APPENDIX A
STATISTICAL METHODOLOGY

FIGURES

ACRONYMS

bgs	below ground surface
COPC	contaminant of potential concern
DEQ	(Oregon) Department of Environmental Quality
EDA	exploratory data analysis
EPC	exposure point concentration
K-M	Kaplan-Meier
MDL	method detection limit
MVUE	minimum variance unbiased estimator
90% UCL	90 percent upper confidence limit
95% UCL	95 percent upper confidence limit
PCB	polychlorinated biphenyl
PQL	practical quantitation limit
QA/QC	quality assurance/quality control
ROS	regression on order statistics
SVOC	semivolatile organic compound
TPH	total petroleum hydrocarbon
VOC	volatile organic compound
USEPA	United States Environmental Protection Agency

A.1 METHODOLOGY FOR CALCULATION OF 95% UCL

A.1.1 Purpose

This section describes the statistical analysis methodology used to calculate the upper confidence limit of the sample mean for various chemical concentrations in surface/subsurface soil (0 to 10 feet below ground surface [bgs]), groundwater, and sediment at the Bradford Island site. The procedures described in this section also incorporate the comments received from the Oregon Department of Environmental Quality (DEQ) (2004) regarding the earlier risk assessment performed for the Bradford Island Landfill.

The 90 percent upper confidence limit (90% UCL) was previously selected to be in compliance with DEQ guidance for estimation of exposure point concentrations (EPCs) for human health and ecological risk assessments (DEQ 2000, 2001, 2003), as described in Section 5.3.2. However, recent development by the United States Environmental Protection Agency (USEPA) Technical Support Center, with the introduction of ProUCL software version 4,[1] suggested that 95 percent upper confidence limit (95% UCL) was widely used and accepted by most experts as EPCs for environmental application. The ProUCL software implemented the latest USEPA guidance (2002a; Singh et al. 2007a, 2007b) for the recommendation of 95% UCL, based on data distribution, data skewness, and sample size. Given this recent technical advancement, the 95% UCL is appropriate to be used in future estimation of EPCs.

A.1.2 Methodology

The main steps of the statistical evaluation for calculating the 95% UCL are as follows:

1. Identify and compile appropriate analytical data.
2. Perform exploratory data analysis (EDA).
3. Test for data distribution assumption.
4. Calculate the 95% UCL.

A brief description of each step follows.

1. Identify and compile appropriate analytical data.

In this step, all available and relevant data are compiled for each exposure area at the Bradford Island site. The required data are extracted from the master electronic database and compiled in Microsoft Excel format for data and statistical analysis. All data in the master electronic database are subjected to a quality assurance/quality control (QA/QC) review and data validation procedure administered by URS personnel, and any data qualifiers assigned through this process are included in the data qualifier field. The specific data fields include location identification, depth (if applicable), sampling date, sample identification, name of chemical parameter, detected concentration, method detection limit (MDL), practical quantitation limit (PQL), unit of measurement, and data qualifiers (if applicable).

[1] ProUCL software only provides recommendation for 95% UCL, not for 90% UCL.

If field duplicates are collected and analyzed, the average concentration among the duplicates is used as a single data point to ensure the data are reasonably independent. Data marked with "R" (rejected) qualifier are excluded in this analysis. Non-detects (concentrations measured below the MDL or "U" qualified data) are estimated by ROS (regression on order statistics) robust method and/or non-parametric Kaplan-Meier (K-M) method, as described in Helsel (2005) and Singh et al. (2007a, 2007b). "J" qualified data (estimated values) are used as recorded.

The analytes are divided into eight groups: inorganics, butyltins, herbicides, pesticides, polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and total petroleum hydrocarbons (TPHs).

2. Perform exploratory data analysis.

The objective of the exploratory data analysis is to discover trends and patterns in the data so that appropriate approaches and limitations in using the data sets can be identified. Both numerical and graphical methods of EDA may be used.

The numerical methods include a table of basic summary statistics, such as mean, standard deviation, minimum, and maximum. These statistics can be used to make inferences concerning the population from which the sample data are drawn. The number of samples, detection rate (i.e., determining the portion of the data set which is censored/non-censored), and range of PQL may also be included to provide further insights. Graphical methods may include histograms, box-and-whisker plots, and normal probability plots. These plots are used to assess the shape and skewness of the data distribution, as well as to inspect any potential outliers (extreme values).

3. Test for data distribution assumption.

The purpose of this step is to check whether the data (raw or log-transformed) can be assumed to be normally distributed and/or the data (raw only) can be assumed to follow a gamma distribution. Based on the results of this evaluation, an appropriate probability distribution can be assumed for the data for use in the calculation of 95% UCL in the next step. This distributional test is performed within the ProUCL software.

The Shapiro-Wilk W test is used to test the normality of the data set at a 5 percent significance level, as described in USEPA guidance (USEPA 2006). The test is first applied to raw data. If this data set passes the normality test, the raw data are assumed to be normally distributed. If the raw data do not pass the normality test, a gamma distribution goodness-of-fit test (at a 5 percent significance level) will then be applied to the data, and if the data pass the gamma distribution goodness-of-fit test, the data are assumed to follow a gamma distribution. Otherwise, the Shapiro-Wilk W test (at 5 percent significance level) will be applied to the log-transformed data. If the log-transformed data pass the normality test, the data are assumed to be lognormally distributed. If the data fail all three tests, the data are assumed to be non-parametric. In all cases, visual inspection of the shape of histograms is performed to confirm the distributional assumption.

4. Calculate the 95% upper confidence limit (UCL).

<u>For datasets without nondetect:</u>

If the data are determined to be normally distributed, the 95% UCL is calculated as follows (USEPA 2002a):

$$UCL = \bar{x} + t_{1-\alpha,n-1}\frac{s}{\sqrt{n}}$$

where $\bar{x}$ = sample mean

t = the Student t value at α significance level, with n-1 degree of freedom

$\alpha = 0.05$ (one-tailed)

n = sample size

s = sample standard deviation

Otherwise, if the data are determined to follow a gamma or lognormal distribution, or if non-parametric assumption is used, the 95% UCL is determined based on the recommendation of the ProUCL software, which takes into account of sample size and data skewness and ensuring adequate coverage of 95% UCL (Singh et al. 2007b). Depending on the sample statistics, the ProUCL software generally recommends one of the following methods:

- For gamma distribution, Approximate Gamma UCL, or Adjusted Gamma UCL.
- For lognormal distribution, Chebyshev Theorem using the minimum variance unbiased estimator (MVUE) of the parameters of a lognormal distribution, or Land's H-statistic.
- For non-parametric assumption, Chebyshev Theorem using the sample arithmetic mean and standard deviation, or Hall's bootstrap method.

The detail statistical steps of the various methods described above are documented in the ProUCL software technical guide (Singh et al. 2007b). A summary of recommended UCL calculation method for datasets without nondetect is provided in Table 15-4 of the ProUCL user guide (Singh et al. 2007a).

<u>For datasets with nondetect(s):</u>

If the data are normally distributed and/or if the data are symmetric or approximately symmetric, the KM (t) method (i.e., Kaplan-Meier estimates using the Student's *t*-distribution cutoff value) is used to calculate the 95% UCL. The equation to compute UCL is the same as the one illustrated above, except that the sample mean and sample standard deviation are substituted by KM estimates of mean and standard deviation.

If the data are assessed to follow a gamma or lognormal distribution, or if the data are assumed to be non-parametric with moderate and high skewness, one of the following methods, in general, is recommended by the ProUCL software for the calculation of UCL:

- UCL based upon KM estimates using the Chebyshev inequality
- UCL based upon KM estimates using the bias-corrected accelerated bootstrap method

The detailed statistical steps of the various statistical methods described above are documented in the ProUCL software technical guide (Singh et al. 2007b). A summary of recommended UCL calculation method for datasets with nondetect(s) is provided in Table 16 of the ProUCL user guide (Singh et al. 2007a).

If the sample size is very small, typically less than four, the UCL is not calculated because of inadequate information on data distribution, and estimates of summary statistics, such as mean and variance, are unreliable. In this case, the maximum detected value is used instead of the 95% UCL. If the sample size is small, typically between four and eight, the UCL calculated is provisional and the result should be interpreted with caution. Additional samples may be required to assertively characterize the data distribution. A target sample size of at least 14 is specified for this project.

If all samples are nondetects or the detection rate is less than 5 percent, the UCL is not calculated for that analyte, as it will not be considered as a constituent of potential concern (COPC) when the reporting limit is less than the decision limit. If the recommended UCL is higher than the maximum detected value, the maximum detected value will be used instead of the calculated UCL.

A.2 METHODOLOGY FOR COMPARING SITE AND AMBIENT CONCENTRATIONS

A.2.1 Purpose

This section describes the statistical analysis methodology used to compare the site and ambient concentrations. The main objective of this statistical analysis is to assess whether chemical concentrations in sediments and tissues from the site area are significantly higher than those concentrations in the reference area, based on the proposed data collection effort described in this report.

A.2.2 Methodology

The comparison of two independent datasets will be used for this nature and extent evaluation. Typically this method will be used to compare the investigation area (i.e., the forebay area) to the corresponding reference area as part of the evaluation to determine if concentrations of COPCs are present at concentrations significantly greater than the reference concentrations. This is a population-to-population comparison to evaluate whether the mean site values are statistically greater than the mean reference values. This statistical analysis is expected to be used for both sediment and tissue data.

Step 1 (identify and compile appropriate analytical data) and Step 2 (perform exploratory data analysis (EDA)) described in Section A.2.1 will be performed on both site and reference areas data prior to the statistical comparison.

Methods of Hypothesis Testing

Hypothesis testing refers to a category of statistical analysis methods that are used to choose between two competing statements or hypotheses. One is called the null hypothesis, denoted by H_0, and the other is called the alternative hypothesis, denoted by H_A. The null hypothesis is the baseline condition that is assumed to be true in the absence of any data. If the data provide sufficiently strong evidence contrary to the null hypothesis, the null hypothesis is rejected and the alternative hypothesis is accepted. If the data do not provide sufficiently strong evidence, one cannot reject the null hypothesis. However, this does not necessarily mean that the null hypothesis is true; it only means that the available data are not sufficient to prove the alternative hypothesis. If the null hypothesis is not rejected, it is important to check the power of the test, which is defined as the probability that the test would be able to detect a specified minimum true difference from the condition defined by the null hypothesis. If the power of the test is sufficiently large, and the null hypothesis is not rejected, one can say with a high degree of confidence that there is no change in the condition defined by the null hypothesis.

For this study, the hypothesis testing methods described in *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (USEPA 2002b) and *Procedural Guidance for Statistically Analyzing Environmental Background Data* (Naval Facilities Engineering Command 1998) are used. For the comparison between the site and reference areas, the hypothesis testing is as follows:

Null hypothesis, H_0: The mean concentration in the forebay is less than or equal to the mean concentration in the upstream reference area.

Alternative hypothesis, H_A: The mean concentration in the forebay is greater than the mean concentration in the upstream reference area.

The next section describes the sequence of tests used, and the use of test results to draw valid conclusions. A flow diagram of the decision process for this type of statistical comparison is provided in Figure A.1. This decision process is to be applied to each of the COPCs to be evaluated for a given medium between the site and reference areas.

Selecting the Appropriate Statistical Tests

The first decision in Figure A.1 is based on the percentage of non-detectable values within a given pair of data sets. If all values in both datasets for a given COPC are detects (left-hand pathway on Figure A.1), the Shapiro-Wilk W test will be used to evaluate the distributions of values in the datasets (i.e., to determine if normally distributed). If the data are neither normal nor lognormal, then a non-parametric Wilcoxon Rank Sum (WRS) test will be performed. If the data fit a normal or lognormal distribution, then the *t*-test will be used for the evaluation. Depending on the calculated variances of the datasets for each COPC, either the form for unequal variances or equal variances will be used to compare the two datasets.

If there are detectable values in at least one of the datasets but not all concentrations are detectable (center pathway on Figure A.1), an evaluation is made on the reporting limits associated with the non-detect data. Each non-detectable result has a reporting limit (RL) associated with it. If at least 10% of the non-detectable values have RLs greater than the maximum detected value for the combined datasets, then rigorous statistical treatment is not possible and professional judgment is required to evaluate whether the site data can be considered to be consistent with the reference values. Alternatively, less rigorous procedures will be considered as part of the professional judgment process.

If fewer than 10% of the non-detectable values have RLs greater than the maximum detected value for the combined datasets, then a statistical evaluation is possible. As shown in the lower half of the center of the flow diagram, if all of these RLs are comparable (i.e., there is one RL), and there are fewer than 90% non-detects, then the Wilcoxon Rank Sum test will be used for the comparison. If on the other hand there are multiple RLs associated with non-detects, then either the Wilcoxon Rank Sum test will be used to compute nonparametric estimates for the comparison with all non-detects evaluated at the highest or median RL, or the Kaplan-Meier method with the Wilcoxon Score test will be used (Helsel 2005). If there are more than 90% non-detects, contingency tables will be used in the comparison.

If all values in both datasets are non-detects (right-hand pathway of the flow diagram), then rigorous statistical treatment is not possible and professional judgment is required to evaluate whether the site data can be considered to be consistent with the reference values. Criteria such as whether the RLs for the site area are less than or equal to the RLs for the reference area, or whether the RLs for the site area are less than screening level criteria may be used in this evaluation. Alternative, less rigorous statistical procedures will also be considered.

A.3 REFERENCES

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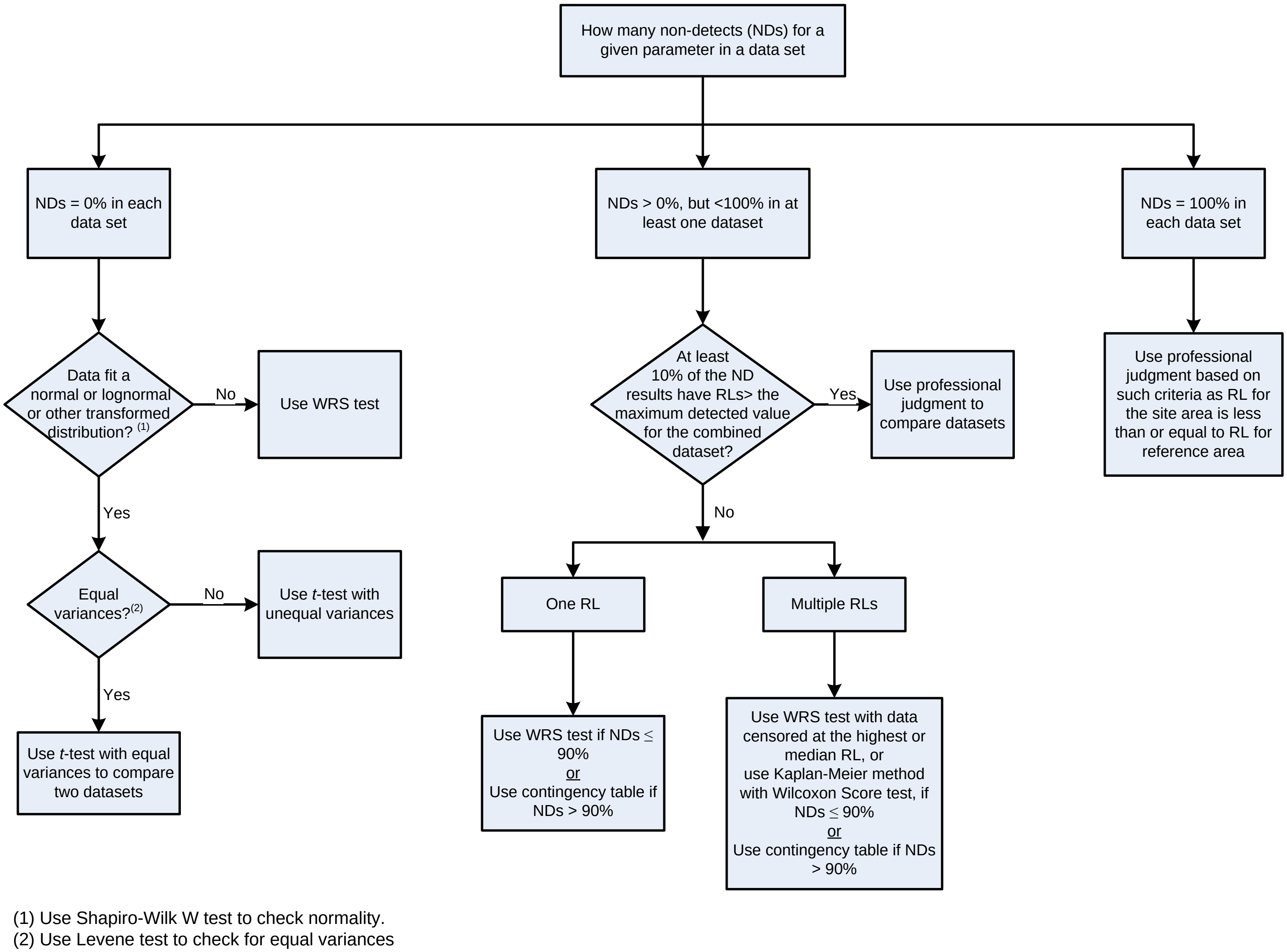

Figure A.1 Comparison of Two Independent Datasets

APPENDIX B
HUMAN HEALTH RISK ASSESSMENT WORK PLAN

Tables

Figures

Acronyms

AOPC	area of potential concern
bgs	below ground surface
BSAF	biota-sediment accumulation factors
COC	contaminant of concern (human health)
COI	contaminant of interest
COPC	contaminant of potential concern (human health)
CRITFC	Columbia River Intertribal Fish Commission
CSM	conceptual site model
CTE	central tendency exposure
DEQ	(Oregon) Department of Environmental Quality
ELCR	estimated (increased) lifetime cancer risks
EPC	exposure point concentration
FS	feasibility study
HHRA	human health risk assessment

HI	hazard index
HQ	hazard quotient
LDW	Lower Duwamish Waterway (Group)
mg/kg	milligram(s) per kilogram
90% UCL	90 percent upper confidence limit
90% UCLM	90 percent upper confidence limit on the arithmetic mean
95% UCL	95 percent upper confidence limit
95% UCLM	95 percent upper confidence limit on the mean of values in a medium
NTCRA	Non-time critical removal action
OU	operable unit
PCB	polychlorinated biphenyl
RAGS	Risk Assessment Guidance for Superfund
RBC	risk-based concentration
Rfd	reference dose
RI	remedial investigation
RME	Reasonable Maximum Exposure
RSET	Regional Sediment Evaluation Team
SF	Slope Factor
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

This appendix provides the detailed approach for the Baseline HHRA to be performed for the Upland and River operable units (OUs). Earlier sections of this document have summarized the scope and status of risk assessments performed to date for the site (Section 4). In Section 6.3, a brief overview was provided describing the management goals for the site, the general objectives of the HHRA, and how the HHRA would be used to accomplish the risk-related management goals.

As noted in Section 6.3, the purpose of a baseline HHRA is to quantitatively evaluate risks to human health from site contamination so that remedial decisions can be made. Screening level and baseline HHRAs estimate exposures and health risks assuming no remedial activities or changes in concentration (DEQ 2000a, 2003; USEPA 1989).

As illustrated in Table 6-1, the status of risk evaluation and availability of data for completion of baseline risk assessments varies among the different AOPCs and OUs at this site. While site characterization is nearly complete for some upland AOPCs, additional data collection is planned for other areas. Therefore, the HHRAs will proceed along different timelines for various portions of the overall site.

For the River OU, the baseline risk assessment will be based upon existing data and upon data collected after the nontime-critical removal action (NTCRA) for contaminated sediments. The NTCRA is proposed for Fall 2007. The delineation of the nature and extent of contamination for the River OU is included in this Remedial Investigation (RI) Work Plan, in particular for the downstream AOPC.

B.1 GENERAL RISK ASSESSMENT OBJECTIVES

The current conceptual site models (CSMs) for the human health exposure scenarios identified at the Upland and River OUs are presented on Figures B-1 and B-2. Section 8 identifies the data gaps and data needs for completion of the risk assessments.

Based on review of existing information, the following primary and supporting risk assessment objectives have been identified for the RI:

- Evaluate suitability of existing data for risk assessment during the RI.
- Determine spatial scope of the risk assessment:
  - Confirm source areas (contaminated media) and past, potential, or current contaminant of interest (COI) releases.
  - Refine OU boundaries for risk assessment purposes.
  - Identify background and upstream concentrations of COIs.
- Refine the CSM and evaluate human health associated with contaminated media:
  - Select human receptors for evaluation.
  - Select contaminants of potential concern (COPCs) for each exposure medium relevant to the identified pathways and receptors.

  - Address relevant comments from DEQ on the Screening Level Risk Assessment for the Landfill.
  - Characterize current and reasonably likely future risks to human and ecological receptors and identify the respective COPCs and contaminants of potential ecological concern.
- Document the risk estimates generated in the risk assessment and provide an interpretation of these results in the RI report.

B.2 REGULATORY GUIDANCE FOR HHRA

To achieve the objectives mentioned above, the steps that will be used to conduct baseline human health risk assessments are based on United States Environmental Protection Agency (USEPA) and DEQ guidance (USEPA 1989; DEQ 2000, 2003). Since DEQ will be overseeing the RI/Feasibility Study (FS), DEQ guidance will take precedence with regard to the nature of the risk assessment process and the format and presentation of results. DEQ risk assessment protocols can be found in Oregon Administrative Rules Section 340-122-0084.

The guidance documents to be used in the performance of the HHRA include:

- *Final Guidance for Identification of Hot Spots* (DEQ 1998a)
- *Guidance for Conducting Beneficial Water Use Determinations at Environmental Cleanup Sites* (DEQ 1998b)
- *Final Guidance, Consideration of Land Use in Environmental Remedial Actions* (DEQ 1998c)
- *Guidance for Conduct of Deterministic Human Health Risk Assessments, Final* (DEQ 2000)
- *Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites* (DEQ 2003)
- *Comments on Revised Draft Level II Ecological Risk Assessment and Baseline Human Health Risk Assessment, Bonneville Lock and Dam Project* (DEQ 2004)
- *Guidance for Evaluation of Bioaccumulative Chemicals of Concern in Sediment, Final* (DEQ 2007a)
- *Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A), Interim Final* (USEPA 1989)
- *Risk Assessment Guidance for Superfund: Volume I Human Health Evaluation Manual. Part B, Development of Risk-Based Preliminary Remediation Goals, Interim* (USEPA 1991)
- *Guidance for Data Usability in Risk Assessment* (USEPA 1992)
- *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (USEPA 2002a)
- *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002b)
- *Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance), Draft* (USEPA 2002c)

- *Human Health Toxicity Values in Superfund Risk Assessments* (USEPA 2003a)
- *Preliminary Remediation Goals* (USEPA 2004a)
- *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings, Draft* (USEPA 2004b)

According to DEQ risk assessment guidance for human health, which follows USEPA guidance (DEQ 2000, 2003; USEPA 1989), the HHRA process consists of the following steps:

- ***Problem Formulation –*** involves evaluating existing site information, determining the nature and extent of contamination using the DQO process (COI identification) and contaminant screening (COPC screening), identifying potentially exposed populations, and developing a CSM.

If complete pathways are identified and additional evaluation is warranted, problem formulation is followed by the baseline risk assessment and includes:

- ***Exposure Assessment –*** involves analyzing contaminant releases, identifying exposure pathways and exposed populations, estimating exposure concentrations, and estimating contaminant intakes by the exposed populations.
- ***Toxicity Assessment –*** involves evaluating qualitative and quantitative toxicity information to determine toxicity values for COPCs (i.e., those values above which humans may experience carcinogenic or adverse non-carcinogenic effects).
- ***Risk Characterization/Uncertainty Analysis –*** summarizes the results from the first three steps of the assessment and presents the quantified risks to human health from individual and multiple chemicals across individual and multiple pathways; identifies contaminants of concern (COCs); and discusses the uncertainty in the risk assessment based on uncertainty in the selection of COCs, the exposure assessment, and the toxicity values used.

The results of the HHRA steps will be documented in the RI report.

B.2.1 Differences between USEPA and DEQ Guidance

As noted in Section 6.3, although the content of HHRAs based on DEQ and USEPA guidance are generally similar, some minor variations exist. DEQ guidance varies from CERCLA guidance in a few areas such as those listed below:

- Formal land and water use determinations of beneficial use
- Screening out of naturally occurring inorganics by comparison with background
- Use of a 90 percent upper confidence limit (90% UCL) value to represent exposure point concentration (EPCs)
- Definition of acceptable risk levels
- Performance of hot spot evaluations

How these issues will be addressed is described in the later sections of this appendix.

B.2.2 Other Relevant Guidance and Projects

Other approaches that may be appropriate for this site will also be included in the evaluation and risk characterization approaches for the site. Examples of other approaches are the sediment evaluation guidelines being developed by the Regional Sediment Evaluation Team (RSET), the risk assessment being conducted for the Portland Harbor Superfund site, and the trophic model approaches developed for the Lower Duwamish Waterway (LDW) Group.

RSET is an interagency workforce composed of membership by USEPA Region 10, DEQ, and the United States Army Corps of Engineers (USACE), among others, and has recently published the *Northwest Regional Sediment Evaluation Framework, Interim Draft* (RSET, September 2006). Many of the approaches suggested in this manual for the evaluation of contaminated sediments are appropriate for application for the In-Water OU. Examples include a tiered approach for the evaluation of sediments and the use of multiple lines of evidence to characterize impacts.

The Lower Willamette Group is in the process of extensive data collection and risk assessment efforts for the Portland Harbor Superfund site (Lower Willamette Group 2004, 2007). Many of the human and ecological receptors evaluated for Portland Harbor overlap with the receptors proposed for evaluation at Bradford Island and the structure of the food web at the two sites bears many similarities. However, the size of the Portland Harbor site, the number and complexity of multiple sources of contamination, and the scale of contamination are far larger than at Bradford Island.

The Bradford Island River OU is much smaller and less complex than Portland Harbor since it is primarily an area of very limited sources of polychlorinated biphenyl (PCBs) occurring at elevated concentrations in sediment. An example of the Portland Harbor approach that is proposed for use at the Bradford Island site is a COI screening process that is similar to the process developed for evaluation of the potential for migration of COIs from upland to offshore environments (DEQ 2005). Other examples include the use of resident fish species that show high fidelity to their small home range, the use of multiple lines of evidence to characterize risks and impacts (DEQ 2004, 2007a), and the comparison of risk estimates for Portland Harbor COIs with risks from upstream areas.

Among its many publications, the LDW Group has focused on developing approaches for the evaluation and use of data for sites contaminated with PCBs (Windward Environmental 2005, 2006). Along with Portland Harbor, the LDW Group has evaluated the advantages and disadvantages of Aroclor and congener data for risk assessment purposes and the use of several well-known trophic food-web models for the purpose of predicting PCB concentrations (as Aroclors or congeners) in fish tissues. The findings and recommendations developed from these studies were helpful in refining the approach proposed for Bradford Island and include the proposed analytical approach for PCBs as well as the use of the AQUAWEB food-web model (based on Arnot and Gobas 2004).

B.3 HHRA FOR UPLAND OU

The Upland OU includes four AOPCs: the Bradford Island Landfill, Sandblast Area, Pistol Range, and Bulb Slope area. Site investigations varying from preliminary to extensive in nature have been conducted at all of these AOPCs. With respect to risk assessment, only the Bradford

Island Landfill has had a draft baseline HHRA. Although the draft report has not been finalized at this time, a list of COPCs has been developed. The Sandblast Area, Pistol Range, Bulb Slope, and Goose Island have been investigated in varying levels of detail, but lack baseline HHRAs.

Therefore, information is sufficient to support the problem formulation phase of the HHRA for all of the upland AOPCs. The problem formulation process is also useful in identifying data gaps and defining the data collection needs for the execution of the baseline HHRA. The approach to the problem formulation for the Upland OU is discussed below followed by the proposed approach for the completion of the baseline HHRA. Because of the wealth of information already available for several of the upland AOPCs, some of the components of the problem formulation are presented in this section. The results of this partial problem formulation were used to identify data gaps and data needs for the completion of the baseline risk assessment. Section 8 and the QAPP documents included with this RI Management Plan provide additional detail on the proposed data collection activities.

B.3.1 Approach to Problem Formulation

The problem formulation phase for the HHRA for the Upland OU will include the following elements, as defined by DEQ (2000):

- Review of existing site information
- Land and water use determination
- Definition of data quality objectives
- Determination of the nature and extent of contamination
- Identification of potentially exposed populations
- Definition of exposure scenarios and exposure routes
- Contaminant screening procedures
- Development of a CSM

B.3.1.1 Existing Site Information and Land and Water Uses

Existing site information for the AOPCs in the Upland OU is contained in numerous reports, as presented in Section 4, and will be supplemented with additional information collected during the RI. A land use determination will be included indicating that in the past and under current conditions, Bradford Island has been used primarily for industrial or waste handling purposes. According to the Bonneville Master Plan, future land use at Bradford Island is expected to remain unchanged. Groundwater at the island is not used for any purpose and will remain so, as described in Section 3.1.7.

Goose Island, although it is not designated as a day-use area, may be accessible to the general public in a “trespasser scenario,” as only a narrow strip of water separates it from the bank. The mouth of nearby Eagle Creek is accessible to the general public; fishermen are known to wade in the water while angling.

B.3.1.2 Sources of Contamination and Nature and Extent of Contamination

The problem formulation will describe the sources of contamination at the known AOPCs on Bradford Island: the Landfill, Sandblast Area, Pistol Range, and Bulb Slope. The nature and extent of contamination at the various AOPCs will be further delineated during the RI. This information will be included in the problem formulation. Primary sources include chemicals released or deposited by former industrial activities onto upland surface and subsurface soils. Secondary sources are affected groundwater and groundwater. A transport pathway from upland to the river may exist by erosion or slope failure of upland soils. Sediment contamination may also occur from overland soil contaminants leaking through a torn catch basin filter sock that is part of the runoff management system in the Sandblast Area vicinity (URS 2006).

B.3.1.3 Identification of COIs and COPCs

DEQ guidance defines COIs as chemicals that are present or may be present at a site. For the purposes of risk assessment, COIs may be further evaluated on the basis of detection frequency, comparison with background, and risk screening. COIs that fail the evaluation are retained as COPCs for inclusion in the quantitative risk assessment while COIs that pass the evaluation are dropped from further consideration.

The partial screening process for existing data for COIs in soil and groundwater for each of the upland AOPCs is described in detail in Section 5.3, and the results are presented in Tables 5-1 through 5-10.

- **Soil.** After the collection of additional data, the COIs that failed these first two elements of the screening process will be further evaluated in the problem formulation with the risk screening step by comparison with risk-based screening levels and concentration-toxicity screens. The sources of human health-based screening values for soil will be consistent with DEQ guidance and will include risk-based concentrations (RBCs) from DEQ (2007) and USEPA Region 6.
- **Groundwater.** In agreement with DEQ comments, the COI list for groundwater was not screened on the basis of detection frequency since the total sample size was generally less than 20. COIs in soil that fail the risk-screening step will be designated as COPCs and will be included in the Baseline HHRA for upland AOPCs. COIs in groundwater that fail the risk screening step will be included in two scenarios: evaluation of hypothetical use of groundwater as a potable water supply and evaluation of direct contact scenarios in surface water of the River OU, if the COIs are also detected in the surface water.

COIs lacking chemical-specific screening values will be retained as COPCs. They will be evaluated quantitatively if acceptable surrogate chemicals are available, or will be discussed in the uncertainty section of the HHRA. Bioaccumulative COIs will also be retained as COPCs, if the screening level values do not include consideration of bioaccumulation-based effects.

The findings of the preliminary screening may be summarized to state that metals and a limited subset of volatile organic compounds (VOCs), semivolatile organic compounds, and PCBs have been detected in surface and subsurface soils at the Landfill and Sandblast Area. A much smaller number of metals, PCBs, and total petroleum hydrocarbons have been detected in the Bulb Slope area. The Pistol Range is associated with only a few metals. Groundwater samples taken in the

Sandblast Area vicinity and the Landfill had detectable levels of several metals, VOCs, and semivolatile organic compounds. Pesticides were detected sporadically in soils and groundwater.

At the end of the COPC selection process, nondetected observations will be replaced with a value of half the reporting limit. The uncertainties associated with this process will be discussed in the uncertainty section of the HHRA.

B.3.1.4 Identification of Receptors and Pathways

Due to the industrial nature of land use at the site, residential receptors are not relevant. Construction and excavation workers engaged in long-term construction of new facilities are also not relevant. However, trench workers who may be engaged in utility repair or other types of soil-disturbing activities may be present and will be included as likely receptors.

Human receptors who may be exposed to COIs and COPCs at the upland AOPCs include:

- Adult outdoor site maintenance worker engaged in activities that do not involve a significant degree of soil disturbance (e.g., landscape workers). These receptors at Bradford Island may be exposed to COIs in surface soil by incidental ingestion, inhalation (dusts and vapors), or dermal uptake of contaminants from soil.
- Adult indoor workers may be exposed to VOCs emanating from subsurface soil and entering the indoor environment by vapor intrusion.
- Trench workers may be exposed to COIs in surface and subsurface soil by incidental ingestion, inhalation (dusts and vapors), or dermal uptake of contaminants from soil. They also may be exposed to COIs in shallow groundwater by incidental ingestion, dermal contact, and vapor inhalation. The only exception would be at the Bulb Slope, which is assumed to be too steep to support routine excavation activities.
- Adult workers at Bradford Island hypothetically may be exposed to COIs in groundwater if it was used as a drinking water supply.
- Child and adult recreationists at Goose Island may be exposed to COIs in sediment by incidental ingestion, inhalation, or dermal uptake of contaminants that may adversely affect health.
- Child and adult subsistence and recreational fishermen may consume fish and shellfish contaminated with bioaccumulative COPCs that erode from upland soils to offshore sediments or discharge from groundwater into the offshore surface water.

B.3.1.5 Conceptual Site Model

A CSM for upland human health exposures is presented as Figure B-1. All of the upland AOPCs on Bradford Island are similar with regard to land and water uses, potentially exposed receptors, and exposure routes, although the sources of contamination and COIs vary from one AOPC to another. Therefore, the exposure pathways for the upland AOPCs are illustrated in a single CSM figure for the Upland OU (Figure B-1). The CSM describes the current understanding of potential contamination sources, receptors of interest, and routes of exposure.

In addition to the upland media, COIs from the upland media may enter the river through transport of soils or groundwater. Surface soils may be transported to sediments in the river through overland washoff or by slope failure. Sediment would then be the source for uptake of bioaccumulative chemicals by fish and shellfish, which may in turn be consumed by humans. Two potentially complete pathways are related to groundwater: direct seepage to the surface water in the river from the island, and indirect vertical upward discharge through near-island contaminated sediments. For the groundwater to sediment to surface water pathway, upward discharge of groundwater may release contaminated porewater from the sediments into the surface water. Consideration of these pathways addresses some of DEQ's earlier comments regarding the Landfill HHRA (DEQ 2004).

At the completion of the problem formulation phase, the current and reasonably likely future exposure scenarios that correspond to the designated and planned uses of land and water at the upland AOPCs will be identified. The exposure pathways that are complete at each AOPC and their associated receptors will be identified. COIs that failed the screening process will be identified as COPCs that require quantitative risk evaluation. The results of the problem formulation, therefore, will define the scope and nature of the more detailed baseline risk assessment.

The data gaps that need to be addressed to complete the problem formulation are described in Section B.3.3.

B.3.2 Approach to Baseline HHRA

After completion of problem formulation, the components of the baseline HHRA include exposure assessment, toxicity assessment, and risk characterization/uncertainty assessment.

B.3.2.1 Exposure Assessment

Exposure refers to the potential contact or intake of an individual with a chemical. In keeping with DEQ guidance, the proposed baseline HHRA will use a deterministic approach to exposure and risk estimation. The methods for calculating potential chemical intakes from soil and groundwater for the populations and exposure pathways selected for quantitative evaluation will follow guidance provided in *Risk Assessment Guidance for Superfund* (RAGS), *Volume I Human Health Evaluation Manual (Part A)* (USEPA 1989) and by DEQ (2000, 2003) while using standard risk assumptions. Quantifying exposure involves estimating chemical intake rates based on the evaluation of chemical releases from the site and estimation of EPCs for specific pathways.

B.3.2.1.1 Exposure Point Concentration

The EPC is a chemical-specific and media-specific value that represents a central tendency exposure (CTE) or Reasonable Maximum Exposure (RME) estimate of the concentration to which a receptor is exposed.

In accordance with DEQ guidance (DEQ 2000) and to address comments received on the landfill risk assessment (DEQ 2004), both RME and CTE estimates will be used in the HHRA. As described in Appendix A and in accordance with the most recent USEPA guidance regarding statistical methodology to be used in EPC estimation (USEPA 2002a, 2002b), the 95th upper confidence limit on the mean of values in a medium (95% UCLM) (air, water, soil) will be used as the EPC representing the RME. The lower of the maximum or the 95 percent upper confidence limit (95% UCL) may also be used, when appropriate. The EPC representing the CTE scenario will be the arithmetic mean of the values in a medium. EPCs may represent a single AOPC or larger exposure areas, as appropriate, and will be estimated using statistical methods recommended by USEPA. EPCs for soil will be based on 0- to 3-foot-below-ground-surface (bgs) depth interval for outdoor workers and recreationists, and 0- to 10-foot-bgs depth interval for trench workers.

B.3.2.1.2 Exposure Dose Estimation

The calculations used to estimate exposure or intake from contact with COCs in soil; groundwater, sediments, surface water, and fish consumption have the same general components: a variable representing chemical concentration, variables describing the characteristics of the exposed population, and an assessment-determined variable that defines the time frame over which exposure occurs. The calculated intakes are expressed as the amount of chemical at the exchange boundary (e.g., skin, lungs, or gut) available for absorption. This appendix presents the equations that will be used to calculate chemical intake associated with EPCs. Chemical-specific intakes will be calculated to quantify exposure to the identified receptor populations using formulas identified in DEQ and will include point value exposure input parameters for exposure (e.g., ingestion, dermal contact, and inhalation) obtained primarily from DEQ guidance (2003).

Intake is calculated as either the average daily dose (ADD) or the lifetime average daily dose (LADD). The ADD is used in the evaluation of noncarcinogenic health effects, while the LADD is used to evaluate carcinogenic effects. These two intake rates differ in the averaging time. When evaluating noncarcinogenic effects, intakes are calculated by averaging intake over the period of exposure. For carcinogens, intakes are calculated by prorating the average daily dose over a lifetime. This approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

Outdoor Workers and Trench Workers

Exposures will be quantified for the outdoor worker and trench worker via incidental ingestion, inhalation and dermal contact with soil (and with groundwater for excavation worker only). Data to be used for the outdoor worker will consist of shallow soil data (0 to 3 feet bgs) and deeper data (0 to 10 feet bgs) for the trench worker. Both CTE and RME doses will be estimated, in compliance with DEQ guidance. The input parameters and assumptions used to estimate exposures are presented in Table B-1 and are drawn primarily from DEQ (2003).

For lead, the child (USEPA 2005) or adult (USEPA 2003b) models will be used to compare site soil levels to a child’s or fetus’ blood lead concentration level of 10 µg/dL (micrograms of lead per deciliter of blood), above which significant health risks occur, and protection of greater than 95 percent of the population from exceeding this value is the decision point.

Indoor Workers

Indoor workers will be evaluated separately using USEPA’s guidance (USEPA 2002c, 2004b) and modified Johnson and Ettinger advanced models for vapor intrusion (SG-ADV Version 3.1, 12/03, GW-ADV Version 3.1, 12/03, or the most recent versions of the models available at the time of execution) and based on maximum or upperbound concentrations of VOCs in soil gas and groundwater. Bulk soil data for VOCs are not proposed for quantitative evaluation of the vapor intrusion pathway, in keeping with USEPA guidance (USEPA 2004b). However, they will be considered in a weight-of-evidence approach, in combination with soil gas and groundwater data. The exposure factor values for the indoor worker are based on DEQ (2003) and assume that a full-time indoor worker is present.

Existing data gaps for the completion of the exposure assessment are described in Section B.3.3.

B.3.2.2 Toxicity Assessment

The toxicity assessment describes the relationship between the magnitude of exposure to a chemical and adverse health effects. This assessment provides, where possible, a numerical estimate of the increased likelihood and severity of adverse effects associated with chemical exposure (USEPA 1989). This section provides a brief description of toxicity values used to calculate total site risks for COIs detected in soil and groundwater.

For purposes of the toxicity assessment, two broad categories of classification exist: noncarcinogens and carcinogens. These classifications were selected because health risks are calculated quite differently for carcinogenic and noncarcinogenic effects. The USEPA developed separate toxicity values for carcinogenic and noncarcinogenic effects, representing the potential magnitude of adverse health effects associated with exposure to chemicals. Toxicity studies with laboratory animals or epidemiological studies of human populations provide the data used to develop these toxicity values. These values represent allowable levels of exposure based on the results of toxicity studies or epidemiological studies. The toxicity values are then combined with the exposure estimates (as presented in the previous section) to develop the numerical estimates of carcinogenic risk and noncancer health risks. These numerical estimates are then used in the risk characterization process to estimate adverse effects from chemicals in soils and groundwater at these sites.

B.3.2.2.1 Toxicity Information for Noncarcinogenic Effects

Noncarcinogenic effects will be evaluated using either reference doses (RfDs) or reference concentrations developed by the USEPA. The RfD is a health-based criterion, expressed as chemical intake rate in units of milligrams per kilogram (mg/kg)/day, and is used in evaluating noncarcinogenic effects. The RfD is based on the assumption that thresholds exist for certain toxic effects such as liver or kidney damage, but may not exist for other toxic effects such as carcinogenicity. In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of adverse effects during a lifetime of exposure (USEPA 1989).

B.3.2.2.2 Toxicity Information for Carcinogenic Effects

Evidence of carcinogenicity of a chemical comes from two sources: lifetime studies with laboratory animals and human studies where excess cancer risk is associated with exposure to the chemical. Numerical estimates of cancer potency are presented as cancer Slope Factors (SFs). Under an assumption of dose-response linearity at low doses, the SF defines the cancer risk due to continuous constant lifetime exposure to one unit of carcinogen (in units of risk per mg/kg/day).

Each SF is accompanied by a weight-of-evidence classification. This classification considers the available data for a chemical to evaluate the likelihood that the chemical is a potential human carcinogen. The evidence is characterized separately for studies in humans and studies in laboratory animals as sufficient, limited, inadequate, no data, or evidence of noncarcinogenicity. USEPA recommends that cancer risk estimates should always be accompanied by a weight-of-evidence classification to indicate the strength of evidence that a chemical is a human carcinogen (USEPA 1986, 1989). Chemicals are classified as Group A, Group B1, Group B2, Group C, Group D, or Group E carcinogens:

- ***Group A chemicals*** (known human carcinogens)—Agents with sufficient evidence to support the causal association between exposure to the agents in humans and cancer
- ***Group B1 chemicals*** (probable human carcinogens)—Agents with limited evidence of possible carcinogenicity in humans
- ***Group B2 chemicals*** (probable human carcinogens)—Agents with sufficient evidence of carcinogenicity in animals but inadequate or a lack of evidence in humans
- ***Group C chemicals*** (possible human carcinogens)—Agents with limited evidence of carcinogenicity in animals and inadequate or a lack of human data
- ***Group D chemicals*** (not classifiable as to human carcinogenicity)—Agents with inadequate human and animal evidence of carcinogenicity or for which no data are available
- ***Group E chemicals*** (evidence of noncarcinogenicity in humans)—Agents with no evidence of carcinogenicity from human or animal studies, or both

B.3.2.2.3 Sources of Toxicity Information

As recommended in DEQ and USEPA guidance (DEQ 2003; USEPA 2003a), toxicity values for COIs will be selected in a hierarchical manner from the sources listed below:

- Integrated Risk Information System on-line database (USEPA)
- Provisional Peer-Reviewed Toxicity Values (USEPA)
- Other peer-reviewed sources (e.g., California EPA)
- Health Effects Assessment Summary Tables
- Toxicity values from National Center for Environmental Assessment
- Other sources

In accordance with current USACE policy and agreement with USEPA's directive on the hierarchy for selection of toxicity values (USEPA 2003a), the peer-reviewed Cal-EPA SFs for trichloroethylene will be used, since no peer-reviewed values for it exist in the Integrated Risk Information System database or in the Provisional Peer-Reviewed Toxicity Value list (Walker and Meyer 2005). PCBs in upland soils will be evaluated only on an Aroclor basis. Slope factors and reference doses for Aroclors will be selected on the basis of their persistence and the pathway of interest, as recommended by USEPA (USEPA 2004a). COPCs without toxicity values will be evaluated quantitatively if acceptable surrogate chemicals are available. If no surrogates are available, the COPCs will be described in the uncertainty section of the HHRA.

No data gaps have been identified for completion of the toxicity assessment. The recommended values from existing HHRA guidance are considered sufficient.

B.3.2.3 Risk Characterization/Uncertainty Analysis

Risk characterization is the process of integrating the previous elements of the risk assessment into quantitative or semiquantitative estimates of risk. Risk characterization consists of risk estimation and uncertainty assessment. Risk estimation or the quantification of risk is then used as an integral component in remedial decision making and selection of potential remedies or actions. Uncertainty assessment describes the level of confidence in the risk estimation.

B.3.2.3.1 Risk Estimation

Based on the exposure and toxicity information, risk is estimated for carcinogens and noncarcinogens. A hazard quotient (HQ) for potential exposures to a noncarcinogenic contaminant in groundwater is calculated as follows:

$$HQ = \frac{Intake}{RfD_o}$$

Estimated noncancer hazards for all noncarcinogenic contaminants are summed to obtain the total hazard index (HI) for multiple exposure routes to soil.

The estimated excess lifetime cancer risk from potential exposure to a carcinogenic chemical with groundwater is calculated as follows:

$$Risk = Intake \ x \ SF_o$$

where SF_o is the oral slope factor in units of $(mg/kg\text{-}day)^{-1}$ (see below). Estimated increased lifetime cancer risks (ELCRs) for all carcinogenic contaminants are summed to obtain the total risk associated with multiple exposure routes (e.g., ingestion, dermal contact, and inhalation) to soil.

Risk Estimates for Outdoor Workers and Trench Workers

As allowed by DEQ's updated guidance for HHRA (DEQ 2003), human health risks will be estimated by first calculating chemical-specific RBCs for each medium and receptor. The RBCs will represent allowable concentrations of individual chemicals corresponding to an acceptable risk level, as defined by DEQ, with a target ELCR of 1×10^{-6} or a noncancer target HQ of 1.0. Both cancer and noncancer RBCs will be estimated for carcinogens and only noncancer RBCs will be calculated for noncarcinogens. Each RBC will include all the relevant exposure routes for a particular receptor and exposure medium (e.g., incidental ingestion of soil, dermal contact with soil, and inhalation of vapors and/or particulates from soil for an outdoor maintenance worker).

To estimate risks at each AOPC or exposure area, the EPC for a chemical (e.g., 95% UCLM of a chemical in soil at the Sandblast Area) will be divided by the relevant RBC (e.g., outdoor maintenance worker soil RBC) for that chemical. The resulting ratio will provide an estimate of the risk and hazard for each relevant pathway and receptor. The summation of all the individual ratios will provide an estimate of cumulative risk due to multiple chemicals. Where the same receptor may be exposed to multiple media (e.g., excavation workers exposed to soil and groundwater), risks may also be summed across media to estimate cumulative multimedia exposure.

Tables B-2 through B-4 provide examples of the equations that will be used to estimate cancer and noncancer RBCs for each upland receptor and exposure medium. Some of the example values may be modified to comply with DEQ's recommended values or to reflect site-specific conditions during the execution of the actual risk assessment.

To estimate risks at each AOPC or exposure area, the EPC for a chemical (e.g., 95% UCLM of a chemical in soil at the Sandblast Area) will be divided by the relevant RBC (e.g., outdoor maintenance worker soil RBC) for that chemical. The resulting ratio will provide an estimate of the risk and hazard for each relevant pathway and receptor, as shown below.

$$\text{Noncancer HQ} = \frac{EPC}{\text{Noncancer RBC}}$$

$$\text{Risk} = \frac{EPC \times 10^{-6}}{\text{Cancer RBC}}$$

The summation of all the individual ratios will provide an estimate of cumulative risk due to multiple chemicals. If the same receptor may be exposed to multiple media (e.g., excavation workers exposed to soil and groundwater), then risks may also be summed across media to estimate cumulative multimedia exposure.

Risks to receptors will be characterized on the basis of ELCRs and noncarcinogenic HQs. For each medium, pathway, and receptor, risks and hazards will be summed to provide estimates of risks and hazards associated with individual chemicals as well as cumulative risks and hazards (HIs) associated with simultaneous exposure to multiple chemicals. Cumulative risks and hazards due to multimedia exposures for the same receptor will also be summed and characterized, as appropriate. In addition to total HQ and HI, non-cancer hazards may also be segregated by target organs and effects, as appropriate. Results for evaluation of lead will be characterized with respect to elevation above recommended blood lead levels.

Risk Estimates for Indoor Workers

Risks related to the vapor intrusion pathway will be estimated using the USEPA versions of the Johnson and Ettinger model mentioned above. Both cancer risks and noncancer hazards will be estimated and summed to provide individual as well as cumulative estimates. Risks to the indoor worker will not be added to any other receptor or pathway since the indoor worker is assumed (conservatively) to spend all his/her exposure time within the structure.

B3.2.3.2 Risk Characterization

Key site-related constituents and pathways will be identified. Constituents and pathways associated with various ranges of risk and hazard will be identified including an ELCR above $1x10^{-4}$, $1x10^{-4}$ to $1x10^{-6}$, and less than $1x10^{-6}$, as well as HQ and HI > 1 and < 1. Chemicals associated with ELCR > $1x10^{-4}$ or HQ > 1 will be identified as constituents of concern. Chemicals identified with ELCR > 1 x 10-6 but less than 1 x 10-4 will be identified for discussion with the agencies and stakeholders. Spatial and temporal trends in COPC distribution will be identified and discussed. Areas or portions of the site with elevated or lower risks (i.e., hot spots and locally unimpacted areas) will be identified. The types of health risks associated with the COPC will be discussed. If necessary, noncancer health effects may be grouped by target organs and similar effects. The level of confidence in the overall risk assessment also will be discussed.

Risk characterization is a process that integrates COPC identification, exposure assessment, and toxicity assessment. No data gaps specific to risk characterization are identified.

B3.2.3.3 Uncertainty Analysis

Many elements of the risk assessment process are subject to uncertainty. Not all the sources of uncertainty, however, are significant or avoidable. The general and site-specific sources of uncertainty in each phase of the risk assessment process will be identified, and their potential to overestimate or underestimate risks will be discussed. Measures for the reduction of significant uncertainty (e.g., additional data collection, additional evaluation) will be discussed.

B.3.3 Data Gaps for Completion of Upland HHRA

This section describes the existing data gaps for the Upland HHRA.

B.3.3.1 Data Gaps for Completion of Problem Formulation

The formal problem formulation for the upland AOPCs and OU will be presented in the RI report. However, data gaps that need to be filled to perform the baseline HHRA were identified on the basis of the preliminary problem formulation performed to date. The data gaps are described below. They are also summarized and presented with the planned data collection efforts in Section 8.

- **Landfill.** Additional current groundwater data are needed at the Landfill and at seep locations to finalize the COPC list for groundwater and to address DEQ comments regarding the groundwater discharge pathway. The data should include VOCs as analytes. Reporting limits for the groundwater data should be equal to or lower than human health-based protective screening levels for potable water. No surface or subsurface soil data are needed for the HHRA since available data are sufficient.
- **Sandblast area.** Data for lead in the available size fraction are needed to verify that lead is a COI in surface and subsurface soils. Subsurface soil data are also needed to identify other COIs that may be related to trench worker exposures. Soil gas data (both exterior and sub-slab, if appropriate) for VOCs are needed to identify COIs for the vapor intrusion pathway to distances that are up to 10 ft away (lateral distance) from existing or potential new structures.

Additional current groundwater data are needed at the Sandblast Area near seep locations to evaluate the groundwater discharge pathway, with reporting limits similar to that described for the Landfill.

- **Pistol range.** Additional current groundwater data are needed at the Pistol Range area and near seep locations to evaluate the groundwater discharge pathway, with reporting limits similar to that described for the Landfill. No surface or subsurface soil data are needed since available data are sufficient.
- **Bulb slope.** No surface or subsurface soil data are needed for the HHRA since available data are sufficient. No groundwater data are needed for the HHRA since no seeps have been located in this vicinity.

B.3.3.2 Data Gaps for Completion of Baseline HHRA

No data gaps exist for completion of the exposure assessment for the outdoor worker and trench worker at the upland AOPCs. The default values in existing HHRA guidance for these receptors and pathways identified for the upland OU are considered sufficiently appropriate and conservative for the baseline HHRA.

Data gaps for exposure assessment of the indoor worker include the following:

- Soil properties data in the vicinity of the sand blast area and existing structures (e.g., soil type, organic matter content, moisture content, bulk density, and porosity).
- Dimensions and foundation types and configurations for existing buildings where vapor intrusion may occur.

Additional data needs may be identified depending on the results and findings of the baseline HHRA. Decisions regarding the purpose and need for additional data (e.g., for refinement of risk estimates) will be made after completion of the baseline HHRA.

No data gaps have been identified for toxicity assessment or risk characterization at this time.

B.4 RIVER OU

River-related human health risks are anticipated to be caused primarily through consumption of contaminated fish and shellfish. However, minor pathways such as direct contact will also be evaluated.

B.4.1 Approach to Problem Formulation

The River OU is separated into two AOPCs: the Bonneville Dam Forebay area and the river downstream of the dam. The problem formulation in the HHRA document will include both the forebay and the downstream segment, as necessary.

B.4.1.1 Existing Site Information and Area Uses

Existing site information for the River OU has been summarized in Section 4. As discussed in Section 3.1.7, designated beneficial uses for surface water in the forebay and downstream areas include multiple uses ranging from public and private domestic water supply to water contact recreation, irrigation, and agriculture. Designated uses by fish include salmon and steelhead migration corridors as well as shad and sturgeon spawning and rearing. No changes are anticipated in the designated uses for this area.

B.4.1.2 Potential Sources of Contamination and Nature and Extent of Contamination

As described in Section 5.1, both in-water placement of waste electrical items and debris, and possible runoff from upland areas on Bradford Island have contributed to sediment contamination. The sources of contamination include PCB-containing electrical equipment and debris, release of PCB oils from transformers, possible leakage of PCB-containing dielectric fluid from capacitors, discarded light bulbs (both fluorescent and nonfluorescent), Landfill debris, sandblast grit, and associated metals. The sources of contamination and releases are spatially distributed along the northern shoreline of Bradford Island as shown on Figure 5-3.

The upland and in-water sources of contaminants discussed above have led to contamination of sediments in the Bonneville Dam Forebay area (i.e., those areas near Bradford Island). Water erosion and river current are believed to have transported these sediments to areas below the dam, which means that a secondary source of contaminated sediments may exist below the dam.

B.4.1.3 Identification of COIs and COPCs

Following the process described in Section 5.3, COIs in sediment that have been identified to date for the River OU include PCBs, copper, lead, and polycyclic aromatic hydrocarbons (including bis[2-ethylhexyl]phthalate) (Table 5-11). The list of COPCs will be confirmed from existing COIs following the screening methods presented in Section 5.3. COPCs identified for the downstream segment may be different from the COPCs identified for the forebay.

COIs from upland areas that may have the potential to be transported to sediments in the River OU were identified as described in Section 5.3 and are listed in Table 5-12. These COIs will be included in the problem formulation and further risk assessment for the River OU. Data gaps related to problem formulation for the River OU are described at the end of this section.

At the end of the RI sampling effort, additional and new COI data will be available for the following media:

- Sediment
- Surface water
- Clam tissue
- Sculpin tissue (whole body)
- Smallmouth bass tissue (whole body)
- Crayfish tissue
- Large-scale sucker tissue (whole body)

These data will be evaluated to identify the site-related COPCs for each medium, as follows:

- COIs in water and sediment that meet the three screening criteria recommended by DEQ will be identified as COPCs for water and sediment. The three criteria include detection frequency greater than 5 percent, exceedances above reference area concentrations (inorganics only), and exceedances above human health-protective screening values (DEQ's bioaccumulation-based values will be used for bioaccumulative chemicals since they would be expected to be protective of direct contact pathways as well). These COPCs will be included in the evaluation of direct contact pathways for water and sediment.
- For crayfish, smallmouth bass, and large-scale sucker, COPCs will be identified on the basis of detection frequency (>5 percent), exceedances above tissue concentrations from reference areas (inorganics in smallmouth bass and crayfish only), and exceedances above DEQ's bioaccumulation-based acceptable tissue levels.
- If site-related COPCs are detected in sediment or water, but not detected in fish and crayfish tissue, they will be included in direct contact pathway evaluation but excluded from fish consumption pathway evaluation.
- If site-related COPCs are detected in fish or crayfish tissue but not detected in sediment or surface water, they will be excluded from the direct contact pathway evaluation but may be included in the fish consumption pathway evaluation. Inclusion in the fish consumption pathway will be determined after a review of the trophic level of the species in which the COPCs were detected, and their attractiveness to anglers. Additional evaluation may also be performed to determine if the COIs detected in fish tissue originated from the forebay sources.
- COIs from upland soils or groundwater will be compared to COIs detected in sediment and surface water, using the process described in Section 5.3, to finalize the COPC list for the River OU.

B.4.1.4 Identification of Receptors and Pathways

Although this portion of the Columbia River is popular with anglers and contact water recreationists, public access to the forebay and the immediate downstream area is limited. The nearest known fishing platform is located 0.5 mile east of the forebay, in the Eagle Creek vicinity. A stakeholder survey was conducted for the Bonneville Dam area (Jones and Stokes 2006). The most popular recreational activities in the area are boating and fishing. Jet-skiing, kayaking, and canoeing were also mentioned as preferred activities by respondents in the survey.

Swimming and wading were not identified as popular activities within the River OU. Anglers are known to wade while fishing near the mouth of Eagle Creek, which is within the backwater area of the dam, and so could have received sediments by current transport. It is also possible that anglers may boat across to Goose Island and fish from the shoreline of the island. Therefore, exposure by direct contact to COPCs in sediments and surface water may occur.

The following human receptors and associated exposure pathways will be addressed in the baseline HHRA:

- Adult and child Native American fish harvesters that fish above Bonneville Dam (near the forebay), who consume potentially contaminated fish

- Adult and child recreationists who may fish near Eagle Creek and downstream of the dam and who may be exposed to COIs by direct contact with sediments there, and may also consume potentially contaminated fish
- Hypothetical adult or child resident downstream from the dam who could use the Columbia River as a water supply, or whose wells could be recharged from the river
- Nontribal high-consumption fishers are a third group of fish consumers who may represent fishing and fish consumption patterns that are different from the tribal subsistence fisher and the sport fisher. Nontribal high consumption anglers include populations such as Asian, Hispanic, and European fishers who may fish on a more regular and frequent basis than sport fisherman, enjoy both resident and anadromous fish, and consume more or all portions of the fish (i.e., whole-body consumption rather than fillets) with higher consumption rates than sport anglers. This consumer is not included for the Forebay but will be included in the downstream evaluation.

It is not known with certainty whether such consumers are present in the forebay area. A survey of stakeholders in the Bonneville area by USACE did not identify respondents by ethnicity (Jones and Stokes 2006). Discussions with Oregon Department of Fish and Wildlife staff in charge of annual creel surveys for this area did not identify any groups that would correspond to nontribal high consumption fishers, other than Russian anglers primarily interested in sturgeon (Weaver, pers. comm., 2007). For the purposes of the baseline HHRA, it will be assumed that nontribal high-consumption fishers are present in the downstream segment and they will be evaluated as a separate receptor group. More discussion of fish consumption patterns is provided in the Exposure Assessment section (Section B.4.2.1).

B.4.1.5 Conceptual Site Model

A CSM for river-related human health risks is presented as Figure B-2. This CSM focuses on potential risks from contaminated sediments located in the forebay, downstream from the dam, and near the mouth of Eagle Creek. It also considers the consumption of fish contaminated by sediments and incidental ingestion of, or dermal contact with, river water and sediment. The contact with sediment potentially occurs near the mouth of Eagle Creek and in areas downstream of the dam.

The preliminary problem formulation for the River OU provided in this section was used to identify data gaps for the HHRA. The data gaps and the corresponding data collection efforts are described in Section 7. It is assumed that a baseline HHRA will be warranted when the additional RI data are collected and the updated problem formulation is completed.

Although the problem formulation for the River OU has not been formalized, it is expected to warrant a baseline HHRA since COIs (partially screened) and potentially complete pathways are present.

The baseline risk assessment for the AOPCs in the river will focus primarily on the fish consumption pathway. Relatively minor pathways such as direct contact with sediment and surface water also will be evaluated on a quantitative basis.

B.4.2 Approach to Baseline HHRA

The baseline HHRA for the River OU will include quantitative evaluation of the receptors and pathways identified in the problem formulation.

B.4.2.1 Exposure Assessment

As with the Upland OU, Tables B-5 through B-8 present the exposure factor values and equations used to calculate chemical intake associated with EPCs. Chemical-specific intakes will be calculated to quantify CTE and RME exposure to the identified receptor populations using formulas identified by DEQ (2000, 2003), RAGS Part A (USEPA 1989), and RAGS Part B (USEPA 1991).

B.4.2.1.1 Exposure Areas

The boundaries of the River OU will be defined during the RI. The area, in general, is divided into upstream, forebay, and downstream segments, based on limits of contamination between the upstream and forebay areas and the limits of transport between the forebay and downstream areas. The Bonneville Dam complex presents a physical barrier to many of the fish species of interest to human receptors. While it is possible that anglers may fish from many locations, the adult resident fish being evaluated in the HHRA are more likely to reside and feed either only in the forebay or only in the downstream segment.

After collection of sediment, water, and tissue data from the forebay and downstream segments, a determination will be made as to whether the HHRA for the River OU should be evaluated as two smaller exposure units (forebay and downstream) or a single larger exposure unit (forebay and downstream combined). It is anticipated that two smaller exposure areas will be evaluated.

B. 4.2.1.2 Direct Contact Pathways for Sediment and Surface Water

Point value exposure input parameters used for estimating chemical intakes associated with exposure to sediment and surface water COIs (e.g., ingestion, dermal contact, and inhalation) were obtained from DEQ (2000, 2003), stakeholder surveys, and other sources. The input parameters and assumptions that will be used to estimate exposures are presented in Tables B-5.

B.4.2.1.3 Fish Consumption Pathway

The two most important factors in evaluating the fish consumption pathway are the factors that represent the concentration of COPCs in fish and fish ingestion rates by humans. Of these, representing site-related concentrations of COPCs in fish and shellfish tissue is the single most important and uncertain element of the estimation of intakes and risks for the fish and shellfish consumption pathway. The selected exposure values for this pathway are presented in Table B-5.

B.4.2.1.3.1 Selection of Fish Species for HHRA

Several sources of information were consulted to identify suitable fish species for evaluation of the fish ingestion pathway. This identification is important because fish species vary widely in their COPC concentrations as well as in their appeal for human consumption. Factors that may affect the concentrations of COPCs in fish tissue with respect to site-related contamination include resident/anadromous status, home range, trophic level, and lipid content. Surveys of anglers have also shown that different angler groups have different preferences for the species consumed. Abundant resident fish species with small home ranges and high site fidelity are more likely to be exposed to site-related COPCs than anadromous and wide-ranging fish species. Therefore, the HHRA will focus on evaluating risks from consumption of resident fish. The conservative assumptions associated with the resident fish consumption scenario are expected to be sufficient to address risks related to consumption of nonresident fish species as well.

Table B-9 lists fish species that are most popular with the three types of angler populations identified as receptors. Their resident/anadromous status, estimated home ranges for the resident species, and trophic level are also listed.

To select the fish species of interest that may have a high degree of exposure to site-related COPCs while at the same time being an edible species of interest to fish consumers, available sources of literature and surveys were consulted. Regional or site-specific studies are preferred since they are expected to be more relevant. For the tribal subsistence fisher, the Columbia River Intertribal Fish Commission consumption study (CRITFC 1994) provided information on the fish species that are popular with tribal anglers and their consumption rates. The HHRA work plan for Portland Harbor (Lower Willamette Group 2004; ATSDR 2006) also provided limited information on tribal fish consumption preferences. A recent survey of 43 stakeholders for the Bonneville area was also useful (Jones and Stokes 2006). According to the Bonneville stakeholder survey, the fish species popular with tribal respondents are salmon and sturgeon, while nontribal respondents consumed smallmouth bass and shad. Many, but not all, of the respondents consumed all of the fish caught. Respondents generally fished from a minimum of two to three locations. None of the respondents referred to consumption of shellfish or crayfish from the area.

The Bonneville area is considered relatively poor in habitat quality for the popular resident sportfish, due to its high steep banks and lack of vegetated areas and weedbeds (Weaver, pers. comm., 2007). It is also unattractive to the general public due to its lack of access, winds and currents (Oregon Bass and Panfish Club 2006). The most popular fishing in this area is for salmon on the Oregon side and sturgeon on the Washington side (Weaver, pers. comm., 2007).

Among the species listed, the smallmouth bass is a resident species that is known to occur in the forebay. It has a small home range and high fidelity to its range and, therefore, has the potential to spend its entire lifetime in the forebay. It is a trophic level 3/4 species feeding on smaller fish such as sculpin, peamouth, and juvenile fish, as well as crayfish and insect larvae. All these characteristics make it likely that the smallmouth bass is a fish species that may represent maximal exposure to site-related COPCs. It is also extremely popular with sport fishers, nontribal high consumption anglers, and also, to some extent, tribal anglers.

For these reasons, the smallmouth bass was selected as the finfish species that will be used to estimate exposure doses for the fish consumption scenario for all receptors.

At the request of DEQ, an additional fish species (large-scale sucker) will also be evaluated but with a higher degree of uncertainty. The large-scale sucker is a fish species belonging to the foraging guild (trophic level 2/3) rather than the carnivorous guild represented by the smallmouth bass. Its diet consists of phytoplankton and zooplankton, clams, insect larvae, crayfish and oligochaetes. Its home range may be from 0.5 to 10 miles (Table B-9). Five specimens of large-scale sucker, collected by USACE in 2006, have been archived. They were collected from two locations, the south shore of Cascade Island and the south shore of Bradford Island. These samples will be analyzed for the range of bioaccumulative and other site-related COIs requested by DEQ. Additional specimens of large-scale sucker may be caught during the River OU sampling effort. The usefulness of large scale sucker data to evaluate site-related contributions to fish tissue concentrations is limited and subject to a high degree of uncertainty because of its much larger home range and lower site fidelity.

The use of and uncertainties associated with use of large-scale sucker tissue data in the HHRA are described in later sections.

Consumption of large-scale sucker may be evaluated after review of the quality of data and sampling success. If the baseline HHRA indicates unacceptable risks for this scenario, the assumptions related to smallmouth bass may be modified by evaluating consumption of additional species and food preparation methods, at a later stage.

Although shellfish consumption appears to be relatively minor or minimal, relative to finfish consumption, crayfish were selected as the shellfish species to represent this dietary item. Crayfish are known to occur in the forebay. They have a large home range and may be exposed to COPCs from sources other than the forebay. However, they are included in this evaluation to provide a comprehensive estimate of the potential exposure pathways. Consumption of crayfish will be evaluated separately from the consumption of finfish due to the uncertainties involved in whether this pathway is even likely to be complete at the site as well as the home range of the crayfish themselves.

B.4.2.1.3.2 Fish Ingestion Rates

Estimates of fish ingestion rates for the various receptor populations were developed by reviewing several national sources including USEPA's *Exposure Factors Handbook* (1997), *Estimated Per Capita Fish Consumption in the United States* (2002d), and *Final Methodology for Developing Ambient Water Quality Criteria* (2000). Regional sources such as DEQ's *Guidance for Evaluation of Bioaccumulative Chemicals of Concern in Sediment* (DEQ 2007a), CRITFC's fish consumption studies (1994), and the *Portland Harbor RI/FS Programmatic Work Plan* (Lower Willamette Group 2004) were also consulted. The most relevant site-specific sources included Jones and Stokes (2006).

Recommended fish consumption rates in national and regional guidance typically combine finfish and shellfish consumption into a single value of grams per day. However, both finfish and shellfish data are proposed for collection in the River OU. Interpretation of site-related contributions to COPC concentrations in crayfish tissue may be subject to a high degree of uncertainty due to the large home-range associated with crayfish. Therefore, the baseline HHRA will evaluate risks due to finfish consumption and shellfish consumption separately, for each of the fish consumer human receptor groups.

Based on the review of these documents, the selected fish ingestion rates for adults and children are provided in Table B-8. In accordance with USEPA (2002d), the selected ingestion rates represent RME estimates of fish consumption (typically 90th to 95th percentile of reported consumption rates) and CTE estimates (typically arithmetic mean consumption rates), based on regional or national studies. The rates are based on uncooked fish weight.

For the tribal fish consumer, RME and CTE ingestion rates for finfish were developed from CRITFC (1994). The reported mean and 95% UCL for adult fish consumers were 63.2 and 175 grams/day, respectively. The proportion of total fish consumption that is comprised of resident finfish species is not provided as a direct estimate. Therefore, it was estimated by developing a ratio based on the average consumption rates of resident fish species and anadromous fish species (10 and 28.8 grams/day, CRITFC 1994, 33). Thus, it was estimated that finfish represent approximately 25 percent of total finfish consumption for tribal fishers (10/38.8= 25.7 percent). This percentage was applied to the mean and 95% UCL of total fish consumption rates to estimate the CTE and RME estimates for adults and children.

Since no local information was available for shellfish consumption, ingestion rates for shellfish were also drawn from national studies (USEPA 2002d). No separate shellfish consumption rates were estimated for the Native American angler since such information was not available. It is expected that the estimates used for the nontribal high consumption angler will be protective of the Native American fisher.

B.4.2.1.3.3 Estimating Concentrations in Fish and Shellfish Tissue

The two methods proposed to estimate fish tissue concentration are:

- Direct measurement of fish species consumed by receptors (arithmetic mean and 95% UCL to represent CTE and RME)
- Modeled concentrations of COPCs in target fish species by the use of food-web models (mean and upper end concentrations).

Both approaches have advantages and disadvantages.

To gain the most effective use of measured fish tissue concentration data in relation to estimating COPC contribution from a particular source, it is, therefore, critical, to select fish species whose residency, home range, and feeding habits can be most closely associated with the types of COPCs to be evaluated and the size of the area to be evaluated.

Direct Measurement

The advantage of direct measurements of COPCs in the fish species of interest (sculpin, smallmouth bass, large-scale sucker) is that it is likely to provide the best estimate of intake by consumers. Comparisons of direct measurements of chemical concentrations in tissues from upstream and Forebay areas may also provide robust conclusions regarding the whether or not there is a statitistically significant difference in tissue concentration between the two areas.

If there is no statistically significant difference between upstream and forebay tissue concentrations in all the fish species that are analyzed, this will serve as evidence that uptake into the biological media does not appear to have occurred.

However, if there is a statistically significant difference in tissue concentrations of one or more analyzed species between the two areas, the disadvantage of this approach is that it may be difficult, if not, impossible to relate the measured COPC concentrations in the fish to site-related contributions and, thus, determine if the site is contributing to unacceptable risk levels. This disadvantage exists because each fish species, by virtue of its resident or anadromous nature, home range, feeding habits, and trophic level may have the potential to be exposed to multiple sources of COPCs at different times and for different periods of duration in its life time. Additionally, because measured tissue concentrations integrate fish uptake of COPCs by all the exposure routes (i.e., water, sediment, diet), it is impossible to identify or separate the contribution of any one of those routes.

Trophic Models

Trophic models are simplified representations of the food-web structure for a habitat of interest. They can be used to illustrate the functional relationships between various environmental and biological variables (e.g., chemical transfer from abiotic media to biological media, predator-prey relationships) and to estimate or predict the values of various foodweb processes, (e.g., chemical transfer rates and concentrations in successive trophic levels). Therefore, a trophic model can be used for predictive purposes, i.e., to predict chemical concentrations in tissues, given the inputs for relevant environmental and biological variables.

The advantage of using food-web models to estimate COPC concentrations in fish or shellfish tissue is that it allows site-specific inputs to be considered in predicting the site-related COPC contribution to fish uptake, by exposure to sediment, water and diet, separately, and in combination. The disadvantage is that models inherently contain simplifying assumptions and uncertainties and model-predicted concentrations may not necessarily be similar to measured concentrations with an acceptable degree of uncertainty. Therefore, a model is used most effectively when its predictions can be validated with measured data to an acceptable degree of uncertainty.

The approach proposed for the current HHRA is to combine use of a food-web model with validation based on measured concentrations in various components of the food web. The selected food-web model is based on Arnot and Gobas (2004). This model has been used successfully at many PCB-contaminated sites and has been evaluated positively with regard to its predictive performance for the Lower Duwamish Waterway (Windward Environmental 2005, 2006) as well as at Portland Harbor (Lower Willamette Group 2005).

The model requires site-specific input values characterizing environmental parameters and COPC concentrations in sediment and surface water (e.g., organic carbon content, temperature). Using these data, the model can predict COPC concentrations in the various trophic levels of the food web based on exposure to sediment, water, and diet. Uncertainty in the model can be further reduced by collecting site-specific data on biological parameters such as lipid and moisture content in the components of the food web (e.g., clams, sculpin). Use of the model will be identical for both the HHRA and Environmental Risk Assessment. Therefore, a detailed description of model use and interpretation is provided in Appendix E to avoid repetition.

Estimates of COPC concentrations in fish and shellfish tissue for the baseline risk assessment will be developed in two ways: model predicted concentrations and measured concentrations. The degree of agreement between the two estimates will be evaluated. If they are in good agreement, exposure estimates will be developed on the basis of whichever estimate appears to be more robustly related to COPC concentrations in sediment and water and has less uncertainty associated with it. Development of criteria for defining acceptable agreement between measured and predicted tissue concentration as well as sensitivity analyses and model performance criteria will be performed as part of the risk assessment. Criteria used by other similar studies (e.g., Windward Environmental 2006) will be evaluated for use at this site.

If the modeled and measured concentrations are not in acceptable agreement, the possible reasons for the lack of agreement will be evaluated. If the reasons for lack of agreement appear to be related to model assumptions (e.g., assumption of 100 percent dietary uptake from forebay may lead to overprediction by model), the model will be refined to obtain better agreement with measured concentrations until an acceptable degree of uncertainty is reached. If the reasons for lack of agreement appear to be related to measured concentrations, (e.g., very large variability in measured tissue concentrations), the options for obtaining better agreement or reducing uncertainty may be limited. In this case, exposure estimates may be based on model-predicted values alone or may be estimated as two separate and parallel estimates, one based on modeled concentrations and one on measured concentrations.

For bioaccumulative COPCs other than PCBs (e.g., mercury, some PAHs), other trophic models or assumptions will be used. The primary approach may be based on site-specific biota sediment accumulation factors (BSAFs) developed from the sediment and tissue data obtained for the Forebay.

B.4.2.1.3.4 Uncertainties in Exposure Assessment

Several conservative assumptions and uncertainties exist with regard to the assumptions made in the fish consumption scenario, as noted below. However, these uncertainties are not proposed to be addressed by data collection activities at this time. They may be addressed at a later stage, if the baseline HHRA indicates unacceptable risks for this pathway.

For all receptors, the estimates of fish species consumption will be assumed in the baseline HHRA as follows:

- Non-tribal high-consumption fishers are present in the Forebay vicinity
- The anglers fish only from locations within the forebay.
- 100 percent of their consumption of resident finfish consists of smallmouth bass that reside exclusively in the forebay for their lifetime.
- The fish are consumed on a whole-body basis.
- COI losses due to fish preparation and cooking methods are not considered.
- It is expected that the choice of the smallmouth bass may overestimate exposure for all the receptors. They will likely consume larger amounts of other fish species that spend far less time in the forebay (e.g., salmon, sturgeon). The recreational fishers and Native American fishers are also more likely to consume selected portions of fish (e.g., fillets) rather than the whole fish.
- Home ranges of some fish species (e.g., large-scale sucker) may greatly exceed the area of the forebay.

B.4.2.2 Toxicity Assessment

Toxicity assessment and risk characterization for the River OU will be similar to the process outlined for the Upland OU. The decision making for the use of PCB-related toxicity values will follow a modification of the tiered approach recommended by USEPA (2000) as follows:

- For the direct contact pathways, the results of the evaluation of correlation between congener to Aroclor data in sediments (based on a sufficient number of paired analyses) and water will be reviewed. If the evaluation supports the use of Aroclor data as an acceptable term for risks related to PCBs, then toxicity data related to the Aroclors detected in sediment and water will be used in the HHRA. This scenario was observed in similar evaluations completed for the Lower Duwamish Waterway (Windward Environmental 2005, 2006) and the Fox River. If no predictable correlation occurs between Aroclors and congeners, toxicity values will be used as follows:
  - Aroclor SFs and RfDs for Aroclor data (expressed as Aroclor-summed Total PCBs)
  - Aroclor slope factors and RfDs for nondioxin-like PCB congeners (expressed as Congener-summed Total PCBs)
  - Toxicity equivalency factors based on 2,3,7,8-TCDD for dioxin-like congeners
  - If multiple Aroclors are detected and Aroclor SFs are used, the upperbound SF for high risk and persistent Aroclors will be used for pathways of incidental ingestion of and dermal contact with sediment; the SF for Aroclors of low-risk and persistence will be used for the ingestion of water-soluble Aroclors and congeners.
  - For the dermal contact pathway, oral toxicity values may be modified by the application of chemical-specific gastro-intestinal absorption f actors.
  - Mercury will be evaluated as inorganic mercury or total mercury
- For the fish consumption pathway, the results of the evaluation between the Aroclor and congener data in sediments will be reviewed, as well as the congener data for fish tissue. The toxicity values will be used as follows:
  - Aroclor SFs and RfDs (high risk and persistence) for nondioxin-like PCB congeners
  - Toxicity equivalency factors based on 2,3,7,8-TCDD for dioxin-like congeners (WHO 2006)
  - Mercury will be evaluated as methyl mercury

Risks for PCBs will be estimated both on an Aroclor basis (total PCBs as Aroclors) and congener basis (total nondioxin-like congeners, total dioxin-like congeners) and will be presented as separate and parallel estimates.

Following USEPA's recommendations regarding the potential for increased sensitivity to carcinogen exposure during early life stages (0-16 years), DEQ's guidance on early life exposure to carcinogenic chemicals is currently limited to residential exposures and other scenarios where children may be exposed to carcinogens (DEQ 2007b). Adjustment factors are available only for a few chemicals, including polycyclic aromatic hydrocarbons. If adjustment factors are available for any of the COPCs identified in fish or crayfish tissue, they will be included in the evaluation of fish tissue consumption by child receptors, as appropriate.

For COPCs without toxicity values, surrogate values based on similar chemicals or chemical class may be used.

B.4.2.3 Risk Characterization/Uncertainty Analysis

The baseline HHRA for the River OU will present the baseline risks for direct contact and fish consumption pathways for all the receptors identified above.

B.4.2.3.1 Risk Estimation

Risk estimation for the River OU will be similar to the process outlined for the Upland OU. ELCR and HQ/HI will be estimated for each receptor-pathway combination. For the fish consumption scenario, multiple estimates of risk may be generated to differentiate among the types of exposure assumptions and toxicity values used. Examples of separate risk estimates that may be presented for the tribal fisher include:

- Forebay and downstream exposure areas
- RME and CTE fish ingestion rates
- Measured and/or predicted concentrations in fish tissue
- PCBs as total Aroclors, total dioxin-like congeners, and nondioxin-like congener-based risk estimates

B.4.2.3.2 Risk Characterization

The risk characterization for the River OU will be similar to that for the Upland OU. Risk driving chemicals and pathways will be characterized relative to the probability and magnitude of risk and hazard with reference to acceptable risk levels.

B.4.2.3.3 Uncertainty Analysis

The discussion of uncertainty for the River OU baseline risk assessment will be both qualitative and quantitative. Uncertainties relating to COPC identification (e.g., Aroclor and congener analyses, usability of data), other exposure assessment parameters (e.g., ingestion rates for fish and shellfish in the area, home ranges for fish species evaluated), toxicity assessment (e.g., effects of nondioxin-like PCBs), and risk characterization (e.g., range of ELCR and HQs) will be discussed.

To understand baseline risks, to make risk management decisions at the time of the RI, and for comparing cleanup goals in the FS, it will be necessary to generate a reliable relationship between aquatic risks and sediment concentrations of key chemicals such as PCBs. The means to do so is to build and reduce uncertainty in the trophic model. Since the use of the food web is a key tool in the River OU risk assessment, the results of sensitivity and uncertainty analyses for this model will be presented. Model refinement will be based on reducing uncertainty in model inputs and assumptions, to the degree practicable, as described in Appendix E. The highest fish consumption risks may be associated with the receptor whose very presence in the Bonneville Area is highly uncertain: the non-tribal high consumption angler. Therefore, additional evaluation of the presence and potential exposures of this receptor may also be undertaken.

B.4.3 Data Gaps for River OU HHRA

This section describes the data gaps for the completion of the HHRA for the River OU.

B.4.3.1 Data Gaps for Completion of Problem Formulation

The formal problem formulation for the River OU will be presented in the RI report. Data gaps that need to be filled to perform the baseline HHRA were identified on the basis of the preliminary problem formulation performed to date. The data gaps are described below. They are also summarized and presented with the planned data collection efforts in Section 8.

- **Reference area.** In order to identify site-related COPCs, concentrations of COIs (particularly PCBs) in sediment, surface water and tissues of the selected target species (clam, sculpin, smallmouth bass) are needed from the reference area, upstream of the forebay. The reference area data will be used for statistical comparisons with forebay data and to provide estimates of non-site-related risks, if needed. The sample size and selection of sample locations should be sufficient to develop reference area concentrations for robust statistical comparisons.

  Aroclor and some congener data are needed for sediment, water, and clams, and congener data are needed for fish tissues. If mercury is identified as a COI, it should be analyzed as total mercury in sediment and water, total mercury and methyl mercury in clam tissue and total mercury in finfish. These analyses are based on the expected speciation of mercury in these media, i.e., mercury in sediment and water is present primarily as inorganic mercury with a small fraction (typically methyl mercury present as 5-10% of total), methyl mercury in invertebrates may constitute approximately 10-20% of total mercury, and almost 100% of mercury in finfish is expected to occur as methyl mercury. Therefore, the methyl mercury content of finfish will be represented by the total mercury analysis.

- **Forebay area.** Concentrations of COIs in sediment to characterize baseline conditions (i.e., after the interim removal action) are needed for sediment, surface water, and tissues of target species in the forebay area. The selected target species include finfish and shellfish species of interest to fish consumers (crayfish, smallmouth bass, large-scale sucker) and other species that are part of the food web or dietary preferences of these edible species (clams, sculpin).

- **Downstream area.** The downstream area is not currently included in the risk assessment since site characterization and delineation of the nature and extent of contamination have not been initiated.

B.4.3.2 Data Gaps for Completion of Baseline HHRA

Data gaps related to exposure assessment (e.g., confirmed presence of non-tribal high consumption angler), and inputs related to trophic model use are not proposed to be addressed at this time. They may be addressed at a later date, if needed, and will be based upon the results and findings of the baseline HHRA. Although some data gaps exist for the toxicity assessment (e.g., reliable information on the toxicity of non-dioxin-like PCB congeners), they are not proposed to be addressed by site-specific data collection activities.

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Table B-1
Exposure Factors for Human Receptors - Soil/Groundwater
Bradford Island

Parameter		Symbol	Units	Outdoor Maintenance Worker		Indoor Office Worker		Trench/ Excavation Worker		Reference/Comment
				Adult		Adult		Adult		
				CTE	RME	CTE	RME	CTE	RME	
Averaging Time	*Carcinogens*	AT_c	d	25,550	25,550	25,550	25,550	25,550	25,550	ODEQ 2003
	Noncarcinogens	AT_{nc}	d	= ED	= ED	= ED	= ED	= ED	= ED	ODEQ 2003
Body Weight		BW	kg	70	70	70	70	70	70	ODEQ 2003
Event Frequency	*Soil contact*	EF_{evd}	events/day	--	--	--	--	2	2	ODEQ 2003
	Groundwater	EF_{evd}	events/day	--	--	--	--	2	2	ODEQ 2003
Event Time	*Groundwater*	t_{event}	hr/event	--	--	--	--	2	2	ODEQ 2003
Exposure Duration	*General*	ED	yr	6	25	6	25	0.5	1	ODEQ 2003, ODEQ 2000
Exposure Frequency	*General*	EF	days/yr	250	250	250	250	--	--	ODEQ 2003, ODEQ 2000
Incidental Soil or Sediment Ingestion Rate (dry weight)		IR_{soil}	kg/day	0.050	0.100	--	--	0.100	0.330	ODEQ 2003, ODEQ 2000
Incidental Ground Water Ingestion Rate		IR_w	L/day	--	--	--	--	0.05	0.05	DEQ 2003, DEQ 2000
Inhalation Rate		IR_{air}	m^3/day	7.0	7.0	7.0	7.0	7.0	7.0	DEQ 2003, DEQ 2000
Soil to Skin Adherence Factor		M	mg/cm^2	0.02	0.10	--	--	0.1	0.3	DEQ 2003, DEQ 2000
Exposed Skin Surface Area	*Soil*	SA	cm^2	3,300	3,300	--	--	3,300	3,300	DEQ 2003, DEQ 2000
	Groundwater	SA	cm^2	--	--	--	--	5,200	5,700	DEQ 2003, DEQ 2000

Notes:

-- = indicates not applicable or not relevant

Almost all parameter values are from ODEQ Guidance for Conduct of Deterministic Human Health Risk Assessments (2000) or Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites (ODEQ 2003).

USEPA 2003. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim.

Table B-2. Summary of Risk Based Concentration Equations
Outdoor Maintenance Worker Exposure to Soil

MEDIA	PATHWAY	RBCs CARCINOGEN EQUATION	RBCs NON-CARCINOGEN EQUATION
SOIL	Incidental Ingestion of Soil	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW}{SF_o \times EF \times ED \times CF \times IR_{soil} \times AF_o}$	$RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW \times RfD_o}{EF \times ED \times CF \times IR_{soil} \times AF_o}$
	Dermal Absorption of Soil	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW}{SF_o \times EF \times ED \times CF \times SA \times M \times abs}$	$RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW \times RfD_o}{EF \times ED \times CF \times SA \times M \times abs}$
	Surficial Soil Exposure to Ambient Inhalation of Vapors	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW \times VF_s}{SF_i \times EF \times ED \times IR_{air-outdoor}}$	$RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW \times RfD_i \times VF_s}{EF \times ED \times IR_{air-outdoor}}$
	Surficial Soil Exposure to Ambient Inhalation of Particulates	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW \times PEF}{SF_i \times EF \times ED \times IR_{air-outdoor}}$	$RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW \times RfD_i \times PEF}{EF \times ED \times IR_{air-outdoor}}$
	Combined Exposure Ingestion+Dermal+Vapor and Particulates Inhalation	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW}{EF \times ED\left[SF_o \times CF(IR_{soil} \times AF_o + SA \times M \times abs) + SF_i \times IR_{air-outdoor}\left(1/VF_s \text{ or } 1/PEF\right)\right]}$	$RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW}{EF \times ED\left[1/RfD_o \times CF(IR_{soil} \times AF_o + SA \times M \times abs) + 1/RFD_i \times IR_{air-outdoor}\left(1/VF_s \text{ or } 1/PEF\right)\right]}$

Symbol	Description	Units
THQ	Target Hazard Quotient for Individual Constituents	---
TR	Target Excess Individual Lifetime Cancer Risk	---
AT_c	Averaging Time for Carcinogens	days
AT_{nc}	Averaging Time for Noncarcinogens	days
BW	Body Weight	kg
CF	Conversion Factor	10^{-6} kg/mg
ED	Exposure Duration	yr
EF	Exposure Frequency	day/yr
ET_w	Exposure Time for Contact With Water	hr/day
SA_w	Skin Surface Area for Water Contact	cm^2
SA	Skin Surface Area	cm^2/day
M	Soil to Skin Adherence Factor	mg/cm^2
abs	Absorption Factor	---
IR_{soil}	Soil Ingestion Rate	mg/day
IR_w	Daily Water Ingestion Rate	L/day
K_p	Dermal coefficient permeability	cm/hr
$IR_{air-indoor}$	Daily Enclosed Space Inhalation Rate	m^3/day
$IR_{air-outdoor}$	Daily Outdoor Inhalation Rate	m^3/day
AF_o	Fraction Ingested from Contaminated Source	---
SF_o	Oral Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
SF_i	Inhalation Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
RfD_o	Oral Reference Dose	mg/(kg-day)
RfD_i	Inhalation Reference Dose	mg/(kg-day)
$VF_{soil,amb}$	Surficial Soil-to-ambient air Volatilization Factor	m^3/kg
PEF	Particulate Emission Factor - Commercial	m^3/kg
$VF_{subsoil,amb}$	Subsurface Soil-to-ambient air Volatilization Factor	$(mg/m^3)/(mg/kg)$
$VF_{gw,amb}$	Groundwater-to- ambient air Volatilization Factor	$(mg/m^3)/(mg/L)$
$VF_{sw,amb}$	Surface Water-to-ambient air Volatilization Factor	$(mg/m^3)/(mg/L)$

References:

EPA 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual - Part B.
EPA 1997. Exposure Factors Handbook. Volumes I-III. An Update to Exposure Factors Handbook EPA/600/8-89/043
ODEQ 2000. Guidance for Conduct of Deterministic Human Health Risk Assessments.
EPA 2001. Supplemental Guidance for Developping Soil Screening Levels for Superfund Sites
ODEQ 2003. Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

Table B-3. Summary of Risk Based Concentration Equations
Trench / Excavation Worker Exposure to Soil

MEDIA	PATHWAY	RBCs CARCINOGEN EQUATION	RBCs NON-CARCINOGEN EQUATION
SOIL	Incidental Ingestion of Soil	$RBCs[mg/kg]=\frac{TR\times AT_c\times BW}{SF_o\times EF\times ED\times CF\times IR_{soil}\times AF_o}$	$RBCs[mg/kg]=\frac{THQ\times AT_{nc}\times BW\times RfD_o}{EF\times ED\times CF\times IR_{soil}\times AF_o}$
	Dermal Absorption of Soil	$RBCs[mg/kg]=\frac{TR\times AT_c\times BW}{SF_o\times EF\times ED\times CF\times SA\times M\times abs}$	$RBCs[mg/kg]=\frac{THQ\times AT_{nc}\times BW\times RfD_o}{EF\times ED\times CF\times SA\times M\times abs}$
	Surficial Soil Exposure to Ambient Inhalation of Vapors	$RBCs[mg/kg]=\frac{TR\times AT_c\times BW\times VF_s}{SF_i\times EF\times ED\times IR_{air-outdoor}}$	$RBCs[mg/kg]=\frac{THQ\times AT_{nc}\times BW\times RfD_i\times VF_s}{EF\times ED\times IR_{air-outdoor}}$
	Surficial Soil Exposure to Ambient Inhalation of Particulates	$RBCs[mg/kg]=\frac{TR\times AT_c\times BW\times PEF}{SF_i\times EF\times ED\times IR_{air-outdoor}}$	$RBCs[mg/kg]=\frac{THQ\times AT_{nc}\times BW\times RfD_i\times PEF}{EF\times ED\times IR_{air-outdoor}}$
	Combined Exposure Ingestion+Dermal+Vapor and Particulates Inhalation	$RBCs[mg/kg]=\frac{TR\times AT_c\times BW}{EF\times ED\left[SF_o\times CF\left(IR_{soil}\times AF_o+SA\times M\times abs\right)+SF_i\times IR_{air-outdoor}\left(\frac{1}{VF_s}\ or\ \frac{1}{PEF}\right)\right]}$	$RBCs[mg/kg]=\frac{THQ\times AT_{nc}\times BW}{EF\times ED\left[\frac{1}{RfD_o}\times CF\left(IR_{soil}\times AF_o+SA\times M\times abs\right)+\frac{1}{RFD_i}\times IR_{air-outdoor}\left(\frac{1}{VF_s}\ or\ \frac{1}{PEF}\right)\right]}$

Symbol	Description	Units
THQ	Target Hazard Quotient for Individual Constituents	---
TR	Target Excess Individual Lifetime Cancer Risk	---
AT_c	Averaging Time for Carcinogens	days
AT_{nc}	Averaging Time for Noncarcinogens	days
BW	Body Weight	kg
CF	Conversion Factor	10^{-6} kg/mg
ED	Exposure Duration	yr
EF	Exposure Frequency	day/yr
ET_w	Exposure Time for Contact With Water	hr/day
SA_w	Skin Surface Area for Water Contact	cm^2
SA	Skin Surface Area	cm^2/day
M	Soil to Skin Adherence Factor	mg/cm^2
abs	Absorption Factor	---
IR_{soil}	Soil Ingestion Rate	mg/day
IR_w	Daily Water Ingestion Rate	L/day
K_p	Dermal coefficient permeability	cm/hr
$IR_{air-indoor}$	Daily Enclosed Space Inhalation Rate	m^3/day
$IR_{air-outdoor}$	Daily Outdoor Inhalation Rate	m^3/day
AF_o	Fraction Ingested from Contaminated Source	---
SF_o	Oral Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
SF_i	Inhalation Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
RfD_o	Oral Reference Dose	mg/(kg-day)
RfD_i	Inhalation Reference Dose	mg/(kg-day)
$VF_{soil,amb}$	Surficial Soil-to-ambient air Volatilization Factor	m^3/kg
PEF	Particulate Emission Factor - Commercial	m^3/kg
$VF_{subsoil,amb}$	Subsurface Soil-to-ambient air Volatilization Factor	(mg/m^3)/(mg/kg)
$VF_{gw,amb}$	Groundwater-to- ambient air Volatilization Factor	(mg/m^3)/(mg/L)
$VF_{sw,amb}$	Surface Water-to-ambient air Volatilization Factor	(mg/m^3)/(mg/L)

References:

EPA 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual - Part B.
EPA 1997. Exposure Factors Handbook. Volumes I-III. An Update to Exposure Factors Handbook EPA/600/8-89/043
ODEQ 2000. Guidance for Conduct of Deterministic Human Health Risk Assessments.
EPA 2001. Supplemental Guidance for Developping Soil Screening Levels for Superfund Sites
ODEQ 2003. Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

Table B-4. Summary of Risk Based Concentration Equations
Trench / Excavation Worker Exposure to Groundwater

MEDIA	PATHWAY	RBCs CARCINOGEN EQUATION	RBCs NON-CARCINOGEN EQUATION
GROUNDWATER	Incidental Ingestion of Water	$RBCs[mg/L] = \frac{TR \times AT_c \times BW}{SF_o \times EF \times ED \times IR_w}$	$RBCs[mg/L] = \frac{THQ \times AT_{nc} \times BW \times RfD_o}{EF \times ED \times IR_w}$
	Dermal Contact With Water	$RBCs[mg/L] = \frac{TR \times AT_c \times BW \times CF}{SF_o \times EF \times ED \times ET_w \times K_p \times SA_w}$	$RBCs[mg/L] = \frac{THQ \times AT_{nc} \times BW \times CF \times RfD_o}{EF \times ED \times ET_w \times K_p \times SA_w}$
	Outdoor Inhalation of Vapor Emissions From Groundwater	$RBCs[mg/L] = \frac{TR \times AT_c \times BW}{SF_i \times EF \times ED \times IR_{air-outdoor} \times VF_{w,amb}}$	$RBCs[mg/L] = \frac{THQ \times AT_{nc} \times BW \times RfD_i}{EF \times ED \times IR_{air-outdoor} \times VF_{w,amb}}$
	Combined Exposure Ingestion+Dermal and Outdoor Vapor	$RBCs[mg/L] = \frac{TR \times AT_c \times BW}{EF \times ED\left[SF_o\left(IR_w + \frac{ET_w \times K_p \times SA_w}{CF}\right) + SF_i \times IR_{air-outdoor} \times VF_{w,amb}\right]}$	$RBCs[mg/L] = \frac{THQ \times AT_{nc} \times BW}{EF \times ED\left[\frac{1}{RfD_o}\left(IR_w + \frac{ET_w \times K_p \times SA_w}{CF}\right) + \frac{1}{RfD_i} \times IR_{air-outdoor} \times VF_{w,amb}\right]}$

Symbol	Description	Units
THQ	Target Hazard Quotient for Individual Constituents	---
TR	Target Excess Individual Lifetime Cancer Risk	---
AT_c	Averaging Time for Carcinogens	days
AT_{nc}	Averaging Time for Noncarcinogens	days
BW	Body Weight	kg
CF	Conversion Factor	1000 cm^3/L
ED	Exposure Duration	yr
EF	Exposure Frequency	day/yr
ET_w	Exposure Time for Contact With Water	hr/day
SA_w	Skin Surface Area for Water Contact	cm^2
SA	Skin Surface Area	cm^2/day
M	Soil to Skin Adherence Factor	mg/cm^2
abs	Absorption Factor	---
IR_{soil}	Soil Ingestion Rate	mg/day
IR_w	Daily Water Ingestion Rate	L/day
K_p	Dermal coefficient permeability	cm/hr
$IR_{air-indoor}$	Daily Enclosed Space Inhalation Rate	m^3/day
$IR_{air-outdoor}$	Daily Outdoor Inhalation Rate	m^3/day
AF_o	Fraction Ingested from Contaminated Source	---
SF_o	Oral Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
SF_i	Inhalation Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
RfD_o	Oral Reference Dose	mg/(kg-day)
RfD_i	Inhalation Reference Dose	mg/(kg-day)
$VF_{soil,amb}$	Surficial Soil-to-ambient air Volatilization Factor	m^3/kg
PEF	Particulate Emission Factor - Commercial	m^3/kg
$VF_{subsoil,amb}$	Subsurface Soil-to-ambient air Volatilization Factor	(mg/m^3)/(mg/kg)
$VF_{gw,amb}$	Groundwater-to- ambient air Volatilization Factor	(mg/m^3)/(mg/L)
$VF_{sw,amb}$	Surface Water-to-ambient air Volatilization Factor	(mg/m^3)/(mg/L)

References:

EPA 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual - Part B.
EPA 1997. Exposure Factors Handbook. Volumes I-III. An Update to Exposure Factors Handbook EPA/600/8-89/043
ODEQ 2000. Guidance for Conduct of Deterministic Human Health Risk Assessments.
EPA 2001. Supplemental Guidance for Developping Soil Screening Levels for Superfund Sites
ODEQ 2003. Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

Table B-5
Exposure Factors for Human Receptors - Sediment/Surface Water/Fish Consumption
Bradford Island

Parameter		Symbol	Units	Recreational Swimmer/Wader				Recreational Angler				Non-tribal High Consumption Angler (1)				Tribal Fish Harvester				Hypothetical Resident Drinking River Water				Reference/Comment
				Adult		Child		Adult		Child		Adult		Child		Adult		Child		Adult		Child		
				CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME	
Averaging Time	*Carcinogens*	AT_c	d	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	25,550	ODEQ 2003
	Noncarcinogens	AT_{nc}	d	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	= ED	ODEQ 2003
Body Weight		BW	kg	70	70	15	15	70	70	15	15	70	70	15	15	70	70	15	15	70	70	15	15	ODEQ 2003
Event Frequency	*Sediment contact*	EF_{evd}	events/day	1	1	1	1	1	1	1	1	--	--	--	--	--	--	--	--	--	--	--	--	ODEQ 2000
	Bathing			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	1	1	1	ODEQ 2000
	Swimming			1	1	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ODEQ 2000
Event Time	*Bathing*	t_{event}	hr/event	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.16	0.25	0.16	0.25	ODEQ 2000
	Swimming			0.5	1.0	0.5	1.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ODEQ 2000
Exposure Duration		ED	yr	9	30	6	6	9	30	6	6	9	30	6	6	9	30	6	6	9	30	6	6	ODEQ 2003
Exposure Frequency	*General*	EF	days/yr	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	350	350	350	350	ODEQ 2003
	Sediment contact			5	150	5	150	21	31	21	31	50	100	50	100	100	150	100	150	--	--	--	--	ODEQ 2003, Prof. judgement
	Bathing			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	350	350	350	350	ODEQ 2003
	Swimming			5	150	5	150	21	31	21	31	50	100	50	100	100	150	100	150	--	--	--	--	ODEQ 2003, Prof. judgement
Incidental Sediment Ingestion Rate (dry weight)		IR_{soil}	kg/day	0.050	0.100	0.100	0.200	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ODEQ 2003, assumed similar to soil
Incidental Surface Water Ingestion Rate		$IR_{w,s}$	L/day	0.05	0.05	0.05	0.05	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	USEPA 1989
Drinking Water Ingestion Rate		$IR_{w,d}$	L/day	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.4	2.0	0.9	1.5	ODEQ 2003
Inhalation Rate		IR_{air}	m^3/day	20.0	20	8.3	8.3	--	--	--	--	--	--	--	--	--	--	--	--	20.0	20.0	8.3	8.3	ODEQ 2003
Sediment to Skin Adherence Factor		M	mg/cm^2	0.07	0.30	0.20	3.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ODEQ 2003, USEPA 2003
Exposed Skin Surface Area	*Sediment contact*	SA	cm^2	5,700	5,700	2,800	2,800	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ODEQ 2003
	Bathing	SA	cm^2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	18,000	22,000	6,600	7,300	ODEQ 2003
	Swimming	SA	cm^2	18,000	22,000	6,600	7,300	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	ODEQ 2003
Finfish Ingestion Rate		--	g/day	--	--	--	--	4.2 (a)	23.3 (a)	2.6 (b)	13.1(b)	4.2 (c)	107.3 (c)	2.6 (d)	73.7 (d)	15.8 (e)	43.8 (e)	4.9 (f)	18.3 (f)	--	--	--	--	USEPA 2002, CRTFC 1994
Dietary Composition		--	--	--	--	--	--	TL 3/4 Fish	TL 3/4 Fish	TL 3/4 Fish	TL 3/4 Fish					TL 3/4 Fish	TL 3/4 Fish	TL 3/4 Fish	TL 3/4 Fish	--	--	--	--	Site-specific
Resident Fish - Trophic Level 3/4		--	--	--	--	--	--	100	100	100	100					100	100	100	100	--	--	--	--	Site-specific
% Fish Consumed from Site		--	%	--	--	--	--	100	100	100	100					100	100	100	100	--	--	--	--	ODEQ 2000
Shellfish Ingestion Rate		--	g/day	--	--	--	--	3.3 (g)	17.9 (g)	NN	NN	3.3 (h)	82.2 (h)	NN	NN	NI	NI	NI	NI	--	--	--	--	USEPA 2002, CRTFC 1994

Notes:

Recreational swimmer/wader includes adults and children who may utilize Goose Island beaches and mouth of Eagle Creek.

-- = indicates not applicable or not relevant

NN = Not needed because finfish ingestion rate based on consumption of finfish and shellfish, See footnotes (b) and (d)

NI = No shellfish consumption indicated in study.

ODEQ 2000. Guidance for Conduct of Deterministic Human Health Risk Assessments.

ODEQ 2003. Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

USEPA 2002. Estimated per Capita Fish Consumption in the United States.

USEPA 2003. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim.

CRITFC. 1994. A Fish Consumption Survey of the Umatilla, Nez Perce, Yakima, and Warm Springs Tribes of the Columbia River Basin.

Professional Judgement:

Recreational angler assumed to wade or swim once a month for 9 months of the year and 1 per weekend for three summer months for CTE; Once a month for nine months and 2 times/week for three summer months (RME);

Non-tribal High Consumption angler assumed to wade or swim once per weekend throughout the year (CTE), and twice per weekend throughout the year (RME).

Tribal angler assumed to wade or swim twice a week throughout the year (CTE) or three times a week throughout the year (RME).

(a) Mean and 95th percentile for uncooked finfish consumption (freshwater and estuarine), US Population Age 18 and older (USEPA 2002)

(b) Mean and 95th percentile for uncooked finfish + shellfish consumption (freshwater and estuarine), US Population Age 14 and younger (USEPA 2002)

(c) Mean and 99th percentile for uncooked finfish consumption (freshwater and estuarine), US Population Age 18 and older (USEPA 2002)

(d) Mean and 99th percentile for uncooked finfish + shellfish consumption (freshwater and estuarine), US Population Age 14 and younger (USEPA 2002)

(e) Tribal adult resident finfish consumption rates estimated as 25% of total mean fish consumption rate (63.2 g/day) and 95% UCL fish consumption rate (175 g/day)

(f) Tribal child resident finfish consumption rate estimated as 25% of total mean total fish consumption rate (19.6 g/day) and 95% UCL fish consumption rate (73 g/day)

(g) Mean and 95th percentile for uncooked shellfish consumption (freshwater and estuarine), US Population Age 18 and older (USEPA 2002)

(h) Mean and 99th percentile for uncooked shellfish consumption (freshwater and estuarine), US Population Age 18 and older (USEPA 2002)

(1) Non-tribal high consumption angler is not present at the forebay but may be present in the downstream section.

Table B-6. Summary of Risk Based Concentration Equations
Recreational Wader Exposure to Sediment

MEDIA	PATHWAY	RBCs CARCINOGEN EQUATION	RBCs NON-CARCINOGEN EQUATION
SEDIMENT	Incidental Ingestion of Sediment	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW}{SF_o \times EF \times ED \times CF \times IR_{sed} \times AF_o}$	$RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW \times RfD_o}{EF \times ED \times CF \times IR_{sed} \times AF_o}$
	Dermal Absorption of Sediment	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW}{SF_o \times EF \times ED \times CF \times SA \times M \times abs}$	$RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW \times RfD_o}{EF \times ED \times CF \times SA \times M \times abs}$
	Combined Exposure Ingestion and Dermal	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW}{EF \times ED \times SF_o \times CF(IR_{sed} \times AF_o + SA \times M \times abs)}$	$RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW \times RfD_o}{EF \times ED \times CF(IR_{sed} \times AF_o + SA \times M \times abs)}$

Symbol	Description	Units
THQ	Target Hazard Quotient for Individual Constituents	---
TR	Target Excess Individual Lifetime Cancer Risk	---
AT_c	Averaging Time for Carcinogens	days
AT_{nc}	Averaging Time for Noncarcinogens	days
BW	Body Weight	kg
CF	Conversion Factor	10^{-6} kg/mg
ED	Exposure Duration	yr
EF	Exposure Frequency	day/yr
ET_w	Exposure Time for Contact With Water	hr/day
SA_w	Skin Surface Area for Water Contact	cm^2
SA	Skin Surface Area	cm^2/day
M	Soil to Skin Adherence Factor	mg/cm^2
abs	Absorption Factor	---
IR_{sed}	Sediment Ingestion Rate	mg/day
IR_w	Daily Water Ingestion Rate	L/day
K_p	Dermal coefficient permeability	cm/hr
$IR_{air\text{-}indoor}$	Daily Enclosed Space Inhalation Rate	m^3/day
$IR_{air\text{-}outdoor}$	Daily Outdoor Inhalation Rate	m^3/day
AF_o	Fraction Ingested from Contaminated Source	---
SF_o	Oral Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
SF_i	Inhalation Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
RfD_o	Oral Reference Dose	mg/(kg-day)
RfD_i	Inhalation Reference Dose	mg/(kg-day)
$VF_{soil,amb}$	Surficial Soil-to-ambient air Volatilization Factor	m^3/kg
PEF	Particulate Emission Factor - Commercial	m^3/kg
$VF_{subsoil,amb}$	Subsurface Soil-to-ambient air Volatilization Factor	(mg/m^3)/(mg/kg)
$VF_{gw,amb}$	Groundwater-to- ambient air Volatilization Factor	(mg/m^3)/(mg/L)
$VF_{sw,amb}$	Surface Water-to-ambient air Volatilization Factor	(mg/m^3)/(mg/L)

References:

EPA 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual - Part B.
EPA 1997. Exposure Factors Handbook. Volumes I-III. An Update to Exposure Factors Handbook EPA/600/8-89/043
ODEQ 2000. Guidance for Conduct of Deterministic Human Health Risk Assessments.
EPA 2001. Supplemental Guidance for Developping Soil Screening Levels for Superfund Sites
ODEQ 2003. Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

Table B-7. Summary of Risk Based Concentration Equations
Recreational Swimmer Exposure to Surface Water

MEDIA	PATHWAY	RBCs CARCINOGEN EQUATION	RBCs NON-CARCINOGEN EQUATION
SURFACE WATER	Incidental Ingestion of Water	$RBCs[mg/L] = \frac{TR \times AT_c \times BW}{SF_o \times EF \times ED \times IR_w}$	$RBCs[mg/L] = \frac{THQ \times AT_{nc} \times BW \times RfD_o}{EF \times ED \times IR_w}$
	Dermal Contact With Water	$RBCs[mg/L] = \frac{TR \times AT_c \times BW \times CF}{SF_o \times EF \times ED \times ET_w \times K_p \times SA_w}$	$RBCs[mg/L] = \frac{THQ \times AT_{nc} \times BW \times CF \times RfD_o}{EF \times ED \times ET_w \times K_p \times SA_w}$
	Combined Exposure Ingestion and Dermal	$RBCs[mg/L] = \frac{TR \times AT_c \times BW}{EF \times ED \times SF_o \left(IR_w + \frac{ET_w \times K_p \times SA_w}{CF} \right)}$	$RBCs[mg/L] = \frac{THQ \times AT_{nc} \times BW \times RfD_o}{EF \times ED \left(IR_w + \frac{ET_w \times K_p \times SA_w}{CF} \right)}$

Symbol	Description	Units
THQ	Target Hazard Quotient for Individual Constituents	---
TR	Target Excess Individual Lifetime Cancer Risk	---
AT_c	Averaging Time for Carcinogens	days
AT_{nc}	Averaging Time for Noncarcinogens	days
BW	Body Weight	kg
CF	Conversion Factor	1000 cm^3/L
ED	Exposure Duration	yr
EF	Exposure Frequency	day/yr
ET_w	Exposure Time for Contact With Water	hr/day
SA_w	Skin Surface Area for Water Contact	cm^2
SA	Skin Surface Area	cm^2/day
M	Soil to Skin Adherence Factor	mg/cm^2
abs	Absorption Factor	---
IR_{soil}	Soil Ingestion Rate	mg/day
IR_w	Daily Water Ingestion Rate	L/day
K_p	Dermal coefficient permeability	cm/hr
$IR_{air\text{-}indoor}$	Daily Enclosed Space Inhalation Rate	m^3/day
$IR_{air\text{-}outdoor}$	Daily Outdoor Inhalation Rate	m^3/day
AF_o	Fraction Ingested from Contaminated Source	---
SF_o	Oral Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
SF_i	Inhalation Slope Factor	$[mg/(kg\text{-}day)]^{-1}$
RfD_o	Oral Reference Dose	mg/(kg-day)
RfD_i	Inhalation Reference Dose	mg/(kg-day)
$VF_{soil,amb}$	Surficial Soil-to-ambient air Volatilization Factor	m^3/kg
PEF	Particulate Emission Factor - Commercial	m^3/kg
$VF_{subsoil,amb}$	Subsurface Soil-to-ambient air Volatilization Factor	(mg/m^3)/(mg/kg)
$VF_{gw,amb}$	Groundwater-to- ambient air Volatilization Factor	(mg/m^3)/(mg/L)
$VF_{sw,amb}$	Surface Water-to-ambient air Volatilization Factor	(mg/m^3)/(mg/L)

References:

EPA 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual - Part B.
EPA 1997. Exposure Factors Handbook. Volumes I-III. An Update to Exposure Factors Handbook EPA/600/8-89/043
ODEQ 2000. Guidance for Conduct of Deterministic Human Health Risk Assessments.
EPA 2001. Supplemental Guidance for Developping Soil Screening Levels for Superfund Sites
ODEQ 2003. Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

Table B-8. Summary of Risk Based Concentration Equations
Recreational Angler and Subsistence Harvester

MEDIA	PATHWAY	RBCs CARCINOGEN EQUATION	RBCs NON-CARCINOGEN EQUATION
SEDIMENT	Fish Consumption	Metals: $RBCs[mg/kg] = \frac{TR \times AT_c}{SF_o \times AF_o \times CF \times BSAF_{metals}\left(\frac{EF_{ad} \times ED_{ad} \times IR_{fish,ad}}{BW_{ad}} + \frac{EF_{ch} \times ED_{ch} \times IR_{fish,ch}}{BW_{ch}}\right)}$	Metals: $RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW_{ch} \times RfD_o}{EF_{ch} \times ED_{ch} \times IR_{fish,ch} \times CF \times AF_o \times BSAF_{metals}}$
		Organics: $RBCs[mg/kg] = \frac{TR \times AT_c}{SF_o \times AF_o \times CF \times \left(\frac{BSAF_{org} \times f_{lipid}}{f_{oc,sed}}\right)\left(\frac{EF_{ad} \times ED_{ad} \times IR_{fish,ad}}{BW_{ad}} + \frac{EF_{ch} \times ED_{ch} \times IR_{fish,ch}}{BW_{ch}}\right)}$	Organics: $RBCs[mg/kg] = \frac{THQ \times AT_{nc} \times BW_{ch} \times RfD_o}{EF_{ch} \times ED_{ch} \times IR_{fish,ch} \times CF \times AF_o\left(\frac{BSAF_{org} \times f_{lipid}}{f_{oc,sed}}\right)}$
WATER	Fish Consumption	$RBCs[mg/kg] = \frac{TR \times AT_c}{SF_o \times AF_o \times CF \times BCF\left(\frac{EF_{ad} \times ED_{ad} \times IR_{fish,ad}}{BW_{ad}} + \frac{EF_{ch} \times ED_{ch} \times IR_{fish,ch}}{BW_{ch}}\right)}$	$RBCs[mg/kg] = \frac{TR \times AT_c \times BW_{ch} \times RfD_o}{EF_{ch} \times ED_{ch} \times IR_{fish,ch} \times CF \times AF_o \times BCF}$

Symbol	Description	Units
THQ	Target Hazard Quotient for Individual Constituents	---
TR	Target Excess Individual Lifetime Cancer Risk	---
AT_c	Averaging Time for Carcinogens	days
AT_{nc}	Averaging Time for Noncarcinogens	days
CF	Conversion Factor	10^{-3} kg/g
BW	Body Weight	kg
ED	Exposure Duration	yr
EF	Exposure Frequency	day/yr
IR_{fish}	Daily Fish Ingestion Rate	g/day
IR_w	Daily Water Ingestion Rate	L/day
AF_o	Fraction Ingested from Contaminated Source	---
SF_o	Oral Slope Factor	1/mg/kg-day
SF_i	Inhalation Slope Factor	1/mg/kg-day
RfD_o	Oral Reference Dose	mg/kg-day
RfD_i	Inhalation Reference Dose	mg/kg-day
$f_{oc,sed}$	Fraction Organic Carbon in Sediments	kg-oc/kg-sediment
f_{lipid}	Lipid Fraction in Fish Tissue	kg-lipid/kg-fish
$BSAF_{metals}$	Transfer Factor Sediment To Fish	kg-sediment/kg-fish
$BSAF_{org}$	Transfer Factor Sediment To Fish	kg-oc/kg-lipid
BCF	Transfer Factor Water to Fish	L-water/kg-Fish

References:

EPA 1989. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA 1991. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual - Part B.
EPA 1997. Exposure Factors Handbook. Volumes I-III. An Update to Exposure Factors Handbook EPA/600/8-89/043
ODEQ 2000. Guidance for Conduct of Deterministic Human Health Risk Assessments.
EPA 2001. Supplemental Guidance for Developping Soil Screening Levels for Superfund Sites
ODEQ 2003. Risk-Based Decision Making for the Remediation of Petroleum-Contaminated Sites.

BSAF may be developed from site-specific sediment and tissue data and by use of trophic model (Arnot & Gobas, 2004).

Table B-9. Selection of Fish Species for River OU HHRA

Fish Species Common Name	Scientific Name	Resident/ Nonresident	Home-range	Trophic Level	Important Dietary Component for Humans?	Native-American Substistence Fisher?	Recreational Fisher?	Non-tribal High Consumption Fisher?	Rationale for inclusion or exclusion in HHRA
American shad	*Alosa sapidissima*	Anadromous	up to 3000 km for reproduction (1)	Level 2/3	Yes, utilized fresh, salted, or smoked, roe is consumed.	X	X	X	Anadramous species, therefore exposure to site-related COIs difficult to estimate
black crappie	*Pomoxis nigromaculatus*	Resident	11.3 km, 5.4 miles, 2-7 miles (PH) (2,3)	Level 3/4	Yes, one of the most consumed fish species by recreational/non-tribal fishers.		X	X	Resident species but home range is much larger than area of forebay; therefore exposure to site-related COIs difficult to estimate. Not selected for HHRA.
brown bullhead	*Ameiurus nebulosus*	Resident	>9 mi, <0.1-16 miles (2)	Level 2/3	Yes, prepared "hot-smoked"			X	Resident species but not known to occur in abundance in Forebay area. Not selected for HHRA.
channel catfish	*Ictalurus punctatus*	Resident	<0.1-99 miles (2)	Level 3/4	Yes, eaten steamed, fried, broiled, boiled, microwaved and baked.			X	Has not been observed or collected from the forebay to date. Not selected for HHRA.
Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous	up to 2000 km for reproduction (4)			X	X	X	Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for HHRA.
common carp	*Cyprinus carpio*	Resident	Up to 1100 km (4)	Level 2/3	Eaten fresh or frozen			X	Has not been observed or collected from the forebay to date. Not selected for HHRA.
cutthroat trout	*Onchorynchus clarki lewisi*	Resident, though sometimes anadromous	2.2 km, 86 km max (5)	Level 3/4	Yes	X	X	X	Residence status varies by life-stage, large home range. Difficult to estimate exposure to site-related COIs. Not selected for HHRA.
eulachon (Pacific smelt)	*Thaleichthys pacificus*	anadromous	up to 160 km (1)	Level 2		X			Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for HHRA.
large-scale sucker	*Catostomus macrocheilus*	Resident	59.5 km (PH), 0.5-10 miles (6)	Level 2/3	Edible but not highly favored	X			Resident species but home range is much larger than area of forebay; planktonic feeding habits may be difficult to relate to sediment COIs; therefore exposure to site-related COIs difficult to estimate. Included in HHRA, at the request of DEQ.
mountain whitefish	*Prosopium williamsoni*	Resident	Unknown	Level 2/3	Yes	X			Has not been observed or collected from the forebay to date. Insufficent information on home range. May be difficult to estimate exposure to site-related COIs. Not selected for HHRA.
northern pikeminnow or northern squawfish	*Ptychocheilus oregonensis*	Resident	21.7 km (PH), 0.5-6 miles, 0.87 mi in LWR, <0.1-13.4 mi (7,8)	Level 3/4		X			A few specimens collected from forebay; home range is larger than smallmouth bass, therefore not selected for HHRA.

Table B-9. Selection of Fish Species for River OU HHRA

Fish Species Common Name	Scientific Name	Resident/ Nonresident	Home-range	Trophic Level	Important Dietary Component for Humans?	Native-American Substistence Fisher?	Recreational Fisher?	Non-tribal High Consumption Fisher?	Rationale for inclusion or exclusion in HHRA
pacific lamprey	*Lampetra tridentata*	Anadromous	Up to 500 km for reproduction (4)	Level 2/3	Yes (Native Americans use as food, Asian as oils for medicine, Europeans as vitamins)	X			Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for HHRA.
rainbow trout steelhead	*Oncorhynchus mykiss*	Resident/anadromous	Unknown	Level 3/4	Yes, fresh, smoked, canned.	X	X	X	Steelhead are sea-run rainbow trout. Difficult to estimate exposure to site-related COIs. Not selected for HHRA.
river lamprey	*Lampetra ayresi*	Resident	Not known, but up to and at least 250 km for reproduction (4)	Level 2/3		X			Subgenus, difficult to distinguish, Information from OFWS 2002. Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for HHRA.
sculpin species	*Cottus* spp.	Resident	1.61 km (PH)	Level 3					Known to occur in the Forebay but not consumed by humans; therefore not selected for direct consumption in HHRA. Selected for validation of trophic model.
smallmouth bass	*Micropterus dolomieu*	Resident	0.8 km (PH), 0.5-5 miles (some up to 30 mi), averages 0.87 mi in LWR, <0.1-6.7 mi (2,8)	Level 3/4	Yes, one of the most consumed fish species by recreational/non-tribal fishers.		X	X	Many specimens collected from forebay; home range is smaller than area of forebay; popular with anglers; selected as primary species for evaluation in HHRA.
walleye	*Stizostedion vitreum (sander vitreus?)*	Resident	3-5 miles (some up to 100 mi), averages 3.9 mi in LWR, <0.1-9.7 mi (2,8)	Level 3/4	Yes, apparently there is great fishing next to some Columbia River dams, record sized fish are caught mid-Columbia.	X	X		Popular species but home range is much larger than forebay area; therefore exposure to site-related COIs difficult to estimate; Not included in HHRA.
western brook lamprey	*Lampetra richardsoni*	Anadromous	Unknown	Level 2		X			Small, non-parasitic, sometimes resident, second most common and widely distributed species in Oregon, dormant for some part of the year (temperature dependent) late winter, (OFWS 2002). Not selected for HHRA.
white sturgeon	*Acipenser transmontanus*	Resident in forebay and upstream, anadromous downstream	Up to 1000 km for reproduction (4)	Level 4	Popular sport fish with all types of anglers.	X	X		Popular species but home range is much larger than forebay area; therefore exposure to site-related COIs difficult to estimate; Not included in HHRA.

Notes
LWR = Lower Willamette River
PH = Portland Harbor Food Web Modeling Report trophic level classification and exposure area
All uncited data from fishbase.org
OFWS 2002. Oregon Fish and Wildlife Service, Information Report Number 2002-01. Oregon Lampreys: Natural History, Status, and Management Issues
Definitions of the trophic levels shown above are as follows:
TL1 - primary producers

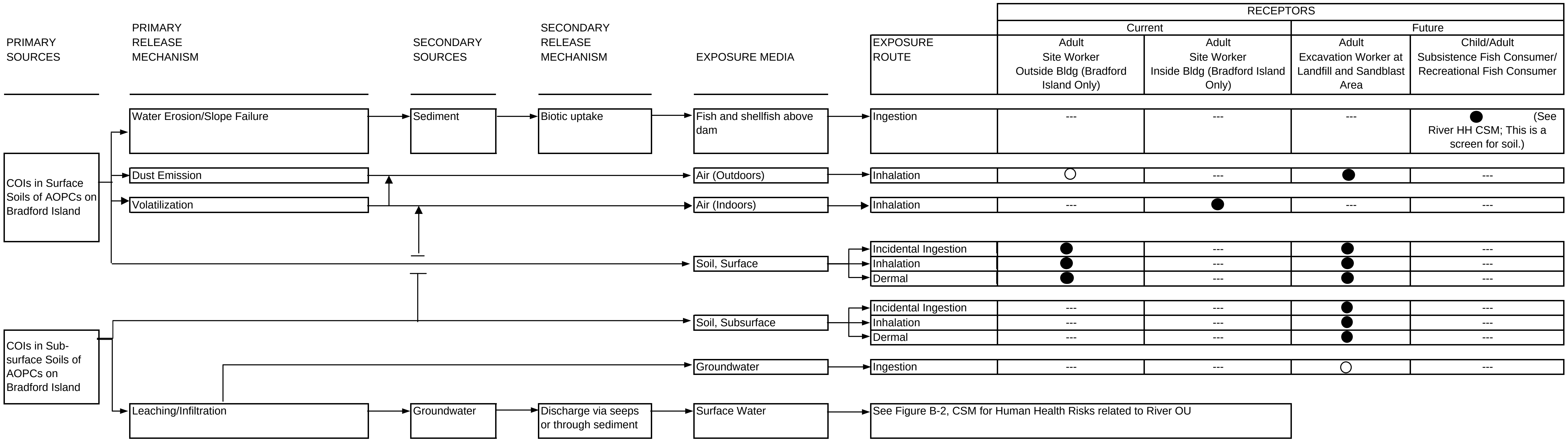
Table B-9. Selection of Fish Species for River OU HHRA

Fish Species Common Name	Scientific Name	Resident/ Nonresident	Home-range	Trophic Level	Important Dietary Component for Humans?	Native-American Substistence Fisher?	Recreational Fisher?	Non-tribal High Consumption Fisher?	Rationale for inclusion or exclusion in HHRA

TL2 - primary consumers (forage fish); mainly consume plant material (algae, phytoplankton) and zooplankton (some invertebrates consumed)
TL3 - secondary consumers; mainly invertivores (some fish consumed)
TL4 - tertiary consumers; piscivores

(1) fishbase.org
(2) Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184. Ottawa, Canada. 966 pages.
(3) Ward, D.L., C.J. Knutsen, R.A. Farr. July 1991. Status and Biology of BlackCrappie and White Crappie in the Lower Willamette River near Portland, Oregon. ODFW Information Report 91-3.
(4) Moyle, P.B. 2002. Inland Fishes of California. University of California Press. 502 pp.
(5) Colyer, W.T., J.C. Kershener, R.H. Hilderbrand. 2005. Movements of Fluvial Bonneville Cutthroat Trout in the Thomas Fork of the Bear River, Idaho, Wyoming. North America Journal of Fisheries Management. Vol. 25, no. 3, pp 954-963.
(6) LaVigne, Henry (Contractor for EPA Region IX, Corvallis, OR). 2002. Personal communications, telephone call with Kim Goule, Fish/Aquatic Biologist, Fishman Environmental Services LLC, Portland, OR. 26 April 2002.
(7) Isaak, D.J., T.C. Bjornn. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Movements and Distributions of Northern Squawfish Downstream of Lower Snake River Dams Relative to the Migration of Juvenile Salmonids Completion Report, Report to Bonneville Power Administration, Contract No. 1988BP91964, Project No. 198200300, 122 electronic pages (BPA Report DOE/BP-91964-5)
(8) North, J.A., L.C. Burner, B.S. Cunningham, R.A. Farr, T.A. Friesen, J.C. Harrington, H.K. Takata, D.L. Ward. 2002. Relationship Between Bank Treatment/Nearshore Development and Anadromous/Resident Fish in the Lower Willamette River. Annual Progress Report. Project sponsored by City of Portland and the Lower Willamette Group.

Figure B-1. CONCEPTUAL SITE MODEL FOR HUMAN EXPOSURE: UPLAND OPERABLE UNIT

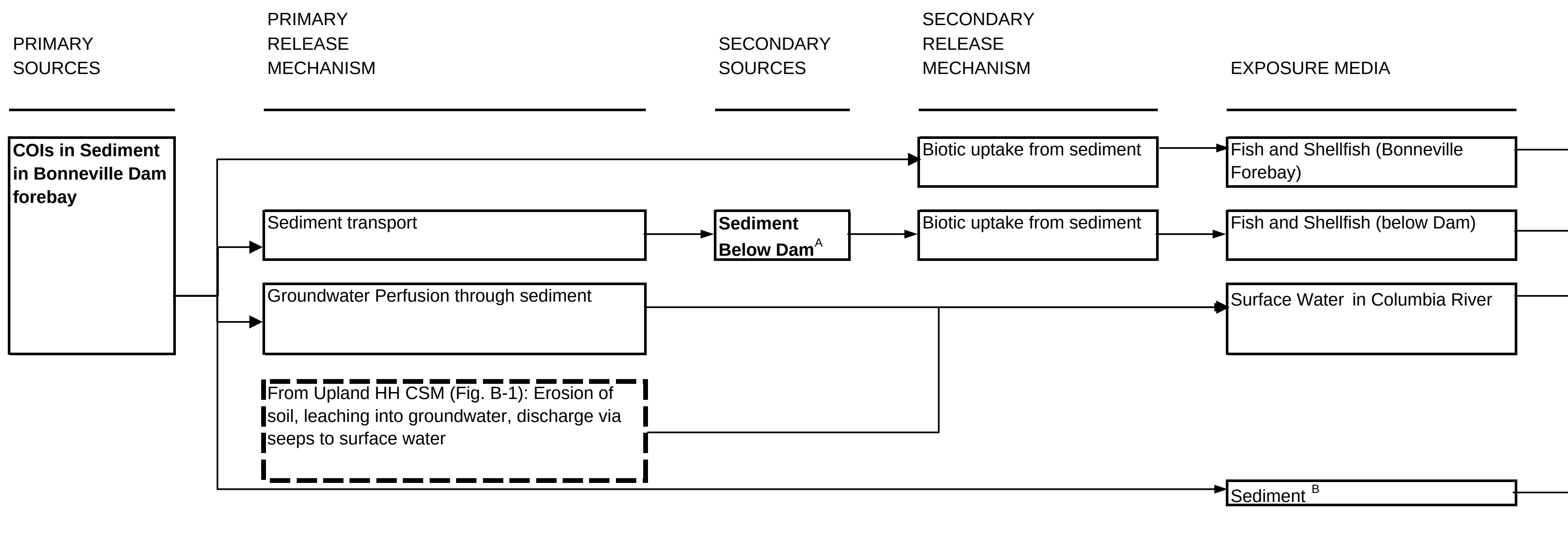


Symbols		
●	=	Complete and potentially significant pathway
○	=	Complete but likely minor pathway
---	=	Incomplete Pathway

AOPCs include:

Landfill
Sandblast Area
Pistol Range
Bulb Slope

Figure B-2. CONCEPTUAL SITE MODEL FOR HUMAN EXPOSURE: RIVER OPERABLE UNIT



Exposure Media	EXPOSURE ROUTE	RECEPTORS – Current/Future: Child/Adult Swimmer/Wader and Recreational Fisher	Current/Future: Child/Adult Native American Subsistence Fisher	Child/Adult Non-tribal High Consumption Fisher[C]	Future: Hypothetical Resident Using River Water
Fish and Shellfish (Bonneville Forebay)	Ingestion	●	●	●	---
Fish and Shellfish (below Dam)	Ingestion	●	●	●	---
Surface Water in Columbia River	Ingestion	○	○	○	●
	Dermal	○	○	○	●
	Inhalation	---	---	---	●
Sediment [B]	Ingestion	●	●	---	---
	Dermal	●	●	---	---

Symbols		
●	=	Complete and potentially significant pathway
○	=	Complete but likely minor pathway
---	=	Incomplete Pathway

[A] Sediment near the fish ladder, Hamilton Creek, Pierce and Ives Islands, or other fishing areas

[B] Sediments near Eagle Creek and in areas downstream of the dam may have been impacted with Bradford Island materials during construction of the Navigation Channel. There are no similarly affected sediments near Goose Island for direct contact.

[C] Non-tribal High Consumption Fisher is not present at the Forebay but may be present in the downstream area.

APPENDIX C
ECOLOGICAL RISK ASSESSMENT WORK PLAN

Tables

Figures

Acronyms

ADD	average daily dose
AOPC	area of potential concern
bgs	below ground surface
BAF	bioaccumulation factor
BERA	baseline ecological risk assessment
CEC	contaminant of ecological concern
cm	centimeter
CPEC	contaminant of potential ecological concern
COI	contaminant of interest
COPC	contaminant of potential concern (human health)
CRITFC	Columbia River Inter-Tribal Fish Commission
CSM	conceptual site model
DEQ	(Oregon) Department of Environmental Quality
EPC	exposure point concentration
ERA	ecological risk assessment
FS	feasibility study
HHRA	human health risk assessment
HI	hazard index
HPAH	high-molecular weight PAH
HQ	hazard quotient
kg	kilogram
lbs	pounds

LDW	Lower Duwamish Waterway (Group)
LOAEL	lowest-observable-adverse-effects level
log K_{ow}	octanol-water partition coefficient
LPAH	low-molecular weight PAH
μg	microgram
mg	milligram
90% UCL	90 percent upper confidence limit
95% UCL	95 percent upper confidence limit
NOAEL	no-observable-adverse-effects level
OU	operable unit
PAHs	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
RI	remedial investigation
RSET	Regional Sediment Evaluation Team
SLV	screening level value
SSL	soil screening level
SVOC	semivolatile organic compound
TRV	toxicity reference value
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound

This appendix provides the detailed approach for the ecological risk assessment (ERA) to be performed for the Upland and River operable units (OUs). Section 4 of this document summarized the scope and status of risk assessments performed to date for the site. In Section 6.3, a brief overview was provided describing the management goals for the site, the general objectives of the ERA, and how the ERA would be used to accomplish the risk-related management goals.

As noted in Section 6.3, the purpose of an ERA is to quantitatively evaluate risks to terrestrial and aquatic ecological receptors from site contamination so that remedial decisions can be made. In accordance with Oregon Department of Environmental Quality's (DEQ's) Level II Screening and Level III Baseline Guidance, exposure estimates and ecological risks will be generated assuming no remedial activities or changes in concentration after the interim removal action is completed in the Bonneville Dam Forebay (DEQ 2001; USEPA 1997a, 1997b). Level I Scoping and Level II Screening evaluations are anticipated for both OUs, including each Upland area of potential concern (AOPC), and, if warranted, a Level III Baseline ERA will be performed on an area of potential concern (AOPC)-specific basis.

The status of risk evaluation and availability of data for completion of Screening and Baseline Risk Assessments varies among the different AOPCs and OUs at this site. While site characterization is nearly complete for some Upland AOPCs, additional data collection is planned for other areas. Therefore, the ERAs may proceed along different timelines for various portions of the overall site. However, the potential for cumulative risks to ecological receptors that could forage over multiple AOPCs in the Upland OU, as well as the River OU, will be addressed when appropriate.

For the River OU, the Screening and Baseline Assessments will be based upon existing data and upon data collected after the nontime-critical removal action for contaminated sediments. The removal action is proposed for late 2007. The delineation of the nature and extent of contamination for the River OU is included in this Remedial Investigation (RI) Work Plan, in particular for the downstream portion.

C.1 GENERAL RISK ASSESSMENT OBJECTIVES

The current conceptual site models (CSMs) for the ecological receptors and associated exposure pathways identified at the Upland and River OUs are presented on Figures C-1 and C-2. Section 8.3 describes the river reference area that will be used to support data evaluation. Sections 8.2 and 8.3 identify the data gaps and data needs for completion of the risk assessments.

Based on review of existing information, the following primary and supporting risk assessment objectives have been identified for the RI:

- Evaluate suitability of existing data for risk assessment during the RI
- Determine spatial scope of the risk assessment:
  - Confirm source areas (contaminated media) and past, potential, or current contaminant of interest (COI) releases
  - Refine OU boundaries for risk assessment purposes
  - Identify background and upstream concentrations of COIs

- Refine the CSM and evaluate ecological risks associated with contaminated media:
  - Select contaminants of potential concern (COPCs) for each exposure medium relevant to the identified pathways and receptors
  - Address relevant comments from DEQ on the Screening Level Risk Assessment for the Landfill
  - Characterize current and reasonably likely future risks to ecological receptors and identify the respective COPCs and contaminants of ecological concern (CECs)
- Document the risk estimates generated in the risk assessment and provide an interpretation of these results in RI report

C.2 REGULATORY GUIDANCE FOR ERA

To achieve the objectives mentioned above, the steps that will be used to conduct problem formulation (i.e., scoping and screening) and baseline ecological risk assessments (BERAs) are based on state and federal guidance documents (primarily DEQ 2001; USEPA 1997a, 1997b). Since DEQ will be overseeing the RI/Feasibility Study (FS), DEQ guidance will take precedence with regard to the nature of the risk assessment process and the format and presentation of results.

The guidance documents to be used in the performance of the ERA include:

- *Final Guidance for Identification of Hot Spots* (DEQ 1998a)
- *Guidance for Conducting Beneficial Water Use Determinations at Environmental Cleanup Sites* (DEQ 1998b)
- *Guidance for Ecological Risk Assessment, Final* (DEQ 2001)
- *Comments on Revised Draft Level II Ecological Risk Assessment and Baseline Human Health Risk Assessment, Bonneville Lock and Dam Project* (DEQ 2004)
- *Guidance for Evaluation of Bioaccumulative Chemicals of Concern in Sediment, Final* (DEQ 2007)
- *Data Usability Guidelines for Risk Assessment* (USEPA 1992)
- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997a)
- *USEPA Region 10 Supplemental Ecological Risk Assessment Guidance for Superfund* (USEPA 1997b)
- *Guidelines for Ecological Risk Assessment* (USEPA 1998)
- *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (USEPA 2002a)
- *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (USEPA 2002b)

- *Guidance for Developing Ecological Soil Screening Levels, Revised Draft* (USEPA 2005a)
- *Ecological Soil Screening Levels, Interim Final* (USEPA 2005b)

C.2.1 Tiered Process of Ecological Risk Assessment

According to the *Guidance for Ecological Risk Assessment* (DEQ 2001), which follows United States Environmental Protection Agency guidance (USEPA 1997a, 1997b), the risk assessment process consists of the following steps: Level 1 Scoping, Level II Screening, Level III Baseline, and Level IV Field Baseline. The purpose of the first three levels (shown on Figure C-3), which are anticipated for the project, is described below. The proposed risk management steps associated with each level is also provided on Figure C-3.

Level 1 Scoping Assessment

- Provide a conservative qualitative determination of whether ecological receptors and exposure pathways are present or potentially present at a site or in the vicinity
- Identify sites that are obviously devoid of ecological important receptors or habitats and where exposure pathways are obviously incomplete
- Identify sites and COIs that warrant additional risk-based evaluation

Level II Screening Assessment

- Construct a site description based on information from site visits and/or surveys, the existing literature, any prior preliminary assessments, and site history (including past and present uses)
- Identify site-specific ecologically important receptors and the relevant and complete exposure pathways between each source medium of concern and these receptors, identify CPECs from among the COIs associated with the site
- Discuss how the physicochemical and toxicological properties of each CPEC may influence exposure pathways and adverse effects
- Define ecologically appropriate assessment endpoints
- Establish potential links between CPECs and responses in site-specific receptors by means of a preliminary conceptual site model
- Make an initial evaluation of the potential for site-related risk

Level III Baseline Assessment

- Determine whether a site, if left unremediated, would pose unacceptable current or reasonably likely future risks to endpoint species;
- Provide the basis for determining if remediation is needed
- Provide information for developing remedial alternatives

- Identify CECs to be addressed further

The Level III BERA consists of the following steps:

- ***Problem Formulation –*** involves defining initial assessment and measurement endpoints, which are linked to management concerns; formulating a CSM that describes key relationships between a contaminant of potential ecological concern (CPEC) and assessment endpoint or among several CPECs and assessment endpoints; and developing an analysis plan (i.e., applying the data quality objective process to establish data needs and methods for conducting the exposure and effects assessment).
- ***Exposure Analysis –*** involves determining the exposure point values for the species of concern. The exposure point value is the concentration or dose of a hazardous substance at the location where contact with ecological receptors is expected to occur.
- ***Ecological Response Analysis –*** estimates the risk of acute or chronic adverse effects to individuals that are also threatened or endangered species. The ecological benchmark value for individuals is based on the no-observable-adverse-effect level (NOAEL) with regard to reproductive success. Effects on species other than those classified as threatened or endangered are made only at the population level, and the ecological benchmark value is based on the median lethal dose/concentration that would affect 50 percent of the population at a low level of probability.
- ***Risk Characterization/Uncertainty Analysis –*** presents the quantified risks for each CPEC-pathway-receptor combination, i.e., for each assessment endpoint. Identifies the CECs warranting further action or evaluation. Also includes a narrative description of the risks and discusses the uncertainty in the risk assessment based on data gaps, CPEC selection and quantification, receptor selection, exposure estimation, effects estimation, and risk characterization.

The results of the ERA steps will be documented in the RI report.

C.2.2 Differences between USEPA and DEQ Guidance

As noted in Section 6.3, although the content of ERAs based on DEQ and USEPA guidance are generally similar, some minor variations exist. DEQ guidance varies from Comprehensive Environmental Response, Compensation, and Liability Act guidance in a few areas such as those listed below:

- Formal land and water use determinations of beneficial use
- Screening out of naturally occurring inorganics by comparison with background
- Use of a 90 percent upper confidence limit (90% UCL) value to represent exposure point concentrations (USEPA recommends the 95% UCL, 1997a)
- Definition of acceptable risk levels
- Performance of hot-spot evaluations

How these issues will be addressed is described in the later sections of this appendix.

C.2.3 Other Relevant Guidance and Projects

Other approaches that may be appropriate for this site will also be included in the evaluation and risk characterization approaches for the site. Examples of other approaches are the sediment evaluation guidelines being developed by the Regional Sediment Evaluation Team (RSET), the risk assessment being conducted for the Portland Harbor Superfund site, and the trophic model approaches developed for the Lower Duwamish Waterway Group (LDW). The evaluation of these approaches for application at Bradford Island is described in Appendix B.2.2 and is not repeated here.

C.3 ERA FOR UPLAND OU

The Upland OU includes four AOPCs: the Bradford Island Landfill, Bulb Slope Area, Sandblast Area, and Pistol Range. Site investigations and risk evaluations varying from preliminary to extensive in nature have been conducted at all of these AOPCs (Table 6-1). Existing data is sufficient to support the Scoping, Screening, and problem formulation phase of the Baseline Assessment for all of the Upland AOPCs. These levels of the ERA process are also useful in identifying data gaps and defining the data collection needs for the execution of a baseline ERA.

C.3.1 Level 1 Scoping Assessment

The tasks required to complete the Level I Assessment are as follows:

- Review existing data
- Perform initial site visit
- Identify COIs
- Evaluate receptor-pathway interactions

Existing site information for the AOPCs in the Upland OU is contained in numerous reports, as presented in Section 4.0, and will be supplemented with additional information collected during the RI. A thorough site characterization has been performed for most of the Upland AOPCs, with few data gaps remaining, and an initial site visit has been conducted as well. The nature and extent of contamination at the various AOPCs will be further delineated during the RI. Based on currently available information, it has been determined that potentially complete ecological exposure pathways are present at all four AOPCs. The list of COIs for each medium of concern associated with the AOPCs is provided in Section 5.3. These lists will be further refined in the Level II Screening Assessment by assuming ecologically relevant exposure depths and possibly additional screening levels.

In an effort to streamline the risk assessment process, the Level I Scoping Assessment (URS 2002) performed for the Landfill will be expanded to the other three AOPCs. The close proximity of the Upland AOPCs to each other and the similarities in habitats and organisms present support this approach. To fulfill the requirements listed above, the ecological setting, site features (topography, structures), nature and extent of all known chemical releases, and any unique site-specific characteristics will be briefly described in the forthcoming Level II Screening and/or Baseline Assessments for these sites.

A land use determination will be included indicating that in the past and under current conditions, Bradford Island has been used primarily for industrial or waste handling purposes. According to the Bonneville Master Plan, future land use at Bradford Island is expected to remain unchanged.

Finally, the sources of contamination at the known AOPCs on Bradford Island will be described. One of the primary objectives of the RI is to complete the nature and extent delineation for all AOPCs. This information will be included in the problem formulation. Primary sources include chemicals released or deposited by former industrial activities onto Upland surface and subsurface soils. Secondary sources include impacted groundwater. A transport pathway from the upland to the river may exist by erosion or slope failure of Upland soils. Sediment contamination may also occur from overland soil contaminants leaking through a torn catch basin filter sock that is part of the runoff management system in the Sandblast Area vicinity (URS 2006).

C.3.2 Level II Screening Assessment and Level III BERA

This section describes the approach for the Screening and Baseline Assessments for the Upland OU. To streamline the ERA process at AOPCs where bioaccumulative chemicals are present, both the Level II Screening Assessment and the Level III BERA will be completed as past of the RI. The level III BERA will incorporate those elements of DEQ guidance that are necessary to complete the evaluation (e.g. food-web modeling) but may not include other elements such as habitat or population surveys unless necessary.

C.3.2.1 General Approach

A separate ecological risk evaluation will be performed for each Upland AOPC. To address the potential for exposure to multiple Upland AOPCs by receptors with large home ranges, OU-wide risks will also be evaluated when appropriate.

A Level I and Level II Assessment will be completed for all AOPCs. There are two reasons why a Level III BERA may be needed for one or more of the Upland AOPCs:

- If bioaccumulative COIs are present; or
- If a Level I and Level II assessment have been completed and indicate the need for a Level III assessment

The Level I and Level II assessment processes and screening values do not adequately address potentially bioaccumulative chemicals. Therefore, risks to upper trophic levels need to be evaluated by the performance of a Level III BERA. Because bioaccumulative chemicals are known to be present at some of the AOPCs in the Upland OU (e.g., DDTs at the Sandblast Area, polychlorinated biphenyl (PCBs) in the Bulb slope area), a BERA is already anticipated to inform remedial decisions for several of the Upland AOPCs. A Level III BERA is also needed for the landfill based on the findings of the Level I and Level II Assessments and to address comments received from DEQ.

If the findings of the conservative Screening Assessment for a particular AOPC indicate that no further investigation is necessary based on the following conclusions, this AOPC will not be included in OU-wide risk estimates:

- All COI concentrations are below Level II screening level values (SLVs) or equivalent screening levels and either no bioaccumulative chemicals are present, or
- All COI concentrations are below Level II SLVs or equivalent screening levels and bioaccumulative chemicals are present at concentrations below reliable sources of generic bioaccumulation screening levels.

AOPCs with COI concentrations above the Level II SLVs protective of birds and mammals via direct toxicity or concentrations of bioaccumulative COIs above screening levels that address both direct toxicity and dietary exposure (e.g., USEPA's Eco soil screening levels (SSLs)) will likely be included in OU-wide risk estimates.

The following five main tasks will be performed for AOPCs identified as requiring a BERA upon completion of the Screening:

1. Refinement of risks to lower trophic level receptors for CPECs identified for these receptor groups.
2. Develop risk estimates (hazard quotients (HQs)) based on direct contact (e.g., incidental soil ingestion) for selected bird and mammal target receptors for nonbioaccumulative CPECs that exceeded generic, direct toxicity-based SLVs.
3. Develop risk estimates based on direct contact (e.g., incidental soil ingestion) and dietary exposure for selected bird and mammal target receptors for CPECs with a potential to bioaccumulate that either exceeded diet-based screening levels or that lack reliable diet-based screening levels.
4. Evaluate OU-wide and combined OU risks to receptors with large home ranges and/or that forage in terrestrial and aquatic habitats.
5. Compare concentrations of anthropogenic CPECs such as polycyclic aromatic hydrocarbons (PAHs) and dioxins, if detected, to regional ambient concentrations to determine if they are elevated at the AOPCs.

The sections below provide the approach to the problem formulation for each of the AOPCs, including the Screening Assessment, as well as the methodology for the Level III BERA to estimate risks posed by Upland contamination sources and River contamination sources. Many of the comments received from DEQ on the Screening Assessment for the Landfill are also relevant to the ERA methodology outlined in this work plan (DEQ 2004). Therefore, consideration of those comments is incorporated into the proposed approach.

C.3.2.2 Identification of COIs, CPECs, and CECs

DEQ guidance defines COIs as chemicals that are present or may be present at a site. For the purposes of risk assessment, COIs may be further evaluated on the basis of detection frequency, comparison with background, and risk screening. COIs that fail the evaluation are retained as CPECs for inclusion in the quantitative risk assessment while COIs that pass the evaluation are dropped from further consideration.

All CPECs identified on the basis of exceedances of SLVs or concerns related to the bioaccumulation pathway are retained for evaluation in the BERA. All CPECs that are demonstrated to exceed acceptable risk levels defined in the BERA, as well as CPECs without screening levels are identified as CECs that require further investigation or remediation (DEQ 2001).

COIs and CPECs in Upland Media

Section 5.3 of the main RI report presents the methodology used to identify the list of COIs for all media associated with the individual AOPCs of the Upland OU for which data are currently available. The partial screening process for existing data for COIs in soil and groundwater for each of the upland AOPCs is described in detail in Section 5.3, and the results are presented in Tables 5-1 through 5-10.

An abundance of environmental data has been collected from the Upland OU during several investigations that have been conducted over the past 10 years (Section 4.0). Although it is premature to identify CPECs prior to the upcoming data collection effort and combining of new and existing datasets, the focused list of COIs developed for each medium will be used to identify data gaps and facilitate sampling efforts in this RI Management Plan and forthcoming Quality Assurance Project Plans. The list of CPECs will be further refined for purposes of the ERA.

Based on the presence of potentially complete exposure pathways and associated analytical data, COIs in the Upland OU were identified for the following media:

- Soil and groundwater of the Landfill
- Soil and groundwater of the Sandblast Area
- Soil of the Pistol Range
- Soil of the Bulb Slope

The findings of the preliminary screening in Section 5.3.2 for in-place soils (0 to 10 feet below ground surface [bgs]) and groundwater may be summarized to state that metals, butyltins, and a limited subset of volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides (herbicides), and PCBs have been detected in surface and subsurface soils at the Landfill and Sandblast Area. A much smaller number of metals, PCBs, and total petroleum hydrocarbons have been detected in the Bulb Slope. The Pistol Range is associated with only a few metals. Groundwater samples taken in the Sandblast Area and Landfill vicinity had detectable levels of several metals, VOCs, and SVOCs. Pesticides were detected sporadically in soils and groundwater.

The COIs for in-place soils were further evaluated in terms of their migration potential, as described in Section 5.3. Similar to the approach used in the Portland Harbor Joint Control Source Strategy (DEQ 2005), the COIs in soil were screened against risk-based concentrations in sediment protective of human and ecological receptors. The COIs in in-place soils that are considered potentially migratory to the River OU include metals, SVOCs, one butyltin, two VOCs, PCBs, and a small subset of pesticides.

For the problem formulation performed for each AOPC during the Screening Assessment, the general screening criteria outlined above will be used to identify CPECs in these media at ecologically relevant exposure depths that require further evaluation. The toxicity-based criteria referred to in the third criterion that will be used in the Screening are described in Section

C.3.2.6. COIs lacking chemical-specific screening values will be retained as CPECs. They will be evaluated quantitatively if acceptable surrogate chemicals are available, or will be discussed in the uncertainty section of the ERA.

Bioaccumulative CPECs

Bioaccumulation is a phenomenon in which concentrations of chemicals accumulate in biological tissues through exposure to environmental concentrations, which results from processes of preferential uptake and retention in adipose and organ tissues. Bioaccumulation occurs as living organisms retain and concentrate chemicals both directly from their surrounding environment (i.e., from soil or water) and indirectly from media that transfer chemicals into dietary components, such as plant or animal tissues. Biomagnification is a form of bioaccumulation in which the concentration of a chemical in a higher trophic level organism (e.g., bird, mammal, or reptile) is greater than the concentration in the food that this organism consumes.

Bioaccumulation and biomagnification are of primary interest in ERAs because of the potential for chemical transfer through the food web, as top-level predatory species feed on prey that may have high tissue residues of bioaccumulative chemicals. Thus, biota that are not directly exposed to chemicals in soil or water may still be adversely affected because of their indirect exposure to these chemicals through consumption of prey items.

Bioaccumulation of nonpolar organic chemicals is generally related to their hydrophobicity or lipophilicity and is approximately estimated by their octanol-water partition coefficient (log K_{ow}). Bioaccumulative chemicals are generally defined as those with a log K_{ow} exceeding 3.5 (with an optimum range between 3.5 and 5.5) or a bioconcentration factor that is greater than 300 (Suter 1993). Documentation supporting the Hazardous Waste Identification Rule (USEPA 1999a) also identifies chemicals that are recognized as having a low, medium, or high potential for bioaccumulation. For bioaccumulation in terrestrial systems, rankings were determined using bioaccumulation factors (BAFs) for earthworms, plants, or vertebrates, or log K_{ow} values for organic chemicals that do not readily metabolize. According to this USEPA document, bioaccumulation potential is defined as follows:

Bioaccumulation Potential	BAF
High	BAF > 1.0
Medium	1.0 >= BAF > 0.1
Low	BAF <= 0.1

The COIs in soil of the Upland OU that demonstrate a medium or high potential for bioaccumulation according to the criteria discussed above will be included in the BERA for avian and mammalian receptors.

C.3.2.3 Receptors of Interest

A simplified model of the terrestrial food web for the Upland OU is presented on Figure C-4. Discussion regarding the selection of avian and mammalian receptors of interest (or "target receptors") occurred in several meetings during 2005 and early 2006 with the technical advisory group for Bradford Island and in response to comments received from DEQ (DEQ 2004). The following terrestrial receptors of interest were selected:

- Terrestrial plants
- Soil invertebrates
- American kestrel (*Falco sparverius*)
- American robin (*Turdus migratorius*)
- Canada goose (*Branta Canadensis*)
- Vagrant shrew (*Sorex vagrans)*

C.3.2.4 Conceptual Site Model

A CSM for Upland ecological receptors is presented as Figure C-1. An exposure pathway is considered complete when, and only when, the following components are present:

- A source of contamination (e.g., waste disposed in a landfill)
- A mechanism of release and transport pathway to an affected medium (spills and leaks to soil)
- A receptor (e.g., plant community, small mammals)
- An exposure route (e.g., route uptake, ingestion)

When any of these elements is missing, the pathway is considered incomplete. By definition, no risk occurs where no complete pathway exists.

All Upland AOPCs on Bradford Island are similar with regard to land and water uses, habitats present, potentially exposed receptors, and exposure routes, although the sources of contamination and COIs vary from one AOPC to another. Therefore, the exposure pathways for the Upland AOPCs are illustrated on a single CSM figure for the Upland OU. The CSM describes the current understanding of potential contamination sources, receptors of interest, and routes of exposure.

Potential Upland OU to River OU Transport Pathways

COIs from the upland media may enter the river through transport of soils or groundwater. Surface soils may be transported to sediments in the river through overland washoff or by slope failure. Sediment would then be the source for uptake of bioaccumulative chemicals by benthic invertebrates and fish, which may in turn be consumed by upper trophic level fish and semiaquatic birds and mammals.

Groundwater may also discharge to the river, but it is not certain that groundwater has contributed significantly to sediment and surface water in the river, as described in the discussion of the monitoring wells at the Landfill. Two potentially complete pathways are related to groundwater: direct seepage to the surface water in the river from the island, and indirect vertical upward discharge through near-island contaminated sediments. For the groundwater to sediment to surface water pathway, upward discharge of groundwater may release contaminated porewater from the sediments into the surface water. Consideration of these pathways addresses some of DEQ's earlier comments regarding the Level II Screening Assessment for the Landfill (DEQ 2004).

To summarize, the key physical migration pathways from the Upland OU to the River OU are as follows:

- Slope failure
- Mobilization of soils via erosion/overland flow
- Groundwater seepage to surface water and sediment

As discussed in Section C.3.2.2, and in further details in Section 5.3.2, a list of COIs in soil with the potential to migrate, or erode from individual Upland AOPCs into the River OU was developed for the RI Management Plan to determine where spatial data gaps may exist to help better define this transport pathway. Further investigation of this pathway will be addressed for aquatic (benthic) receptors in the River OU RI using a similar methodology as described in Section 5.3.2 (i.e., comparison of COI concentrations in erosive Upland soils to sediment screening values protective of the benthic community and piscivorous wildlife). Once sediment-related risks to receptors of the River OU are characterized, an evaluation of the potential contribution of Upland soils to contamination in the River will be performed for the necessary chemicals (i.e., those risk drivers in sediment, or CECs, that are also present in soil above sediment SLVs). Groundwater from the bank of the north shore of Bradford Island vicinity will also be compared to ecologically relevant criteria and standards protective of freshwater aquatic life in surface water.

Assessment of Upland Pathways

As illustrated in the CSM, the affected Upland media include surface soils, subsurface soils, and groundwater. Soils are the source for uptake of bioaccumulative chemicals by terrestrial plants, soil invertebrates, and small mammals, which are consumed by upper trophic level receptors. The following Upland-related exposure pathways are identified for the Upland OU:

- Root uptake of contaminants potentially present in surface and subsurface soil by terrestrial plants
- Ingestion of and dermal contact with contaminants potentially present in surface and subsurface soil by soil invertebrates
- Incidental ingestion of and dermal contact with potentially contaminated surface soil (all avian and mammalian receptors) and subsurface soil (vagrant shrew)
- Inhalation of soil-related particulates and VOCs originating from shallow and subsurface soils by burrowing animals

- Ingestion of terrestrial dietary components (e.g., plants, soil invertebrates, and small mammals) by upper trophic level receptors
- Incidental ingestion of and dermal contact with potentially contaminated sediment or surface water by aquatic life and aquatic-dependent wildlife, including aquatic prey consumption by upper trophic levels (e.g., fish and wildlife)

As was assumed for the Landfill, the ecologically relevant soil depth interval is expected to be limited primarily to chemicals in the upper 3 feet at the Upland AOPCs (URS 2004a). Surface soils will be defined as 0 to 1 foot bgs, and subsurface soils defined as 0 to 3 feet bgs. Rooting depths for plants and burrowing depths for invertebrates and mammals will be assumed to occur within the upper 3 feet of soil, and it will be assumed that all terrestrial receptors are exposed to soils from this depth interval. Although not all birds and mammals burrow, these receptors typically consume organisms that are exposed to soils below the surface. More refined exposure depths may be considered for nonburrowing animals in the BERA.

Groundwater is only a medium of concern if it has the potential to enter a surface water body; otherwise, exposure to groundwater is an incomplete pathway for most terrestrial receptors with the possible exception of plants. Groundwater levels in the Upland OU are deeper than 3 feet bgs, i.e., root depth zone for terrestrial plants (DEQ 2001). Therefore, exposure of plants to groundwater is not expected to occur. The ERA for aquatic life and aquatic dependent wildlife is addressed in the River OU assessment (Section C.4).

The exposure pathways that are complete at each AOPC and their associated receptors will be evaluated in the problem formulation phase preceding the Screening. COIs that fail the screening process will be identified as CPECs that require quantitative risk evaluation. The results of the problem formulation, including the Screening, therefore, will define the scope and nature of the more detailed baseline risk assessment.

The formal problem formulation for the Upland AOPCs and OU will be presented in the RI report. However, data gaps that need to be filled to perform the Screening Assessment, or combined Screening and Baseline Assessments for certain AOPCs, were identified on the basis of the preliminary problem formulation performed to date. The data gaps are outlined in the data quality objective table prepared for the Upland OU (Table 8-2). They are summarized and presented with the planned data collection efforts in Section 8.2.

C.3.2.5 Assessment Endpoints

Assessment endpoints are explicit expressions of the actual environmental value to be protected, and may be perceived as an environmental characteristic. If these endpoints are found to be significantly affected they can trigger further action. The recommended assessment endpoints for the ecological receptors addressed in the Upland OU are tabulated in Table C-1 as follows:

- Protection of the terrestrial plant community and soil-dwelling invertebrate populations that may be exposed to COIs in soil to maintain species diversity, abundance, and nutrient cycling
- Protection of herbivorous small birds (Trophic Level 1) represented by Canada geese with no unacceptable effects on reproduction, growth, or development at the population level due to COIs in soil and terrestrial plants

- Protection of invertivorous birds (Trophic Level 2), represented by the robin, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and invertebrates
- Protection of carnivorous small mammals (Trophic Level 2-3), represented by the vagrant shrew, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and invertebrates
- Protection of top-level predatory birds (Trophic Level 3-4), represented by the American kestrel, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and small mammals
- Protection of aquatic biota (invertebrates and fish) that may be exposed to COIs in groundwater discharged to surface water/sediment of the Columbia River due to soil disturbance and placement of sandblast grit or other wastes on the Upland surface soils

The disturbed nature of some of the Upland AOPCs, e.g., Landfill, which has been graded and continuously subjected to vegetation control activities, and precludes high quality habitat and species diversity. Furthermore, no state- or federally listed threatened and endangered terrestrial species are known to occur on the island, with the exception of the bald eagle (which is being evaluated for the River OU), and site-related effects on an individual basis are only of concern for this receptor. Because the Screening will be performed in accordance with DEQ’s guidance, the methodology for evaluating risks to both threatened and endangered and nonthreatened and endangered species will be included in the assessment. Recommendations in support of remedial decisions will primarily be based on risks to nonthreatened and endangered terrestrial species.

C.3.2.6 Exposure Analysis

Exposure characterization is the process of estimating the magnitude, frequency, and duration of site-specific exposure concentrations and doses of chemicals to a receptor. To assess whether COI concentrations at the site have the potential to cause adverse effects in the selected ecological receptors, it is first necessary to develop reasonable estimates of the concentrations or doses to which the receptors might be exposed.

Exposure Point Concentrations

The exposure point concentration (EPC) is the concentration of a chemical in an environmental medium at the point of contact for the receptor (e.g., the concentration of a chemical in soil at a sampling location that could serve as habitat for the receptor). For terrestrial plants and soil invertebrates, the EPC is estimated as a function of the COI concentration measured in soil. For higher trophic level receptors, the exposure dose may be estimated as a function of the COI concentration in relevant environmental media and several other parameters related to biological transfer through the food web and the manner in which receptors use the site (e.g., dietary composition, feeding strategy, food ingestion rate, length of time a receptor is expected to forage/nest at the site based on their home range size and seasonal behavior).

EPCs will be developed for surface soils defined as 0 to 1 foot bgs, as well as surface and subsurface soils (0 to 3 feet bgs) for all terrestrial receptors. More refined exposure depths may be considered for nonburrowing animals in the BERA.

Plants and Invertebrates. In accordance with DEQ guidance for Screening Assessment, EPCs in soil will be calculated for receptors with limited or no mobility (i.e., plants and invertebrates) using the maximum detected concentration in soil and sediment. Use of the maximum concentration of each COI is a conservative approach that serves to protect stationary receptors that could conceivably be exposed to the maximum concentration throughout their entire life span if located in a potential hot-spot area. If further evaluation of plants and invertebrates is necessary in the BERA, a less conservative EPC (such as the 95% UCL) may be used to estimate risks at the community level, due to the absence of threatened or endangered plant and invertebrate species in the terrestrial habitat.

Birds and Mammals. For food web-based receptors such as birds and mammals, the EPC will be based upon the 95% UCL on the mean concentration in soil and will be estimated using statistical methods recommended by USEPA (2002a, 2002b). The lower of the 95% UCL and maximum detected concentration in soil will define the EPC for birds and mammals in the Screening and BERA. Appendix A provides the methods that will be used to calculate the 95% UCL. This value provides an estimate of the representative concentration more relevant to terrestrial wildlife receptors that generally are mobile and not continuously exposed to site-related COIs in one geographic location. Soil EPCs will be directly compared to DEQ's SLVs protective of birds and mammals or equivalent soil benchmarks in the Screening (Section C.3.2.7).

Exposure doses calculated for terrestrial wildlife receptors in the BERA will be estimated using the EPCs for soil discussed above and exposure algorithms that calculate the average daily dose (ADD) for the selected receptors. An interim step to development of the ADD is the estimation of EPCs in biotic media (i.e., dietary items consumed by wildlife) through the application of BAFs. The algorithms, selected exposure parameters, and preferred sources of BAFs are provided in Appendix D. BAFs drawn from sources other than DEQ's preferred sources or developed using alternative methodology will be reviewed for consistency with DEQ guidance prior to use. Once all of the RI data are collected and the final list of COIs has been established for the Upland OU, an interim draft table presenting the BAFs for each COI and tissue type will be submitted for DEQ's review.

C.3.2.7 Effects Analysis

The identification of toxic effects and chronic toxicity thresholds resulting from exposure to COIs comprises the effects assessment phase of the Screening or Baseline Assessments. A qualitative and quantitative description of the relationships between COI concentrations or doses and the nature of possible effects elicited in exposed receptors, populations, or ecological communities is discussed in this section. The goal of the effects assessment is to identify risk-based SLVs and toxicity reference values (TRVs) that are most relevant to the receptors and assessment endpoints identified for the Upland OU.

Screening levels, or SLVs, are expressed as concentrations in media (i.e., milligram [mg] of chemical/kilogram [kg] of soil). Although "screening levels" are typically associated with exposure via direct contact, and are also commonly referred to as direct toxicity benchmarks, limited sources of generic media-based screening levels address both direct contact and dietary exposure for birds and mammals. In contrast, diet-based TRVs protective of birds and mammals are expressed as a daily dose normalized to body weight (mg of chemical/kg of body weight/day).

Measurement Endpoints

Measurement endpoints are measurable changes in an attribute of an assessment endpoint that allow an evaluation of whether or not the ecological resource is being sufficiently protected. Measurement endpoints are typically characterized in two parts: measures of exposure and measures of effect. Measures of exposure are measurable characteristics or attributes of an assessment endpoint or an acceptable surrogate (e.g., COI concentrations in soil or tissue). Measures of effect are measurable responses in the assessment endpoint or its surrogate associated with lowest adverse effects or acceptable no-effect thresholds (e.g., ecologically protective screening values for soil and tissue). The measures of exposure and measures of effect proposed for the assessment endpoints are provided in Table C-1. Measurement endpoints for the Upland ERA will include measured EPCs in soil, measured or modeled EPCs in water or sediment, modeled concentrations of CPECs in terrestrial organism tissues, and field observations (e.g., areas of distressed vegetation or bare soil, visible sandblast grit, or lack thereof).

Direct Toxicity and Diet-Based Screening Levels for Soil

For the assessment of potential ecological effects associated with direct exposure to nonbioaccumulative COIs, the EPCs derived for soils will be compared to the SLVs (Table C-2) protective of the individual receptor of interest groups (e.g., terrestrial plants, soil-dwelling invertebrates, and terrestrial wildlife).

In addition, SSLs that address both toxicity from direct contact with soil and dietary exposure (e.g., USEPA's Eco-SSLs; 2005b) for birds and mammals will also be compared to the soil EPCs developed for these receptor groups, when available. In the absence of reliable and readily available diet-based SSLs, potentially bioaccumulative COIs will be retained as CPECs for the BERA. These steps will be performed for all Upland AOPCs in the Screening Assessment. Other sources of screening levels may also be incorporated into the evaluation, especially if more up-to-date toxicity data are available at the time the Screening is conducted.

In the event that potential effects to terrestrial plants or soil invertebrates are demonstrated for COIs in soil through the Screening, less conservative and more site-specific SLVs may be applied to gain a better understanding of the actual risk at the community or population level. As no threatened or endangered plant or invertebrate species are present on the island, this approach is still considered to be adequately protective of these receptor groups. If the potential for adverse effects to mammals or birds is demonstrated through the Screening, risks to the selected avian and mammalian target receptors (Section C.3.2.2) will be estimated using TRVs to develop HQs.

Toxicity Reference Values for Food-Web Exposure

TRVs are used to characterize risks to wildlife on a more site-specific basis than is provided by use of generic, media-specific screening concentrations. For the evaluation of bioaccumulative COIs (defined in Section C.3.2.2) that fail the screening, TRVs will be used in the calculation of

HQs for the BERA. HQs will be developed from TRVs based on NOAELs and TRVs based on lowest observable adverse effect levels (LOAELs). A NOAEL-based TRV represents a chronic exposure dose that is derived from an estimated threshold dose at which no adverse effects to an organism are expected to occur. Whereas, a LOAEL-based TRV corresponds to an estimated dose that is attributed to an observed effect in the test organism. As recommended in DEQ's comments on the Level II Screening Assessment for the Landfill (DEQ 2004), TRVs for CPECs that lack a NOAEL or LOAEL will be generated by either multiplying or dividing, depending on the desired TRV, the available TRV by a factor of five.

Because the body weight of a test species used to establish a TRV can vary substantially from the body weight of the receptor species used in an ERA, allometric scaling methods are often used to account for these differences. Allometric adjustments are based on the concept that smaller animals have higher metabolic rates and, thus, the detoxification rate is more rapid for these organisms. Such adjustments result in a lower, i.e., more stringent, TRV for larger animals. Allometric adjustments are typically not recommended for avian receptors (Mineau et al. 1996; Sample and Arenal 1999). The necessity of these conversions for mammals will be evaluated in the BERA. To avoid applying allometric adjustments unnecessarily, TRVs derived from studies on larger aquatic-dependent mammals similar to the mink will be used to calculate HQs for this receptor.

The following sources of toxicity information will be consulted for the selection of TRVs for the current evaluation:

- *Portland Harbor Remedial Investigation-Feasibility Study, Comprehensive Round 2 Site Characterization Summary and Data Gaps Analysis Report* (Lower Willamette Group 2007)
- *Ecological Soil Screening Levels, Interim Final (Eco-SSLs)* (USEPA 2005b)
- *Toxicological Benchmarks for Wildlife, 1996 Revision* (Sample et al. 1996)
- USEPA Integrated Risk Information System, last updated in January 2007 (USEPA 2007)
- *Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities, Peer Review Draft* (USEPA 1999b)

TRVs extrapolated from these sources represent generally conservative values drawn from a review of the toxicological literature. Once all of the RI data are collected and the final list of COIs has been established for the Upland and River OUs, an interim draft table presenting the avian and mammalian TRVs for each COI will be submitted for DEQ's review.

NOAEL TRVs and LOAEL TRVs will be used in a manner similar to the receptor designator (Q) approach described for the direct toxicity (i.e., SLV) Screening (Section C.3.2.8). For listed threatened and endangered species, protection is focused on the individual members of the receptor population and, therefore, use of a NOAEL TRV is appropriate. For nonthreatened and endangered species, protection is focused on the receptor population as a whole, so use of a LOAEL TRV may be appropriate. This logic complies with DEQ's guidance for a BERA (DEQ 2001). However, the guidance recommends use of a median lethal dose or concentration to evaluate population-level effects to nonthreatened and endangered species. This element of DEQ's guidance will not be included in the BERA for the Upland OU. Instead, LOAEL, and to a lesser extent NOAEL, TRVs will be used to assess potential effects to populations.

With the exception of the bald eagle, no state- or federally listed threatened and endangered avian or mammalian species are known to occur on the island; thus, site-related effects on an individual basis are only of concern for the eagle (which is being evaluated for the River OU). Because the Screening Assessment will be performed in accordance with DEQ's guidance, risks to both threatened and endangered and nonthreatened and endangered species will be included in the evaluation. However, recommendations to support the remedial decisions for the Upland OU will primarily be based on risks to non-listed species.

C.3.2.8 Risk Characterization

Risk characterization is the process of integrating the previous elements of the risk assessment into quantitative or semiquantitative estimates of risk. Risk characterization consists of risk estimation and uncertainty assessment. Risk estimation or the quantification of risk is then used as an integral component in remedial decision making and selection of potential remedies or actions. Uncertainty assessment describes the level of confidence in the risk estimation.

The following subsections describe the approaches that will be used to estimate risks in the Screening and Baseline Assessments and provide a brief discussion of the general uncertainties associated with risk assessment.

Screening Assessment

Toxicity Ratios for Individual COIs within a Given Medium. Toxicity ratios will be developed in accordance with DEQ's Level II Screening Assessment guidance (DEQ 2001), based on the following equations and logic:

$$T_{ij} = \frac{C_{ij}}{SLV_{ij}}$$

COIs with T_{ij} > Q

will be retained as CPECs.

where:

T_{ij} = Toxicity ratio for COI *i* in medium *j* (unitless)

C_{ij} = Environmental concentration of COI *i* in medium *j* (mg COI per kg environmental medium;

SLV_{ij} = Screening level value for COI *i* in medium *j* (mg COI per kg environmental medium)

Q = Receptor designator that dictates the level of protection appropriate for a certain site (unitless)

If T_{ij} for a specific COI is greater than the receptor designator (Q) appropriate for the site, then further investigation of the COI is warranted and it will retained as a CPEC. As defined by DEQ, Q is equal to 1.0 for listed threatened and endangered species and Q equals 5.0 for nonthreatened and endangered species.

Evaluation of Multiple COIs Simultaneously within a Given Medium. To assess the potential for cumulative effects attributed to multiple COIs within soil, all COIs present in a given medium will be collectively compared to SLVs. Based on the toxicity ratios estimated from the equation above, the incremental effects from each COI will be identified from the approach expressed in the following equation:

$$\text{COIs with } \frac{T_{ij}}{T_j} \geq \frac{1}{N_{ij}} \times Q$$

will be retained as CPECs.

where:

T_{ij} = Toxicity ratio for COI *i* in medium *j* (unitless)

T_j = Summation of toxicity ratios for *i* COIs in medium *j* (unitless)

N_{ij} = Total number of *i* COIs in medium *j* for which an SLV is available (unitless)

Q = Receptor designator that dictates the level of protection appropriate for a certain site (unitless)

If the toxicity ratio for a specific COI is a high contributor to the total risk for a given medium, represented by the summation of all toxicity ratios (T_j), then further investigation of the COI is warranted and it will be retained as a CPEC. This approach allows evaluation of the incremental risks associated with simultaneous exposure to multiple COIs. As stated previously, Q is equal to 1.0 for listed threatened and endangered species and Q equals 5.0 for nonthreatened and endangered species.

Baseline Assessment

To derive risk estimates for birds and mammals at the site, the ADDs of bioaccumulative COIs that fail the Screening will be compared to selected TRVs. The HQ for each COI will be calculated by dividing the ADD for a specific target receptor by the respective TRV:

$$HQ = \frac{ADD}{TRV}$$

The HQ provides a mathematically derived index that expresses the relationship between the predicted exposure dose (the ADD) and a representative “safe” dose (the TRV). If the HQ>1.0, that is, exposure is greater than the toxicity-related threshold, it indicates that risks to the receptor of interest may exist at the site. If the HQ<1, then exposure is less than the toxic concentration, and adverse effects are not expected.

As previously discussed, two TRVs will incorporated into the analysis: one based on a NOAEL and a second based on an observed adverse effect in a test species (LOAEL). If the HQ based on the NOAEL TRV is less than 1, adverse effects are extremely unlikely because of the inherent conservatism (protectiveness) built into the exposure and effects assessments, for example, maximizing the exposure potential coupled with a conservative TRV. If the HQ derived using the LOAEL TRV is greater than 1, it indicates that exposure exceeds a known effect concentration for a test organism that is assumed to be directly applicable for the site-specific receptor; such exposure pathways warrant attention with respect to potential remedial activity. If the estimated exposure exceeds the NOAEL TRV (i.e., the NOAEL TRV-based HQ is >1.0) but is less than the LOAEL TRV, (i.e., the LOAEL TRV-based HQ is <1.0), then that complete exposure pathway will be considered in greater detail before conclusions about likely risk can be made. For nonthreatened and endangered terrestrial species known to be present on Bradford Island, less emphasis will be placed on COIs that have NOAEL TRV-based HQs above 1. However, the range of HQs developed for each receptor and CPEC will be considered in the risk characterization.

Hazard indices (HIs) are ideally calculated for the appropriate COI groups identified as those chemicals demonstrating similar modes of toxicity, or those that affect the same target organ. HIs are estimated by calculating the summation of HQs for COI groups that meet these criteria. The implications of HQs greater than or less than 1.0 discussed above, will also applied to HIs.

Due to a lack of data regarding additive effects associated with exposure to multiple chemicals (especially for nonhuman receptors), professional judgment will be used in the development of HIs. In the absence of information to support the ideal approach for identifying COIs with similar modes of toxicity, HQs for all chemicals are sometimes added or HQs are added for chemicals with similar molecular structures. More often now, however, the HI concept is being omitted (i.e., Portland Harbor [Lower Willamette Group 2007] and Lower Duwamish Waterway [Windward Environmental 2003]) because the utility of this step for remedial decision-making is questionable. Exposure conditions that result in additive, synergistic, or antagonistic effects to wildlife receptors is largely unknown. In fact, it is U.S. Department of the Navy (Navy) policy that HQs for ecological receptors are evaluated on an individual basis and should not be compared or added (Navy 1999).

As discussed with DEQ (teleconference held on July 12, 2007), toxicity ratios (i.e., Level II HQs) for all COIs will be added for the Level II Screening Assessment. For the Level III BERA, HIs will be calculated based on the following chemical groupings in an effort to derive more meaningful HIs than by simply adding all HQs:

- Inorganics (including butyltins) - Adequate avian and mammalian toxicity data may be available for several inorganics detected at the site; therefore, a review of the literature will be performed to support a case for developing the HI for inorganics. In the event that no information is available for a particular inorganic, it will automatically be included in the HI for this chemical class.
- Low-molecular-weight PAHs (LPAHs) – The toxicity of PAHs is highly variable and is driven by the number of ring structures and molecular weight (Eisler 1987). LPAHs consist of fewer than four fused benzene rings and have molecular weights less than 200. LPAHs are more soluble and bioavailable in aqueous solution than high-molecular-weight PAHs (HPAHs) and are associated with acute toxicological effects on biota. LPAHs are much less persistent in the environment, are not considered bioaccumulative, and are readily metabolized by birds and mammals (USEPA 2005a). For these reasons, it is not likely that they elicit reproductive and developmental effects.
- HPAHs – These PAHs consist of four or more fused benzene rings and have a molecular weight greater than 200. HPAHs exhibit greater environmental persistence than LPAHs, which is attributed to their higher hydrophobicity. Due to their size, HPAHs are

relatively immobile and exhibit extremely low volatility and solubility (Eisler 1987). Bioaccumulation potential tends to increase as the molecular weight of PAHs increases and HPAHs are generally associated with carcinogenic effects. Chronic exposure to these carcinogenic PAHs may also produce non-carcinogenic effects by destroying hematopoietic, lymphoid, and reproductive tissues (Eisler 1987). Generating separate risk estimates for HPAHs and LPAHs is further supported by the recently published USEPA Eco-SSL for PAHs (USEPA 2007b).

- Organochlorine pesticides and herbicides and PCBs – Persistent, lipophilic chlorinated compounds such as chlorinated pesticides, herbicides, and PCBs are associated with a variety of ecotoxicological effects. Effects include mortality and neurotoxicity at high doses. At lower doses, effects include endocrine disruption and impairment of reproductive, developmental and neurological functions. Dioxin-like PCBs can alter gene expression by the activation of the aryl hydrocarbon (Ah-R) receptor. Both dioxin-like and non-dioxin-like PCBs may also act through many other modes of toxicity, the most common of which as characterized as narcosis (a non-specific mechanism of toxicity associated with organic compounds). Chlorinated pesticides such as DDTs can interfere with the nervous system and may also impair the endocrine system by exerting estrogenic effects. PCBs and chlorinated pesticides are highly persistent, have the potential to biomagnify in the food web, and are known to elicit similar developmental and reproductive effects in birds and mammals. Although they may act through different mechanisms of toxicity, their HQs will be added to generate an HI for persistent and bioaccumulative chlorinated compounds.

- Non-PAH Semi-Volatile Organic Compounds (VOCs) – These compounds are known to exist in soils of the Upland OU and will be included in the food web evaluation if they demonstrate a potential for bioaccumulation (Section C.3.2.2). Phthalates are known to be present in Upland OU soils and have the potential to bioaccumulate in terrestrial ecosystems. Phthalates tend to have low water solubility, adsorb to sediments, and dissolve easily in oils. Phthalate esters metabolize to monoesters, which deregulate cellular activity by mimicking endogenous ligands (Wexler 1998). Experiments with fish have not found extensive bioaccumulation of these compounds, although rat studies have found fetotoxcity and teratogenic effects. Increased incidences of carcinomas and adenomas observed in rats caused EPA to label bis(2-ethylhexyl)phthalate a probable human carcinogen. The HQs for phthalates will be added to generate an HI for total phthalates. If other bioaccumulative SVOCs are identified for the Upland OU, the decision to include their HQs in HI summations will be evaluated on a case by case basis and will be discussed with DEQ at the time of the risk assessment.

Generating HIs for birds and mammals based on these groupings will likely provide more usable information for decision-making than a single HI reflective of every chemical, especially given the relatively large number of COIs associated with the Upland OU. Volatile organic compounds will not be included in the evaluation of dietary exposure by wildlife, as these compounds are not considered bioaccumulative (i.e., most have log Kows <3.5; Suter 1993). Direct exposure by avian and mammalian receptors to VOCs in soil through incidental ingestion will be addressed by use of the SLVs in the Level II Screening Assessment.

As described in Section C.3.2.1, the potential for exposure to multiple Upland AOPCs by receptors with large home ranges will be assessed through the development OU-wide risks, when appropriate. For these receptors, HQs for CPECs common to the AOPCs included in the OU-wide BERA will be summed, and HIs will be calculated for the appropriate COI groups.

Uncertainty Assessment

Many elements of the risk assessment process are subject to uncertainty. Not all the sources of uncertainty, however, are significant or avoidable. The general and site-specific sources of uncertainty in each phase of the risk assessment process will be identified, and their potential to overestimate or underestimate risks will be discussed. Measures for the reduction of significant uncertainty (e.g., additional data collection, additional evaluation) also will be discussed.

C.3.2.9 Data Gaps for Upland OU

The appropriate level of ecological risk assessment for the upland AOPCs and OU will be presented in the RI report. However, data gaps that need to be filled to perform the ERA were identified on the basis of the data and information available to date (Table 8-2). The data gaps are described below. They are also summarized and presented with the planned data collection efforts in Section 8.

- **Landfill.** Additional current groundwater data are needed at the landfill and at seep locations to finalize the COPC list for groundwater and to address DEQ comments regarding the groundwater discharge pathway. The data should include VOCs as analytes. Reporting limits for the groundwater data should be equal to or lower than ecologically based protective screening levels for aquatic biota. Additional surface soil data are needed in the gully area to characterize potential risks to ecological receptors.
- **Sandblast Area.** Data for lead in the available size fraction are needed to verify that lead is a COI in surface and subsurface soils. Additional current groundwater data are needed at the Sandblast Area near seep locations to evaluate the groundwater discharge pathway, with reporting limits similar to that described for the landfill.
- **Pistol Range.** Additional current groundwater data are needed at the Pistol Range area and near seep locations to evaluate the groundwater discharge pathway, with reporting limits similar to that described for the Landfill. No surface or subsurface soil data are needed since available data are sufficient.
- **Bulb Slope.** No surface or subsurface soil data are needed for the ERA since available data are sufficient. No groundwater data are needed for the ERA since no seeps have been located in this vicinity.

No data gaps related to the receptors of interest or toxicity assessment have been identified for the ERA for the Upland OU.

C.4 ERA FOR RIVER OU

Site investigations in the River OU have been focused entirely above the dam, particularly in the Forebay area, with some additional information on upland "background" or "reference" stations that are believed to be unaffected by any releases from Bradford Island. Like most of the AOPCs in the Upland OU, the River OU has been investigated in varying levels of detail, but no formal Scoping, Screening, or Baseline Assessment has been performed to date.

The River OU is comprised of two main segments that are being investigated concurrently during the RI: the Bonneville Dam Forebay area and the river downstream of the dam. The ERA for the River OU will include both segments, as necessary. No data are currently available downstream of the dam and, therefore, it is not considered to be an AOPC, but sediment and clam samples will be collected from the Bonneville pool and analyzed as part of the RI.

Based on previous site investigations, the expected depth of sediment in the forebay is approximately one to three inches, which is underlain with bedrock. The sediments are primarily comprised of sandy and silty particles. Additional profile data will be collected during the RI to more accurately characterize sediment of the forebay.

Information is sufficient to support the Scoping, Screening, and problem formulation phase of the Baseline Assessment for the Forebay. These levels of the ERA process are also useful in identifying data gaps and defining the data collection needs for the execution of a baseline ERA. However, more data are needed to characterize the nature and extent of contamination in the River OU and estimate EPCs and associated ecological risks.

C.4.1 Level 1 Scoping Assessment

The main purpose of a Scoping Assessment and framework for this part of the ERA process is described in Section C.3.1 for the Upland OU.

Designated beneficial uses for surface water in the Forebay and downstream areas include multiple uses such as those supporting fish and aquatic life, and wildlife (Section 3.1.7). Designated uses by fish include salmon and steelhead migration corridors as well as shad and sturgeon spawning and rearing. No changes are anticipated in the designated uses for this area.

Existing site information for the River OU has been summarized in Section 4.5. Although site characterization has been performed for targeted areas of the Forebay based on the presence of waste-related items in debris piles that were removed in 2002, several data gaps remain that will be addressed during the RI. Based on currently available information, it has been determined that potentially complete ecological exposure pathways are present at the River OU. The list of COIs for each medium of concern associated with the Forebay is provided in Section 5.3.

In an effort to streamline the risk assessment process, information relevant to the river presented in the Level I Scoping Assessment performed for the Landfill (URS 2002) and in the Engineering Evaluation and Cost Analysis (URS 2005) will be compiled to address the elements of a Scoping Assessment for the River OU. However, a formal Scoping Assessment will not be submitted prior to the Screening and Baseline Assessments given the multiple stakeholder discussions regarding the nature of contamination in the river, potential receptors and exposure pathways, etc. The ecological setting, site features, and nature and extent of all known chemical releases will be briefly described in the forthcoming Screening and Baseline Assessments.

Finally, the sources of contamination to the Forebay and downstream will be provided. As described in Section 5.1, both in-water placement of waste electrical items and debris, and possible runoff from upland areas on Bradford Island, have contributed to sediment contamination. The sources of contamination include PCB-containing electrical equipment and debris, release of PCB oils from transformers, possible leakage of PCB-containing dielectric fluid from capacitors, discarded light bulbs (both fluorescent and nonfluorescent), landfill debris, sandblast grit, and associated metals. The sources of contamination and releases are spatially distributed along the northern shoreline of Bradford Island as shown on Figure 5-3.

The upland and in-water sources of contaminants discussed above have led to contamination of sediments in the Forebay area of Bonneville Dam (i.e., those areas near Bradford Island). Water erosion and river current are believed to have transported these sediments to areas below the dam, which means that a secondary source of contaminated sediments may exist below the dam.

C.4.2 Level II Screening Assessment and Level III BERA

The main purposes of Screening and Baseline Assessments and the general approach that will be used to perform these levels of ERA process are the same as those described in Section C.3.2 for the Upland OU. Level II and Level III Assessments have not been conducted for the River OU.

The sections below provide the approach to the problem formulation for the River OU, including the Screening Assessment, as well as the methodology for the Level III BERA to estimate risks posed by upland contamination sources and river contamination sources. Many of the comments received from DEQ on the Screening Assessment for the Landfill are also relevant to the ERA methodology outlined in this work plan (DEQ 2004). Therefore, consideration of those comments is incorporated into the proposed approach.

C.4.2.1 Identification of COIs and CPECs

This section summarizes the approach for identifying COIs and CPECs in the River OU.

COIs and CPECs in River Media

Section 5.3 of the main RI report presents the methodology used to identify the list of COIs for biotic media associated with the Forebay area of the River OU (Table 5-11). An abundance of environmental data has been collected from the River OU during several investigations that have been conducted over the past several years (Section 4.0). Although it is premature to identify CPECs prior to the upcoming data collection effort and combining of new and existing datasets, the focused list of COIs developed for each medium will be used to identify data gaps and facilitate sampling efforts in this RI Management Plan and forthcoming Quality Assurance Project Plans. The list of CPECs will be further refined for purposes of the ERA following the procedures outlined in Section C.3.2.1.

Based on the presence of potentially complete exposure pathways and associated analytical data, COIs in the River OU were identified for sediment and surface water in Section 5.3.2. These COIs include PCBs, copper, lead, PAHs, and a couple of non-PAH SVOCs (including bis[2-ethylhexyl]phthalate).

In addition, COIs in the Forebay sediment that could migrate downstream were also identified in Section 5.3.2 to determine if related data collection will be of benefit to delineating the extent of sediment transport downstream of the Forebay (Table 5-12). The COIs for Forebay sediments were further evaluated in terms of their potential to migrate downstream of Bonneville Dam, as described in Section 5.3. Similar to the approach used in the Portland Harbor (DEQ 2005), the

COIs in sediment were screened against risk-based concentrations in sediment protective of human and ecological receptors. The COIs in Forebay sediments that are considered potentially migratory to the downstream area include some metals, SVOCs (mainly HPAHs), PCBs, and one total petroleum hydrocarbon mixture.

For the problem formulation performed during the Screening Assessment, the general screening criteria outlined in Section C.3.2.2 for the Upland OU will also be used to identify CPECs in media of the River OU. The toxicity-based criteria referred to in the third criterion that will be used in the Screening are listed in Section C.4.2.6. COIs lacking chemical-specific screening values will be retained as CPECs. They will be evaluated quantitatively if acceptable surrogate chemicals are available, or will be discussed in the uncertainty section of the ERA.

Bioaccumulative CPECs

To identify potentially bioaccumulative CPECs in sediment, DEQ's *Guidance for Evaluation of Bioaccumulative Chemicals of Concern in Sediment* (DEQ 2007), which relies on the *Northwest Regional Sediment Evaluation Framework, Interim Final* (RSET 2006), will be consulted. In the RSET document, chemicals are grouped into four classifications based on their potential for bioaccumulation in an aquatic environment:

- List 1. Primary Bioaccumulative Contaminants of Concern (arsenic, cadmium, lead, mercury, selenium, tributyltin, hexachlorobenzene, pentachlorophenol, fluoranthene, pyrene, chlordane, DDTs, dioxins/furans, and PCBs)
- List 2. Candidate Bioaccumulative Contaminants (e.g., chromium VI, endosulfan, some chlorinated naphthalenes)
- List 3. Potentially Bioaccumulative Contaminants (e.g., antimony, HPAHs, some LPAHs, several chlorinated pesticides)
- List 4. Not Currently Considered Bioaccumulative Contaminants (e.g., chromium, copper, nickel, silver, zinc, endrin, heptachlor, trichlorethene, tetrachloroethylene)

These classifications are defined based on the chemical-specific log K_{ow}, concentrations and frequency of detections in site sediment and/or tissue, and other criteria defined in Appendix A of the RSET sediment evaluation framework (RSET 2006).

Based on discussions with DEQ (teleconferences held on July 12, 2007 and July 26, 2007 between DEQ and URS on behalf of the USACE), the list of bioaccumulative chemicals in sediment will consist of chemicals listed in Table A-1 of DEQ's 2007 guidance and any other chlorinated pesticides that might be detected (only chlordane, dieldrin, and DDTs are currently listed in the guidance). This list corresponds to List 1 above ("Primary Bioaccumulative Contaminants of Concern") developed in the RSET, with the addition of dieldrin. The same list will represent bioaccumulative chemicals for the human health risk assessment as well. Any modifications that may occur to DEQ's Table A-1 (2007) will be considered at the time of the risk assessment for the River OU.

Although only a subset of inorganics and PAHs are considered bioaccumulative according to DEQ's guidance (i.e., five inorganics and two PAHs), the laboratory will analyze for all chemicals associated with EPA Methods 200.8 (inorganics) and 8270-SIM (PAHs). As agreed to during the teleconferences with DEQ, all detected inorganics and individual PAHs will be evaluated for direct toxicity effects to fish and invertebrates, if tissue residue benchmarks are available (see Section C.4.2.6 for benchmark sources). However, only the five inorganics and two PAHs (if detected) will be carried forward into the trophic model and bioaccumulation evaluation for human and ecological consumers of fish and shellfish.

The COIs in sediment of the River OU with a potential for bioaccumulation according to the criteria discussed above (RSET guidance, Hazardous Waste Identification Rule documentation, and DEQ's request) will be included in the BERA for avian and mammalian receptors. Tissue samples of selected invertebrate and fish species will be analyzed for these COIs to assist with the estimation of risk through dietary exposure.

C.4.2.2 Receptors of Interest

A simplified food-web model for the River OU is presented on Figure C-5. Discussion regarding the selection of aquatic receptors of interest (or "target receptors") occurred in several meetings during 2005 and early 2006 with the technical advisory group for Bradford Island. The following aquatic or semiaquatic receptors of interest were selected:

- Benthic invertebrates represented by the clam (*Corbicula fluminea*) and crayfish (*Pacifastus spp.*)
- Resident fish represented by the sculpin (*Cottus spp.*) and smallmouth bass (*Micropterus dolomieu*)
- Osprey (*Pandion haliaetus)*
- Bald eagle
- Mink
- Large-scale sucker (*Catostomus macrocheilus*) has been added at the request of DEQ and is discussed further in the text.

Table C-3 illustrates the trophic levels represented by the invertebrate and fish target receptors, as well as the justification for selecting these particular species to represent the sediment food web of the Forebay. Table C-4 provides a summary of the fish species that may be consumed by osprey, eagles, and mink, whether they are present in the Forebay, their home range, and resident/ anadromous status. Section C.4.2.5 describes the fish species that were selected for the diets of the semiaquatic wildlife for purposes of estimating site-related risks.

Although considered to be semiaquatic and highly reliant upon the riverine environment for resources, the bald eagle and the mink may both frequent the uplands, where they would likely supplement their primarily aquatic diet with upland prey items, such as small mammals. In the event that unacceptable risks are demonstrated for the eagle or mink from exposure to media of the River OU, more realistic assumptions that incorporate refinements to their dietary compositions may be considered.

C.4.2.3 Conceptual Site Model

A CSM for ecological receptors of the River OU is presented on Figure C-2. This CSM focuses on potential risks from contaminated sediments located in the Forebay and downstream of Bonneville Dam. As illustrated in the CSM, the affected river media include sediment, surface water, and benthic and aquatic biota. The following aquatic-related exposure pathways are identified for the River OU:

- Uptake of contaminants potentially present in surface water by aquatic organisms (plants, aquatic invertebrates, and fish)
- Ingestion of and dermal contact with contaminants potentially present in sediment and surface water by benthic invertebrates
- Incidental ingestion of and dermal contact with potentially contaminated surface water (all avian and mammalian receptors) and sediment (mink)
- Ingestion of benthic and aquatic dietary components (e.g., invertebrates and fish) by upper trophic level receptors (fish and wildlife)

These exposure pathways and their associated receptors will be evaluated in the problem formulation phase preceding the Screening. COIs that fail the screening process will be identified as CPECs that require quantitative risk evaluation. The results of the problem formulation, including the Screening, therefore, will define the scope and nature of the more detailed baseline risk assessment.

The formal problem formulation for the River OU will be presented in the RI report. However, data gaps that need to be filled to perform the combined Screening and Baseline Assessments were identified on the basis of the preliminary problem formulation performed to date. The data gaps are outlined in the data quality objective table prepared for the River OU (Table 8-3). They are summarized and presented with the planned data collection efforts in Section 8.3.

C.4.2.4 Assessment Endpoints

The recommended assessment endpoints for the ecological receptors addressed in the River OU are listed below.

- Protection of aquatic biota (invertebrates and fish) that may be exposed to COIs in sediment or surface water that originated from Upland OU sources (e.g., groundwater or soil washoff) or from the former in-water debris piles and related activities.
- Protection of piscivorous mammals, represented by the mink, against unacceptable effects on reproduction, growth, or development at the population level due to COIs in sediment, invertebrates, water, and aquatic food.
- Protection of top-level predatory birds, represented by the American bald eagle and osprey, against unacceptable effects on reproduction, growth, or development at the population level due to COIs in sediment, water, and aquatic food.

Protection on an individual basis will be the focus for state- or federally listed threatened and endangered species (i.e., bald eagle) that may occur from exposure to media of the River or Upland OU.

C.4.2.5 Exposure Analysis

A brief introduction to the Exposure Analysis phase of the ERA was provided for the Upland OU (Section C.3.2.5).

The boundaries of the River OU will be defined during the RI. The investigation area associated with this OU is divided into upstream, Forebay, and downstream segments, based on limits of contamination between the upstream and Forebay areas, and the limits of transport between the Forebay and downstream areas. After collection of sediment, water, and tissue data from the Forebay and downstream segments, a determination will be made as to whether the ERA for the River OU should be evaluated as two smaller exposure units (Forebay and downstream) or a single larger exposure unit (Forebay and downstream combined). It is anticipated that two smaller exposure areas will be evaluated.

Exposure Point Concentrations

For plankton, aquatic plants and invertebrates, fish, and benthic invertebrates, the EPC is estimated as a function of the COI concentration measured in water, sediment, or tissue. For carnivorous piscivorous birds and mammals, the exposure dose may be estimated as a function of the COI concentration in relevant environmental media and several other parameters related to biological transfer through the food web and the manner in which receptors use the site.

All water, sediment, and clam tissue samples will be analyzed for PCBs as Aroclors and a subset will be analyzed for PCBs as congeners. All crayfish, sculpin, smallmouth bass, and large-scale sucker samples will be analyzed for congeners only. Therefore, EPCs in abiotic and biotic media collected from the site may be calculated for the following PCB groupings:

- Individual Aroclors
- Total PCBs as the sum of Aroclors
- Total PCBs as sum of 209 nondioxin-like congeners
- 2,3,7,8-TCDD Toxic Equivalents for the 12 dioxin-like PCB congeners

To address the potential for overland transport of COIs in potentially erosive soils of the Upland OU into sediment of the River OU (Sections C.3.2.2 and C.3.2.3); EPCs in soil (0 to 1 foot bgs) will be evaluated at the Screening level. Once sediment-related risks to receptors of the River OU are characterized, an evaluation of the potential contribution of Upland soils to contamination in the River will be performed for the necessary chemicals (i.e., those risk drivers in sediment, or CECs, that are also present in soil above sediment SLVs).

As performed in the ERA for Portland Harbor (Lower Willamette Group 2007), dietary exposure doses for the avian receptors will be evaluated through two methods:

- Dietary doses that are compared to dietary TRVs, and
- Egg tissue concentrations that are compared to bird egg TRVs (expressed as COI concentration in tissue).

Osprey and eagle egg tissue residue concentrations will be estimated using fish prey tissue concentrations and prey tissue-to-egg tissue biomagnification factors. The objective of this additional method to assessing risk to piscivorous bird is to protect sensitive life stages.

Aquatic Organisms (plankton, aquatic plants, pelagic invertebrates, and fish). For the Screening Assessment, EPCs in flowing surface water will be calculated as the 95% UCL for mobile aquatic receptors. Collection of the following types of water samples will be attempted as part of the RI and will be evaluated in the ERA for aquatic organisms:

- Surface water data collected from the Forebay
- Groundwater data collected from wells located along the northern shore of Bradford Island (at the point of discharge to the river)
- Seep samples from the groundwater wells vicinity, as available

It is likely that seep data will be limited, and too few samples will preclude calculation of a 95% UCL. A point by point comparison to the appropriate water quality criteria will be performed for the seeps.

No mixing or dilution will be assumed for groundwater entering the river in the Screening Assessment. However, the actual COI concentrations in surface water at the point of groundwater discharge are likely to be much lower than the concentrations measured in the monitoring well. Furthermore, aquatic receptors are generally mobile and would also not be continuously exposed to site-related COIs in one location of the river. If a more refined evaluation of the groundwater to surface water pathway is warranted in the BERA, the potential for groundwater to impact the river will be further assessed through comparisons of COI concentrations in groundwater and concentrations measured in seeps, as well as actual surface water concentrations near the expected point of groundwater discharge from the island.

In addition to comparing water concentrations measured at the site to water quality criteria, fish tissue residue concentrations will be compared to critical tissue residues protective of this receptor group as another line of evidence to assess the potential for risk to fish. For the Screening Assessment, the COI concentrations measured in fish tissue collected from the Forebay will be compared to the appropriate tissue residue screening level. Depending on the sample size for each fish species (sculpin, smallmouth bass, and large-scale sucker), the 95% UCL or maximum detected concentration will be selected as the EPC in fish tissue. If further assessment of risks to fish is warranted in the BERA based on the evaluation performed for sculpin and smallmouth bass, fish tissue concentrations estimated for these and additional species through the aquatic food-web model selected for the site (i.e., AQUAWEB) may be compared to screening levels.

Benthic Invertebrates. For the Screening Assessment, EPCs in sediment and Upland soils (0 to 1 foot bgs) for benthic invertebrates will be represented by the maximum detected concentration. Use of the maximum concentration of each COI is a conservative approach that serves to protect stationary receptors that could conceivably be exposed to the maximum concentration throughout their entire life span if located in a potential hot-spot area. If further evaluation of the benthic community is necessary in the BERA, a less conservative EPC (such as the 95% UCL) may be used to estimate risks at the community level, due to the absence of threatened or endangered benthic invertebrate species.

Birds and Mammals. For semiaquatic birds and mammals, the EPC will be based upon the 95% UCL concentration in sediment, Upland soils, and water and will be estimated using statistical methods recommended by USEPA (2002a, 2002b). The lower of the 95% UCL and maximum detected concentration in sediment and surface water will define the EPC for birds and mammals in the Screening and BERA. These EPCs for sediment, Upland soils, and water will be directly compared to DEQ's SLVs protective of birds and mammals or equivalent benchmarks.

Upland soils will not be carried to the BERA for the River OU for the estimation of receptor-specific HQs. However, the results of the Screening will be used to evaluate the potential contribution of Upland soils to contamination in the River for the risk drivers identified in sediment at the end of the risk characterization for the River OU, or CECs, that are also present in soil above sediment SLVs. Based on this information a determination can be made as to whether Upland source controls may be warranted.

Exposure doses calculated for piscivorous wildlife receptors in the BERA will be estimated using the EPCs for sediment and water discussed above and exposure algorithms that calculate the ADD for the selected receptors. An interim step to development of the ADD is the estimation of EPCs in dietary items consumed by birds and mammals (e.g., benthic invertebrates and fish) through the application of site-specific biota-sediment accumulation factors (BSAFs) and trophic transfer factors. The selected exposure parameters, methods that may be used to develop BSAFs, and algorithms that will be used to calculate ADDs are provided in Appendix D. A description of the aquatic food-web model that will be used to estimate EPCs in fish (AQUAWEB [Arnot and Gobas 2004]) and the biological and chemical input parameters that will be collected from the site (as opposed to using literature-based defaults) to facilitate calculation of these EPCs is provided in Appendix E .

Several sources of information were consulted to identify suitable fish species for evaluation of the fish ingestion pathway for the eagle, osprey, and mink. This identification is important because fish species vary widely in their CPEC concentrations, as well as in their appeal for ecological consumption. Factors that may affect the CPEC concentrations in fish tissue with respect to site-related contamination include resident/anadromous status, home range, trophic level, and lipid content. According to the *Wildlife Exposure Factors Handbook* (USEPA 1993), www.fishbase.org, and work performed for the Portland Harbor (Lower Willamette Group 2004, 2007), the following species are consumed by the semiaquatic target receptors and may be present in the Forebay:

- Osprey - carp, black and white crappie, bullhead, salmonids, peamouth, northern squawfish, yellow perch, large-scale suckers, northern pikeminnow, largemouth and smallmouth bass, and mountain whitefish
- Eagle - bullhead, suckers, smallmouth bass, peamouth, perch, salmon, trout, shad, carp, salmon, steelhead, and black crappie
- Mink – sculpin, carp, large-scale suckers, and smallmouth bass (and crayfish)

Among the species listed, the smallmouth bass is a resident species that is known to occur in the Forebay. It has a small home range and high fidelity to its range and, therefore, has the potential to spend its entire lifetime in the Forebay. It is a Trophic Level 3/4 species feeding on benthos (e.g., crayfish), Trophic Level 2/3 fish (e.g., sculpin), and predatory fish, mainly juveniles. All of these characteristics make it likely that the smallmouth bass is a fish species that may represent maximal exposure to site-related CPECs in sediment. In addition, PCB concentrations measured in fish species identified as receptors of concern in the Round 2 ERA performed for Portland Harbor were highest in the smallmouth bass (as shown in Tables 4-8 through 4-13 of Appendix G of Lower Willamette Group 2007). The 95% UCLs for Total PCB concentrations (as congeners) measured in these fish species in the Round 2 ERA from highest to lowest were as follows (in micrograms [µg] PCBs/kg wet weight tissue): smallmouth bass (1,960) > large-scale sucker (1,540) > northern pikeminnow (1,350) > sculpin (1,300).

For these reasons and those presented in Tables C-3 and C-4, the smallmouth bass was selected as the finfish species that will be used to estimate exposure doses for the fish consumption scenario for all receptors. The mink will also be assumed to prey on sculpin. As large-scale suckers comprise a large portion of the diets of ospreys and eagles that forage in the Lower Columbia River, the five sucker samples already collected from the Forebay will be analyzed for PCBs to decide whether or not inclusion of these data are useful for purposes of evaluating risks to semiaquatic wildlife. If sucker data are deemed useful, then further sampling may be needed to generate a more robust dataset for this fish species to be incorporated into the ERA. Due to the sucker's large foraging range in comparison to the size of the Forebay, the uncertainties regarding the actual site-related contribution of CPECs in sucker tissue will be thoroughly evaluated prior to incorporating this species.

For all avian receptors, it will be assumed that 100 percent of their finfish consumption consists of smallmouth bass that reside exclusively in the Forebay for their lifetime. For the mink, it will be assumed that 100 percent of its invertebrate and finfish consumption consists of crayfish (33 percent), sculpin (33 percent), and smallmouth bass (33 percent) that reside exclusively in the Forebay for their lifetime. It is likely that the choice of the smallmouth bass may overestimate exposure for the receptors since they will likely consume larger amounts of other fish species that spend far less time in the Forebay (e.g., salmonids, large-scale suckers). If the BERA indicates unacceptable risks for this scenario, this uncertainty may be reduced by evaluating consumption of additional species, such as the sucker.

In the absence of bird egg tissue data from the site, EPCs for osprey and eagle eggs will be estimated through the method described in Appendix D. The concentration calculated in bird egg tissue is a function of the fish tissue concentrations consumed by the birds and a biomagnification factor (BMF), which addresses transfer of a COI from fish tissue to bird egg tissue. As the approach to calculating prey tissue concentrations will be estimated in AQUAWEB (Arnot and Gobas 2004) based on EPCs in sediment and water (i.e., the lower of the 95% UCL and maximum detected concentration) these EPCs will also be reflected in the bird egg tissue concentrations.

C.4.2.6 Effects Analysis

A brief introduction to the Effects Analysis phase of the ERA was provided for the Upland OU (Section C.3.2.7).

Measurement Endpoints

Measurement endpoints corresponding to the assessment endpoints identified in Section C.4.2.4 are detailed in Table C-1. The measures of exposure and measures of effect proposed for the assessment endpoints are provided in Table C-1. Measurement endpoints for the River ERA will include measured EPCs in sediment, measured or modeled EPCs in water and biota tissues, and field observations.

Direct Toxicity and Diet-Based Screening Levels for Sediment, Water, and Tissue

For the Screening phase of the problem formulation that will be performed for the Forebay, potential ecological effects associated with direct exposure to COIs in sediment and water (surface water, groundwater, or seeps) by benthic invertebrates and aquatic organisms will be evaluated through comparison of the EPCs derived for these media to the selected SLVs (Table C-2). The following sources will be consulted for direct toxicity-based screening levels that are protective of these generic receptor groups potentially exposed to freshwater sediment and surface water:

Sediment

- DEQ's Level II SLVs for freshwater sediments (2001)
- Round 2 Ecological Risk Assessment for Portland Harbor (Lower Willamette Group 2007)
- Other sources (e.g., MacDonald et al. 2000)

Surface Water

- DEQ's water quality criteria protective of freshwater organisms (Criteria Continuous Concentrations, i.e., chronic exposure; Oregon Administrative Rules, Section 340-041, Tables 33A, 33B, and 33C)
- National Ambient Water Quality Criteria for freshwater protective of aquatic life (Criteria Continuous Concentrations; USEPA 2006a)

In addition, tissue and sediment screening levels that address dietary exposure for fish, birds, and mammals (i.e., DEQ's Sediment Bioaccumulative SLVs and Acceptable Tissue Levels for fish and shellfish; DEQ 2007) will also be compared to the appropriate EPCs developed for these receptor groups, when available. In the absence of reliable and readily available diet-based screening levels protective of piscivorous wildlife for all COIs detected in sediment and tissue, potentially bioaccumulative COIs will be retained as CPECs for the BERA. Other sources of screening levels in addition to those listed above may be incorporated into the evaluation, as necessary. Once all of the RI data are collected and the final list of COIs has been established for the River OU, an interim draft table presenting the screening values for each COI in tissue will be submitted for DEQ's review.

In the BERA, less conservative and more site-specific toxicity data may be incorporated for the COIs that fail the Screening against direct toxicity-based SLVs for benthic invertebrates and aquatic organisms to gain a better understanding of the actual risk at the community or population level. For example, Probable Effects Thresholds (MacDonald et al. 2000) for sediment may be used to supplement no- or lowest-effects based risk estimates to benthic invertebrates. Furthermore, COI concentrations measured or predicted in benthic invertebrate and fish tissue will be compared to critical fish tissue residue levels selected from the following sources:

- United States Army Corps of Engineers (USACE)/USEPA Environmental Residue and Effects Database (ERED) (USACE/USEPA 2005)
- *Portland Harbor Remedial Investigation-Feasibility Study, Comprehensive Round 2 Site Characterization Summary and Data Gaps Analysis Report* (Lower Willamette Group 2007)
- *A Methodology for Deriving Tissue Residue Benchmarks for Aquatic Biota: A Case Study for Fish Exposed to 2,3,7,8-Tetrachlorodibenzo-p-Dioxin and Equivalents* (Steevens et al. 2005)

For listed or proposed-for-listing threatened and endangered species of invertebrates or fish, No Effects Residues may be used to estimate the protection of individuals, while Lowest Effects Residues may be appropriate for protection at the population level.

The list of chemicals that will be subjected to the critical tissue residue analysis for fish will be compiled based on the CPECs in sediment that have EPCs above the Bioaccumulative SLVs protective of fish. Any CPECs that lack sediment screening levels protective of fish through dietary exposure will also be retained for the fish tissue evaluation. Bioaccumulative or biomagnifying chemicals detected in fish collected from the Forebay for which the concentration in sediment is below the Bioaccumulative SLV for fish will not be eliminated from the evaluation. These chemicals will be retained for a semiquantitative uncertainty discussion to understand the approximate magnitude of potential risk posed to fish and piscivorous wildlife from exposure to the concentrations measured in fish tissue caught from the site vicinity. Based on current and historical operations at the Upland and River OUs and available empirical data, a determination will be made as to whether these chemicals could originate from Bradford Island or if the fish tissue concentrations reflect exposure to other contaminant sources in the river.

If the potential for adverse effects to mammals or birds is demonstrated through the Screening against generic SLVs, risks to the selected avian and mammalian target receptors (Section C.4.2.2) will be estimated using TRVs to develop HQs in the BERA. All COIs in sediment with EPCs above the Bioaccumulative SLVs protective of piscivorous birds and mammals and the remaining potentially bioaccumulative COIs in sediment that lack these SLVs will be retained as CPECs for the BERA. As stated above, bioaccumulative or biomagnifying chemicals detected in fish collected from the Forebay for which the concentration in sediment was below the bioaccumulative SLV for birds and mammals will be retained for a semiquantitative uncertainty discussion.

Toxicity Reference Value for Food-Web Exposure

A general description of the types of TRVs that will be used for wildlife, level of protection associated with these TRVs, preferred sources of TRVs for this project, and appropriateness of allometric adjustments presented in Section C.3.2.6 for the Upland OU also applies to the River OU. To provide an adequate level of protection to the only special-status wildlife species known to occur at the site, i.e., bald eagle, NOAEL TRVs will be used to assess site-related effects on an individual basis for this target receptor. Recommendations to support the remedial decisions for the River OU will be based on risks at the individual level for threatened and endangered species and at the population level for nonlisted species.

In addition to the diet-based TRVs for birds, bird egg TRVs, such as those selected for the Portland Harbor Round 2 ERA (Lower Willamette Group 2007), will be compared to EPCs estimated in osprey and eagle eggs (Section C.4.2.5). These egg tissue TRVs are residue concentrations in eggs representative of NOAELs and LOAELs selected from the literature.

To establish the appropriate approach for combing the various types of PCB data that will be collected during the RI to generate baseline risks to aquatic receptors, these data will be analyzed to determine if a functional relationship exists between congener and Aroclor data in sediments and water exists. If the evaluation supports the use of Aroclor data as an acceptable term for risks related to PCBs, then toxicity data related to the Aroclors detected in sediment and water will be used in the BERA. This scenario was observed in similar evaluations completed for the Lower Duwamish Waterway (Windward Environmental 2005, 2006) and the Fox River.

The likely combinations of TRVs and EPCs that will be used to calculate HQs are as follows:

- TRVs for individual Aroclors to be compared to individual Aroclor data
- TRVs for Total PCBs to be compared to Total PCBs data as the sum of Aroclors
- TRVs for Total PCBs to be compared to Total PCBs data as the sum of 209 nondioxin-like congeners
- TRVs for 2,3,7,8-TCDD to be compared to Toxic Equivalents (TEQs) for the 12 dioxin-like PCB congeners

If the use of Aroclors alone is not supported at this site, risks for PCBs will be estimated on both an Aroclor basis and a congener basis.

C.4.2.7 Risk Characterization

Risk characterization for the River OU will be similar to the process outlined for the Upland OU.

The discussion of uncertainty for the River OU BERA will be both qualitative and quantitative. Uncertainties relating to CPEC identification (e.g., Aroclor and congener analyses, usability of data), other exposure assessment parameters (e.g., home ranges for fish, birds, and mammals and fish ingestion rates), toxicity assessment (e.g., effects of nondioxin-like PCBs), and risk characterization (e.g., HQs and HIs) will be discussed.

To understand baseline risks, to make risk management decisions at the time of the RI, and for comparing cleanup goals in the FS, it will be necessary to generate a reliable relationship between aquatic risks and sediment concentrations of key chemicals such as PCBs. The means to do so is to build and reduce uncertainty in the trophic model. Trophic model risk hypotheses will be used to refine the preliminary risk model, which was presented in the in-water Engineering Evaluation/Cost Analysis (URS 2005). This model will be updated according to comments received on the Evaluation/Analysis; however, it uses a good many assumptions and model defaults, e.g., it was built primarily for local resident fish and populations of subsistence fishermen and wildlife that consume them, and assumes that 100 percent of fish consumed are within the Forebay. Since the use of the Trophic Trace Model is a key tool in the River OU risk assessment, the results of sensitivity and uncertainty analyses for this model will be presented.

C.4.2.8 Data Gaps for River OU

Data gaps that need to be filled in order to perform the baseline ERA were identified on the basis of the preliminary data and information available to date. The data gaps are described below. They are also summarized and presented with the planned data collection efforts in Section 8.

- **Reference area.** In order to identify site-related COPCs, concentrations of COIs (particularly PCBs) in sediment, surface water and tissues of the selected target species (clam, sculpin and smallmouth bass) are needed from the reference area, upstream of the Forebay. The reference area data will be used for statistical comparisons with forebay data in order to provide estimates of non-site-related risks, if needed. The sample size and selection of sample locations should be sufficient to develop reference area concentrations for robust statistical comparisons.

Aroclor and some congener data are needed for sediment, water and clams, and congener data for fish tissues. If mercury is identified as a COI, it should be analyzed as total mercury in sediment and water, total mercury and methyl mercury in clam tissue and total mercury in finfish. These analyses are based on the expected speciation of mercury in these media, i.e., mercury in sediment and water is present primarily as inorganic mercury with a small fraction (typically methyl mercury present as 1-10% of total), methyl mercury in invertebrates may constitute approximately 60 to 80% of total mercury, and almost 100% of mercury in finfish is expected to occur as methyl mercury. Therefore, the methyl mercury content of finfish will be represented by the total mercury analysis.

- **Forebay area.** Concentrations of COIs in sediment to characterize baseline conditions (i.e., after the interim removal action) are needed for sediment, surface water and tissues of target species in the Forebay area. The selected target species include finfish and shellfish species of interest to fish consumers (crayfish, smallmouth bass, large-scale sucker) and other species which are part of the food web or dietary preferences of these edible species (clams, sculpin).
- **Downstream area.** The downstream area is not currently included in the risk assessment since site characterization and delineation of the nature and extent of contamination have not been initiated.

Proposed data collection for large-scale sucker. Large-scale sucker are a resident fish species of large home-range, known to occur in the Lower Columbia River. A few specimens have been collected from the Forebay. Large-scale sucker are of some interest for both the human heath risk assessment (HHRA) and ERA. They are among the species consumed Native American fish harvesters in the general area, although consumption rates for the sucker are much lower than for other more popular fish species (Columbia River Inter-Tribal Fish Commission [CRITFC] 1994, Tables 17-19). Suckers are not among the fish species of interest to recreational anglers.

Suckers may be more important in the Forebay, as one of the important components of the diet of piscivorous birds (bald eagle, osprey) (USEPA 1993). Although the contribution from site-related sources to COI concentrations in sucker tissue may be difficult to demonstrate (because of its large home-range), the sucker was included as fish species for tissue analysis, at the request of DEQ.

To simplify sampling efforts, an attempt was made to identify the size of large-scale suckers that would be useful for exposure assessment in both the HHRA and ERA. Suckers typically attain a maximum length of 24 inches and may live to 15 years (www.fishbase.org). It was assumed that anglers would be unlikely to keep and consume fish that were less than 12 inches long. Bald eagles and osprey have an approximate weight limit of 4 pounds (lbs) for capture and lifting of prey (http://www.hangingrocktower.org/birds/osprey.htm, http://www.baldeagleinfo.com/eagle/eagle3.html).

Length-weight relationships for this particular species were not readily available. Therefore, length-weight relationships for the sucker family were utilized to determine the fish length corresponding to 4 lbs (www.fishbase.org). The length was calculated using the following relationship, where weight is expressed in grams and length in centimeter (cm):

Weight = 0.0121 X ($L^{3.0225}$)

The length corresponding to 4 lbs (1.57 kg) is approximately 19 inches (49 cm).

Collection of large-scale suckers in the length range of 1- in –19 in is expected to furnish data that can be used for both the HHRA and the ERA. More fish will be collected than needed and stored. Initially, 14-21 fish will be analyzed on a whole-body basis. If the results of the HHRA indicate unacceptable risks associated with large-scale sucker consumption, the stored fish may be analyzed on a fillet basis to assist in refinement of risk estimates.

Although the problem formulation for the River OU has not been formalized, it is expected to warrant a baseline HHRA since COIs (partially screened) and potentially complete pathways are present.

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Table C-1. Assessment and Measurement Endpoints for Ecological Risk Assessment

Assessment Endpoints	Measurement Endpoints	
	Measures of Exposure	**Measures of Effect**
Upland OU		
Protection of the **terrestrial plant community** and **soil invertebrate** populations that may be exposed to COIs in soil to maintain species diversity, abundance, and nutrient cycling.	Measured concentrations in soil from 0 to 3 feet bgs that reduce survival, growth, and/or productivity of the plant or soil invertebrate communities.	Potential toxicity due to exceedances of screening values related to maintenance of the terrestrial plant community, based on a 20% reduction (or greater) in growth or yield (DEQ 2001; Efroymson et al. 1997a). Potential toxicity due to exceedances of screening values related to maintenance of the soil-dwelling invertebrate community, based on a 20% reduction (or greater) in growth, reproduction, or activity (DEQ 2001; Efroymson et al. 1997b).
Protection of herbivorous birds (trophic level 1), represented by the **Canada goose**, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and terrestrial plants.	Measured concentrations in soil from 0 to 3 foot bgs and estimated concentrations in plant tissues that reduce reproduction, health, and/or survival of populations of avian herbivores.	Potential or observed toxicity due to exceedances of screening values and/or acceptable hazard quotients related to survival, growth, and reproduction of resident populations of Canada geese (DEQ 2001; Efroymson et al. 1997c; USEPA 2005b; Sample et al. 1996).
Protection of invertivorous birds (trophic level 2), represented by the **robin,** with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and invertebrates.	Measured concentrations in soil from 0 to 3 foot bgs and estimated concentrations in invertebrate tissues that reduce reproduction, health, and/or survival of populations of avian invertivores.	Potential or observed toxicity due to exceedances of screening values and/or acceptable hazard quotients related to survival, growth, and reproduction of resident populations of robins (DEQ 2001; Efroymson et al. 1997c; USEPA 2005b; Sample et al. 1996).
Protection of carnivorous small mammals (trophic level 2-3), represented by the **vagrant shrew,** with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and invertebrates.	Measured concentrations in soil from 0 to 3 feet bgs and estimated concentrations in invertebrate tissues that reduce reproduction, health, and/or survival of populations of carnivorous small mammals.	Potential or observed toxicity due to exceedances of screening values and/or acceptable hazard quotients related to survival, growth, and reproduction of resident populations of vagrant shrews (DEQ 2001; Efroymson et al. 1997c; USEPA 2005b; Sample et al. 1996).

Table C-1. Assessment and Measurement Endpoints for Ecological Risk Assessment

Assessment Endpoints	Measurement Endpoints	
	Measures of Exposure	**Measures of Effect**
Protection of top-level predatory birds (trophic level 3-4), represented by the **American kestrel**, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in soil and small mammals.	Measured concentrations in soil from 0 to 3 foot bgs and estimated concentrations in small mammal tissues that reduce reproduction, health, and/or survival of populations of top-level predatory birds.	Potential or observed toxicity due to exceedances of screening values and/or acceptable hazard quotients related to survival, growth, and reproduction of resident populations of American kestrels (DEQ 2001; Efroymson et al. 1997c; USEPA 2005b; Sample et al. 1996).
River OU		
Protection of the trophic level 1 infaunal community with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in sediment and porewater.	Measured concentrations in sediment from 0 to 1 foot bgs and surface water that reduce reproduction, health, and/or survival of populations in the trophic level 1 infaunal community.	Potential toxicity due to exceedances of screening values protective of the benthic community or observed toxicity in toxicity tests (DEQ 2001; LWG 2007; MacDonald et al. 2000).
Protection of the trophic level 1 epibenthic community with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in sediment and surface water.	Measured concentrations in sediment from 0 to 1 foot bgs and surface water (or groundwater discharging to the river) that reduce reproduction, health, and/or survival of populations in the epibenthic community.	Potential toxicity due to exceedances of screening values protective of the benthic and aquatic communities or observed toxicity in toxicity tests (DEQ 2001; LWG 2007; MacDonald et al. 2000; Suter et al. 1996; DEQ Water Quality Criteria [WQC] OAR 340-041; USEPA WQC 2006).
Protection of the trophic level 1 epibenthic and infaunal community, represented by the **Asian clam**, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in sediment, porewater, and surface water.	Measured concentrations in sediment from 0 to 1 foot bgs, surface water (or groundwater discharging to the river), and clam tissue that reduce reproduction, health, and/or survival of populations of trophic level 1 epibenthic community.	Potential toxicity due to exceedances of screening values protective of the benthic community or observed toxicity in toxicity and bioaccumulation tests based on survival, growth, and reproduction of resident populations of Corbicula clam (DEQ 2001; LWG 2007; MacDonald et al 2000; Suter et al. 1996; DEQ Water Quality Criteria [WQC] OAR 340-041; USEPA WQC 2006).

Table C-1. Assessment and Measurement Endpoints for Ecological Risk Assessment

Assessment Endpoints	Measurement Endpoints	
	Measures of Exposure	**Measures of Effect**
Protection of the trophic level 2-3 epibenthic community, represented by the **crayfish**, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in sediment and surface water.	Measured concentrations in sediment from 0 to 1 foot bgs, surface water (or groundwater discharging to the river), and tissue that reduce reproduction, health, and/or survival of populations of the trophic level 2-3 epibenthic community.	Potential toxicity due to exceedances of screening values protective of the benthic community or observed toxicity in toxicity and bioaccumulation tests based on survival, growth, and reproduction of resident populations of crayfish (DEQ 2001; LWG 2007; MacDonald et al 2000; Suter et al. 1996; DEQ Water Quality Criteria [WQC] OAR 340-041; USEPA WQC 2006).
Protection of herbivorous or invertivorous fish (trophic level 1-2), represented by the **largescale sucker**, with no unacceptable effects on reproduction, growth, or development on the population level due to COIs in sediment, surface water, and prey.	Measured concentrations in sediment from 0 to 1 foot bgs, surface water (or groundwater discharging to the river), and fish tissues that reduce reproduction, health, and/or survival of populations of trophic level 1-2 fish.	Potential toxicity due to exceedances of screening values protective of the aquatic community or observed toxicity in bioaccumulation and toxicity tests based on survival, growth, and reproduction of resident populations of trophic level 1-2 fish (DEQ 2001; LWG 2007; MacDonald et al 2000; Suter et al. 1996; USEPA's AWQC documents; USACE ERED database).
Protection of invertivorous and piscivorous fish (trophic level 2-3), represented by the **smallmouth bass**, with no unacceptable effects on reproduction, growth, or development on the population level due to COIs in sediment, surface water, and prey.	Measured concentrations in sediment from 0 to 1 foot bgs, surface water (or groundwater discharging to the river), and fish tissues that reduce reproduction, health, and/or survival of populations of trophic level 2-3 fish.	Potential toxicity due to exceedances of screening values protective of the aquatic community or observed toxicity in bioaccumulation and toxicity tests based on survival, growth, and reproduction of resident populations of trophic level 2-3 fish (DEQ 2007; LWG 2007; USACE ERED database; DEQ Water Quality Criteria [WQC] OAR 340-041; USEPA WQC 2006).

Table C-1. Assessment and Measurement Endpoints for Ecological Risk Assessment

Assessment Endpoints	Measurement Endpoints	
	Measures of Exposure	**Measures of Effect**
Protection of trophic level 3-4 predatory fish, represented by the **walleye pike** and **northern pikeminnow**, with no unacceptable effects on reproduction, growth, or development on the population level due to COIs in sediment, surface water, and prey fish.	Measured concentrations in sediment from 0 to 1 foot bgs, surface water (or groundwater discharging to the river), and fish tissues that reduce reproduction, health, and/or survival of populations of top-level predatory fish.	Potential toxicity due to exceedances of screening values protective of the aquatic community or observed toxicity in bioaccumulation and toxicity tests based on survival, growth, and reproduction of resident populations of top-level predatory fish (DEQ 2007; LWG 2007; USACE ERED database; DEQ Water Quality Criteria [WQC] OAR 340-041; USEPA WQC 2006).
Protection of large carnivorous mammals (trophic level 3-4), represented by the **mink**, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in sediment, aquatic invertebrates, and fish.	Measured concentrations in sediment from 0 to 1 foot bgs and fish and shellfish tissues that reduce reproduction, health, and/or survival of populations of large carnivorous mammals.	Potential or observed toxicity due to exceedances of screening values and/or acceptable hazard quotients related to survival, growth, and reproduction of resident populations of mink (DEQ 2001; DEQ 2007; LWG 2007; USEPA 2005b; Sample et al. 1996).
Protection of top-level piscivorous threatened or endangered birds (trophic level 3-4), represented by the **bald eagle**, with no unacceptable effects on reproduction, growth, or development on an individual level due to COIs in sediment and fish.	Measured concentrations in sediment from 0 to 1 foot bgs and fish tissues that reduce reproduction, health, and/or survival of populations of top-level piscivorous birds.	Potential or observed toxicity due to exceedances of screening values and/or acceptable hazard quotients related to survival, growth, and reproduction of individual bald eagles (DEQ 2001; DEQ 2007; LWG 2007; USEPA 2005b; Sample et al. 1996).
Protection of top-level piscivorous birds (trophic level 4), represented by the **osprey**, with no unacceptable effects on reproduction, growth, or development on a population level due to COIs in sediment and fish.	Measured concentrations in sediment from 0 to 1 foot bgs and estimated concentrations in fish tissues that reduce reproduction, health, and/or survival of populations of top-level piscivorous birds.	Potential or observed toxicity due to exceedances of screening values and/or acceptable hazard quotients related to survival, growth, and reproduction of resident populations of osprey (DEQ 2001; DEQ 2007; LWG 2007; USEPA 2005b; Sample et al. 1996).

Table C-2.
Sources of Screening Levels to Be Used for Screening of Contaminants of Interest for Ecological Receptors

Medium	**Source and Screening Benchmark** [a]	
Soil	Plants	DEQ Level II SLVs for Terrestrial Plants (2001)
		ORNL Plant Benchmarks (Efroymson 1997a) USEPA Interim Ecological Soil Screening Levels for Plants (Eco-SSLs), Revised (2005b)
		Primary literature sources of phytotoxicity studies (ICF Incorporated 1989; Hulzebos et al. 1993
		Screening levels for plants in USEPA's Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities (1999b)
	Soil Invertebrates	DEQ Level II SLVs for Soil Invertebrates (2001) USEPA Interim Ecological Soil Screening Levels for Soil Invertebrates (Eco-SSLs), Revised (2005b)
		ORNL Benchmarks for Soil and Litter Invertebrates and Heterotrophic Processes (Efroymson 1997b)
		Primary literature sources of phytotoxicity studies (ICF Incorporated 1989)
		Screening levels for invertebrates in USEPA's Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities (1999b)
	Birds	DEQ Level II SLVs for Birds (2001) USEPA Interim Ecological Soil Screening Levels for Birds (Eco-SSLs), Revised (2005b)
		ORNL Preliminary Remediation Goals for Ecological Endpoints - lowest for avian target species used (Efroymson 1997c)
	Mammals	DEQ Level II SLVs for Mammals (2001) USEPA Interim Ecological Soil Screening Levels for Mammals (Eco-SSLs), Revised (2005b)

Table C-2.
Sources of Screening Levels to Be Used for Screening of Contaminants of Interest for Ecological Receptors

Medium	**Source and Screening Benchmark** [a]	
		ORNL Preliminary Remediation Goals for Ecological Endpoints - lowest for mammalian target species used (Efroymson 1997c)
Sediment	Benthic Invertebrates	DEQ Level II SLVs for Freshwater Sediments (2001) Portland Harbor RI/FS Comprehensive Round 2 Report, Appendix G (LWG 2007) Primary literature sources (e.g., MacDonald et al. 2000)
	Fish	Chemical specific NOAA publications (e.g., Meador 2000)
		DEQ Bioaccumulation SLVs for freshwater fish (DEQ 2007)
	Piscivorous Wildlife	DEQ Bioaccumulation SLVs for birds and mammals (2007)
Surface Water	Plankton, Aquatic Plants, Water-Column Invertebrates, Fish	DEQ Water Quality Criteria - Freshwater Chronic Values presented in OAR 340-041, Tables 33A, 33B, and 33C
		DEQ Level II SLVs for Freshwater Organisms (2001)
Groundwater [a]	Hypothetical Run-out into River without Attenuation: Plankton, Aquatic Plants, Water-Column Invertebrates, Fish	DEQ Water Quality Criteria - Freshwater Chronic Values presented in OAR 340-041, Tables 33A, 33B, and 33C DEQ Level II SLVs for Freshwater Organisms (2001)

[a] Groundwater data will be compared to screening levels for surface water based on the assumption that groundwater discharges to surface water of the river and may be modified by surface water data.

Table C-3
Selection of Benthic Invertebrate and Fish Species for Food-web Modeling, Bradford Island

Trophic Level	Selected Surrogate for Tissue Collection	Diet	Reasons for Selection
Level 4 Piscivores and Top-Level Predatory Fish	Smallmouth Bass	benthos (crayfish), predatory fish (mainly juveniles), sculpin	Small home range compared to other Level 3, and esp. Level 4, fish. Known to exist near Bradforld Island. Important food source for wildlife (and humans), as well as food source for larger predatory fish (eaten by humans and wildlife). Conservative surrogate for predatory fish consumed by wildlife. No top-level predators selected due to large home ranges/low site fidelity; however, these most relevant in terms of consumption by humans and piscivorous wildlife. It would be very difficult to associate tissue concentrations with site-related contamination. Example: Sturgeon have large home ranges and are actually considered anadromous. Even though some individuals are "dam-locked" and are therefore not anadramous, an adult's diet consists of resident and anadromous fish species (impossible to determine site contribution).
Level 3 Invertivores/Piscivores	Sculpin	benthos, small (and juvenile) fish	Small home range compared to other invertivorous fish - very territorial. Could be used to represent juvenile fish portion of smallmouth diet in foodweb model because diet similar to salmonids and other anadramous species (would be conservative surrogate because juvenile fish expected to eat more plant material than adult sculpin).
Level 2 Forage Fish	None	Zooplankton, plant material, some invertebrates	None selected, but level of exposure by invertivorous and predatory fish (Level 3/4) is expected to be higher; crayfish and sculpin can be used as conservative surrogates for Level 2 fish. Largescale sucker samples already collected from the Forebay will be analyzed for PCBs and evaluated to decide whether or not inclusion of these data are useful for purposes of evaluating risks to semi-aquatic wildlife.
Level 1 Benthic Invertebrates	Crayfish	Omnivorous, scavenger; juveniles eat aquatic invertebrates and plants; adults cannibalistic (highly opportunistic), feed mainly on animal materials	Relatively small home range compared to most fish specis, so tissue levels reflect site-related exposure. Occupy unique niche in food chain - consume benthos and predatory fish (constraints in food chain model do no allow representation of this feeding guild, so measured data needed). Could be used as surrogate for Level 2 species (herbivore/omnivore - not proposed for collection), which is also a conservative surrogate for juvenile fish that represent important food source for smallmouth. Longer lifespan than most benthic species = higher level of exposure and accumulation (higher body burden expected). Important food source for wildlife (mink), predatory fish (smallmouth), and humans.
	Clams	Sediment and plankton	Immobility makes them ideal for understanding sediment to biota transfer at site (e,g., bioavailability). Epibenthic - exposed to bedded sediment and surface water at interface (containing suspended particulates). Lab bioassays could be used to verify field results (i.e., bioaccumulation testing and chemical analysis on tissues). Important food source for upper trophic levels, as well as food source for crayfish.

Table C-4
Selection of Fish Species for Tissue Analyses

Fish Species Common Name	Scientific Name	CRBFCS species?	Resident/ Nonresident	Home-range (PH exposure area)	Trophic Level	Diet	Habitat Preferences	Osprey Prey?	Bald Eagle Prey?	Mink Prey?	Rationale for inclusion or exclusion in ERA
American shad	*Alosa sapidissima*	No	Anadromous	up to 3000 km for reproduction (1)	Level 2/3	Feed on plankton, mainly copepods and mysids; occasionally on small fishes. Feeding ceases during upstream spawning migration and resumes during downstream, post-spawning migration.	Most of life spent at sea, returns to streams to breed.				Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for ERA.
black crappie	*Pomoxis nigromaculatus*	No	Resident	11.3 km, 5.4 miles, 2-7 miles (PH) (2,3)	Level 3/4	Planktonic crustaceans and larvae of many types, larger individuals feed on small fishes.	Inhabit lakes, ponds, sloughs, and backwaters and pools of streams. Usually occurs among vegetation over mud or sand, most common in clear water.	33%			Resident species but home range is much larger than area of forebay; therefore exposure to site-related COIs difficult to estimate. Not selected for ERA.
bridgelip sucker	*Catostomus columbianus*	Yes	Resident	Unknown	Level 2/3	Algae and bottom invertebrates.	Inhabits lake margins, backwaters, rocky riffles, and sand or silt runs of creeks and small to medium rivers.		8.6-19.5%		Has not been observed or collected from the forebay to date. Range unknown. Not selected for ERA.
brown bullhead	*Ameiurus nebulosus*	No	Resident	>9 mi, <0.1-16 miles (2)	Level 2/3	Mollusks, insects, leeches, crayfish and plankton, worms, algae, plant material, fishes, and fish eggs. Juv. Feed on chironomid larvae, cladocerans, ostracods, amphipods, bugs and mayflies. Nocturnal feeder.	Pools and sluggish runs over soft substrates in creeks and small to large rivers; found in impoundments, lakes, and ponds.	37.7%	24.8%		Resident species but not known to occur in abundance in Forebay area. Not selected for ERA.
channel catfish	*Ictalurus punctatus*	Yes	Resident	<0.1-99 miles (2)	Level 3/4	Small fish, crustaceans including crayfish, clams and snails, aquatic insects and small mammals.	Inhabit rivers and streams and prefers clean, well oxygenated water; also in ponds and reservoirs.		21.8%		Has not been observed or collected from the forebay to date. Not selected for ERA.
Chinook salmon	*Oncorhynchus tshawytscha*	Yes	Present, anadromous	up to 2000 km for reproduction (4)				20.8	15.5-21%		Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for ERA.
common carp	*Cyprinus carpio*	No	Resident	Up to 1100 km (4)	Level 2/3	Aquatic insects, crustaceans, annelids, mollusks, weed and tree seeds, wild rice, aquatic plants and algae	Favor large water bodies with slow flowing or standing water and soft bottom sediments	67%	1-17.3%		Has not been observed or collected from the forebay to date. Not selected for ERA.
cutthroat trout	*Onchorynchus clarki lewisi*	No	Resident, though sometimes anadromous	2.2 km, 86 km max (5)	Level 3/4	Small fishes, crustaceans, and insects.	Prefers relatively small streams with gravel bottoms and gentle gradients, spawning adults migrate from sea to streams	5%			Residence status varies by life-stage, large home range. Difficult to estimate exposure to site-related COIs. Not selected for ERA.

Table C-4
Selection of Fish Species for Tissue Analyses

Fish Species Common Name	Scientific Name	CRBFCS species?	Resident/ Nonresident	Home-range (PH exposure area)	Trophic Level	Diet	Habitat Preferences	Osprey Prey?	Bald Eagle Prey?	Mink Prey?	Rationale for inclusion or exclusion in ERA
eulachon (Pacific smelt)	*Thaleichthys pacificus*	Yes	anadromous	up to 160 km (1)	Level 2	Feeds on plankton only while at sea.	Most of life spent at sea, returns to freshwater streams to spawn				Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for ERA.
large-scale sucker	*Catostomus macrocheilus*	Yes	Resident	59.5 km (PH), 0.5-10 miles (6)	Level 2/3	Young feed on planktonic cladocerans, copepods, ostracods, and mites; chironomid, trichopteran and ephemeropteran larvae; and bottom ooze. Adults feed on algae, diatoms, insects, amphipods, and mollusks. Salmon eggs.	Occurs in pools and runs of medium to large rivers; also found in lakes.	10.6%, yes	4%, yes		Resident species but home range is much larger than area of forebay; planktonic feeding habits may be difficult to relate to sediment COIs; therefore exposure to site-related COIs difficult to estimate. Included in ERA, at the request of DEQ.
mountain whitefish	*Prosopium williamsoni*	Yes	Resident	Unknown	Level 2/3	Benthic organisms such as aquatic insect larvae, mollusks, fishes, and fish eggs (including their own), but may feed on plankton and surface insects.	Lakes and fast, clear, or silty streams				Has not been observed or collected from the forebay to date. Insufficent information on home range. May be difficult to estimate exposure to site-related COIs. Not selected for ERA.
northern pikeminnow or northern squawfish	*Ptychocheilus oregonensis*	No	Resident	21.7 km (PH), 0.5-6 miles, 0.87 mi in LWR, <0.1-13.4 mi (7,8)	Level 3/4	Terrestrial insects, plankton, aquatic larvae and crustaceans, adults eat small fish; 66.7% Salmonidae, 7.3% Cottidae, 2.4% Percopsidae, 1.7% Catostomidae, 1.4% Cyprinidae, 0.3% Clupeidae (fishbase.org)	lakes, ponds, occasionally in runs of small to large rivers (fishbase.org)	19.3%			A few specimens collected from forebay; home range is larger than smallmouth bass, therefore not selected for ERA.
pacific lamprey	*Lampetra tridentata*	No	Anadromous	Up to 500 km for reproduction (4)	Level 2/3	Ammocoetes remain in burrows filter feeding for 3 to 7 years.	Juv. Burrow into silt and feed on algae, later live as ectoparasites feeding off of freshwater or saltwater fish, spawn in gravels just upstream of riffles and often near silty pools and banks				Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for ERA.
peamouth chub	*Mylocheilus caurinus*	No	Present in Columbia River	> 9 mi (PH)	Level 3/4	Sculpins, mayfly, caddisfly, crustaceans	lakes and slow-flowing areas of small and medium rivers, common around vegetation.				Resident species but home range is much larger than area of forebay; therefore exposure to site-related COIs difficult to estimate. Not selected for ERA.
rainbow trout steelhead	*Oncorhynchus mykiss*	Yes	Resident/anadromous	Unknown	Level 3/4	Adults feed on aquatic and terrestrial insects, mollusks, crustaceans, fish eggs, minnows, and other small fishes. Young feed on zooplankton.	Capable of adapting to seawater, survive better in lakes than in streams, require moderate to fast flowing, well oxygenated waters for breeding, live in cold lakes.		4.5%	52-56% of diet	Steelhead are sea-run rainbow trout. Difficult to estimate exposure to site-related COIs. Not selected for ERA.

Table C-4
Selection of Fish Species for Tissue Analyses

Fish Species Common Name	Scientific Name	CRBFCS species?	Resident/ Nonresident	Home-range (PH exposure area)	Trophic Level	Diet	Habitat Preferences	Osprey Prey?	Bald Eagle Prey?	Mink Prey?	Rationale for inclusion or exclusion in ERA
river lamprey	*Lampetra ayresi*	No	Resident	Not known, but up to and at least 250 km for reproduction (4)	Level 2/3	Probably similar to Brook lamprey.	Deep waters of main stem rivers				subgenus, difficult to distinguish, Information from OFWS 2002. Anadramous species, therefore exposure to site-related COIs difficult to estimate. Not selected for ERA.
sculpin species	*Cottus* spp.	No	Resident	1.61 km (PH)	Level 3	Planktonic crustaceans and aquatic insect larvae, especially that of mideges and mayflies. Larger sculpins feed on minnows and other fishes.	Rubble and gravel riffles of rivers and rocky lake shores				Known to occur in the Forebay but not consumed by humans; therefore not selected for direct consumption in ERA. Selected for validation of trophic model.
smallmouth bass	*Micropterus dolomieu*	No	Resident	0.8 km (PH), 0.5-5 miles (some up to 30 mi), averages 0.87 mi in LWR, <0.1-6.7 mi (2,8)	Level 3/4	Young feed on plankton and immature aquatic insects, adults eat crayfish and aquatic insects, terrestrial insects. Sometime cannibalistic.	Shallow rocky areas of lakes, clear and gravel-bottom runs and flowing pools of rivers, cool flowing streams and reservoirs fed by such streams.		3.8%		Many specimens collected from forebay; home range is smaller than area of forebay; diet is relevant to site-related COIs; selected as primary species for evaluation in ERA
walleye	*Stizostedion vitreum*	Yes	Resident	3-5 miles (some up to 100 mi), averages 3.9 mi in LWR, <0.1-9.7 mi (2,8)	Level 3/4	Insects and fishes, crayfish, snails, frogs, mudpuppies, and small mammals when fish are scarce. Feeds at night.	Lakes, pools, backwaters, and runs of mediume to large rivers; prefers large, shallow lakes with high turbidity.				Higher trophic level species whose home range is much larger than forebay area; therefore exposure to site-related COIs difficult to estimate; Not included in ERA.
western brook lamprey	*Lampetra richardsoni*	No	Anadromous	Unknown	Level 2	Filter feeders consuming mostly diatoms.	Spawn in small gravels upstream of riffles, burrow in silty areas, small ammocoetes burrow in finer silt and shallower water, larger ones choose sandier more organic rich soil in deeper water.				Small, non-parasitic, sometimes resident, second most common and widely distributed species in Oregon, dormant for some part of the year (temperature dependent) late winter, (OFWS 2002). Not selected for ERA.
white sturgeon	*Acipenser transmontanus*	Yes	Resident in forebay and upstream, anadromous downstream	Up to 1000 km for reproduction (4)	Level 4	Adults feed on fishes; younger ones feed on chironomids, small crustaceans, insects, and mollusks.					Higher trophic level species whose home range is much larger than forebay area; therefore exposure to site-related COIs difficult to estimate; Not included in ERA.
yellow perch	*Perca flavescens*	No	Present in Columbia River	Unknown	Level 3/4	Immature insects, larger invertebrates, fishes, and fish eggs. Feeds during day.	Lakes, ponds, pools of creeks, and river; also found in brackish water and in salt lakes. Most commonly found in clear water near vegetation.	11.6%	3.6%		Higher trophic level species whose home range is unknown. Not abundant in forebay; therefore exposure to site-related COIs difficult to estimate; Not included in ERA.

Notes

PH = Portland Harbor Food Web Modeling Report trophic level classification and exposure area

Ecological receptor diet compositions reflect dietary proportions from all studies, so proportions do not sum to 100%

CRBFCS = Columbia River Basin Fish Contaminant Survey 1996-1998, USEPA

Table C-4
Selection of Fish Species for Tissue Analyses

Fish Species Common Name	Scientific Name	CRBFCS species?	Resident/ Nonresident	Home-range (PH exposure area)	Trophic Level	Diet	Habitat Preferences	Osprey Prey?	Bald Eagle Prey?	Mink Prey?	Rationale for inclusion or exclusion in ERA

All uncited data from fishbase.org

OFWS 2002. Oregon Fish and Wildlife Service, Information Report Number 2002-01. Oregon Lampreys: Natural History, Status, and Management Issues

Definitions of the trophic levels shown above are as follows:

TL1 - primary producers

TL2 - primary consumers (forage fish); mainly consume plant material (algae, phytoplankton) and zooplankton (some invertebrates consumed)

TL3 - secondary consumers; mainly invertivores (some fish consumed)

TL4 - tertiary consumers; piscivores

(1) fishbase.org

(2) Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184. Ottawa, Canada. 966 pages.

(3) Ward, D.L., C.J. Knutsen, R.A. Farr. July 1991. Status and Biology of BlackCrappie and White Crappie in the Lower Willamette River near Portland, Oregon. ODFW Information Report 91-3.

(4) Moyle, P.B. 2002. Inland Fishes of California. University of California Press. 502 pp.

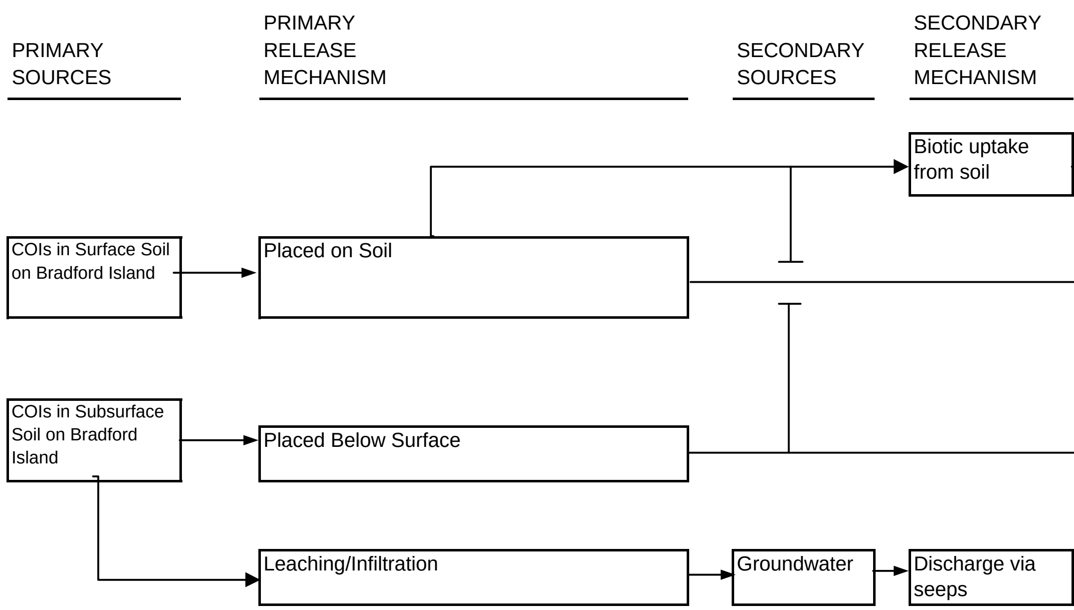
(5) Colyer, W.T., J.C. Kershener, R.H. Hilderbrand. 2005. Movements of Fluvial Bonneville Cutthroat Trout in the Thomas Fork of the Bear River, Idaho, Wyoming. North America Journal of Fisheries Management. Vol. 25, no. 3, pp 954-963.

(6) LaVigne, Henry (Contractor for EPA Region IX, Corvallis, OR). 2002. Personal communications, telephone call with Kim Goule, Fish/Aquatic Biologist, Fishman Environmental Services LLC, Portland, OR. 26 April 2002.

(7) Isaak, D.J., T.C. Bjornn. Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Movements and Distributions of Northern Squawfish Downstream of Lower Snake River Dams Relative to the Migration of Juvenile Salmonids Completion Report, Report to Bonneville Power Administration, Contract No. 1988BP91964, Project No. 198200300, 122 electronic pages (BPA Report DOE/BP-91964-5)

(8) North, J.A., L.C. Burner, B.S. Cunningham, R.A. Farr, T.A. Friesen, J.C. Harrington, H.K. Takata, D.L. Ward. 2002. Relationship Between Bank Treatment/Nearshore Development and Anadromous/Resident Fish in the Lower Willamette River. Annual Progress Report. Project sponsored by City of Portland and the Lower Willamette Group.

Figure C-1. CONCEPTUAL SITE MODEL FOR ECOLOGICAL EXPOSURES: UPLAND OU

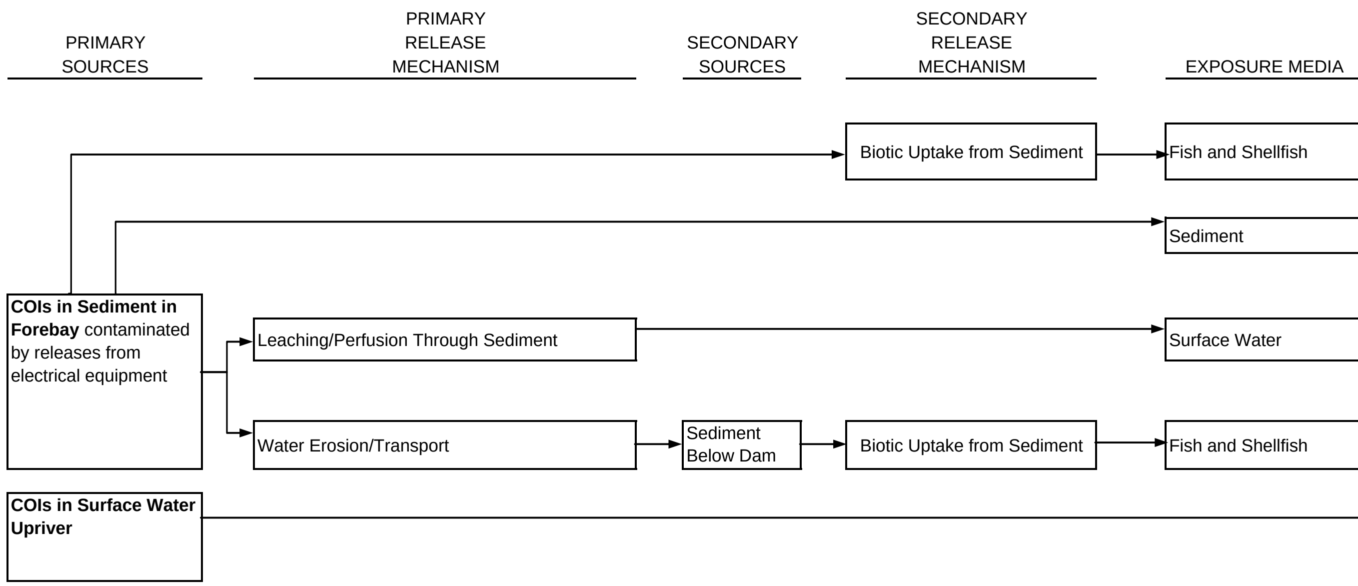


EXPOSURE MEDIA	EXPOSURE ROUTE	RECEPTORS* Aquatic Community (plankton, fish) (Aquatic)	American Kestrel (Terrestrial)	Vagrant Shrew (Terrestrial)	Invertivore American Robin (Terrestrial)	Herbivore Canada Goose (Terrestrial)
Terrestrial plants, invertebrates, mammals	Ingestion	---	●	●	●	●
Soil, Surface	Incidental ingestion	---	●	●	●	●
	Dermal	---	○	○	○	○
	Inhalation	---	○	○	○	○
Soil, Subsurface	Incidental ingestion	---	○	●	○	○
	Dermal	---	---	○	---	---
	Inhalation	---	---	○	---	---
Surface Water	Ingestion	●	●	●	●	●
	Dermal	●	○	○	○	○

Symbols		
●	=	Complete and potentially significant pathway
○	=	Complete but likely minor pathway
---	=	Incomplete Pathway

* Popular and Scientific Names
American Kestrel, *Falco sparverius*
Osprey, *Pandion haliaetus*
Robin, *Turdus migratorius*
Vagrant Shrew, *Sorex vagrans*
California ground squirrel (*Otospermophilus beecheyi*)
Canada Goose, *Branta canadensis*

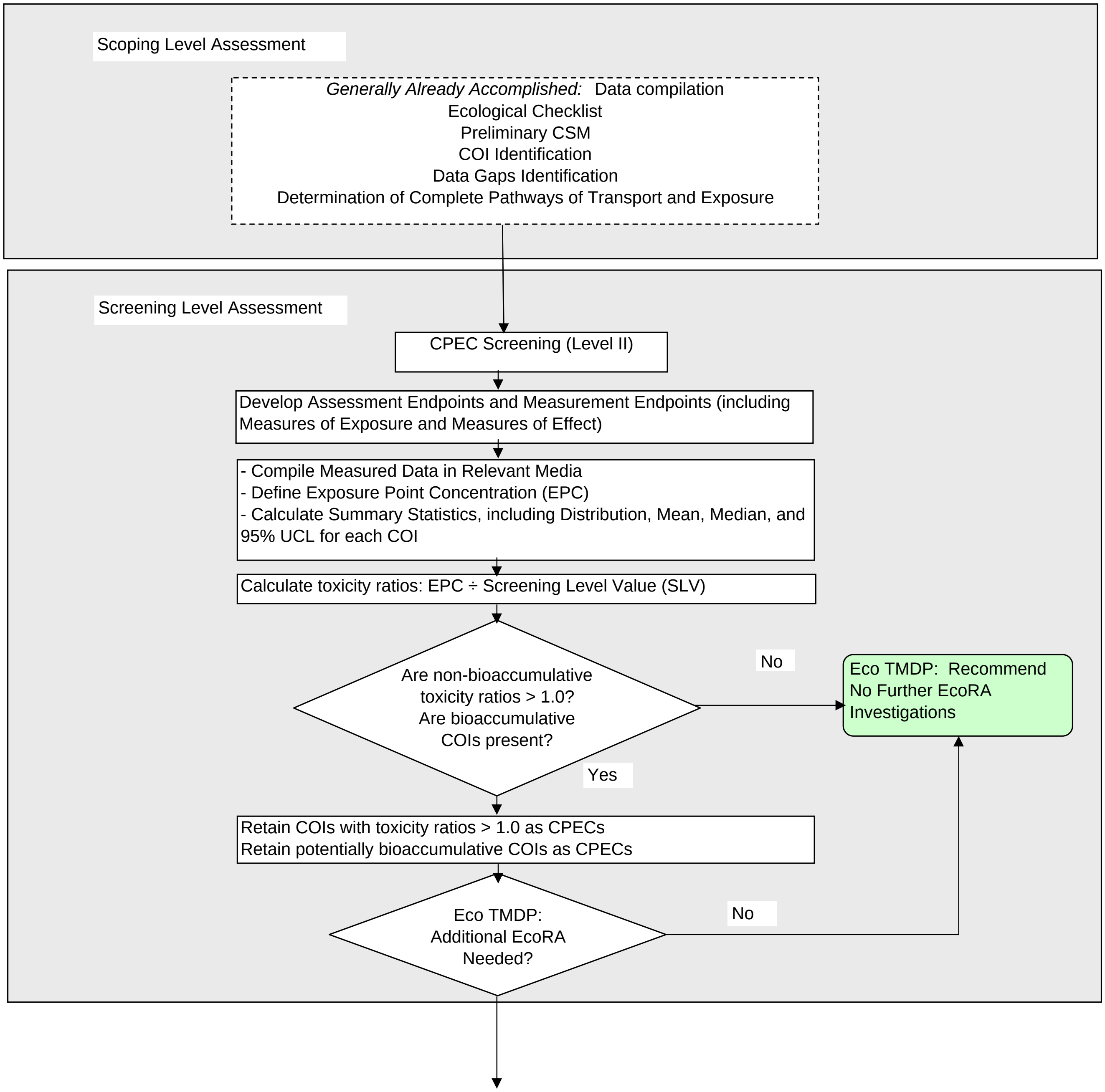
Figure C-2. CONCEPTUAL SITE MODEL FOR ECOLOGICAL EXPOSURES: RIVER OU

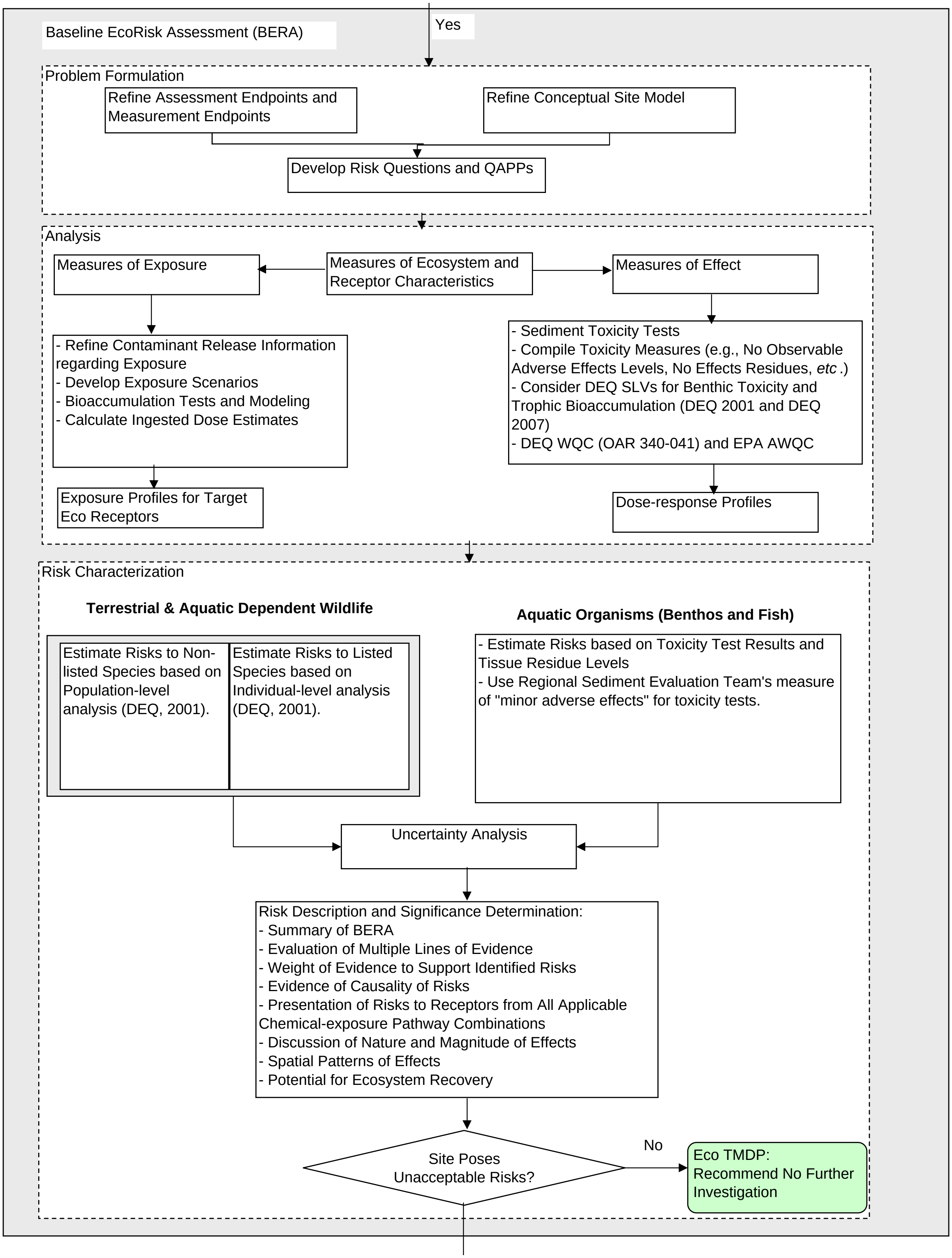


Exposure Media	EXPOSURE ROUTE	RECEPTORS Current/Future: Benthic Invertebrates (Aquatic)	Pelagic Organisms (Aquatic)	Anadromous fish (Aquatic)	Resident Fish (Aquatic)	Bald Eagle (Aquatic Dependent)	Mink (Juvenile) (Aquatic Dependent)	Osprey (Aquatic Dependent)
Fish and Shellfish	Ingestion	---	---	○	●	●	●	●
Sediment	Incidental Ingestion	●	---	○	●	---	○	---
Sediment	Dermal / Uptake	●	○	○	●	---	○	---
Surface Water	Ingestion	●	●	●	●	●	●	●
Surface Water	Dermal / Uptake	○	○	○	●	---	---	---
Fish and Shellfish	Ingestion	---	---	○	●	●	●	●
COIs in Surface Water Upriver	Ingestion	●	●	●	●	●	●	●
COIs in Surface Water Upriver	Dermal / Uptake	○	○	○	●	---	---	---

Symbols		
●	=	Complete and potentially signficant pathway
○	=	Complete but likely minor pathway
---	=	Incomplete Pathway

Figure C-3: Ecological Risk Assessment Process




Yes
Baseline EcoRisk Assessment (BERA)
Problem Formulation
Refine Assessment Endpoints and Measurement Endpoints
Refine Conceptual Site Model
Develop Risk Questions and QAPPs
Analysis
Measures of Exposure
Measures of Ecosystem and Receptor Characteristics
Measures of Effect
- Refine Contaminant Release Information regarding Exposure
- Develop Exposure Scenarios
- Bioaccumulation Tests and Modeling
- Calculate Ingested Dose Estimates
- Sediment Toxicity Tests
- Compile Toxicity Measures (e.g., No Observable Adverse Effects Levels, No Effects Residues, etc .)
- Consider DEQ SLVs for Benthic Toxicity and Trophic Bioaccumulation (DEQ 2001 and DEQ 2007)
- DEQ WQC (OAR 340-041) and EPA AWQC
Exposure Profiles for Target Eco Receptors
Dose-response Profiles
Risk Characterization
Terrestrial & Aquatic Dependent Wildlife
Aquatic Organisms (Benthos and Fish)
Estimate Risks to Non-listed Species based on Population-level analysis (DEQ, 2001).
Estimate Risks to Listed Species based on Individual-level analysis (DEQ, 2001).
- Estimate Risks based on Toxicity Test Results and Tissue Residue Levels
- Use Regional Sediment Evaluation Team's measure of "minor adverse effects" for toxicity tests.
Uncertainty Analysis
Risk Description and Significance Determination:
- Summary of BERA
- Evaluation of Multiple Lines of Evidence
- Weight of Evidence to Support Identified Risks
- Evidence of Causality of Risks
- Presentation of Risks to Receptors from All Applicable Chemical-exposure Pathway Combinations
- Discussion of Nature and Magnitude of Effects
- Spatial Patterns of Effects
- Potential for Ecosystem Recovery
Site Poses Unacceptable Risks?
No
Eco TMDP: Recommend No Further Investigation

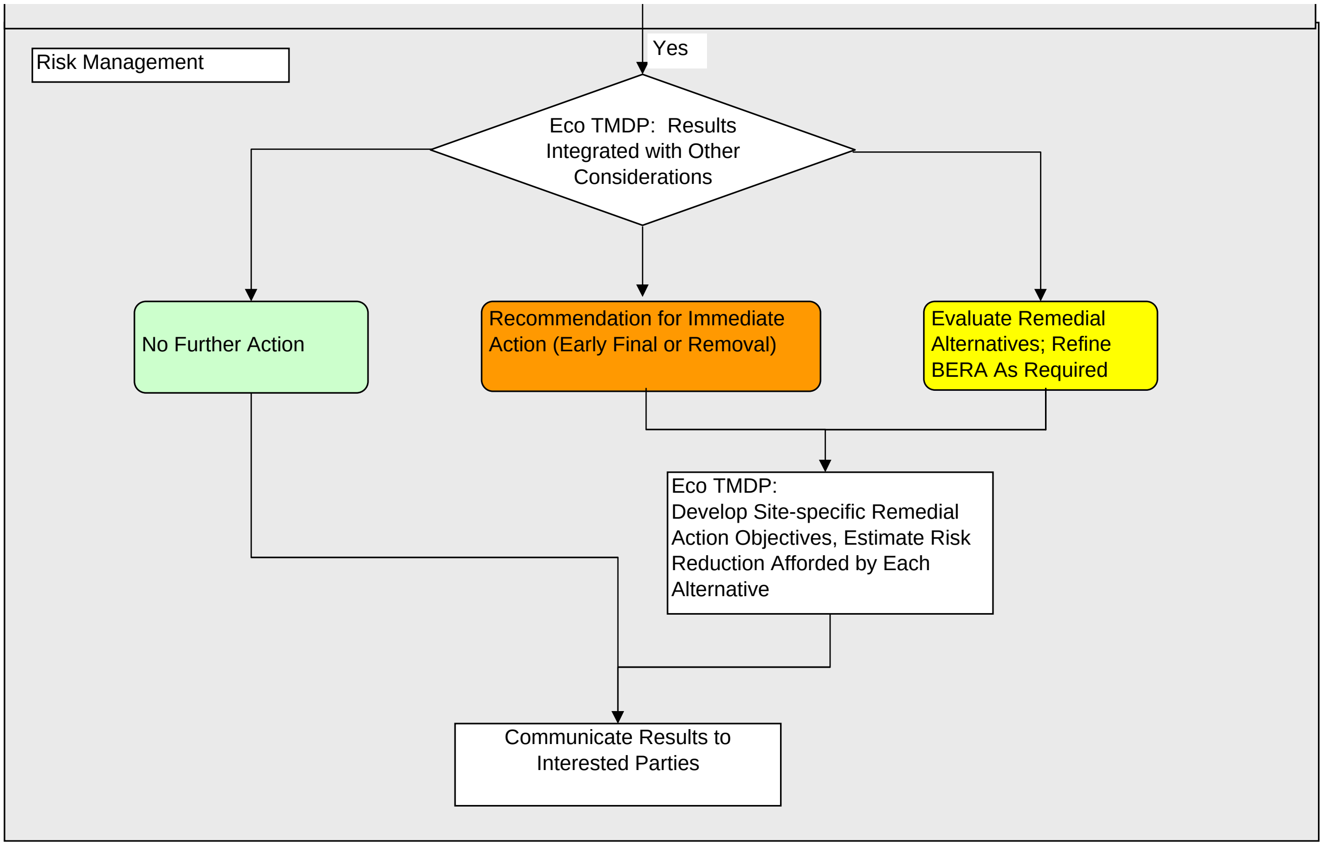
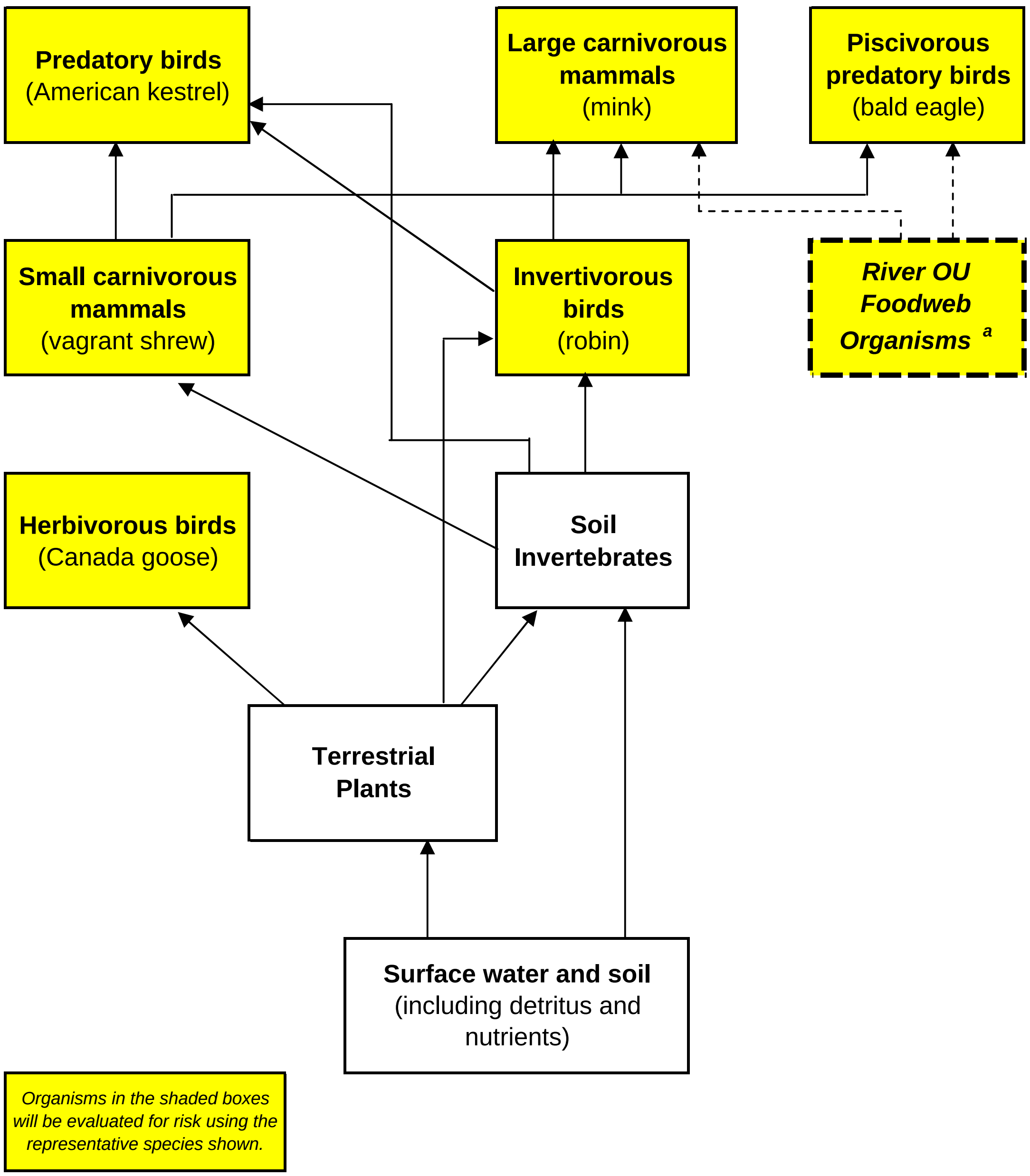
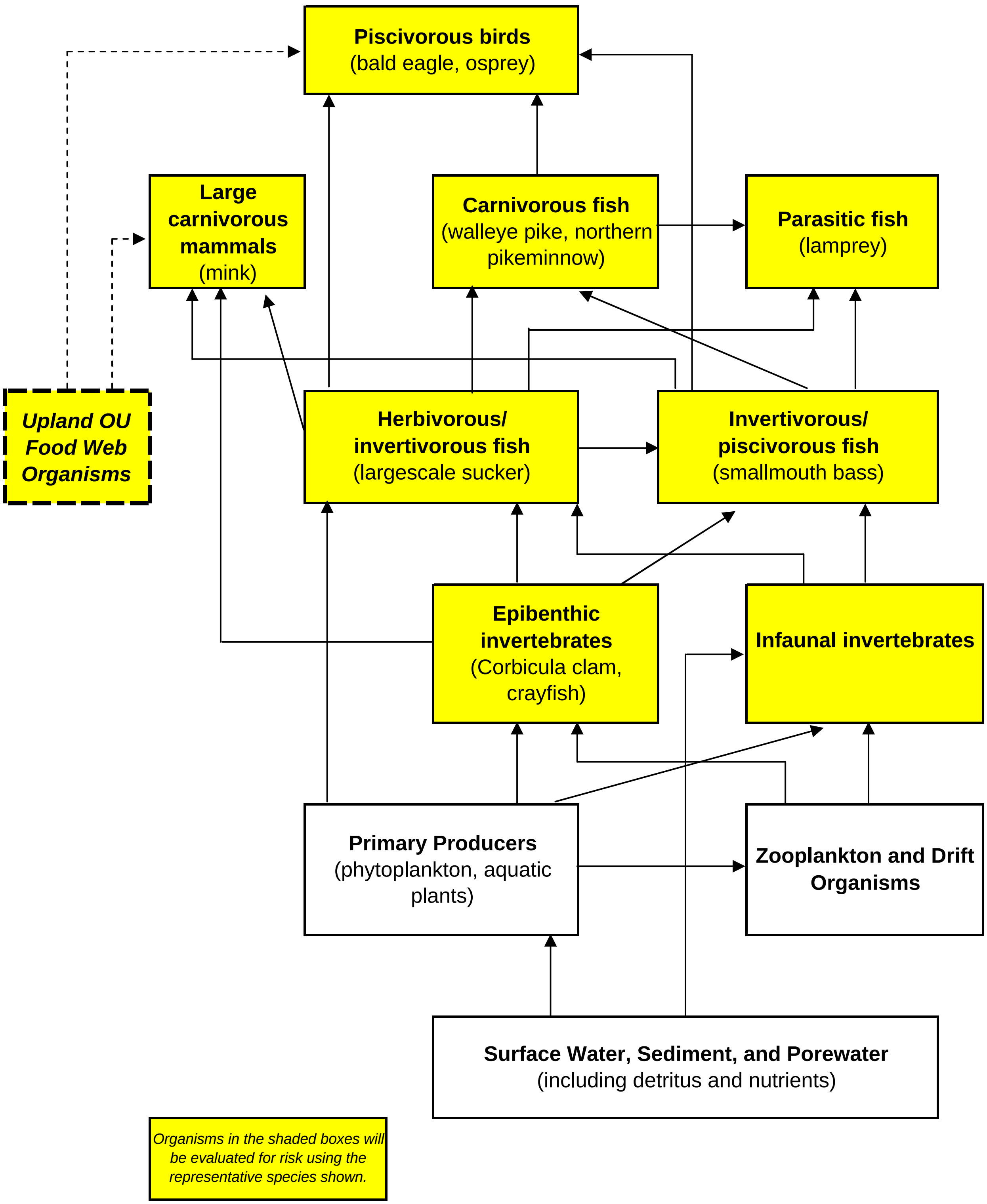

Yes
Risk Management
Eco TMDP: Results Integrated with Other Considerations
No Further Action
Recommendation for Immediate Action (Early Final or Removal)
Evaluate Remedial Alternatives; Refine BERA As Required
Eco TMDP:
Develop Site-specific Remedial Action Objectives, Estimate Risk Reduction Afforded by Each Alternative
Communicate Results to Interested Parties

Figure C-4
Upland OU Food Web
Bradford Island



[a] Risk assessment performed for terrestrial wildlife receptors (100% use of Upland OU) assumed to be protective of aquatic-dependent wildlife receptors.

Figure C-5
River OU Food Web Model
Bradford Island



APPENDIX D
EXPOSURE FACTORS AND INTAKE EQUATIONS FOR ERA

Table

Acronyms

ADD	average daily dose
AOPC	area of potential concern
AUF	area use factor
BAF	bioaccumulation factor
BCF	bioconcentration factor
BERA	baseline ecological risk assessment
BMF	biomagnification factor
BSAF	biota-to-sediment accumulation factor
COI	contaminant of interest
CPEC	contaminant of potential ecological concern
DEQ	(Oregon) Department of Environmental Quality
dw	dry weight
EPC	exposure point concentration
ERA	Ecological Risk Assessment
HQ	hazard quotient
LOAEL	lowest-observable-adverse-effects level
log K_{ow}	octanol-water partition coefficient
mg/kg-bw/day	milligrams chemical per kilogram body weight of the receptor per day

90% UCL	90 percent upper confidence limit
95% UCL	95 percent upper confidence limit
NOAEL	no-observable-adverse-effects level
ORNL	Oak Ridge National Laboratory
OU	operable unit
PUF	plant uptake factor
RI	remedial investigation
ROI	receptor of interest
SF	seasonality factor
SLV	screening level value
SSL	soil screening level
TRV	toxicity reference value
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

The basic unit of exposure for a receptor of interest (ROI) is the exposure point concentration (EPC), defined as the concentration of a chemical in a specific environmental medium at the point of contact for the receptor, i.e., the concentration of a chemical in soil at a sampling location that could serve as habitat for the receptor. For relatively stationary ROIs expected to contact the soil (e.g. plants and invertebrates), the EPC is estimated as a function of the chemical of interest (COI) concentration measured in soil. For higher trophic level ROIs, the exposure dose is estimated as a function of the COI concentration in relevant environmental media and several other parameters related to biotransfer through the food-web and the manner in which receptors use the site (e.g., dietary composition, feeding strategy, food ingestion rate, length of time a receptor is expected to forage/nest at the site based on their home range size and seasonal behavior).

In this assessment, EPCs will be calculated for plants and invertebrates (maximum detected concentration in soil), birds and mammals (95 percent upper confidence limit [95% UCL] on the mean concentration in soil), and aquatic organisms and aquatic-dependent wildlife (maximum detected concentration in groundwater). The reasons for using these receptor-specific EPCs are described below. The methods that will be used to calculate the 95% UCLs are presented in Appendix A.

For the direct toxicity screening, these EPCs will be compared to their respective screening level values (SLVs). For the evaluation of the bioaccumulation pathway relevant to birds and mammals, the 95% UCL will be used to estimate the average daily dose (ADD), or exposure dose, for the selected ROIs. Then, the exposure dose will be compared to a safe dose (toxicity reference value [TRV]) that is not expected to pose an unacceptable risk to a ROI in order to develop site-specific hazard quotients (HQs) for each contaminant of potential ecological concern (CPEC) (as defined in Appendix C). The approach described here is generally consistent with Oregon Department of Environmental Quality (DEQ) guidance (DEQ 2001), except the 95% UCL will be used instead of the 90 percent upper confidence limit [90% UCL]. Although it may not include all the potential elements of a Level III Baseline Risk Assessment (BERA) (e.g., habitat quality assessments, community and population surveys), a food-web model will be used to estimate risks due to bioaccumulative CPECs, as was done for the Level II Screening Assessment for the Landfill (URS 2004). This was performed for the Landfill because the SLVs for birds and mammals do not adequately address the bioaccumulation pathway.

In the absence of bird egg tissue data from the site, EPCs for osprey and eagle eggs will be estimated as a function of the fish tissue concentrations consumed by the birds and a fish tissue to bird egg tissue biomagnification factor (BMF), which addresses transfer of a CPEC from fish tissue to bird egg tissue. As the approach to calculating fish prey tissue concentrations will be estimated in AQUAWEB (Arnot and Gobas 2004) based on EPCs in sediment and water (i.e., the lower of the 95% UCL and maximum detected concentration), these EPCs will also be reflected in the bird egg tissue concentrations.

D.1 CONCENTRATIONS IN ABIOTIC MEDIA

As per DEQ guidance (2001), the maximum detected concentration in soil or sediment will be selected as the EPC for plants and invertebrates. Use of the maximum concentration of each COI is a conservative approach that serves to protect stationary receptors that could feasibly be exposed to the maximum concentration throughout their entire life span if they are located in a potential hot spot area. The lower of the 95% UCL and maximum detected concentration in soil, sediment, or soil gas will be the selected EPC for birds and mammals. This value provides an estimate of the representative concentration more relevant to terrestrial wildlife receptors that generally are mobile and not continuously exposed to site-related COIs in one geographic location. The maximum detected concentration in groundwater nearest to the point of discharge to the river will be selected as the EPC for aquatic receptors and aquatic-dependent wildlife. The actual concentration in surface water beyond the point of groundwater discharge is likely to be much lower than this value. Furthermore, aquatic receptors are generally mobile and would also not be continuously exposed to site-related COIs in one location of the river. Although the DEQ Level II guidance allows for the groundwater EPC to be represented by the 90% UCL, use of the maximum detected concentration from the most recent sample collection will be used in the current evaluation at the specific request of DEQ.

The remainder of this section provides a description of the manner in which CPEC concentrations in dietary components will be estimated for bioaccumulative chemicals. EPCs in biotic media at the site (e.g., plants, invertebrates, small mammals, and fish) will be used to calculate the ADD of each bioaccumulative CPEC for the selected ROIs. The ADD is defined the average mass of the CPEC ingested in milligrams chemical per kilogram body weight of the receptor per day (mg/kg-bw/day).

D.2 CONCENTRATIONS IN BIOTIC MEDIA

Exposure to CPECs as they transfer through the food web was assessed by evaluating the bioaccumulation potential in each food source for the wildlife receptors. The following list summarizes the biotic items that comprise the diets of each ecological receptor as they forage in the terrestrial habitat (Upland Operable Unit [OU]) or aquatic habitat (River OU):

- Vagrant shrew and American robin – soil invertebrates (represented by earthworms)
- Canada goose – terrestrial plants
- American kestrel – small mammals
- Bald eagle –fish
- Mink –fish and benthic invertebrates
- Osprey – fish

A combination of regression-derived bioaccumulation factors (BAFs), median BAFs, and octanol-water partition coefficient ($\log K_{ow}$) based BAFs from the literature will be used predict tissue concentrations in the absence of site-specific data for certain dietary items (mainly in the Upland OU). The regression-based approach is typically preferred because it provides a more site-specific prediction of a CPEC concentration in a certain dietary tissue, as it incorporates the site EPC. The following provides the standard log-linear regression equation:

$$\ln[tissue_{dry\,weight}] = B0 + B1(\ln[soil_{dry\,weight}])$$

where:

$\ln[tissue_{dry\,weight}]$ = Natural logarithm of the tissue concentration (mg chemical per kg tissue dry weight);

B0 = Chemical-specific intercept based on tissue type;

B1 = Chemical-specific slope based on tissue type; and

$\ln[soil_{dry\,weight}]$ = Natural logarithm of the chemical concentration detected in site soils and sediment, i.e., EPC (mg chemical per kg soil or sediment dry weight)

The following subsections provide the equations used to estimate tissue concentrations of the specific dietary items listed above.

D.2.1 Concentrations in Upland OU Dietary Items

This section describes the process and potential literature sources that will be used to estimate concentrations in terrestrial plants, soil invertebrates, and small mammals. Once all of the RI data are collected and the final list of COIs has been established for the Upland OU, an interim draft table presenting the BAFs for each COI and tissue type will be submitted for DEQ's review.

Terrestrial Plants

For the diet of the Canada goose, CPEC concentrations in vegetation will be estimated by applying the measured concentration in soil by the literature-derived soil – plant uptake factor (PUF). The following equation was used to estimate CPEC concentrations in terrestrial plants:

$$C_{plants}\ (\text{mg/kg-dw}) = C_{soil}\ (\text{mg/kg}) \times PUF$$

where:

C_{plant} = Estimated CPEC concentration in terrestrial plants (mg CPEC per kg plant dry weight);

C_{soil} = Lower of the 95% UCL or maximum concentration of a CPEC measured in soils (mg CPEC per kg soil dry weight); and

PUF = Plant uptake factor from the literature (mg CPEC per kg plant dry weight / mg CPEC per kg soil dry weight, or kg soil dry weight per kg plant dry weight).

Literature-based PUFs will be drawn from several sources including the following:

- Adaptive Risk Assessment Modeling System (ARAMS) databases (United States Army Corps of Engineers [USACE] 2006)
- Risk Assessment Information System (RAIS) database (Oak Ridge National Laboratory [ORNL] 2006)

- Eco-Soil Screening Levels (SSLs) (United States Environmental Protection Agency [USEPA] 2005)

If they are not available from existing databases, PUFs may be developed by using equations provided in these literature sources. In the absence of empirically derived PUFs or equations to estimate plant tissue concentrations (i.e., regression models), equations to estimate PUFs for organic chemicals are typically based on the octanol-water partition coefficient (K_{ow}) of the chemical.

Soil Invertebrates

For the diet of the vagrant shrew and American robin, CPEC concentrations in soil invertebrates will be estimated by applying the measured concentration in soil by the literature-derived soil – earthworm bioconcentration factor (BCF). The following equation will be used to estimate CPEC concentrations in terrestrial invertebrates:

$$C_{invertebrate}\ (mg/kg\text{-}dw) = C_{soil}\ (mg/kg) \times BCF_{worm}$$

where:

$C_{invertebrate}$ = Estimated CPEC concentration in terrestrial invertebrates, as represented by earthworms (mg CPEC per kg invertebrate dry weight);

C_{soil} = Lower of the 95% UCL or maximum concentration of a CPEC measured in soils (mg CPEC per kg soil dry weight); and

BCF_{worm} = Earthworm BCF from the literature (kg soil dry weight per kg worm dry weight).

Literature-based BCFs for soil invertebrates will be drawn from several sources including the following:

- ARAMS databases (USACE 2006)
- RAIS database (ORNL 2006)
- Eco-SSLs (USEPA 2005)

If they are not available from existing databases, earthworm BCFs may be developed by using equations provided in these literature sources. In the absence of empirically derived BCFs or equations to estimate worm tissue concentrations (i.e., regression models), equations to estimate BCFs for organic chemicals are typically based on the K_{ow} of the chemical, the organic carbon content (f_{oc}) of the soil and estimated lipid content (f_{lipid}) of earthworms.

Small Mammals

For the diet of the American kestrel, CPEC concentrations in small mammals will be estimated by applying the measured concentration in soil by the literature derived soil – small mammal BAF. The following equation will be used to estimate inorganic CPEC concentrations in terrestrial small mammals:

$$C_{small\ mammals}\ (mg/kg\text{-}dw) = C_{soil}\ (mg/kg) \times BAF_{mammals}$$

where:

$C_{small\ mammal}$ = Estimated CPEC concentration in small mammals (mg CPEC per kg small mammal dry weight);

C_{soil} = Lower of the 95% UCL or maximum concentration of a CPEC measured in soils (mg CPEC per kg soil dry weight); and

$BAF_{mammals}$ = Small mammal uptake factor for inorganic CPECs from the literature (kg soil dry weight per kg small mammal dry weight).

This equation reflects the assumption that small mammal tissue burdens are at equilibrium with soil concentrations. Conceptually, the model for chemical uptake by small mammals is: soil → food → small mammal. Incidental ingestion of soil by small mammals is considered to be a minor pathway compared to food ingestion and is not accounted for in the development of the small mammal uptake factors (Sample et al. 1998). This assumption is justified due to the small volume of soil consumed by a rodent compared to the volume of food consumed on a daily basis.

Literature-based BAFs for small mammals will be drawn from several sources including the following:

- ARAMS databases (USACE 2006)
- RAIS database (ORNL 2006)
- Eco-SSLs (USEPA 2005)

If they are not available from existing databases, BAFs may be developed by using equations provided in these literature sources. In the absence of empirically derived BAFs or equations to estimate small mammal tissue concentrations (i.e., regression models), equations to estimate BAFs for organic chemicals are typically based on the K_{ow} of the chemical and concentration of the CPEC in diet of the small mammal (typically assumed to be soil invertebrates; USEPA 2005). Due to a lack of reliable diet-based models for inorganic CPECs, the BAFs generated by the ORNL (Sample et al. 1998), and recently updated by the USEPA (2005), and the associated methodology, may also be integrated into the equation to generate inorganic CPEC concentrations in small mammals.

D.2.2 Concentrations in River OU Dietary Items and Bird Eggs

This section describes the process and potential literature sources that will be used to estimate concentrations in benthic invertebrates, fish, and bird eggs. Also provided are the general equations and approach for calculating site-specific tissue concentrations based on data that may be collected in the River OU.

The AQUAWEB model may be used to predict the potential for risk to aquatic-dependent wildlife (Arnot and Gobas 2004). This model will be used to predict concentrations in tissues of aquatic organisms (e.g., plankton, plants, invertebrates, and fish) through consideration of concentrations in the fish’s diet (e.g., benthic invertebrates), concentrations in surface water, and metabolic processes that regulate chemical uptake in a fugacity-based approach for hydrophobic organic chemicals. A more detailed presentation of the AQUAWEB model is provided in Appendix E.

Benthic Invertebrates

For the partial diet of the mink, CPEC concentrations in benthic invertebrates will be estimated using field-collected data as well as by the development of invertebrate-based biota-to-sediment accumulation factors (BSAFs). This approach has been extensively discussed in Section 6.3 and in Appendix B.

Although field-collected tissue data will likely be used directly in the AQUAWEB model, back-calculated BSAFs may be necessary to serve as preliminary cleanup goals or simply to further understand risks associated with a localized area of the site that lacks tissue data. Should BSAFs for inorganics be calculated, the uncertainties regarding these values will be emphasized. Often there is no clear relationship between concentrations of inorganics in sediment and tissue, as organisms are able to bioregulate these constituents over natural ranges of concentrations (Lower Willamette Group 2007).

The general forms of the equations for estimation of CPEC concentrations in benthic invertebrates are:

Inorganics

$$C_{benthic\ invertebrates}\,(mg/kg) = C_{sediment}\,(mg/kg) \times BSAF_{invertebrates}$$

Organics

$$C_{benthic\ invertebrates}\,(mg/kg) = \underline{C_{sediment}\,(mg/kg) \times BSAF \times f_{lipid}}\ /\ \text{foc}$$

where:

$C_{benthic\ invertebrate}$	=	Estimated CPEC concentration in benthic invertebrates (mg of CPEC per kg of benthic invertebrate [dry or wet weight]);
$C_{sediment}$	=	EPC in sediment (mg of CPEC per kg of sediment [dry weight]); and
$BSAF_{invertebrate}$	=	CPEC-specific biota sediment accumulation factor for benthic invertebrates (kg organic carbon per kg lipid); and
f_{lipid}	=	Lipid content of benthic invertebrates (kg lipid per kg organism [dry or wet weight]); and
foc	=	Fraction of organic carbon in sediment (kg organic carbon per kg sediment [dry weight])

For inorganic CPECs, the BSAF represents the ratio of the concentration of a chemical in tissue of a benthic organism to the concentration of the chemical in sediment. For organic CPECs, the BSAF represents the ratio of the lipid-normalized concentration of a chemical in tissue of a benthic organism to the organic carbon-normalized concentration of the chemical in sediment. The partitioning of hydrophobic organic chemicals between sediment and benthic biota is controlled primarily by the organic carbon content of the sediment, the lipid content of the organism, and chemical-specific factors. BSAFs for organic CPECs will be normalized to organic carbon and lipid to allow comparisons among different types of sediment and organisms.

The following generalized equations will be used to estimate site-specific BSAFs, when necessary:

$BSAF_{inorganic} = C_{invertebrate\ tissue\ wet\ or\ dry\ weight}/C_{sediment\ dry\ weight}$

$BSAF_{organic} = (C_{invertebrate\ tissue\ wet\ or\ dry\ weight}/\text{fraction of lipid})/(C_{sediment\ dry\ weight}/\text{fraction of organic carbon})$

Site-specific BSAFs will be calculated for CPECs that have at least one detection in either sediment or tissue within the same sampling area. BSAFs may be represented on a dry weight or wet weight basis. The uncertainties inherent in these BSAF equations, especially for inorganics, are recognized due to numerous conditions that influence bioavailability, uptake, and accumulation in tissue, which vary widely from site to site. However, they will be used as necessary in the absence of any other available methods for calculating BSAFs. Several inorganics bioconcentrate at various levels, but most do not biomagnify like DDTs, PCBs, and dioxin and, therefore, do not pose as significant of a risk to upper trophic levels (DEQ 2007) (see Appendix C, Section C.3.2.2 for definitions of these terms).

Depending on the spatial distribution of contaminants, the nature of the semi-aquatic wildlife receptors, their foraging range and feeding habits, and the density of sampling, the approaches listed below may be used to determine if a functional relationship between paired sediment and tissue exists, as well as to select BSAFs for invertebrates:

- Univariate regression
- Multivariate regression
- Averaging across co-located sample pairs.
- Using the average and high-end BSAFs from a range of sample pairs
- Site-specific sediment bioaccumulation tests
- Literature-based BSAFs
- Customizing literature-based regression slopes to site concentrations.

Without reviewing the data, the most suitable approach for the site in terms of data analysis and interpretation method cannot be adequately determined. A more detailed description of each method applied, which will include some or all of those listed above, will be provided in the forthcoming remedial investigation (RI). The selected approach will be one that best represents the data set and the project needs.

Fish

For the diet of the osprey and the partial diet of the mink and the bald eagle, CPEC concentrations in fish will be estimated from field-collected data and algorithms used in the AQUAWEB model (Arnot and Gobas 2004; presented in Appendix E).

Bird Eggs (Osprey and Eagle)

Osprey and eagle egg tissue residue concentrations will be estimated using fish prey tissue concentrations and prey tissue-to-egg tissue BMFs. The objective of this additional method to assessing risk to piscivorous birds is to protect sensitive life stages.

The following equation will be used to estimate bird egg tissue concentrations:

$$C_{bird\ egg}\ (mg/kg) = C_{fish}\ x\ BMF$$

where:

$C_{bird\ egg}$ = Estimated chemical concentration in bird egg tissue (mg of chemical per kg of egg [dry or wet weight]);

C_{fish} = Measured or estimated chemical concentration in fish (mg of chemical per kg of fish [dry or wet weight])

BMF = Fish to bird egg biomagnification factor from the literature (unitless).

The BMFs specific to each CPEC will be selected from region-specific literature, as performed in the Round 2 Ecological Risk Assessment (ERA) for Portland Harbor (Lower Willamette Group 2007). Bird egg TRVs, such as those selected for the Portland Harbor ERA, will be compared to EPCs estimated in osprey and eagle eggs. These egg tissue TRVs are residue concentrations in eggs representative of no-observable-adverse-effects levels (NOAELs) and lowest-observable-adverse-effects levels (LOAELs) selected from the literature.

D.3 AVERAGE DAILY DOSE

The ADDs to wildlife receptors were calculated using (1) the EPCs identified for soil, sediment, surface water, and dietary items, and (2) receptor-specific exposure parameters. The ADD is a component of the HQ and represents the average amount of a chemical that an individual member of a receptor population ingests under the assumption that the population forages primarily at the site. The ADD is a function of a receptor's foraging behavior and is dependent upon life history strategies such as home range size, dietary preferences, food ingestion rates, and seasonal behavior. Diets of the selected wildlife receptors were assumed to consist of some combination of relevant food types: terrestrial plants, soil invertebrates, small mammals, benthic invertebrates, and/or fish. Surface water ingestion will be included for terrestrial receptors in areas of potential concern (AOPCs) where surface water is present. Surface water ingestion will be included for all aquatic-dependent receptors.

The general equation for calculation of an ADD, for "i" food types, is:

$$ADD = \frac{\left(IR_{food} \sum_{i=1}^{n} \left(C_{food_i} \times df_i \right) + \left(IR_{soil/sed} \times C_{soil/sed} \right) + \left(IR_{water} \times C_{water} \right) \right)\ x\ AUF\ x\ SF}{BW}$$

where:

ADD = Average daily dose of a CPEC to a ROI that forages at the site (mg CPEC ingested per kg body weight per day)

IR_{food} = Ingestion rate of food (kg food wet or dry weight ingested per day)

n_i	=	Number of food types
C_{foodi}	=	Concentration of CPEC in food type "i" (mg CPEC per kg food type "i" wet or dry weight)
df_i	=	Dietary fraction (proportion in the diet) of food type "i" (unitless; $\Sigma i = 1$)
$IR_{soil/sed}$	=	Ingestion rate of soil or sediment (kg soil or sediment dry weight ingested per day)
$C_{soil/sed}$	=	Concentration of CPEC in soil or sediment (mg CPEC per kg soil or sediment dry weight)
IR_{water}	=	Ingestion rate of water (L water ingested per day)
C_{water}	=	Concentration of CPEC in water (mg CPEC per L water)
BW	=	Body weight of the receptor (kg)
AUF	=	Area Use Factor, site area size ÷ home range size (unitless)
SF	=	Seasonality Factor, as a fraction of one year (unitless)

Receptor-specific exposure parameters (IR_{food}, IR_{soil}, BW, AUF, SF) are presented in Table D-1 and described below.

Body Weights

Body weight values for the ROIs were selected based on primary literature presented in USEPA's *Wildlife Exposure Factors Handbook* (USEPA 1993). The following values are presented in Table D-1:

- Clench and Leberman (1978), as cited in USEPA (1993), reported the mean adult female and male body weight for the American robin as 77.3 grams.
- The mean body weight for the vagrant shrew of 7 grams is presented in Volume I, Section 2.2.1 of the *Exposure Factors Handbook* (in the profile for the short-tailed shrew, body weight data for similar species is provided).
- An average of all the adult female body weights given in the primary literature, cited in Volume I of USEPA (1993), was calculated to determine the body weight for the Canada goose (3.0 kg).
- Bloom (1973), as cited in USEPA (1993), reported mean adult male and female body weights for the American kestrels in California. The selected body weight of 0.116 kg is an average of the Bloom (1973) male and female body weights.
- Wiemeyer (1991), as cited in USEPA (1993), reported adult female body weights for bald eagles as 4.5 kg.
- Hornshaw et al. (1983), as cited in USEPA (1993), reported average farm-raised adult female body weights for mink, in the spring to be 0.974 kg.

- Poole (1984), as cited in USEPA (1993), reported adult female osprey body weights during courtship to be 1.88 kg.

Food Ingestion Rates

Allometric equations developed by Nagy (2001) were used to estimate food ingestion rates for bird and mammal target receptors. All food ingestion rates for terrestrial receptors are provided in dry weight, while both wet and dry weight-based food ingestion rates for aquatic-dependent wildlife.

Due to the widely varying feeding preferences, activity levels, and internal digestion processes of the individual ROIs, non-species specific equations provided in Tables 2 and 3 of Nagy (2001) for "all mammals" and "all birds" were used to estimate food ingestion rates. The following Nagy (2001) general equation was used to calculate both wet and dry weight ingestion, rates presented in Table D-1:

$$y = a(\text{grams body mass})^b$$

where:

y	=	dry or fresh matter intake per day (kg per day dry or wet weight)
a	=	coefficient (unitless) (0.323/0.794 dry/fresh matter respectively for mammals, and 0.638/2.065 dry/fresh matter respectively for birds)
b	=	allometric slope factor (unitless) (0.744/0.773 dry/wet matter respectively for mammals, and 0.685/0.689 dry/wet matter respectively for birds)

Incidental Soil/Sediment Ingestion Rates

Percent soil or sediment measured in the diets of species with similar feeding habits to those of the ROIs, as reported in Beyer et al. (1994), were selected in order to calculate soil and sediment ingestion rates. For species without an adequate surrogate (American kestrel), the default percent soil in diet of 2% was used (Beyer et al. 1994). A soil ingestion rate was calculated for the upland receptors (American robin, vagrant shrew, and Canada goose) and a sediment ingestion rate was calculated for the mink. However, in the absence of data specific to the mink the percent soil in the diet of the raccoon was used as a surrogate for the percent sediment in the diet of the mink. For the vagrant shrew, the percent soil in diet for a white-footed mouse (2%) was doubled to account for a higher soil ingestion rate expected for a shrew.

A sediment ingestion rate was not estimated for the bald eagle or osprey because prey is typically caught near the water surface (Zeiner et al. 1990) and there is no beach area or shoreline at the River OU. In the Portland Harbor ERA, eagles and ospreys were assumed to consume a very small amount of sediment while foraging at the shoreline (Lower Willamette Group 2007). This scenario is not applicable to the River OU because exposure to sediment is not expected to occur due to the deep water levels present and lack of foraging area near the site precluding sediment contact by the avian target receptors. Therefore, incidental ingestion of sediment was not considered a potentially complete exposure pathway for piscivorous birds at the site.

The following general equation was used to calculate incidental soil and sediment ingestion rates, presented in Table D-1:

Incidental soil/sediment ingestion rate = Dry weight food ingestion rate * fraction of soil (or assumed sediment) in diet (Beyer et al. 1994)

Incidental Surface Water Ingestion Rates

In AOPCs where surface water is present, surface water ingestion rates were calculated for the ROIs using the following allometric equations, as cited in USEPA (1993):

$$\text{Liters/day (birds)} = 0.059(BW)^{0.67}$$

$$\text{Liters/day (mammals)} = 0.099(BW)^{0.9}$$

Home Range

With the exception of the vagrant shrew and American kestrel, home ranges were based on primary literature presented in USEPA's *Wildlife Exposure Factors Handbook* (USEPA 1993). The general selection criteria for home ranges were as follows:

- Studies performed on the target receptor were preferred over the use of surrogate species.
- Ranges calculated for breeding females were preferred over those for females, which were preferred over those for males (data for juveniles were not selected).
- Studies performed in the Pacific Northwest and/or habitats similar to that of the site (i.e., riverine environment) were preferred over studies in other locations or habitats.
- For the aquatic-dependent wildlife receptors, home ranges reported in terms of river length were selected.
- Home ranges or foraging ranges were preferred over territory size.
- More recent studies were preferred over older studies.

The following values are presented in Table D-1:

- Weatherhead and McRae (1990), as cited in USEPA (1993), reported a foraging home range of 0.15 hectares (0.37 acres) for adult, male and female American robins.
- Hawes (1977), as cited in Zeiner et al. (1990), reported an average non-breeding home range of 0.10 ha (0.26 acres) for the vagrant shrew. Since the average breeding home range reported in the same study is larger (0.82 acres), the non-breeding home range was selected.
- Eberhardt et al. (1989a), as cited in USEPA (1993), reported a home range of 983 hectares (2430 acres) for the adult female Canada goose in Washington.
- California Wildlife Biology, Exposure Factor, and Toxicity Database (Cal/ECOTOX) (Office of Environmental Health Hazard Assessment 2002) was consulted for the

American kestrel home range value. Balgooyen (1976) reported an average home range for breeding American kestrels as 109.4 hectares (270 acres).

- Grubb (1980), as cited in USEPA (1993), reported a range of territory length for a pair of adult bald eagles in Washington as 1.4 - 7.2 km. To be protective of this recently delisted species (delisted as a State and federally-listed threatened and endangered species however, still protected under the Bald and Golden Eagle Protection Act of 2004 and the Lacy Act of 1990), the lower range of 1.4 km was selected as the foraging distance.
- Gerell (1970), as cited in USEPA (1993), reported a mean mink home range for adult females of 1.85 km.
- Dunstan (1973), as cited in USEPA (1993), reported a mean foraging range for adult male osprey as 1.7 km. Of the three foraging radius studies cited for the osprey in USEPA (1993), 1.7 km was the lowest value.

Area Use

Exposures to wildlife species are a function in part of the size of the impacted area (i.e., the site) and the foraging behavior of the organism. The smaller the site, the less likely the animal is to encounter it during normal feeding activities, particularly if the site is smaller than the amount of foraging habitat required by the organism.

Although the nature and extent of contamination varies within the site area, it is unlikely that ROIs would forage exclusively within a single area. However, evaluation of CPEC concentrations measured in the site area as a whole reflect a sampling bias toward more impacted locations, potentially resulting in overestimation of likely exposures. Additionally, industrial activity and land cover are likely to limit the use of some areas by wildlife ROIs due to the degradation of habitat, although samples from these areas are included in the data set used to characterize the concentrations of CPECs at the site.

The area use factors (AUFs) for each receptor are specific to each AOPC. A seasonality factor (SF) of 1.0 was assumed for all ROIs, because all are resident species and could feasibly be in the area of Bradford Island for their entire life span.

DEQ's earlier comments regarding the use of an AUF of 1.0 for vagrant shrew will be incorporated into the risk assessments for the AOPCs in the Upland OU (URS 2004; DEQ 2004).

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Table D-1
Exposure Factors for Ecological Receptors
Bradford Island

Parameter	Symbol	Units	American Robin	Vagrant Shrew	Canada Goose	American Kestrel	Bald Eagle	Mink	Osprey	Reference/Comment
Habitat	--	--	Terrestrial	Terrestrial	Terrestrial	Terrestrial	Aquatic-dependent	Aquatic-dependent	Aquatic-dependent	(A)
Operable Unit	OU	--	Upland	Upland	Upland	Upland	River	River	River	--
Trophic Level	--	--	Level 3	Level 3	Level 2	Level 4	Level 4	Level 2-4	Level 3-4	(A)
Occurrence	--	--	Resident	Resident	Resident	Resident	Resident	Resident	Resident	--
Status	--	--	None	None	None	None	Federally protected *	None	None	(B)
Home Range	--	acres or km	0.37 acres (C)	0.26 acres (A)	2,430 acres (C)	270 acres (D)	1.4 km (C)	1.85 km (C)	1.7 km (C)	For aquatic-dependent wildlife, home range based on length of riverine habitat.
Area Use Factor	AUF	fraction of site	Receptor- and AOPC-specific	Receptor- and AOPC-specific	Receptor- and AOPC-specific	Receptor- and AOPC-specific	Receptor- and AOPC-specific	Receptor- and AOPC-specific	Receptor- and AOPC-specific	General equation (1)
Seasonality Factor	SF	fraction of one year	1	1	1	1	1	1	1	All are resident species
Body Weight	BW	kg	0.0773	0.007	3.0	0.116	4.5	0.974	1.88	(C)
Dietary Composition	--	--	Soil-dwelling invertebrates	Soil-dwelling invertebrates	Aboveground vegetation	Small mammals	Trophic level 3-4 fish	Benthic invertebrates, trophic level 2-3 fish, and trophic level 3-4 fish	Trophic level 3-4 fish	(A,C) Professional judgment also used
Diet - Plant material	df_i	fraction of diet	0	0	1	0	0	0	0	(A,C) Professional judgment also used
Diet - Soil-dwelling invertebrates	df_i	fraction of diet	1	1	0	0	0	0	0	(A,C) Professional judgment also used
Diet - Small mammals	df_i	fraction of diet	0	0	0	1	0	0	0	(A,C) Professional judgment also used
Diet - Trophic level 2-3 fish	df_i	fraction of diet	0	0	0	0	0	0.33	0	(A,C) Professional judgment also used
Diet - Trophic level 3-4 fish	df_i	fraction of diet	0	0	0	0	1	0.33	1	(A,C) Professional judgment also used
Diet - Benthic invertebrates	df_i	fraction of diet	0	0	0	0	0	0.33	0	(A,C) Professional judgment also used
Food Ingestion Rate	IR_{food}	kg/day dw	0.013	0.0014	0.15	0.017	0.20	0.054	0.11	(E)
		kg/day ww	NA	NA	NA	NA	0.68	0.16	0.37	(E)
Fraction of Soil or Sediment in Diet	--	fraction of diet	0.104	0.04	0.082	0.02	NA	0.094	NA	(F) (2)
Incidental Soil or Sediment Ingestion Rate	IR_{soil}	kg/day dw	0.0013	0.000055	0.013	0.00033	NA	0.0051	NA	General equation (3)
Incidental Surface Water Ingestion Rate	IR_{water}	L/day	0.011	0.0011	0.12	0.014	0.16	0.097	0.09	(C) (4)
Concentration in Food - type *i*	$C_{food\ i}$	mg/kg dw	Food-specific chemical concentration	Food-specific chemical concentration	Food-specific chemical concentration	Food-specific chemical concentration	Food-specific chemical concentration	Food-specific chemical concentration	Food-specific chemical concentration	Measured/modeled concentration
Concentration in Soil/Sediment	$C_{soil/sed}$	mg/kg dw	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	NA	Measured concentration
Concentration in Surface Water	C_{water}	mg/L	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Chemical-specific	Measured concentration

Notes:
AOPC = area of potential concern
BW = body weight
dw = dry weight
kg = kilogram
km = kilometer
L = liter
mg = milligram
NA = not applicable
SF = seasonality factor
ww = wet weight

* Although the bald eagle has recently been delisted as a State and federally-listed threatened and endangered species, it is protected under the Bald and Golden Eagle Protection Act of 2004 and Lacy Act of 1990.

(1) Area Use Factor (AUF) = area of the site divided by the area of home range; DEQ's recommendation regarding AUF = 1 for the vagrant shrew will be considered for the Upland OU.
Because part of Bradford Island is managed as Canadian goose habitat, an AUF of 1.0 will be used for the goose regardless of its home range.
(2) Percent soil or sediment in diet reported for species with similar feeding habits used to develop soil and sediment ingestion rates (Beyer et al. 1994). For species without an adequate surrogate, the default percent soil in diet of 2% was used (Beyer et al., 1994).
For the vagrant shrew, the percent soil in diet for a white-footed mouse (2%) was doubled to account for a higher soil ingestion rate expected for a shrew.
(3) $IR_{soil} = IR_{food\ dw}$ * fraction of soil/sediment in diet
(4) Surface water ingestion will only be relevant for receptors in AOPCs where surface water is present.

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(E) Nagy KA. 2001. Food requirements of wild animals: predictive equations for free-living mammals, reptiles, and birds. Nutrition Abstracts and Reviews, Series B 71, 21R-31R.
If species-specific empirical data not available, then the generic equations for "all mammals" or "all birds" used to estimate IR_{food}.
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APPENDIX E
PROPOSED TROPHIC MODEL FOR PCBS – RIVER OU

Tables

Acronyms

COI	contaminant of interest
DEQ	(Oregon) Department of Environmental Quality
ERA	Ecological Risk Assessment
HHRA	Human Health Risk Assessment
LDW	Lower Duwamish Waterway (Group)
log K_{ow}	octanol-water partition coefficient
OU	operable unit
PCB	polychlorinated biphenyl
RI/FS	remedial investigation/feasibility study

E.1 INTRODUCTION

Food-web exposure to polychlorinated biphenyls (PCBs) is the primary exposure pathway of concern for human and ecological receptors at the River Operable Unit (OU). The objective of the human health risk assessment (HHRA) and ecological risk assessment (ERA) is to evaluate if there are unacceptable risks related to this pathway and, if so, to develop preliminary remediation goals that would be associated with acceptable risk levels.

As noted in Appendix B, the use of measured fish tissue concentrations from edible fish or prey items for human health and ecological risk assessments provides a “snapshot” of risks to these receptors. However, such data do not provide any indication of the sources of exposure for the selected fish or quantifiable estimates of the contribution from site-related sources. Therefore, an aquatic food-web model is proposed for use at the River OU.

Trophic models are simplified representations of the food-web structure for a habitat of interest. They can be used to illustrate the functional relationships between various environmental and biological variables (e.g., chemical transfer from abiotic media to biological media, predator-prey relationships) and to estimate or predict the values of various foodweb processes, (e.g., chemical transfer rates and concentrations in successive trophic levels). Therefore, a trophic model can be used for predictive purposes, i.e., to predict chemical concentrations in tissues, given the inputs for relevant environmental and biological variables.

Trophic modeling (or food-web modeling) is an essential element of the remedial investigation/feasibility study (RI/FS) process at sites where bioaccumulative, hydrophobic, organic chemicals such as PCBs are of concern. The primary goal of using a trophic model is to develop predictive relationships among chemical concentrations in soil or sediment, water, and tissues. These relationships are then used to develop preliminary remediation goals in sediment and water that are associated with acceptable levels of risk for consumers associated with the food-webs at these sites. For the aquatic environment, trophic models typically focus on sediment, water, and fish tissues.

E.2 SELECTION OF TROPHIC MODEL

A number of models are available to predict the transfer of bioaccumulative chemicals through the food web (Gobas 1993; Arnot and Gobas 2004). The model selected for application at the River OU is AQUAWEB (Arnot and Gobas 2004).

This model was selected for several reasons: it represents the most recent and up-to-date model available for aquatic environments; it has been used with a reasonable degree of satisfaction at several other PCB-contaminated sites (Fox River, Hudson River); and it was recently evaluated as the best-performing model for use at Portland Harbor in comparison with several other models (Trophic Trace, Ecofate) (Lower Willamette Group 2004).

The model is appropriate for use at Bradford Island for the following reasons:

- It is appropriate for modeling of resident species with small home ranges. This is relevant to the Forebay where the selected target species are primarily resident species with small home ranges (clams, crayfish, sculpin, and smallmouth bass). The large-scale sucker, included at the Oregon Department of Environmental Quality’s (DEQ’s) request, is a resident species but has a large home range.

- In the initial evaluation for Portland Harbor, the model performed exceptionally well in predicting tissue concentrations for several of the same target species that have been selected for the Forebay, i.e., crayfish, sculpin, and smallmouth bass.
- The model can address crayfish, one of the target species proposed for sampling and evaluation for the River OU.
- The model can address both sediment and water column inputs for PCBs. This feature may assist in differentiating between site-related sources of PCBs in sediment and non-site-related sources of PCBs transported by river water.
- The model was found to perform well at a spatial scale that is appropriate for the River OU (scales less than 1 river mile).
- Prediction accuracy of the model was within a factor of 4 of measured tissue concentrations whereas the prediction accuracy of other models was within a factor of 10.

E.3 MODEL FEATURES

The Arnot and Gobas model is a mechanistic, steady-state model that uses a number of physical, chemical, and biological parameters to predict concentrations of organic chemicals in plankton, invertebrate, and fish tissues. The input values use a combination of site-specific data and literature-derived default values. These values are then used to model a number of metabolic and kinetic processes within the organism to predict concentrations in each compartment of the food web.

The Arnot and Gobas (2004) model is a revision to the 1993 model, and improvements have been made that apparently result in better predictions of chemical uptake and bioconcentration by lower trophic levels (phytoplankton, zooplankton, and invertebrates) and trophic transfer in fish. The 1993 model consistently underpredicted the results demonstrated by the empirical data to a greater degree and frequency compared to the 2004 model (Gobas and Arnot 2005). In addition, the new model can account for PCBs in the dissolved as well as suspended phase, whereas the old model only addresses the dissolved phase; and the new model allows for adjustments to accommodate scavengers (crayfish) in the food web, whereas the old model cannot.

The key revisions incorporated into the 2004 model are: (1) new model for partitioning of chemicals into organisms, (2) new kinetic model for predicting concentrations in algae and phytoplankton, (3) new allometric relationships for predicting gill ventilation rates in a wide range of aquatic species, and (4) new mechanistic model for predicting biomagnification (gastrointestinal magnification of organics). The revisions enable more accurate predictions of bioaccumulation factors, but the model input requirements are basically the same as the old model, with the exception of the concentration of suspended solids in the water column. Each revision made to the model listed above resulted in incremental reductions in the model error compared to the 1993 model for each part of the food web. The revised model allows for more confidence in the exposure assessment of nonionizing hydrophic organics with a wide range of octanol-water partition coefficients (log K_{ow}) (1 to 9). Finally, aquatic groups addressed in the revised model include macrophytes, algae, phytoplanton, zooplankton, invertebrates, and fish of various trophic levels. The first three groups of organisms, which are primarily exposed to water column-related contaminants and comprise the basis of the aquatic food web, are not included in the 1993 model.

E.4 MODEL USE FOR BASELINE HHRA AND ERA

The input values for the model are categorized as physical/chemical inputs and biological inputs. Tables E-1 and E-2 list the input variables and indicate which inputs may be customized to project needs by collecting site-specific data. The inputs that will be modified by collection of site-specific data are also indicated. Table E-3 provides the equations that form the core of the model along with definitions of terms.

Model use for the River OU will comprise the following steps:

- Collect baseline data for selected site-specific physical, chemical, and biological input variables after completion of interim removal action.
- Identify other literature sources for site-specific inputs for which Forebay data are not being collected (e.g., use Portland Harbor assumptions [Lower Willamette Group 2004] or model defaults for dietary composition).
- Develop a preliminary set of scenarios for predicting tissue concentrations of PCB congeners and Aroclors in clams, crayfish, sculpin, and smallmouth bass.
- Run model to evaluate agreement between preliminary predictions and measured concentrations in the target species.
- Evaluate model sensitivity to specific parameters (e.g., PCB concentrations in sediment and water, log K_{ow} values for congeners, dietary composition of target species).
- Evaluate uncertainties in model inputs and outputs.
- Refine input parameters, as needed and practicable, to decrease uncertainty to acceptable levels.
- Use predicted tissue concentrations as inputs in exposure dose estimation for human and ecological receptors.
- If HHRA and ERA predict unacceptable risks, use model to back-calculate preliminary remediation goals in sediment that would be associated with acceptable risk levels in fish tissue.

E.5 SENSITIVITY AND LIMITATIONS OF THE MODEL

The use of any model to represent natural systems inherently involves incorporation of simplifying assumptions. These simplifications, in conjunction with the variability and uncertainty that are present in model parameters, contribute to limitations in the use of the model in model results. Most models are typically more sensitive to variations in some parameters than others. Sensitivities and limitations of this model that may affect the usefulness of the model outputs for this project includes the following (Lower Willamette Group 2005):

- Parameters that are known to greatly influence the sensitivity of the model include log K_{ow} values for chemicals, dietary absorption efficiency, and percent moisture for biota.

Parameters identified as moderately sensitive parameters include lipid content, dissolved oxygen, water temperature, and PCB concentrations in sediment and water.

- At this time, the model cannot incorporate the use of spatial limits for exposure area. Therefore, modeling uptake of PCBs by species whose home range is larger than the site area is not readily possible.
- The model cannot incorporate the use of temporal limits for exposure duration. Therefore, modeling uptake of PCBs by species whose residence time in the site area is less than year-round or less than lifetime is not readily possible.
- The use of adjusted dietary fractions or dietary concentrations to reflect spatial or temporal area use factors of less than 1.0 will be explored, if needed, for the appropriate receptors (e.g., large-scale sucker).
- The model also cannot account for exposure to multiple sources of the same chemical within a medium.
- The model is not recommended for use with metals or PAHs. Other models should be used for these chemicals if they are designated as contaminants of interest (COIs) at the Forebay.

E.6 UNCERTAINTIES IN MODEL USE AND RESULTS

Uncertainties in the modeling results may arise from the range of real values that may be associated with individual model parameters, data gaps associated with model inputs and variations in the estimates of transfer mechanisms and rate constants. The following uncertainties are anticipated with the use of this model at the Forebay.

- Seasonal variations in surface water chemistry may also influence model predictive accuracy.
- Use of proxy values for nondetected concentrations in water or use of data from non-XAD samples may overestimate PCB concentrations in water.
- Typical data gaps that may contribute to model uncertainty include lack of measured data for lower-trophic-level biota such as plankton, insects, and small benthic invertebrates.
- Sediment, water, and tissue data collection will occur both before and after the interim removal action. While the sediment and water data will represent both pre-removal and post-removal baseline conditions, the tissue data will actually be representative of long-term exposure prior to, during and immediately after the removal action (depending on the age of the sampled species). Therefore, comparing predicted tissue concentrations using only pre-removal or post-removal sediment and water data with measured tissue concentrations representing long-term exposures may contribute to reduced agreement between predicted and measured values.
- Agreement between predicted and measured tissue concentrations for large home-range fish such as large-scale sucker may be problematic.

E.7 REFERENCES

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Table E-1. Environmental Inputs for Trophic Model

SYMBOL	DESCRIPTION	UNITS	VALUES	PROPOSED DATA COLLECTION
ADOC	DOC-octanol proportionality constant	unitless	0.35	--
APOC	POC-octanol proportionality constant	unitless	0.08	--
CB	Chemical concentration in biota	g/kg	Site-specific	**X**
CDi	Chemical concentration in diet food item (i)	g/kg	Site-specific	**X(a)**
COX	Dissolved oxygen concentration	mg/L	Site-specific	**X**
CS	Chemical concentration in sediment	g/kg	Site-specific	**X**
CSOC	Organic carbon normalized chemical concentration in sediment	g/(kg OC)	Site-specific	**X**
CSS	Concentration of suspended solids in water	kg/L	Site-specific	**X**
CWD	Freely dissolved chemical concentration in water	g/L	Site-specific	**X**
CWDP	Freely dissolved chemical concentration in sediment pore water	g/L	Site-specific	C
CWT	Total chemical concentration in water	g/L	Site-specific	**X**
DDOC	Disequilibrium factor for DOC	unitless	Site-specific	C
DPOC	Disequilibrium factor for POC	unitless	Site-specific	C
KGB	Gut-biota partition coefficient	unitless	Site-specific	C
KM	Metabolic transformation rate constant	d^{-1}	Site-specific	C
KOC	Organic carbon-water partition coefficient	L/(kg OC)	Site-specific	C
KOW	Octanol-water partition coefficient	unitless	Site-specific	C
MB	Mass of chemical in the organism	g	Site-specific	C
S	Degree of oxygen saturation in the water column	%	Site-specific	C
T	Mean annual water temperature	°C	Site-specific	**X**
t	Time	d	Site-specific	C
XDOC	Dissolved organic carbon concentration in water	kg/L	Site-specific	**X**
XPOC	Particulate organic carbon concentration in water	kg/L	Site-specific	**X**

Notes

--	Model default value
C	Calculated by model from other site-specific data
X	Proposed for data collection from Forebay and Reference areas
X (a)	Dietary items selected for analysis include clams, sculpin, crayfish and a limited number of large-scale sucker
Source	Arnot, J. and Gobas, F. 2004. A food-web bioaccumulation model for organic chemicals in aquatic ecosystems. Env. Tox. Chem. 23:2343-2355.

Table E-2. Biological Inputs for Trophic Model

SYMBOL	DESCRIPTION	UNITS	VALUES	PROPOSED DATA COLLECTION
ϕ	Bioavailable solute fraction	unitless	Site-specific	C
β	NLOM-octanol proportionality constant	unitless	0.035	--
εL	Dietary absorption efficiency of lipid	%	Site-specific	C
	Dietary absorption efficiency of lipid (fish)	%	92%	--
	Dietary absorption efficiency of lipid (invertebrates)	%	75%	--
	Dietary absorption efficiency of lipid (zooplankton)	%	72%	--
εN	Dietary absorption efficiency of non-lipid organic matter (NLOM)	%	Site-specific	C
	Dietary absorption efficiency of non-lipid organic matter (NLOM) (fish)	%	60%	--
	Dietary absorption efficiency of non-lipid organic matter (NLOM) (invertibrates)	%	75%	--
	Dietary absorption efficiency of non-lipid organic matter (NLOM) (zooplankton)	%	72%	--
εW	Dietary absorption efficiency of water	%	25%	--
ED	Intestinal tract chemical transfer efficiency	%	Site-specific	C
EDA*	Constant for dietary uptake by fish	unitless	3.0×10^{-7}	--
EDB*	Constant for dietary uptake by fish	unitless	2	--
EW	Gill chemical transfer efficiency	%	Site-specific	C
GD	Feeding rate	kg/d	Site-specific	C
GF	Feces elimination rate	kg/(kg-d)	Site-specific	C
GV	Ventilation rate	L/d	Site-specific	C
K1	Gill uptake rate constant	L/(kg-d)	Site-specific	C
K1A	Constant for uptake by algae, phytoplankton, aquatic macrophytes	unitless	6.0×10^{-5}	--
K1B	Constant for uptake by algae, phytoplankton, aquatic macrophytes	unitless	5.5	--
K2	Gill elimination rate constant	d^{-1}	Site-specific	C
KBW	Biota-water partition coefficient	unitless	Site-specific	C
KD	Dietary uptake rate constant	kg/(kg-d)	Site-specific	C
KE	Fecal egestion rate constant	d^{-1}	Site-specific	C
KG	Growth rate constant	d^{-1}	Site-specific	C
	Growth rate constant (slow)	d^{-1}	0.03 d^{-1}	--
	Growth rate constant (mean annual)	d^{-1}	0.08 d^{-1}	--
	Growth rate constant (active)	d^{-1}	0.13 d^{-1}	--
KPW	Phytoplankton-water partition coefficient	unitless	Site-specific	C
Mo	Fraction of respiratory ventilation involving overlying water	unitless	Site-specific	C
Mp	Fraction of respiratory ventilation involving sediment pore water	unitless	Site-specific	C
PDi	Fraction of diet containing food item (i)	unitless	Site-specific	C

Table E-2. Biological Inputs for Trophic Model

SYMBOL	DESCRIPTION	UNITS	VALUES	PROPOSED DATA COLLECTION
PSE	Particle scavenging efficiency	%	Site-specific	C
QL	Lipid transport parameter	L/d	Site-specific	C
QW	Aqueous transport parameter	L/d	Site-specific	C
VLBi	Lipid fraction of biota (i)	kg/(kg ww)	Site-specific	**X (a)**
VLD	Lipid fraction in diet (weighted average)	kg/(kg ww)	Site-specific	**X (a)**
VLG	Lipid fraction in gut	kg/(kg ww)	Site-specific	C
VLP	Lipid fraction of phytoplankton	kg/(kg ww)	Site-specific	C
VNB	Non-lipid organic matter (NLOM) fraction of biota	kg/(kg ww)	Site-specific	**X (a)**
VND	Non-lipid organic matter (NLOM) fraction in diet (weighted average)	kg/(kg ww)	Site-specific	**X (a)**
VNG	Non-lipid organic matter (NLOM) fraction in gut	kg/(kg ww)	Site-specific	C
VNP	Non-lipid organic matter (NLOM) fraction in phytoplankton	kg/(kg ww)	Site-specific	C
VWB	Water content of the organism	kg/(kg ww)	Site-specific	**X (a)**
VWD	Water content of the diet (weighted average)	kg/(kg ww)	Site-specific	**X (a)**
VWG	Water content of GIT contents	kg/(kg ww)	Site-specific	C
VWP	Water content of phytoplankton	kg/(kg ww)	Site-specific	C
WB	Weight of organism	kg	Site-specific	**X (a)**

Notes

--	Model default value
C	Calculated by model from other site-specific data
X (a)	Proposed for data collection from Forebay and Reference areas Biota and dietary items selected for analysis include clams, sculpin, crayfish and a limited number of large-scale sucker
Source	Arnot, J. and Gobas, F. 2004. A food-web bioaccumulation model for organic chemicals in aquatic ecosystems. Env. Tox. Chem. 23:2343-2355.

Table E-3. Summary of Equations and Parameters for the Arnot and Gobas (2004) Food Web Bioaccumulation Model

BIOTA MASS BALANCE

$$\frac{dMB}{dt} = \begin{array}{c}\{WB \cdot (K1 \cdot [Mo \cdot \phi \cdot CWT + Mp \cdot CWDP] + KD \cdot \sum PDi \cdot CDi)\} \\ -(K2 + KE + KG + KM) \cdot MB\end{array} \quad (1)$$

$$CB = \frac{\{K1 \cdot (Mo \cdot \phi \cdot CWT + Mp \cdot CWDP) + KD \cdot \sum PDi \cdot CDi\}}{K2 + KE + KG + KM} \quad (2)$$

$$CB = MB/WB \quad (3)$$

$$CWDP = CSOC/KOC \quad (4)$$

FLUXES

Common Parameters

$$KBW = K1/K2 = VLB \cdot KOW + VNB \cdot \beta \cdot KOW + VWB \quad (5)$$

$$KPW = VLP \cdot KOW + VNP \cdot 0.35 \cdot KOW + VWP \quad (6)$$

$$\begin{array}{c}\phi = CWD/CWT = \\ 1/(1 + XPOC \cdot DPOC \cdot APOC \cdot KOW + XDOC \cdot DDOC \cdot ADOC \cdot KOW)\end{array} \quad (7)$$

Gill Uptake

fish, inverts, zoo

$$K1 = EW \cdot GV/WB \quad (8a)$$

algae, phyto, macrophyte

$$K1 = 1/(A + (B/KOW)) \quad (8b)$$

alternate

$$K1 = 1/[(WB/QW) + (WB/QL)/KOW] \quad (8c)$$

$$QW = 88.3 \cdot WB^{0.6} \quad (8d)$$

$$QL = 0.01 \cdot QW \quad (8e)$$

$$EW = 1/(1.85 + (155/KOW)) \quad (8f)$$

$$GV = 1400 \cdot WB^{0.65}/COX \quad (8g)$$

$$COX = (-0.24 \cdot T + 14.04) \cdot S \quad (8h)$$

Gill Elimination

$$K2 = K1/KBW \quad (9a)$$

phyto

$$K2 = K1/KPW \quad (9b)$$

Dietary Uptake

$$KD = ED \cdot GD/WB \quad (10a)$$

$$ED = 1/\left(A^{*} \cdot KOW + B^{*}\right) \quad (10b)$$

coldwater fish, zoo, invert

$$GD = 0.022 \cdot WB^{0.85} \cdot \exp(0.06 \cdot T) \quad (10c)$$

filter-feeders

$$GD = GV \cdot CSS \cdot PSE \quad (10d)$$

Fecal Elimination

$$KE = GF \cdot ED \cdot KGB/WB \quad (11a)$$

$$GF = \{(1-\varepsilon L) \cdot VLD + (1-\varepsilon N) \cdot VND + (1-\varepsilon W) \cdot VWD\} \cdot GD \quad (11b)$$

$$VLD = \sum PDi \cdot VLBi \quad (11c)$$

$$KGB = \frac{VLG \cdot KOW + VNG \cdot \beta \cdot KOW + VWG}{VLB \cdot KOW + VNB \cdot \beta \cdot KOW + VWB} \quad (11d)$$

$$VLG = \frac{(1-\varepsilon L) \cdot VLD}{[(1-\varepsilon L) \cdot VLD + (1-\varepsilon N) \cdot VND + (1-\varepsilon W) \cdot VWD]} \quad (11e)$$

$$VNG = \frac{(1-\varepsilon L) \cdot VND}{[(1-\varepsilon L) \cdot VLD + (1-\varepsilon N) \cdot VND + (1-\varepsilon W) \cdot VWD]} \quad (11f)$$

$$VWG = \frac{(1-\varepsilon L) \cdot VWD}{[(1-\varepsilon L) \cdot VLD + (1-\varepsilon N) \cdot VND + (1-\varepsilon W) \cdot VWD]} \quad (11g)$$

Growth Dilution

T ~ 10°C

$$KG = 0.0005 \cdot WB^{-0.2} \quad (12a)$$

T ~ 25°C

$$KG = 0.00251 \cdot WB^{-0.2} \quad (12b)$$

Table E-3. Summary of Equations and Parameters for the Arnot and Gobas (2004) Food Web Bioaccumulation Model

SYMBOL	DESCRIPTION	UNITS
ϕ	Bioavailable solute fraction	unitless
β	NLOM-octanol proportionality constant	unitless
εL	Dietary absorption efficiency of lipid	%
εN	Dietary absorption efficiency of non-lipid organic matter (NLOM)	%
εW	Dietary absorption efficiency of water	%
ADOC	DOC-octanol proportionality constant	unitless
APOC	POC-octanol proportionality constant	unitless
CB	Chemical concentration in biota	g kg^{-1}
CDi	Chemical concentration in diet food item (i)	g kg^{-1}
COX	Dissolved oxygen concentration	mg L^{-1}
CS	Chemical concentration in sediment	g kg^{-1}
CSOC	Organic carbon normalized chemical concentration in sediment	g kg^{-1} OC
CSS	Concentration of suspended solids in water	kg L^{-1}
CWD	Freely dissolved chemical concentration in water	g L^{-1}
CWDP	Freely dissolved chemical concentration in sediment pore water	g L^{-1}
CWT	Total chemical concentration in water	g L^{-1}
DDOC	Disequilibrium factor for DOC	unitless
DPOC	Disequilibrium factor for POC	unitless
ED	Intestinal tract chemical transfer efficiency	%
EDA*	Constant for dietary uptake by fish	unitless
EDB*	Constant for dietary uptake by fish	unitless
EW	Gill chemical transfer efficiency	%
GD	Feeding rate	kg d^{-1}
GF	Feces elimination rate	kg kg^{-1} d^{-1}
GV	Ventilation rate	L d^{-1}
K1	Gill uptake rate constant	L kg^{-1} d^{-1}
K1A	Constant for uptake by algae, phytoplankton, aquatic macrophytes	unitless
K1B	Constant for uptake by algae, phytoplankton, aquatic macrophytes	unitless
K2	Gill elimination rate constant	d^{-1}
KBW	Biota-water partition coefficient	unitless
KD	Dietary uptake rate constant	kg kg^{-1} d^{-1}

Table E-3. Summary of Equations and Parameters for the Arnot and Gobas (2004) Food Web Bioaccumulation Model

SYMBOL	DESCRIPTION	UNITS
KE	Fecal egestion rate constant	d^{-1}
KG	Growth rate constant	d^{-1}
KGB	Gut-biota partition coefficient	unitless
KM	Metabolic transformation rate constant	d^{-1}
KOC	Organic carbon-water partition coefficient	L kg^{-1} OC
KOW	Octanol-water partition coefficient	unitless
KPW	Phytoplankton-water partition coefficient	unitless
MB	Mass of chemical in the organism	g
Mo	Fraction of respiratory ventilation involving overlying water	unitless
Mp	Fraction of respiratory ventilation involving sediment pore water	unitless
PDi	Fraction of diet containing food item (i)	unitless
PSE	Particle scavenging efficiency	%
QL	Lipid transport parameter	L d^{-1}
QW	Aqueous transport parameter	L d^{-1}
S	Degree of oxygen saturation in the water column	%
T	Mean annual water temperature	°C
t	Time	d
VLBi	Lipid fraction of biota (i)	kg kg^{-1} ww
VLD	Lipid fraction in diet (weighted average)	kg kg^{-1} ww
VLG	Lipid fraction in gut	kg kg^{-1} ww
VLP	Lipid fraction of phytoplankton	kg kg^{-1} ww
VNB	Non-lipid organic matter (NLOM) fraction of biota	kg kg^{-1} ww
VND	Non-lipid organic matter (NLOM) fraction in diet (weighted average)	kg kg^{-1} ww
VNG	Non-lipid organic matter (NLOM) fraction in gut	kg kg^{-1} ww
VNP	Non-lipid organic matter (NLOM) fraction in phytoplankton	kg kg^{-1} ww
VWB	Water content of the organism	kg kg^{-1} ww
VWD	Water content of the diet (weighted average)	kg kg^{-1} ww
VWG	Water content of GIT contents	kg kg^{-1} ww
VWP	Water content of phytoplankton	kg kg^{-1} ww
WB	Weight of organism	kg
XDOC	Dissolved organic carbon concentration in water	kg L^{-1}

Table E-3. Summary of Equations and Parameters for the Arnot and Gobas (2004) Food Web Bioaccumulation Model

SYMBOL	DESCRIPTION	UNITS
XPOC	Particulate organic carbon concentration in water	kg L^{-1}

SYMBOL	DESCRIPTION	VALUE
β	NLOM-octanol proportionality constant	0.035
ADOC	DOC-octanol proportionality constant	0.35
APOC	POC-octanol proportionality constant	0.08
For algae, phytoplankton, aquatic macrophytes		
K1A	Constant	6.0×10^{-5}
K1B	Constant	5.5
KG	Growth rate constant (slow)	0.03 d^{-1}
KG	Growth rate constant (mean annual)	0.08 d^{-1}
KG	Growth rate constant (active)	0.13 d^{-1}
Fish		
EDA*	Constant	3.0×10^{-7}
EDB*	Constant	2.0
εL	Dietary absorption efficiency of lipid	92%
εN	Dietary absorption efficiency of non-lipid organic matter (NLOM)	60%
Invertebrates		
εL	Dietary absorption efficiency of lipid	75%
εN	Dietary absorption efficiency of non-lipid organic matter (NLOM)	75%
Zooplankton		
εL	Dietary absorption efficiency of lipid	72%
εN	Dietary absorption efficiency of non-lipid organic matter (NLOM)	72%
All freshwater species		
εW	Dietary absorption efficiency of water	25%