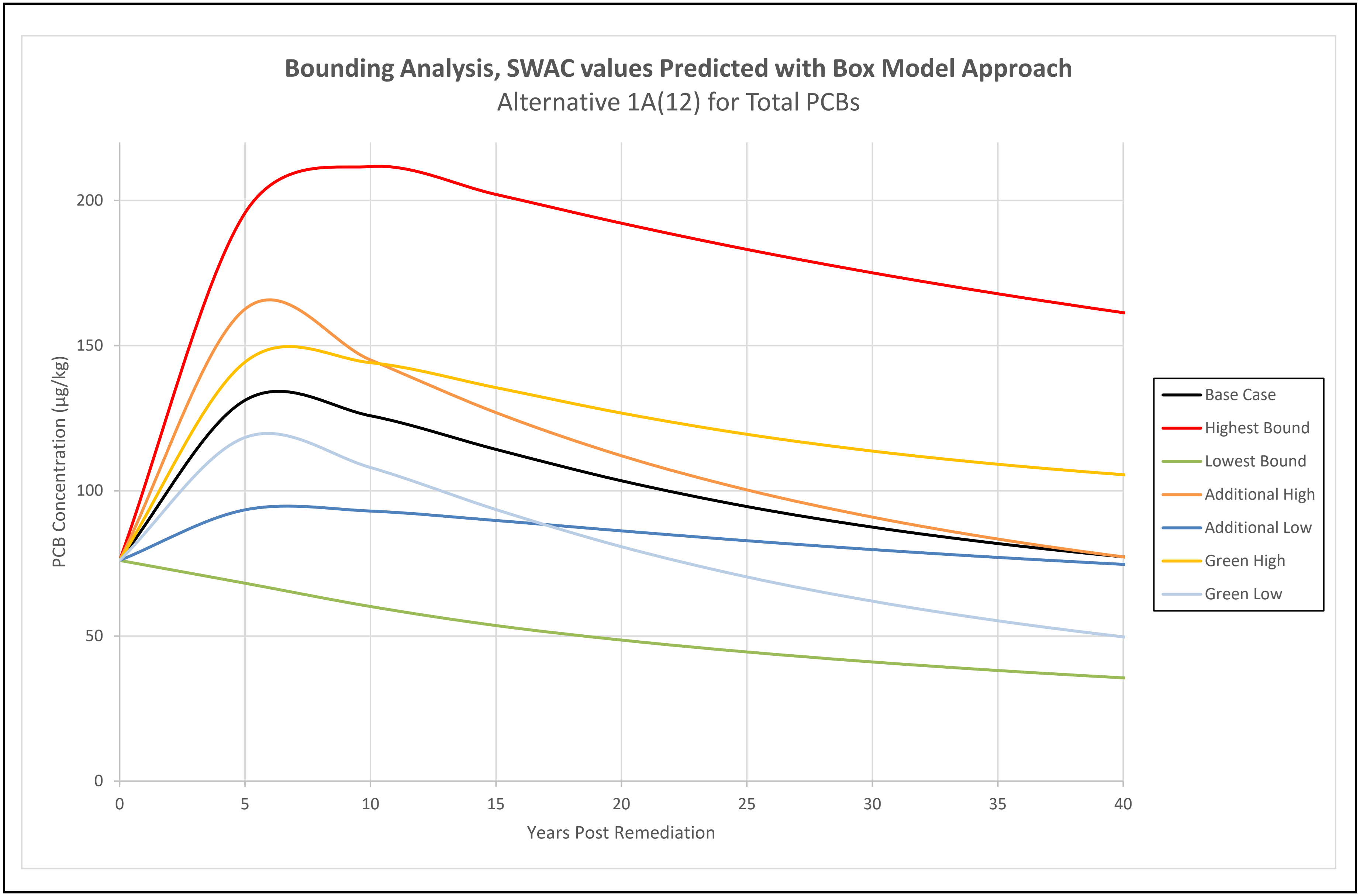


Figure 5a
Bounding Analysis, SWAC Values Predicted with Box Model Approach, Alternative 1A(12)
Feasibility Study - Appendix J
East Waterway Study Area

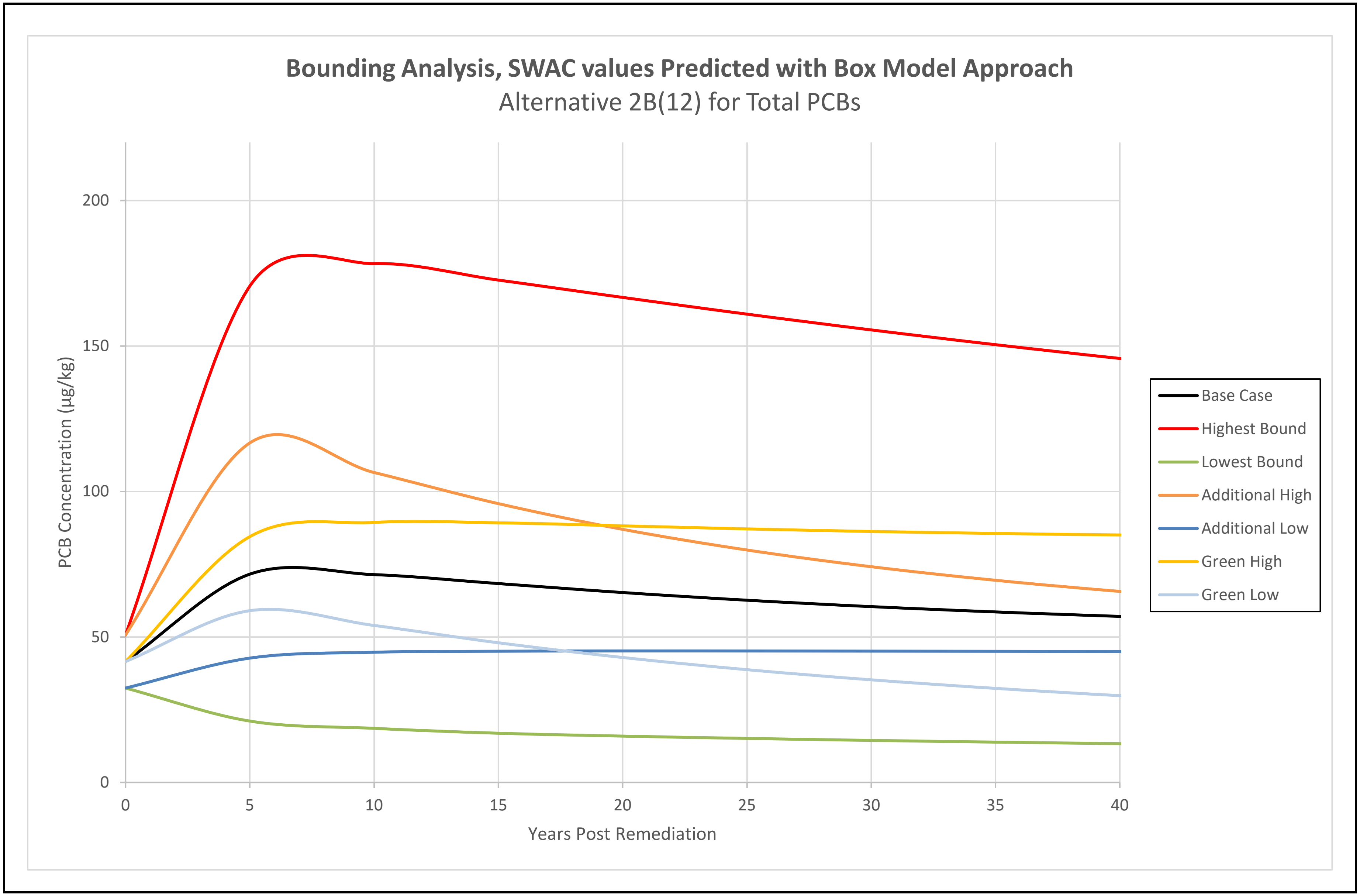


Figure 5b
Bounding Analysis, SWAC Values Predicted with Box Model Approach, Alternative 2B(12)
Feasibility Study - Appendix J
East Waterway Study Area

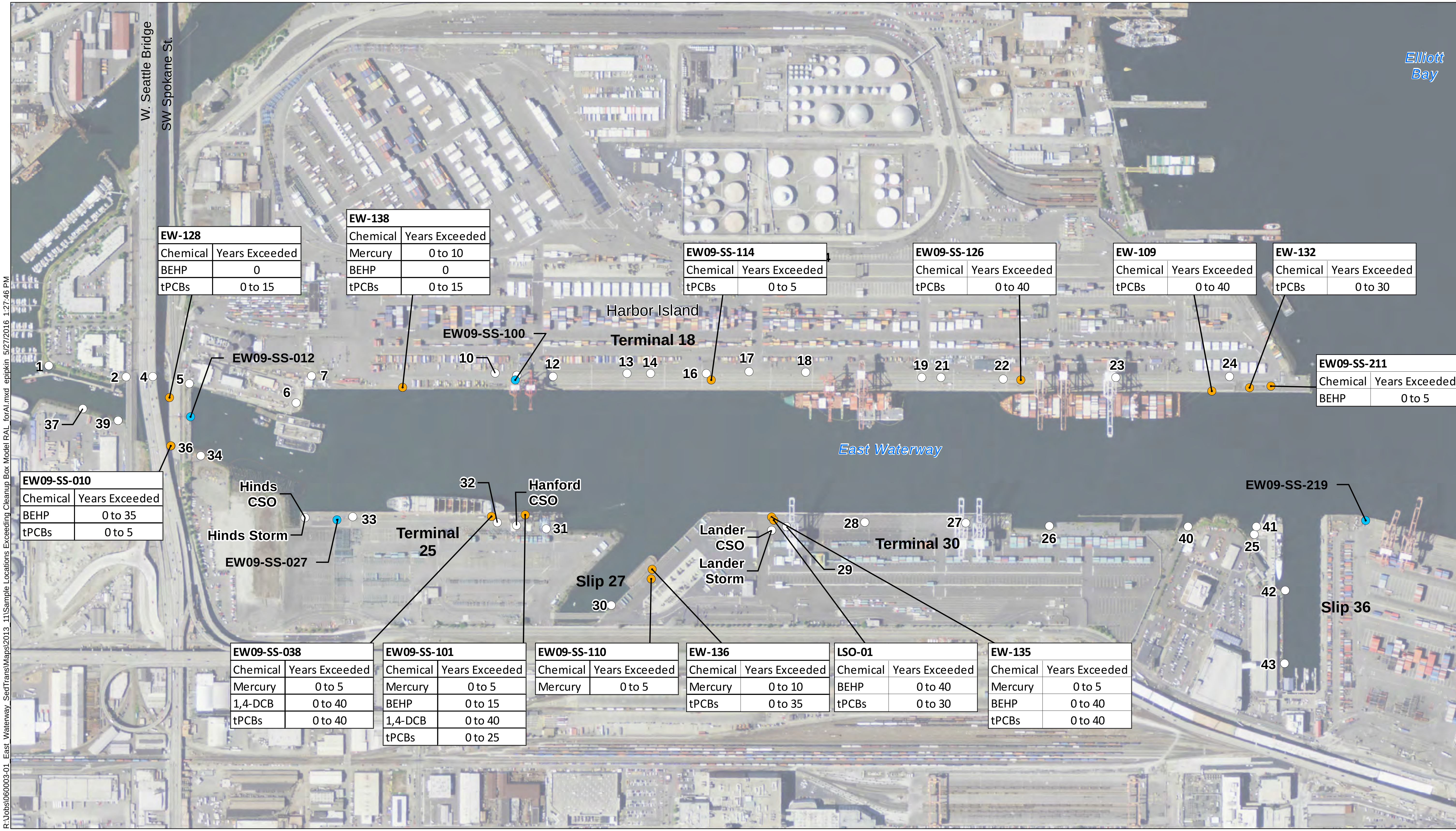
NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.

● Point Mixing Model Sample Location
○ Outfall Locations (within PTM Model)

0 500 1,000
Scale in Feet

N

Figure 6
Point Mixing Model Sample Locations
Feasibility Study - Appendix J
East Waterway Study Area

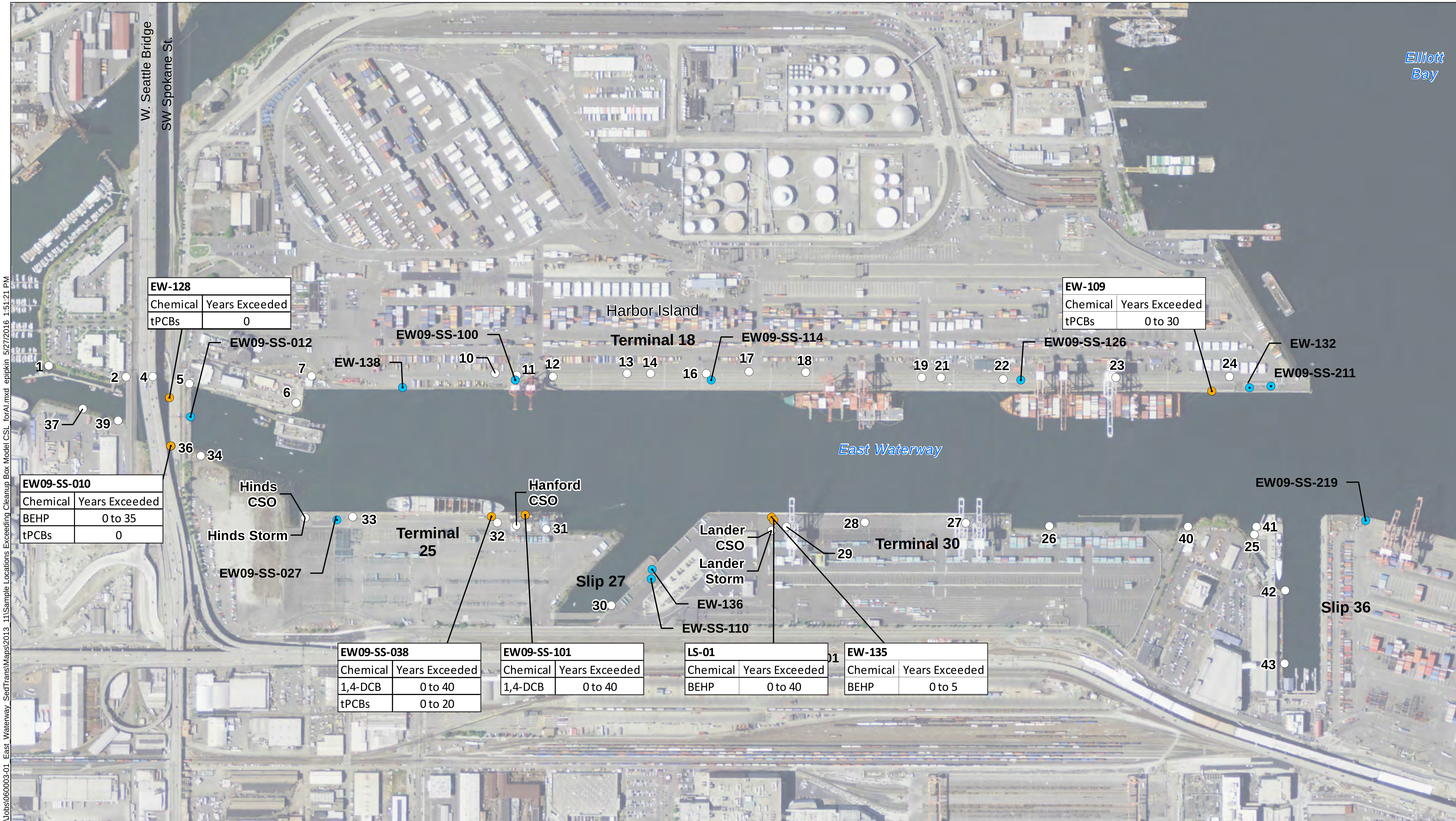


NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Only COCs predicted to exceed the RAL are shown; other COCs that are not predicted to exceed the RAL are not shown.

- Sample Location
- Sample Location with RAL Exceedance
- Outfall Locations (within PTM Model)

0 500 1,000
Scale in Feet

Figure 7a
Point Mixing Model Results, Benthic RAL Exceedances
Feasibility Study - Appendix J
East Waterway Study Area



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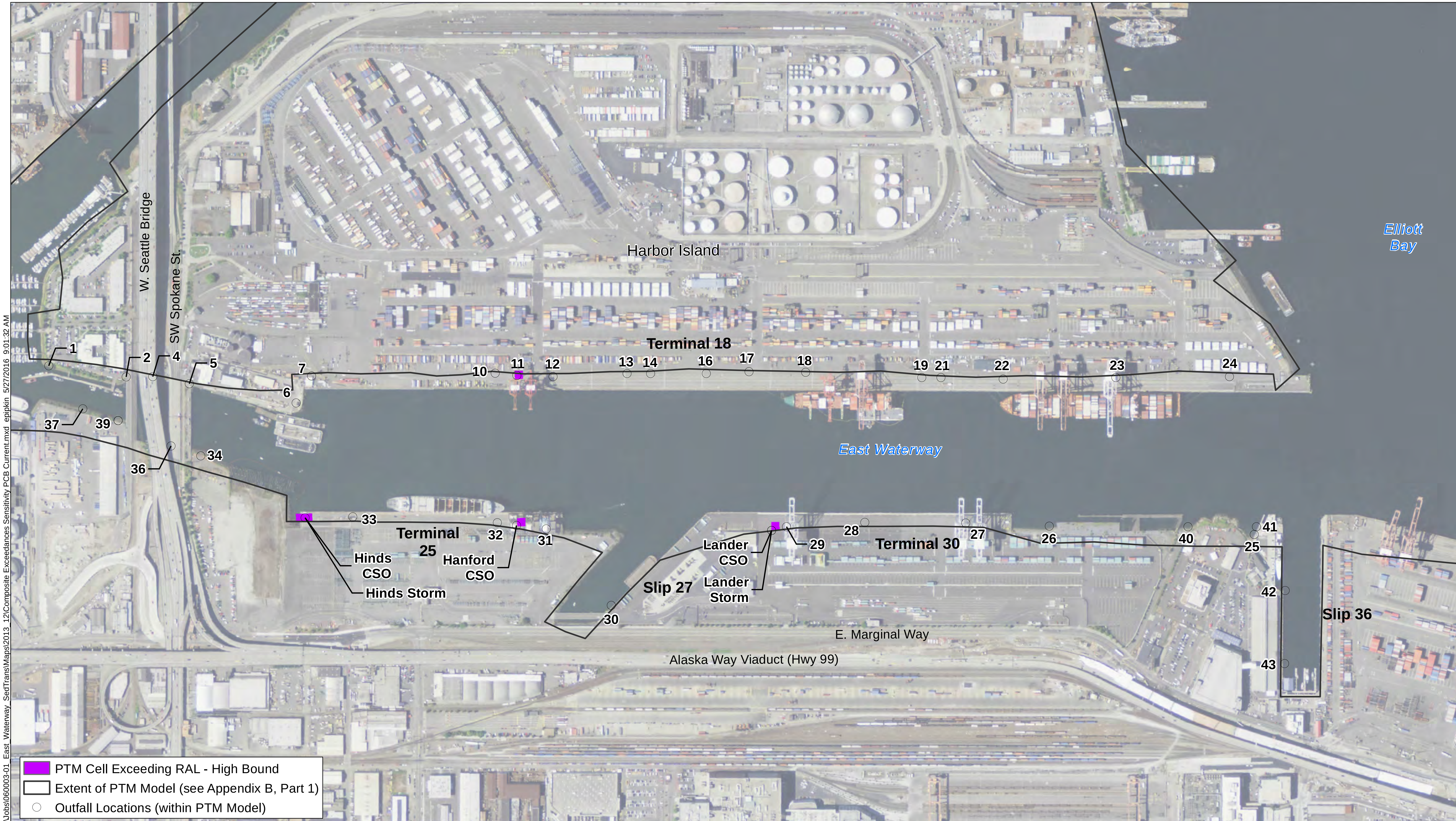
NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Only COCs predicted to exceed the CSL are shown; other COCs that are not predicted to exceed the CSL are not shown.

- Sample Location
- Sample Location with CSL Exceedance
- Outfall Locations (within PTM Model)

0 500 1,000

Scale in Feet

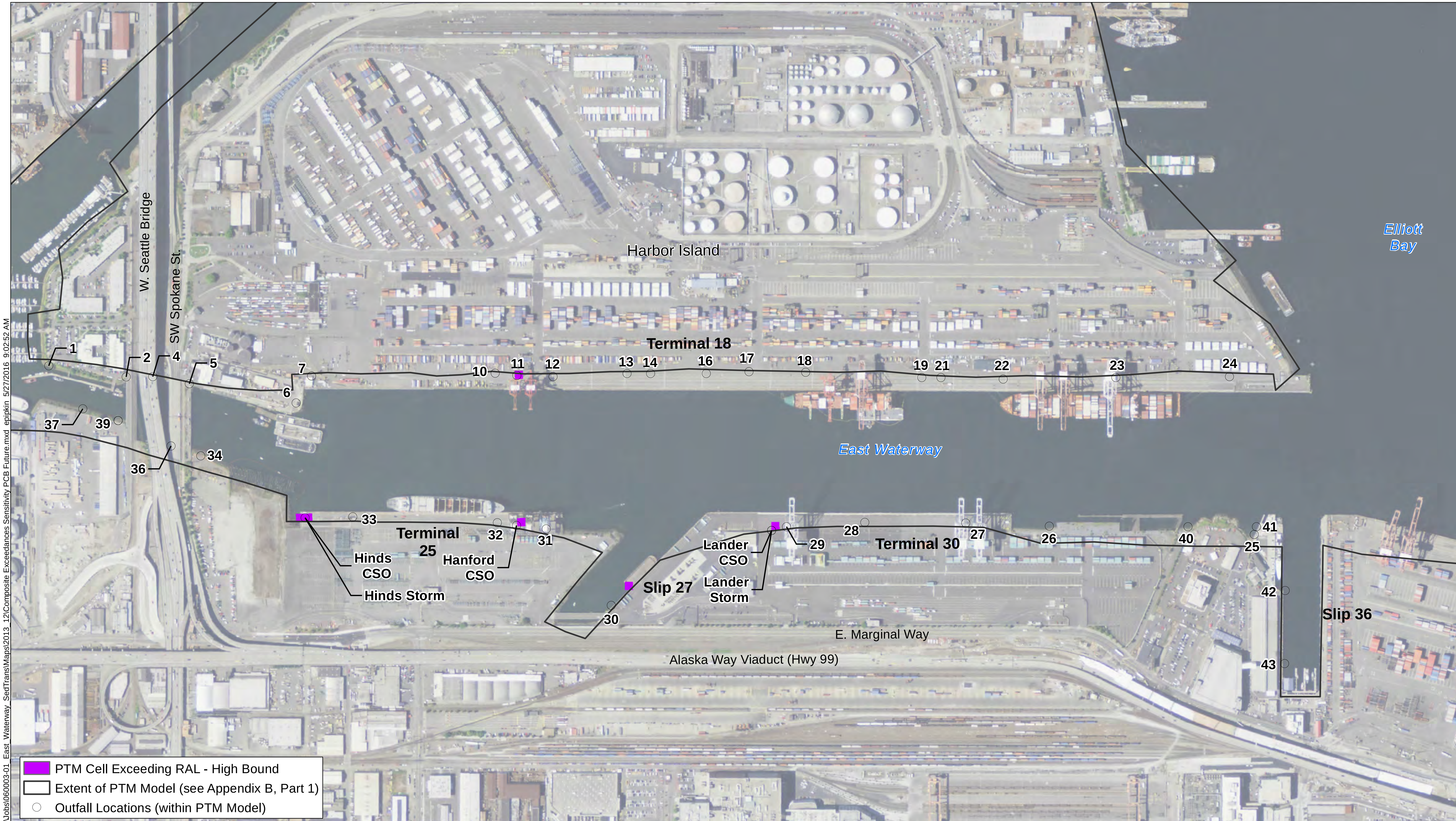
Figure 7b
Point Mixing Model Results, Benthic CSL Exceedances
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. tPCB SQS is 12 mg/kg-OC.
4. RAL is equal to SQS.
5. No Exceedences for Low Bound Simulation.

0 500 1,000
Scale in Feet

Figure 8a
Grid Model Bounding Analysis, tPCB Years 0 to 10
Feasibility Study - Appendix J
East Waterway Study Area

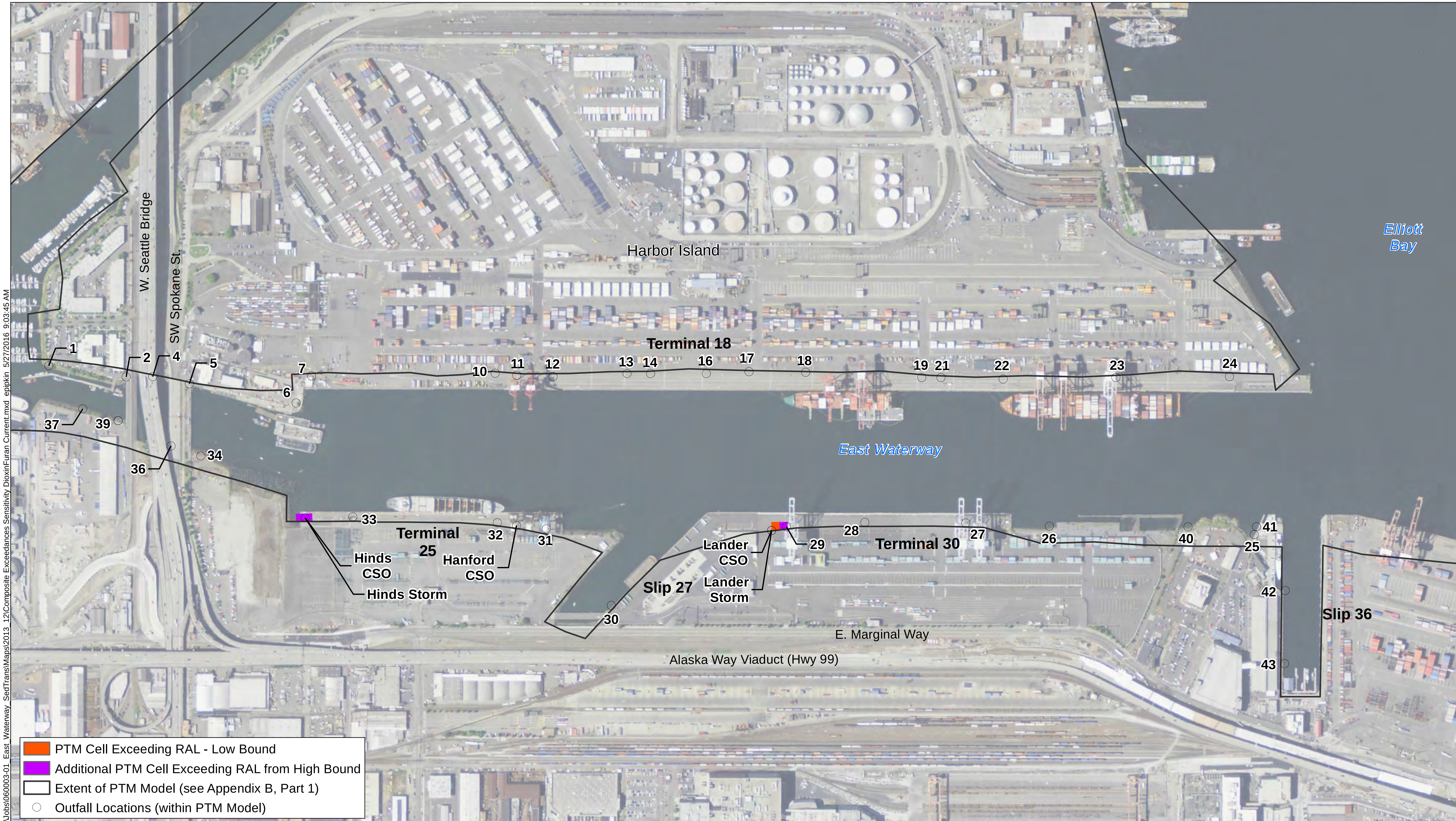


R:\Jobs\060003-01_East_Waterway_SedTrans\Maps\2013_12\Composite Exceedances Sensitivity PCB Future.mxd epipkin 5/27/2016 9:02:52 AM

NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. tPCB SQS is 12 mg/kg-OC.
4. RAL is equal to SQS.
5. No Exceedences for Low Bound Simulation.

0 500 1,000
Scale in Feet

Figure 8b
Grid Model Bounding Analysis, tPCB Years 11 to 30
Feasibility Study - Appendix J
East Waterway Study Area



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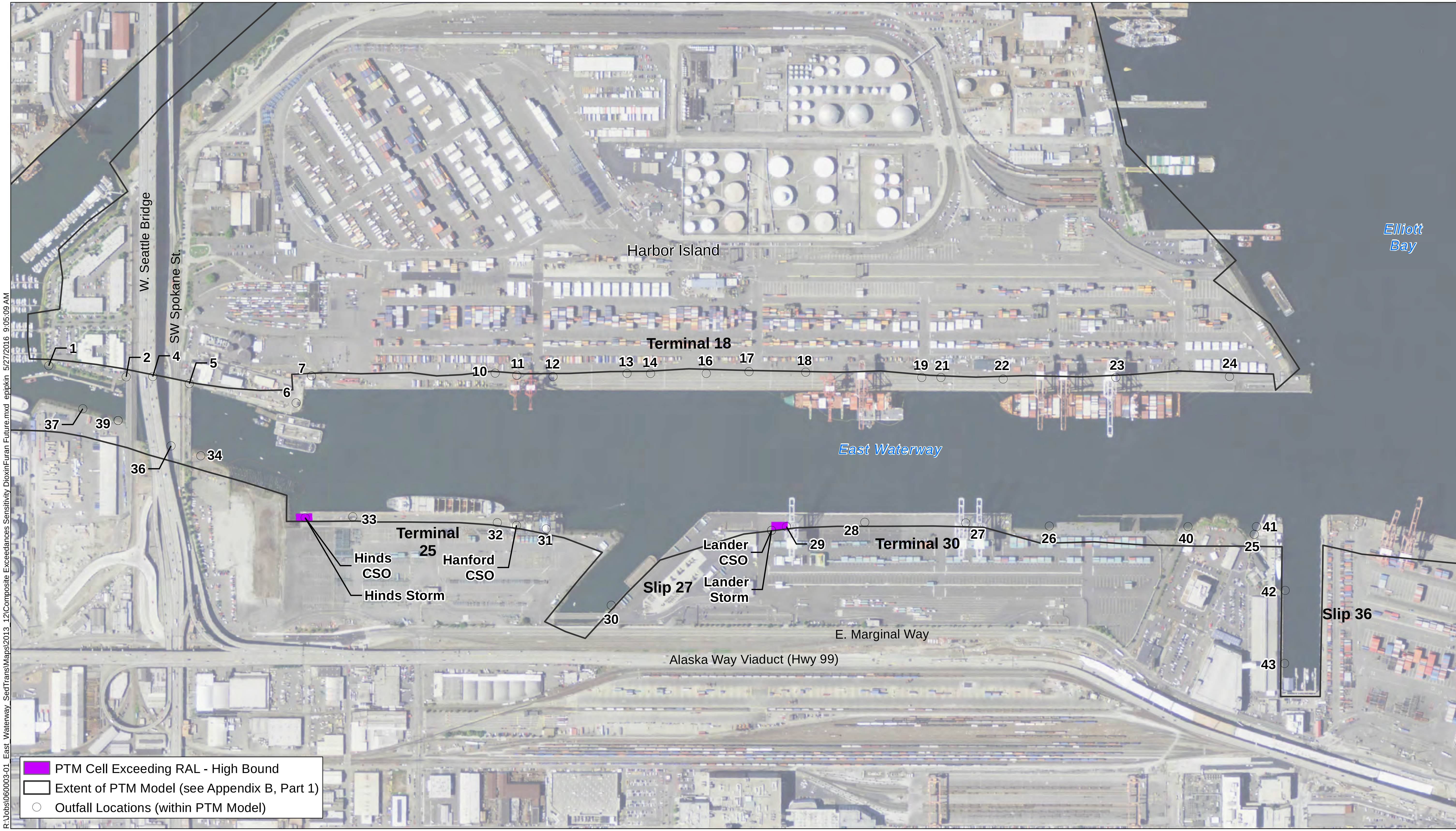
NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Dioxin/Furan RAL is 25 ng TEQ/kg dw.

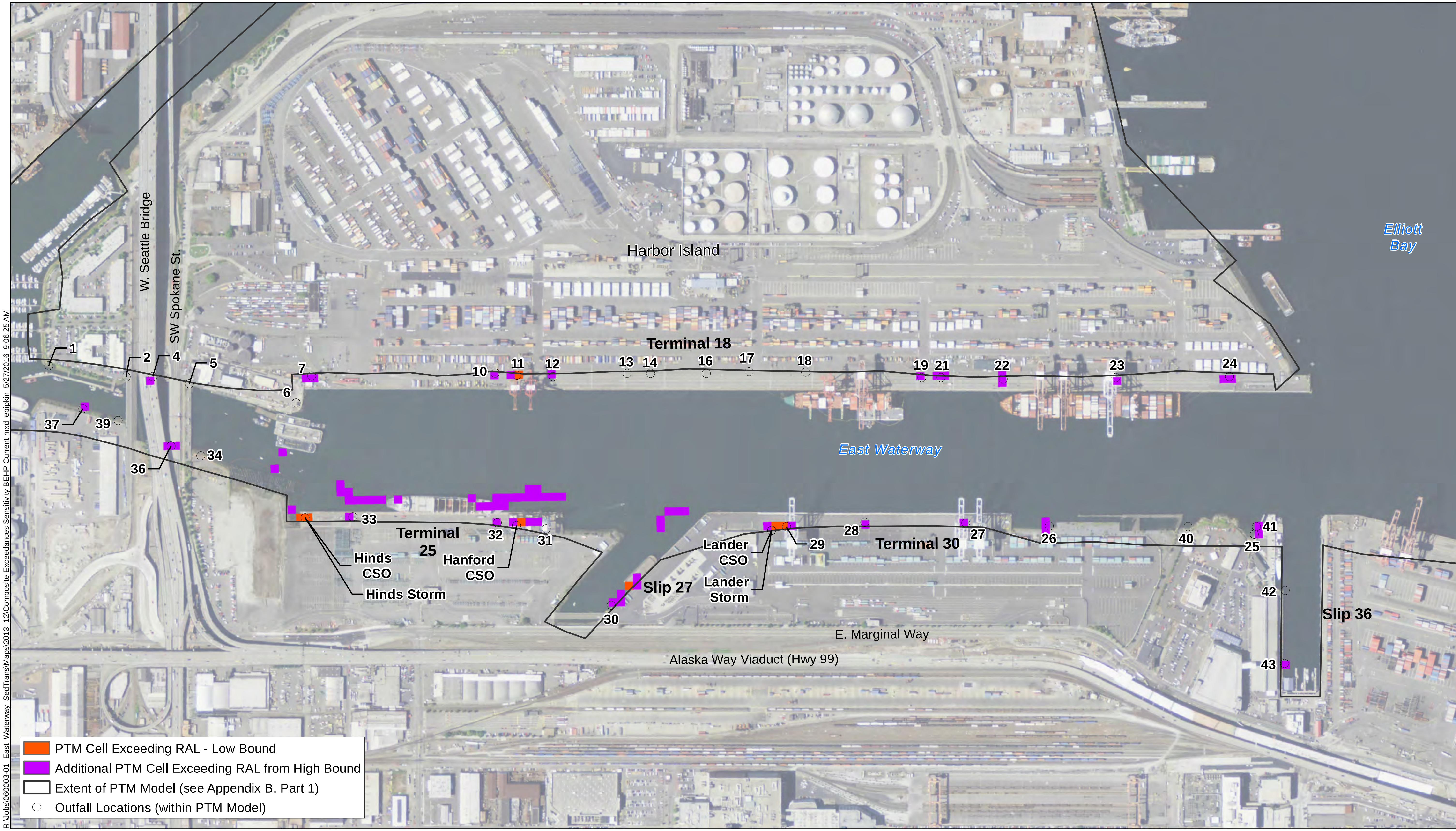
0 500 1,000
Scale in Feet

Figure 9a
Grid Model Bounding Analysis, Dioxin/Furan Years 0 to 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. Dioxin/Furan RAL is 25 ng TEQ/kg dw.
4. No Exceedences for Low Bound Simulation.

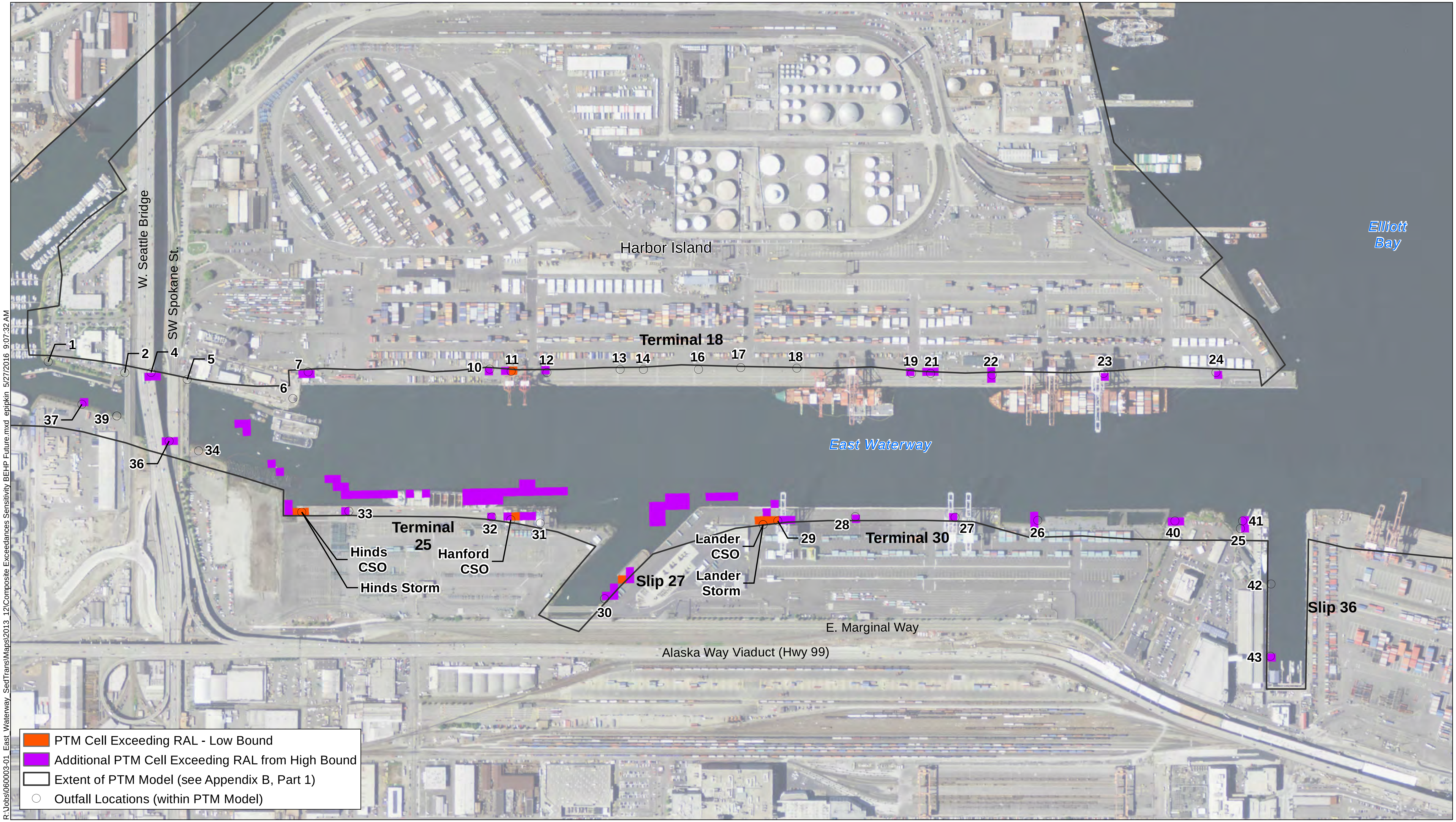
Figure 9b
Grid Model Bounding Analysis, Dioxin/Furan Years 11 to 30
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. BEHP SQS is 47 mg/kg-OC.
4. RAL is equal to SQS.

0 500 1,000
Scale in Feet

Figure 10a
Grid Model Bounding Analysis, BEHP Years 0 to 10
Feasibility Study - Appendix J
East Waterway Study Area



NOTES:
1. Horizontal Datum: WA State Plane North, NAD83, Meters.
2. Aerial photo is NAIP, 2011.
3. BEHP SQS is 47 mg/kg-OC.
4. RAL is equal to SQS

0 500 1,000
Scale in Feet

Figure 10b
Grid Model Bounding Analysis, BEHP Years 11 to 30
Feasibility Study - Appendix J
East Waterway Study Area