Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment

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II. APPROVAL

This guidance document has been approved for use by the Department of Environmental Quality Land Quality Division.

[Alan Kiphut] 1/31/2007

Alan Kiphut, Division Administrator — Date

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List of Acronyms

90UCL	90% Upper confidence level of the mean
ATL_h	Acceptable tissue levels for humans
ATL_{hC}	Acceptable tissue levels of carcinogens for humans
ATL_{hN}	Acceptable tissue levels of noncarcinogens for humans
ATL	Acceptable tissue level
ATL_w	Acceptable tissue levels for wildlife
$ATL_{w\text{-}egg}$	Acceptable tissue levels for egg development
AWQC	Ambient water quality criteria
BCF	Bioconcentration factor
BCOI	Bioaccumulative contaminant of interest
BMF	Biomagnification factor
BMF_{egg}	Biomagnification factor for egg development
BSAF	Biota-sediment accumulation factor (for organic chemicals)
CASRN	Chemical Abstracts Service Registry Number
C_{BAC}	Cumulative bioaccumulation index for an individual chemical;
COI	Contaminant of interest
COPC	Contaminant of potential concern
CRITFC	Columbia River Inter-Tribal Fish Commission
CSM	Conceptual site model
CTL	Critical tissue level (for fish)
DEQ	Department of Environmental Quality
DQO	Data quality objectives
EC_{tissue}	Equilibrium contaminant tissue concentration in fish
EE/CA	Engineering evaluation/cost assessment
EPC	Exposure point concentration
f_{oc}	Fraction of organic carbon in the sediment
f_L	Fraction of lipid content in the organism
FS	Feasibility study
IQR	Interquartile Range
Kd	Distribution coefficient for inorganics
MDL	Method detection limit
mg/kg ww	The mg/kg concentration is based on the wet weight of the sample
N	Total number of contaminants in sediment at the site
ND	Non detect
NFA	No further action
OAR	Oregon Administrative Rule
PAHs	Polynuclear Aromatic Hydrocarbons

R_{BAC}	Bioaccumulation index for each individual chemical in the sediment
RI	Remedial Investigation
SLV	Screening level value
SLV_{BH}	Sediment bioaccumulation screening level for humans
SLV_{BW}	Sediment bioaccumulation screening level for wildlife
SSD	Species sensitivity distribution
T&E	Threatened or endangered
TRV	Toxicity Reference Value
UCL	Upper confidence limit of the arithmetic mean
90UCL	90% upper confidence limit of the arithmetic mean

1. INTRODUCTION

This document describes a process used by the Oregon Department of Environmental Quality (DEQ) to evaluate chemicals found in sediment for their potential contribution to risk as a result of bioaccumulation. It is presented here as an example of a method that others may use for that purpose, if appropriate. Its use, however, is not required.

The revised environmental cleanup law and associated administrative rules adopted by the Environmental Quality Commission in 1997 provide that ***any removal or remedial action performed under the law and rules shall attain a degree of cleanup of the hazardous substance and control further release of the hazardous substance that assures protection of present and future public health, safety and welfare and of the environment.***

This guidance describes several ways to determine if hazardous substances released to sediment have the potential to bioaccumulate to the point where the contaminants adversely affect either the health of the fish or other aquatic organisms, or the health of animals or humans that consume them.

This guidance supplements existing risk assessment guidance, and only addresses the evaluation of bioaccumulative chemicals in sediment. Guidance documents for assessing risk to human health (DEQ, 2000) or ecological receptors (DEQ, 2001b) provide the framework for the complete risk assessment process.

Bioaccumulation is a general term applied when there is a net accumulation of a chemical by an organism as a result of uptake from all routes of exposure. As used in this document, the term bioaccumulation includes *bioconcentration*, which is the net accumulation of a dissolved chemical directly from water by an aquatic organism, and *biomagnification*, which refers to the process by which chemicals tend to accumulate to higher concentrations at higher levels in the food web due to dietary accumulation.[1]

Bioaccumulation of contaminants from sediments to benthic organisms and their subsequent transfer through the food web provides an exposure pathway to higher-level organisms (Figure 1). Because sediments can contain significantly higher concentrations of some chemicals than the overlying water, it is important to evaluate the potential for such chemicals to accumulate in aquatic organisms. This information is needed to help predict potentially adverse effects on fish, shellfish, and other aquatic prey animals, or on wildlife or humans that consume them.

[1] Chemicals that biomagnify generally create more risk than those that only bioconcentrate. Many metals bioconcentrate to varying degrees but do not biomagnify like PCBs, DDT, and dioxin.

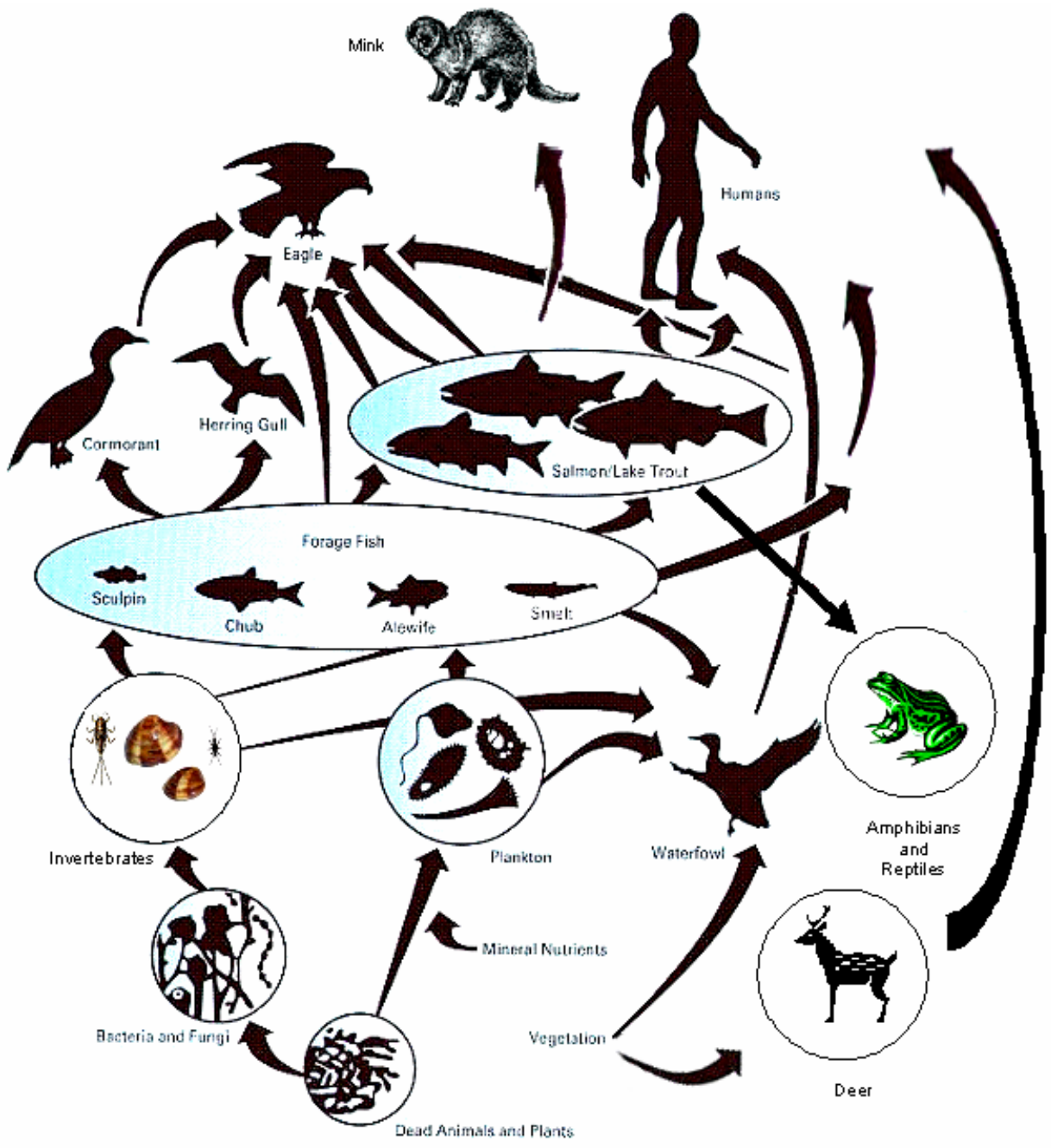

Figure 1. An Example of a Food-Web

Since Oregon's Environmental Cleanup Rules require responsible parties to evaluate contaminants capable of bioaccumulation,[2] this guidance is designed to help you:

- Recognize options for evaluating the bioaccumulation potential of chemicals;
- Identify chemicals in sediment that could present a bioaccumulation risk; and

Estimate the likelihood that these chemicals pose a threat to humans or wildlife as a result of eating fish, shellfish, and other aquatic organisms from a particular location. Chemicals identified as bioaccumulative compounds in this guidance were developed through a consensus-based process with the Regional Sediment Evaluation Team (RSET), which is developing screening levels to guide disposal options for dredged sediment, and review of more recent fish tissue testing results from the lower Willamette basin[3]. The toxicity of those chemicals and chemicals that do not bioaccumulate must also be addressed in the risk assessment. Both must be evaluated at sites with contaminated sediment since neither is a predictor of the presence or consequences of the other. Further, the bioaccumulation related risks and toxicity of contaminants in sediment need to be considered within the overall risk assessment for a facility that addresses all impacted media and routes of exposure. For additional assistance consult DEQ's *Guidance for Ecological Risk Assessment* (DEQ, 2001b) and *Guidance for Conduct of Deterministic Human Health Risk Assessments* (DEQ, 2000). This document does not address the evaluation of the interface between contaminated groundwater and sediment, or the evaluation of potential toxic effects from the bioconcentration of Polynuclear Aromatic Hydrocarbons (PAHs) and metals in benthic organisms. If these pathways are a concern, please contact your DEQ project manager.

2. SUMMARY OF THE PROCESS

2.1 INVESTIGATION OF THE SITE

As with any remedial investigation (RI), it is very important that you determine the full magnitude and extent of the contamination and identify all contaminants of interest at the site. The preliminary conceptual site model (CSM) that illustrates the potential current and reasonably likely future exposures to human and ecological receptors will support the development of data quality objectives[4] (DQOs) for the RI. DQOs should be consistent with the DEQ Cleanup

[2] Oregon Administrative Rules (OAR) 340-122-084(3)(d) requires "…information regarding the toxicological effects, ecological effects, bioconcentration potential, bioaccumulation potential, biomagnification potential, and persistence of the identified contaminants of ecological concern, …"

[3] The list of bioaccumative compounds specifically identified in this guidance may be expanded by DEQ on a project specific basis where high concentrations of a hazardous substance possessing chemical properties consistent with the criteria used in the RSET process has been detected in sediment and has been detected in fish tissue studies conducted elsewhere in the watershed.

[4] Additional information on the DQO process can be viewed at http://www.hanford.gov/dqo/index.html

Program Quality Assurance Policy (DEQ, 2001a) to ensure the data is of sufficient quality to apply this guidance and complete the risk assessment. The DQO development will need to address analytical requirements such as method detection limits (see Table A-7), and background concentrations of naturally occurring elements (see Appendix B). In this guidance document we assume that you have already completed the CSM and DQO development tasks satisfactorily.

Before you can evaluate the potential for bioaccumulation you need to determine if any individuals of a threatened or endangered (T&E) aquatic or terrestrial fish-eating species or their critical habitat are present within the locality of the facility using the methodology provided in DEQ's *Guidance for Ecological Risk Assessment* (DEQ, 2001b). This is necessary in order to determine what set of screening levels apply to your site. If there is no current or reasonably likely future use of the locality of the facility by a T&E species, use numbers from the "Population" column in the "Birds" or "Mammals" sections of tables referred to later in this document. If you cannot rule out the presence of a T&E species with reasonable certainty, use the numbers from the "Individual" columns in the tables.

In urban settings, determining the LOF may be complicated or inconclusive due to widespread presence of elevated levels of chemicals in sediment upstream of the facility that exceed the screening criteria in this guidance. Under these circumstances, you should consult with the DEQ project manager and toxicologist on how to complete the bioaccumulation screening and/or develop the feasible removal or remedial action options to address site-specific contamination that exceeds both the screening and ambient levels. Also see Example 3, Section 6 below.

2.2 Evaluation of Bioaccumulation

Since food webs can be quite complex, for the purposes of this guidance document we will focus only on the relationships illustrated in Figure 2. We would like to determine if the concentrations of contaminants in sediment are high enough to bioaccumulate in fish and other aquatic organisms to the point where the contaminants affect either the health of humans or animals that consume the fish or other aquatic organisms, or the health of the aquatic organisms themselves. The methods discussed in this document evaluate potential bioaccumulation by:

- Comparing the measured concentration of contaminants in sediment to sediment screening level values (SLVs) for humans and relevant classes of wildlife;
- Comparing the estimated or measured concentration of contaminants in fish tissue to acceptable tissue levels (ATLs) for humans and relevant classes of wildlife and/or to critical tissue levels (CTLs) in fish;
- Measuring bioaccumulation with laboratory or *in situ* tests; or
- Modeling bioaccumulation with site-specific fish or benthic invertebrate tissue data and a food web model.

The steps described in this guidance document are outlined in Section 2.3 and illustrated in Figure 3.

Note: For convenience, the process discussed in Section 2.3 is presented in a traditional "tiered" format, starting with the easiest, least costly, and most generic methods and proceeding up to more detailed, more costly, and more site-specific methods. You are not, however, required to perform all of the steps or follow the suggested order.

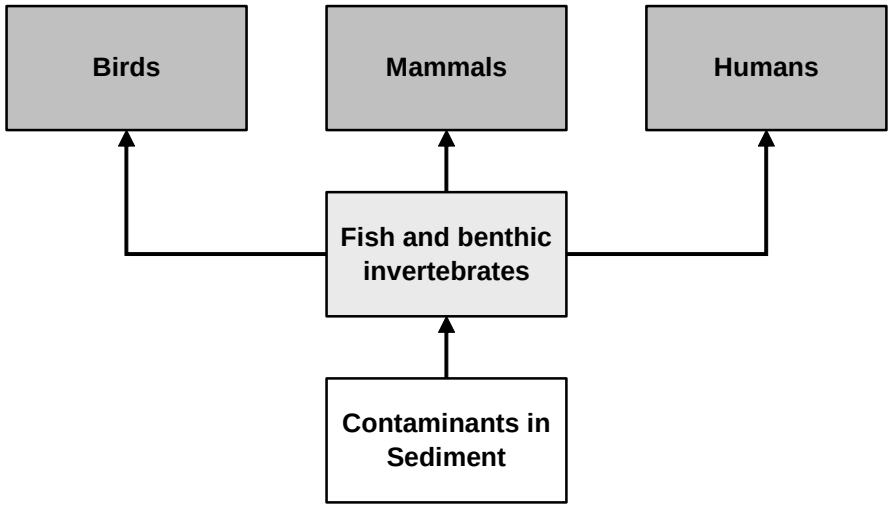

Figure 2. Simplified Food Web Showing Pathways Discussed in this Document

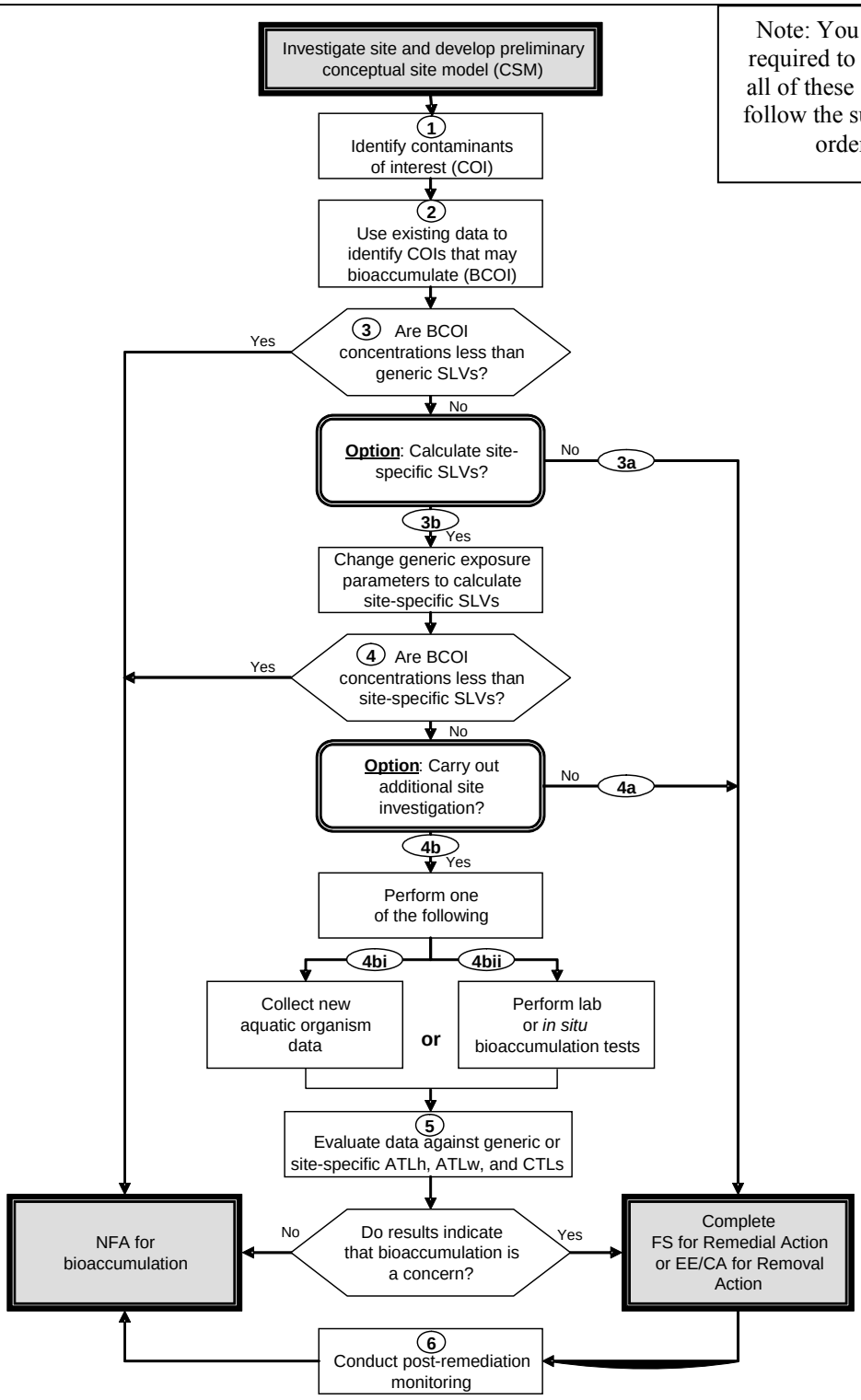

Figure 3. Assessing Chemicals for Bioaccumulation

2.3 OUTLINE OF THE PROCESS

1. Identify the contaminants of interest (COIs) in sediment at the site.

2. Use existing data to determine which COIs, if any, are bioaccumulating contaminants of interest (BCOIs). Table 1 shows the BCOIs that DEQ is considering. This list was compiled using the approach developed by EPA and incorporated as List 1 in the *Interim Final Northwest Regional Sediment Evaluation Framework* (USEPA/USACE 2006)

3. Compare the concentration of each BCOI in sediment at each location to its generic bioaccumulation screening level value. If the concentration is lower, no further action is required with respect to bioaccumulation for that COI. If the BCOI concentration is greater than its generic SLV, consider an area-wide statistical evaluation of the exposure point concentration taking into account the appropriate range of relevant species. This is consistent with DEQ's general screening approach, using the maximum concentration, or the 90 percent upper confidence limit of the arithmetic mean, whichever is lower. However, for benthic organisms that are stationary or range over small distances, a comparison with the maximum concentration is appropriate. If the BCOI concentration is still greater than its generic SLV, do one of the following:

   a. Evaluate the feasibility of cleaning up areas exceeding SLV levels to the generic SLV or to non-detect[5] (ND), whichever is higher, or, for a naturally occurring chemical, to its background concentration.[6] Do this by either

      i. A feasibility study and a remedial action, or

      ii. An engineering evaluation/cost analysis and a removal; or

   b. Use information from the site along with the equations for the generic SLVs to calculate a site-specific SLV and then continue with Step 4.

4. Compare the concentration of each BCOI in sediment at each location to its *site-specific* bioaccumulation screening level value. If the concentration is lower, no further action is required with respect to bioaccumulation for that COI. If the BCOI concentration is greater than its *site-specific* SLV, consider an area-wide statistical evaluation of the exposure point concentration taking into account the appropriate range of relevant species. This is consistent with DEQ's general screening approach, using the maximum

[5] Analytical method reporting limits (MRLs) must be considered when the data quality objectives (DQOs) are developed for a sediment investigation. In many cases the reporting or quantitation limits of approved methods, such as those found in EPA's SW-846, are below the bioaccumulation SLV. For some compounds the SLV is below the lowest attainable reporting limits with cleanup procedures for sample extracts to eliminate matrix interferences. Only under these circumstances, would DEQ consider using the MRL as a cleanup goal.

[6] OAR 340-122-0115(8) defines background as "the concentration of hazardous substance, if any, existing in the environment in the location of the facility before the occurrence of any past or present release or releases."

concentration, or the 90 percent upper confidence limit of the arithmetic mean, whichever is lower. However, for benthic organisms that are stationary or range over small distances, a comparison with the maximum concentration is appropriate. If the BCOI concentration is still greater than its site-specific SLV, do one of the following:

a. Evaluate the feasibility of cleaning up areas exceeding SLV levels to the site-specific SLV or to ND, whichever is higher, or, for a naturally occurring chemical, to its background concentration. Do this by either

   i. A feasibility study and a remedial action, or

   ii. An engineering evaluation/cost analysis and a removal; or

b. Collect data on the concentration of BCOIs in fish or benthic invertebrate tissue using one of the following methods, and then continue with Step 5.

   i. Collect existing tissue data from an area that is applicable to your site (*e.g.*, has appropriate fish home range and analytes) or data from fish caught or benthic invertebrates collected at your site for this purpose; or

   ii. Perform laboratory or *in situ* bioaccumulation tests on sediment from the site.

5. Compare the estimated or measured concentration of each BCOI in fish or benthic invertebrate tissue to appropriate acceptable tissue levels (ATLw and ATLh) or critical tissue levels (CTL). If the concentration is lower, no further action is required with respect to bioaccumulation for that COI and you should continue with a regular toxicity evaluation. If the BCOI concentration is greater than the ATL or CTL, the COI must be considered a chemical of potential concern (COPC) with respect to bioaccumulation and must be cleaned up to a bioaccumulation-based level or to ND, whichever is higher; or, for a naturally occurring compound, to its background concentration. Do this by either

   a A feasibility study and a remedial action, or

   b An engineering evaluation/cost analysis and a removal action.

6. Monitor the site to confirm that the goals of your remedy have been met.

The steps summarized above are described in more detail in Sections 3 - 6.

3. CONTAMINANTS OF INTEREST

Use historical information about your site as well as data collected during the site investigation to compile a list of COIs. From the list of COIs, develop a list of BCOIs for the sediment at the site by considering factors like:

- The release of potentially bioaccumulative chemicals like arsenic, cadmium, chlordane, DDT, dieldrin, dioxins and furans, fluoranthene, hexachlorobenzene, lead, mercury, pentachlorophenol, PCBs, pyrene, selenium, and tributyltin;
- All potential sources of contamination at the site including stormwater runoff;
- Pervasive legacy chemicals like PCBs and pesticides; and
- Tissue data from fish and other aquatic species in the vicinity of your site.

Screen the chemicals on your BCOI list by following the procedures in Sections 4 - 6.

4. SEDIMENT SCREENING LEVELS

4.1 GENERIC SEDIMENT SCREENING LEVELS

Note: If adequate fish/shellfish-tissue data are already available, you may be able to skip the initial screening steps and go directly to the tests discussed in Section 5.

When screening for potential bioaccumulative chemicals, you must consider risk from exposure not only to individual contaminants, but also to multiple contaminants present together in sediment.[7] For fish and mobile fish-eating species, use the 90% upper confidence limit of the arithmetic mean (90UCL[8]) sediment concentration or the maximum sediment concentration, whichever is less, as the appropriate exposure point concentration (EPC).

To determine exposures to individual chemicals, compare the EPC of each bioaccumulative COI in the sediment to its generic SLV or to natural background concentration listed in Table A-1 in Appendix A. This relationship, the bioaccumulation index (R_{BAC}), is defined by the following equation:

$$R_{BAC} = \frac{EPC}{SLV} \qquad [1]$$

where:

R_{BAC} = bioaccumulation index for an individual COI (unitless);

EPC = exposure point concentration of a given COI in sediment (mg/kg); and

[7] This is "cumulative risk" as described in OAR 340-122-084(1)(i).

[8] You can calculate 90UCL with spreadsheets available on the Internet from either the DEQ (http://www.deq.state.or.us/lq/rbdm.htm) or the EPA (http://www.epa.gov/nerlesd1/tsc/software.htm).

SLV = screening level value for the COI (mg/kg) and receptor class from Table A-1.

If the R_{BAC} is greater than 1 for any individual COI, that chemical is a contaminant of potential concern (COPC) on the basis of the generic SLVs and could be a bioaccumulation threat to humans or wildlife that consume fish, shellfish, and other aquatic organisms.

Next, determine if there is a potential for a group of two or more contaminants to generate cumulative bioaccumulation risk.[9] To do this, add up the R_{BAC} values for a particular receptor class.[10] If the sum is less than 1 there is no unacceptable cumulative risk as a result of bioaccumulation.

If the sum of all of the R_{BAC} values is greater than 1, examine the value of R_{BAC} for each COI in that receptor class. If R_{BAC} is greater than 0.1 for any individual COI in that class, that COI is a COPC on the basis of the generic SLVs, and cumulative exposure of bioaccumulative chemicals could be a threat to humans or wildlife that consume fish, shellfish, and other aquatic organisms.

This cumulative screening approach will capture chemicals that are contributing to an overall bioaccumulation risk, but individually would not be screened in. You may have to repeat this process for each class of receptors at the site.

An example of the calculations discussed above is provided in Example 1.

[9] This refers to two or more chemicals accumulated in tissue; not merely present in sediment.

[10] As used in this document, "receptor class" refers to a group of animals the members of which have similar exposure pathways and responses to the bioaccumulative chemicals of concern at a given site.

Example 1

During an investigation, you find that there are five chemicals of interest at your site (Chemical A through Chemical E in Column 1 of the table below). Using data from the investigation, you evaluate exposure point concentrations (Column 2) and look up bioaccumulation screening level values (Column 3) for each of the five COIs. You then use this information to calculate the bioaccumulation index for each of the COIs (Column 4).

Two of the R_{BAC} values are greater than 1 (B and E). Therefore, Chemicals B and E fail the individual bioaccumulation screen. Because the sum of the bioaccumulation indices is greater than 1, examine the index of each remaining COI to see if it exceeds 0.1 (Column 4). Chemical D meets that criterion and therefore fails the cumulative bioaccumulation screen.

As a result of this analysis Chemicals B, D, and E are bioaccumulative COPCs for the site.

Bioaccumulative Chemical of Interest (BCOI)	Sediment Exposure Point Concentration (EPC; mg/kg)	Bioaccumulation Screening Level Value (SLV; mg/kg)	Bioaccumulation Index R_{BAC} = EPC / SLV	Is R_{BAC} > 0.1 and Cumulative Bioaccumulation Index > 1?
Chemical A	5.0	64	0.078	No
Chemical B	3.3	3	**1.1**	**Yes**
Chemical C	0.20	14	0.014	No
Chemical D	15	23	0.65	**Yes**
Chemical E	3.2	1	**3.2**	**Yes**
		Sum R_{BAC} =	**5.0**	

If one or more of the COPCs are naturally-occurring chemicals, you may want to carry out additional sampling to evaluate the background concentrations of those chemicals. If the natural background is higher than the SLV or ND, then you should use the background concentration as the screening level. Information about the background concentrations of metals can be found in Appendix B.

<u>SUMMARY</u>: If there are no COPCs on the basis of the generic SLVs, either on an individual basis (Equation 1) or a cumulative basis, no further action is required for bioaccumulation.

If you identify one or more bioaccumulative COPCs as a result of the process described in Section 4.1, you can either:

- **Carry out a response action addressing each COPC at the site as discussed in Section 6; or**
- **Use site-specific information in the SLV equations to derive site-specific SLVs and screen the BCOIs against the site-specific values as discussed in Section 4.2.; or**
- **Proceed to collection of fish/shellfish data for comparison with ATLs/CTLs**.

4.2 SITE-SPECIFIC SEDIMENT SCREENING LEVELS

If you choose not to take a response action on the basis of generic SLVs, you have the option of using site-specific SLVs to evaluate bioaccumulation potential. You can do this by modifying one or more of the parameters in the exposure equations used to develop the generic ATLs and SLVs based on site-specific conditions. These equations are given in Appendix C and Appendix D.

Site-specific parameters that may be appropriate for your site are factors like BSAF values (Burkhard, 2003 and 2006), fish consumption rates for humans, fish ingestion rates for wildlife, area-use factors, or other factors like fraction of organic carbon in the sediment or fraction of lipid content in the organism. Sites should be evaluated to determine if there are subsistence fishers or if tribal treaty rights are a beneficial use. If subsistence fishing is occurring or if tribal treaty rights apply to the body of water, appropriate fish consumption rates should be used to develop site-specific screening values (Table A-2 in Appendix A).

If you are considering making any changes like this, be sure to discuss your proposed changes with the DEQ project manager and get approval prior to making them.

After calculating site-specific SLVs, compare the EPC of each BCOI to its *site-specific* bioaccumulative screening level as described in Sub-section 4.1. If any of the COIs are COPCs on the basis of the site-specific SLVs, bioaccumulation could be a threat to humans or wildlife that consume fish, shellfish, and other aquatic organisms.

Evaluate if there is a potential for a group of two or more contaminants to generate cumulative bioaccumulation risk as described in Sub-section 4.1, substituting the site-specific SLVs for the generic SLVs.

SUMMARY: If there are no COPCs on the basis of the *site-specific* SLVs, either on an individual basis (Equation 1) or a cumulative basis, no further action is required for bioaccumulation.

If you identify one or more bioaccumulative COPCs as a result of the process described in Section 4.2, you can either:

- **Carry out a response action for each COPC at the site as discussed in Section 6, or**
- **Use existing or collect new aquatic organism data to determine if an unacceptable bioaccumulation risk is present, or**
- **Use bioaccumulation test data to determine if an unacceptable bioaccumulative risk is present as discussed in Section 5.**

5. ACCEPTABLE FISH TISSUE LEVELS

5.1 ACCEPTABLE TISSUE LEVELS

If you choose not to take a response action on the basis of site-specific SLVs, you have the option of using existing bioaccumulation bioassay data, if available, or performing biological tests to evaluate bioaccumulation potential. Compared with modeling or use of generic BSAF values, empirical testing is preferred for evaluating bioaccumulation because relationships between total chemical concentrations in sediment and their concentrations in fish are very complex. Biological availability, environmental effects, and interactions between chemicals and receptors are difficult to quantify and are, therefore, sources of uncertainty.

Using bioassay data, risk to humans, wildlife that eat fish, and to the fish themselves due to bioaccumulation can be evaluated by comparing fish tissue data to the following criteria:

- Acceptable tissue levels for humans (ATLh);
- Acceptable tissue levels for wildlife (ATLw); and
- Critical tissue levels (CTL) for fish.

ATLh values are concentrations of bioaccumulative chemicals in fish tissue that will not result in an unacceptable risk to humans who consume the fish at the stated ingestion rate. Table A-3 contains generic ATLh values for carcinogens and noncarcinogens at different fish consumption rates. The fish consumption rates cover the range considered by EPA in deriving ambient water quality criteria (AWQC). We assume that the fish consumed are resident fish potentially impacted by chemicals in sediment.

ATLw values are concentrations of bioaccumulative chemicals in fish tissue that will not cause significant adverse effects to birds and mammals that consume the fish. Table A-3 lists generic ATLw values. The Great Blue Heron was selected as the receptor representing protection of piscivorous birds. The eagle (individual) and osprey (population) were selected as the receptors for protection of eggs from piscivorous birds.

CTL values are concentrations of bioaccumulative chemicals in tissue that will not cause significant adverse effects on the health of fish, shellfish, and other aquatic organisms containing those chemicals. Table A-4 lists generic CTL values protective of populations and individuals of threatened or endangered species.

The derivation of the three tissue-level parameters ATLh, ATLw and CTL are discussed in Appendix C. The equations used to calculate ATLs for humans and wildlife are given in Sections C.1 and C.2, respectively, and the equations for CTLs are in Section C.3. If appropriate, you may use these equations to calculate *site-specific* ATLs or CTLs, which you can use in place of the generic values. Then use the equations in Appendix D to calculate site-

specific SLVs based on site-specific ATLs or CTLs. Methods for obtaining tissue levels are described in Section 5.2.

Fish and shellfish are expected to contain background levels of naturally-occurring inorganic chemicals. DEQ has not determined background levels of chemicals in fish and shellfish tissues, so a comparison of measured contaminant levels with regional background tissue levels cannot be made at this time.

5.2 Determining Tissue Levels

5.2.1 Using Fish/Shellfish -Tissue Data

If fish/shellfish -tissue data are available from the site or a comparable nearby location, you can use those data to evaluate bioaccumulation potential. Key parameters from the data set should, of course, match those that are required to evaluate bioaccumulation potential for your project. For example, you would need to have similar contaminants, fish/shellfish species, and aquatic environment to ensure that your calculations would have a high probability of mimicking the bioaccumulation that is occurring at the site. If appropriate fish/shellfish -tissue data are not available, you can collect fish/shellfish from your site or use caged fish, mussels, or other *in situ* caged animals for this purpose. In some cases caged mussels may be preferred since that test is somewhat more standardized.

> If you intend to use an exotic species such as fathead minnows or *Corbicula* in a caged test, you should contact the Oregon Department of Fish and Wildlife and the US Fish and Wildlife Service because you must not introduce exotic species into an area where they are not already present.

The home ranges of fish and other aquatic organisms collected at a site have uncertainties associated with them. Conservative assumptions on home ranges, however, can still be used to develop screening levels for evaluating a site. Although uncertainties in life history of species of concern will exist for all ecological species, there are ways that uncertainty can be reduced within the process, including the collection of fish and invertebrates with a smaller home range, and that maintain a strong connection with the sediment. These species may include clams, sculpin, or crayfish. Somewhat larger ranging, but localized fish such as smallmouth bass may also be appropriate. The selection of localized species for site-specific evaluations will reduce the uncertainty. During the development of the screening bioaccumulative values, it is assumed that birds, mammals, and humans eat similar amounts of benthic invertebrates as they do fish and that rates of bioaccumulation are similar. Total ingestion rates used to calculate ATLs are based on fish but could be proportioned out for dietary preferences on a site-specific basis to adjust ATLs for birds, mammals, and humans. Collection of benthic invertebrates and vertebrates help to refine the exposure modeling. If you are considering this option, be sure to discuss this with

the DEQ project manager to ensure that appropriate aquatic species are collected and analyses performed.

If fluoranthene and/or pyrene are COIs at your site, then sampling of tissue should consider a range of invertebrates and vertebrates at your site to account for the difference in metabolic capabilities. In addition, it may be necessary to conduct a literature search for an appropriate bird TRVs for fluoranthene, as it was not available at the time of this guidance development.

Life expectancy of fish is also an important factor in selecting an appropriate candidate fish to sample. For many bioaccumulative chemicals, the longer the life expectancy of the fish, the greater potential for bioaccumulation. Life expectancy along with life history should be considered in selecting relevant fish species to sample.

To evaluate the bioaccumulation potential, compare tissue data to the ATLh values in Table A-3, the ATLw values in and Table A-4, and the CTL values in Table A-5. Use the 90UCL or the maximum concentration, whichever is less, as the tissue concentration. Concentrations greater than the table values indicate that bioaccumulation could be a threat to humans or wildlife that consume aquatic organisms or to the organisms themselves.

SUMMARY: If there are no COPCs on the basis of measured fish and/or shellfish tissue concentrations and ATLs or CTLs, no further action is required for bioaccumulation.

If you identify one or more bioaccumulative COPCs as a result of the process described in Sub-section 5.2.1, you can either:

- **Carry out a response action for each COPC at the site as discussed in Section 6; or**
- **If you think that chemicals in fish are not due to exposure to your site sediments, perform controlled bioaccumulation tests, either in the lab or in situ, as described in Sub-section 5.2.2. Use the fish/shellfish-tissue data from one or more of these tests to determine if an unacceptable bioaccumulative risk is present**.

5.2.2 Bioaccumulation Bioassays

If you decide to use bioaccumulation bioassays, the DEQ recommends that you use one or more of the tests described in Appendix E. Questions about these tests or proposals for different tests should be directed to the DEQ project manager.

If you use one of these tests, you can either assume that fish tissue concentrations equal the invertebrate tissue concentrations, or use the invertebrate tissue concentrations in a food-web model to estimate fish-tissue concentrations for the species of interest.

6. RESPONSE ACTIONS

6.1 IF A BIOACCUMULATOR IS DETECTED

After evaluating the options for assessing bioaccumulation that are previously described in this document, if you have one or more chemicals that are bioaccumulators, and present or potentially present unacceptable risk you will have to develop a response action to bring the risk from these compounds down to acceptable levels.

A response action can be carried out by means of an engineering evaluation/cost analysis (EE/CA) and a removal, or by a feasibility study (FS) and a remedial action depending on where you are in the overall site evaluation and remediation process. Your target cleanup level would be the generic SLV, the site-specific SLV, or ND, whichever is highest.

If you have information showing clearly that one or more of the BCOIs are present as a result of area-wide contamination from other sources in addition to site-specific releases, you should bring that information to the DEQ to discuss the need to develop a broader approach, potentially on a watershed basis, for remedial action in the area. Examples 2 and 3 show how to determine the baseline level of such contaminants depending upon the number of available data points. Note, however, that although it may not be feasible to remediate to below ambient levels, if these concentrations exceed acceptable risk levels ambient concentrations will not be the final cleanup levels for the site and additional remediation may be necessary in the future. A periodic review of conditions will be required, typically on a five to ten year cycle.

Example 2

This example for determining ambient concentrations is for a site with at least 5, but less than 50, upstream samples.

At Site A, 17 sediment samples are collected in the upstream area and the resulting contaminant concentrations are evaluated statistically to determine the 90UCL for each contaminant. The method used for this calculation depends on the frequency of detection of each contaminant.

1. If the frequency of detection is greater than or equal to 85% and there are at least 9 samples, calculate the 90^{th} percentile of the data as follows:

   a. First, determine if the data are normally or log normally distributed using a standard statistical test such as Shapiro-Wilk or Kolmogorov-Smirnov.

   b. Depending on the distribution of the data, calculate the 90^{th} percentile of the data.

2. If the frequency of detection is greater than or equal to 85% and there are at least 5 samples but less than 9 samples, calculate the 95^{th} percentile of the data by using the interquartile (IQR) approach as follows:

   a. Arrange the data in numerical order from the lowest to the highest value and determine the median of the data set.

   b. Identify the datum that lies halfway between the median and the highest datum. This value is the

upper quartile. The datum that lies halfway between the median and the lowest datum is the lower quartile. If there is an even number of samples in any group there will not be a single datum at the halfway point. In that case, calculate the average of the two data points that are on each side of the halfway point.

c. Calculate the IQR as the difference between the upper quartile and lower quartile.

d. Estimate the 95th percentile of the data as the median of the data set plus 2 times the IQR. Use this estimate to approximate the 90th percentile of the data set.

3. If the frequency of detection is greater than or equal to 50% but less than 85% and there are at least 5 samples, calculate the 90th percentile of the data by Cohen's method as described in Case 2 of the *Supplement to Statistical Guidance for Ecology Site Managers* (WDOE 1998).

4. If the frequency of detection is less than 50%, use the maximum detected value for the 90th percentile of the data.

5. If all samples are non-detect, use the minimum repeatedly achieved reporting limit for the 90th percentile of the data.

After using the appropriate method(s) to calculate the 90th percentile for the data set, the ambient/baseline value for each chemical is the lesser of the 90th percentile and the maximum detected concentration unless that value is less than the minimum repeatedly-achieved reporting limit, in which case the minimum repeatedly-achieved reporting limit is used.

Ambient/baseline values are not estimated for data sets with fewer than 5 samples.

The results of the analysis for site A are presented in Table F-1 in Appendix F.

Implications: Active cleanup areas are identified in sediment at the site through a combination of risk-based levels and exceedances of ambient/baseline concentrations. In this case, because the ambient concentrations were generally low, it was determined that this cleanup would be protective considering what the residual site-wide concentrations would be, after the remedial action.

Example 3

This example is for a site with 50 or more data points in the water body both upstream and downstream of the site.

A broad-scale sediment sampling effort is conducted in the water body impacted by Site B. This includes the collection of approximately 300 sediment samples. The results are evaluated as follows:

1. Sort the concentration data by contaminant. Where a contaminant is not detected, use a value of ½ the analytical detection limit. If a detection limit is not reported by the laboratory, use 0.167 times the analytical reporting limit because analytical reporting limits are typically about 3 times the analytical detection limit. DEQ will also consider more sophisticated methods for addressing non-detect values.

2. List the results for each contaminant from lowest to highest concentration and plot them on a linear graph (see Figure F-1 in Appendix F for an example with DDE data).

3. The intersection of the asymptote to the lower part of the curve with the y-axis on the right side of the plot is considered to be the maximum baseline concentration.

For the DDE example in Figure F-1 the baseline value is 7 ppb.

Implications: Although the health-based screening criteria for DDE, considering the potential for bioaccumulation and associated food chain impacts, is 0.03 ppb, DEQ concluded that active cleanup of DDE at the site to concentrations below 7 ppb was not feasible. A remedial action objective for DDE was established at the baseline concentration of 7 ppb. Once cleanup to this concentration was achieved, DEQ issued a conditional No Further Action determination, which indicated that further active remediation was not required at the site at this time, but that a full NFA could not be provided until protective concentrations were achieved through a combination of implementation of watershed-wide source control actions by other parties and natural recovery. Periodic review of conditions will be required on ten year cycle.

6.2 IF NO BIOACCUMULATOR IS DETECTED

If no chemicals exceed ATLs or CTLs, then the risk assessment would conclude the bioaccumulation pathway does not pose an unacceptable risk, and would similarly present conclusions concerning the risk evaluation for toxicity, and risks associated with other media of concern.

6.3 COMPLIANCE MONITORING

After you complete the removal action or the remediation you will have to monitor the site to confirm that the objective of reducing the availability of site-related contaminants to fish, shellfish, and other aquatic prey animals has been achieved. This could include sediment sampling, and/or biota sampling, if relevant. In cases where the sediment work has been part of a larger project to improve a watershed, estimating the reduction in the overall contaminant load may be another way to assess success.

Appendix A.

Tables for Bioaccumulation Screening

Table A-1

Table A-1a: Sediment Bioaccumulation Screening Level Values (SLVs)

Chemical	**CASRN**	**Birds** *(a)* (mg/kg dry wt)		**Mammals** *(b)* (mg/kg dry wt)		**Fish** (mg/kg dry wt)		**Humans** *(c)* (mg/kg dry wt)		**Inorganic Background** (mg/kg dry wt.)
		Individual *(d)*	**Population** *(e)*	**Individual** *(d)*	**Population** *(e)*	**Freshwater**	**Marine**	**General** *(f)*	**Subsistence** *(g)*	**Freshwater**
Arsenic	7440-38-2	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	7
Cadmium	7440-43-9	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	1
Chlordane	12789-03-6	0.010	0.051	0.028	0.056	0.00050	0.00047	0.00037	4.6E-5	NA
DDT (Total)	NA	0.00043 9.5E-5 *(i)*	0.0013 0.00034 *(i)*	0.0049	0.024	0.00039	0.00039	0.00033 *(j)*	4.0E-5 *(j)*	NA
Dieldrin	60-57-1	0.00037	0.0018	0.0012	0.0061	0.0022	0.0022	8.1E-6	1.0E-6	NA
Dioxin / Furan Congeners	NA	Table A-1b	Table A-1b	Table A-1b	Table A-1b					NA
Fluoranthene	206-44-0	NA	NA	360	1,800	37	37	510	62	NA
Hexachlorobenzene	118-74-1	NA	NA	NA	NA	61	61	0.019	0.0023	NA
Lead	7439-92-1	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	17
Mercury (measured as total inorganic mercury)	7439-97-6	*(h) (k)*	*(h) (k)*	*(h) (k)*	*(h) (k)*	*(h)*	*(h)*	*(h)*	*(h)*	0.07
Pentachlorophenol	87-86-5	NA	NA	0.33	3.3	0.31	0.17	0.25	0.030	NA
PCB Congeners	NA	Table A-1b	Table A-1b	Table A-1b	Table A-1b	Table A-1b	Table A-1b	Table A-1b	Table A-1b	NA
PCBs (total as Aroclors) **Bird egg**	NA	0.057 0.0018 *(i)*	0.17 0.091 *(i)*	0.044	0.084	0.022	0.047	0.00039	4.8E-5	NA
Pyrene	129-00-0	NA	NA	18,000	90,000	1.9	1.9	380	47	NA
Selenium	7782-49-2	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	*(h)*	2
2,3,7,8-TCDD **Bird egg**		7.0E-7 1.7E-6 *(i)*	3.5E-6 3.5E-6 *(i)*	5.2E-8	1.4E-6	5.6E-7	5.6E-7	9.1E-9	1.1E-9	NA
Tributyltin	56-35-9	1.6	4.1	0.73	1.1	0.0023	0.00037	0.085	0.010	NA

NA = not applicable or not available
Footnotes follow Table A-1b below

Table A-1b: SLVs for Designated Dioxin/Furan and PCB Congeners

CHEMICAL	CASRN	Birds *(a)* (mg/kg dry wt)		Mammals *(b)* (mg/ dry wt)		Fish (mg/kg dry wt)		Humans *(c)* (mg/kg dry wt)	
		Individual *(d)*	Population *(e)*	Individual *(d)*	Population *(e)*	Freshwater	Marine	General	Subsistence
Dioxin/Furan Congeners									
2,3,7,8-TCDD		7.0E-7 1.7E-6 *(i)*	3.5E-6 3.5E-6 *(i)*	5.2E-8	1.4E-6	5.6E-7	5.6E-7	9.1E-9	1.1E-9
1,2,3,7,8-PeCDD		2.1E-5	1.1E-4	1.5E-6	4.2E-5	1.7E-5	1.7E-5	2.7E-7	3.4E-8
1,2,3,4,7,8-HxCDD		4.2E-4	2.1E-3	1.5E-5	4.2E-4	3.4E-5	3.4E-5	2.7E-6	3.4E-7
1,2,3,6,7,8-HxCDD		2.1E-3	1.1E-2	1.5E-5	4.2E-4	1.7E-3	1.7E-3	2.7E-6	3.4E-7
1,2,3,7,8,9-HxCDD		2.1E-4	1.1E-3	1.5E-5	4.2E-4	1.7E-3	1.7E-3	2.7E-6	3.4E-7
1,2,3,4,6,7,8-HpCDD		5.3E-1	2.7E+0	3.9E-3	1.1E-1	4.3E-1	4.3E-1	6.9E-4	8.5E-5
OCDD		5.3E+0	2.7E+1	1.3E-1	3.6E+0	4.3E+0	4.3E+0	2.3E-2	2.8E-3
2,3,7,8-TCDF		5.9E-6	3.0E-5	4.3E-6	1.2E-4	9.5E-5	9.5E-5	7.7E-7	9.4E-8
1,2,3,7,8-PeCDF		5.9E-5	3.0E-4	1.4E-5	4.0E-4	9.5E-5	9.5E-5	2.6E-6	3.1E-7
2,3,4,7,8-PeCDF		7.0E-7	3.5E-6	1.7E-7	4.7E-6	1.1E-6	1.1E-6	3.0E-8	3.7E-9
1,2,3,4,7,8-HxCDF		2.1E-4	1.1E-3	1.5E-5	4.2E-4	1.7E-4	1.7E-4	2.7E-6	3.4E-7
1,2,3,6,7,8-HxCDF		2.1E-4	1.1E-3	1.5E-5	4.2E-4	1.7E-4	1.7E-4	2.7E-6	3.4E-7
2,3,4,6,7,8-HxCDF		2.1E-4	1.1E-3	1.5E-5	4.2E-4	1.7E-4	1.7E-4	2.7E-6	3.4E-7
1,2,3,7,8,9-HxCDF		2.1E-4	1.1E-3	1.5E-5	4.2E-4	1.7E-4	1.7E-4	2.7E-6	3.4E-7
1,2,3,4,6,7,8-HpCDF		5.3E-2	2.7E-1	3.9E-3	1.1E-1	4.3E-2	4.3E-2	6.9E-4	8.5E-5
1,2,3,4,7,8,9-HpCDF		5.3E-2	2.7E-1	3.9E-3	1.1E-1	4.3E-2	4.3E-2	6.9E-4	8.5E-5
OCDF		5.3E+0	2.7E+1	1.3E-1	3.6E+0	4.3E+0	4.3E+0	2.3E-2	2.8E-3
PCB Congeners *(m)*									
3,3',4,4'-TCB	PCB 77	8.0E-6	4.0E-5	3.0E-4	8.1E-3	3.2E-3	3.2E-3	5.2E-5	6.4E-6
3,4,4',5-TCB	PCB 81	4.0E-6	2.0E-5	9.8E-5	2.7E-3	6.5E-4	6.5E-4	1.7E-5	2.1E-6
2,3,3',4,4'-PeCB	PCB 105	3.9E-3	1.9E-2	9.4E-4	2.6E-2	6.2E-2	6.2E-2	1.7E-4	2.1E-5
2,3,4,4',5-PeCB	PCB 114	4.0E-2	2.0E-1	9.8E-4	2.7E-2	6.5E-2	6.5E-2	1.7E-4	2.1E-5
2,3',4,4',5-PeCB	PCB 118	4.9E-2	2.4E-1	1.2E-3	3.3E-2	7.9E-2	7.9E-2	1.2E-4	2.6E-5

2',3,4,4',5-PeCB	PCB 123	4.9E-2	2.4E-1	1.2E-3	3.3E-2	7.9E-2	7.9E-2	2.1E-4	2.6E-5
3,3',4,4',5-PeCB	PCB 126	3.9E-6	1.9E-5	2.8E-7	7.8E-6	6.2E-5	6.2E-5	5.0E-8	6.2E-9
2,3,3',4,4',5'-HxCB	PCB 156	4.9E-3	2.4E-2	1.2E-3	3.3E-2	7.9E-2	7.9E-2	2.1E-4	2.6E-5
2,3,3',4,4',5-HxCB	PCB 157	4.9E-3	2.4E-2	1.2E-3	3.3E-2	7.9E-2	7.9E-2	2.1E-4	2.6E-5
2,3',4,4',5,5'-HxCB	PCB 167	4.9E-2	2.4E-1	1.2E-3	3.3E-2	7.9E-2	7.9E-2	2.1E-4	2.6E-5
3,3',4,4',5,5'-HxCB	PCB 169	4.9E-4	2.4E-3	1.2E-6	3.3E-5	7.9E-2	7.9E-2	2.1E-7	2.1E-8
2,3,3',4,4',5,5'-HpCB	PCB 189	2.7E-1	1.4E-0	6.6E-3	1.8E-1	4.3E-1	4.3E-1	1.2E-3	1.4E-4

Notes for Table A-1:

Values represented from food web model going from sediment to fish and then to piscivorous birds, mammals, and humans.
See Appendix D for the SLV development methodology.

(a) The Great Blue Heron was the selected receptor for protection of piscivorous birds. The eagle (individual) and the osprey (population) were the selected receptors for protection of eggs from piscivorous birds.
(b) Mink was the selected piscivorous mammal receptor.
(c) Calculated from SLV = foc x ATL / (BSAF x fL) where ATL is the acceptable tissue level for humans. See Table A-3.
(d) Based on individual ATLs derived from a no observed adverse effects level (NOAEL). See Table A-3.
(e) Based on population ATLs derived from a low observed adverse effects level (LOAEL). See Table A-3.
(f) Based on general/recreational fish ingestion rate of 0.0175 kg/day.
(g) Based on subsistence/ tribal fish ingestion rate of 0.1424 kg/day.
(h) Screen using either site specific or default regional background concentrations (shown in the column on the right in this table).
(i) Value represents the safe level for bird egg development based on methodology in Appendix C. SLV listed for DDT is protective of bird egg development for DDE.
(j) Value for DDE.
(k) Sites with mercury contamination should collect actual fish tissue data at the site. Site-specific conditions regulate the methylization process form sediment or water into aquatic receptors.
(l) Based on CTLs (Table A-4).
(m) The presentation of SLVs for dioxin-like PCB congeners does not imply that analysis of PCB congeners in sediment samples will be required. Analysis of PCB congeners in fish and shellfish (see Table A-3a) is usually more relevant. However, if analysis of PCB congeners is performed in sediment, the SLVs can be used as screening values.

Table A-2.

Table A-2a: Exposure Parameters Used to Calculate Screening Level Values

Parameter	Units	Description	Value
$ATLh_C$	mg/kg	Acceptable carcinogen tissue level	Calculated
$ATLh_N$	mg/kg	Acceptable noncarcinogen tissue level	Calculated
ARL_C	unitless	Acceptable risk level for carcinogens	1×10^{-6}
ARL_N	unitless	Acceptable risk level for non-carcinogens	1
AT	Years	Averaging time	70
ED	Years	Exposure duration	30
SFo	$(mg/kg/day)^{-1}$	Slope factor – oral	See Table 2b
RfD	mg/kg/day	Reference dose	See Table 2b
BW	Kg	Body weight – adult human	70
IR_P	Kg/day	Ingestion rate of fish by humans (from EPA's AWQC for general and subsistence)	Recreational & General = 0.0175 Subsistence & Tribal = 0.1424
SLV_{BH}	mg/kg	Sediment bioaccumulation screening level for humans	Calculated
BSAF	Kg-oc/Kg-lipid	Biota-sediment accumulation factor for organics	See Table 6
f_{oc}	Unitless	Fraction of total organic carbon	0.01
f_L	Unitless	Fraction of lipid content	Humans = 0.03 Wildlife = 0.05
TRV_W	mg/kg/day	Toxicity reference value for wildlife	See Table 7
IR_W	Kg/day	Ingestion rate (wet wt.) by wildlife	Heron = 0.42 Mink = 0.137
BW_W	Kg	Body weight – wildlife	Heron = 2.39 Mink = 1
ATL_W	mg/kg	Acceptable tissue level for wildlife	See Table 3
$ATL_{W\text{-}egg}$	mg/kg	Acceptable tissue level for bird eggs (Wiemeyer et al. 1993)	See Table 3
BMF_{egg}	Unitless	Biomagnification factor – fish tissue to bird eggs (Henny 2003)	See Table 6
SLV_{BW}	mg/kg	Sediment bioaccumulation SLV for fish-eating wildlife	Calculated

NA = not applicable or not available
Footnotes follow Table A-2b below

Table A-2b: Table: Human Toxicity Values Used to Calculate Screening Level Values

CHEMICAL	CASRN	Slope Factor *(a)* $(mg/kg/day)^{-1}$	Reference Dose *(a)* (mg/kg/day)
Arsenic	7440-38-2	1.5	0.0003
Cadmium	7440-43-9	NA	0.001
Chlordane	12789-03-6	0.35	0.0005
4,4'-DDD	72-54-8	0.24	0.0005
4,4'-DDE	72-55-9	0.34	0.0005
4,4'-DDT	50-29-3	0.34	0.0005
DDT (Total)	NA	0.34*(c)*	0.0005
Dieldrin	60-57-1	16	0.00003
Dioxin and Furan Congeners (as 2,3,7,8-TCDD TEQ)	NA	1.5×10^5	NA
Fluoranthene	206-44-0	NA	0.04
Hexachlorobenzene	118-74-1	1.6	0.0008
Lead	7439-92-1	*(d)*	*(d)*
Mercury (measured as organic mercury)	7439-97-6	NA	0.0001
Pentachlorophenol	87-86-5	0.12	0.03
PCB Congeners (as 2,3,7,8-TCDD TEQ)	NA	1.5×10^5	NA
PCBs (total as Aroclors)	NA	2	0.00002
Pyrene	129-00-0	NA	0.03
Selenium	7782-49-2	NA	0.005
Tributyltin	56-35-9	NA	0.0003

Notes for Table A-2

(a) Source: EPA's Integrated Risk Information System (IRIS), 2006.
(b) NA = not applicable.
(c) Use the slope factor for 4,4'-DDE.
(d) Slope factors and RfDs are not available for lead. In their study of the Columbia River Basin (USEPA 2002c), EPA used the Integrated Exposure Uptake Biokinetic (IEUBK) model and the Adult Lead Model (ALM) to calculate acceptable levels of lead in fish consumed by humans.

Table A-3

Table A-3a: Acceptable Tissue Levels (ATLs) for Chemicals in Fish/Shellfish Consumed by Wildlife and Humans

		Wildlife				Humans			
		Birds (mg/kg wet wt.)		Mammals (mg/kg wet wt.)		Carcinogens (mg/kg wet wt.)		Non-carcinogens (mg/kg wet wt.)	
CHEMICAL	CASRN	**Individual** *(c)*	**Population** *(d)*	**Individual** *(c)*	**Population** *(d)*	**General / Recreational** *(a)*	**Subsistence / Tribal** *(b)*	**General / Recreational** *(a)*	**Subsistence / Tribal** *(b)*
Arsenic	7440-38-2	13	64	7.6	38	0.0062	0.00076	1.2	0.15
Cadmium	7440-43-9	8.4	42	5.6	28	NA	NA	4.0	0.49
Chlordane	12789-03-6	1.2	6.1	3.3	6.7	0.027	0.0033	2.0	0.25
DDT (Total) **Bird egg**	NA	0.051 0.013 *(e,g,j)*	0.15 0.048 *(e,h,j)*	0.58	2.9	0.027	0.0034	2.0	0.25
Dieldrin	60-57-1	0.044	0.22	0.15	0.73	0.00058	0.000072	0.12	0.015
Dioxin and Furan Congeners	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoranthene	206-44-0	NA	NA	190	950	NA	NA	160	20
Hexachlorobenzene	118-74-1	NA	NA	NA	NA	0.0058	0.00072	3.2	0.39
Lead	7439-92-1	9.3	46	34	170	NA	NA	0.5 *(k)*	0.5 *(k)*
Mercury (measured as total inorganic mercury or methyl mercury)	7439-97-6	0.074 0.18 *(f)*	0.15 0.89 *(f)*	0.12	0.20	NA	NA	0.40	0.049
Pentachlorophenol	87-86-5	NA	NA	0.18	1.8	0.078	0.0096	120	15
PCB Congeners	NA	NA	NA	NA	NA	NA	NA	NA	NA
PCBs (total as Aroclors) *(i)*	NA	1.1 0.035 *(e,g)*	3.4 1.8 *(e,h)*	0.88	1.7	0.0047	0.00057	0.08	0.0098
Pyrene	129-00-0	NA	NA	9,500	47,000	NA	NA	120	15
Selenium	7782-49-2	0.23	0.46	0.036	0.88	NA	NA	20	2.5
TCDD, 2,3,7,8-, TEQ **Bird egg**	NA	8.0E-6 1.9E-5 *(e,g)*	4.0E-5 4.0E-5 *(e,h)*	5.8E-7	1.6E-5	6.2E-8	7.6E-9	NA	NA
Tributyltin	56-35-9	39	96	17	26	NA	NA	1.2	0.15

Table A-3b: ATLs for Selected Dioxin/Furan Congeners in Fish/Shellfish Consumed by Wildlife and Humans

	Birds (mg/kg wet wt.) *(c)*		**Mammals** (mg/kg wet wt.) *(d)*		**Carcinogens** (mg/kg wet wt.)	
	Individual *(e)*	**Population** *(f)*	**Individual** *(e)*	**Population** *(f)*	**General/Rec** *(a)*	**Subsistence/Tribal** *(b)*
Dioxin/Furan Congeners						
2,3,7,8-TCDD	8.0E-6 1.9E-5 *(e)*	4.0E-5 4.0E-5 *(e)*	5.8E-7	1.6E-5	6.2E-8	7.6E-9
1,2,3,7,8-PeCDD	8.0E-6	4.0E-5	5.8E-7	1.6E-5	6.2E-8	7.6E-9
1,2,3,4,7,8-HxCDD	1.6E-4	8.0E-4	5.8E-6	1.6E-4	6.2E-7	7.6E-8
1,2,3,6,7,8-HxCDD	8.0E-4	4.0E-3	5.8E-6	1.6E-4	6.2E-7	7.6E-8
1,2,3,7,8,9-HxCDD	8.0E-5	4.0E-4	5.8E-6	1.6E-4	6.2E-7	7.6E-8
1,2,3,4,6,7,8-HpCDD	8.0E-3	4.0E-2	5.8E-5	1.6E-3	6.2E-6	7.6E-7
OCDD	8.0E-2	4.0E-1	2.0E-3	5.4E-2	2.1E-4	2.5E-5
2,3,7,8-TCDF **Bird egg**	8.0E-6 3.3E-4 *(g)*	4.0E-5 1.7E-3 *(h)*	5.8E-6	1.6E-4	6.2E-7	7.6E-8
1,2,3,7,8-PeCDF	8.0E-5	4.0E-4	2.0E-5	5.4E-4	2.1E-6	2.5E-7
2,3,4,7,8-PeCDF	8.0E-6	4.0E-5	2.0E-6	5.4E-5	2.1E-7	2.5E-8
1,2,3,4,7,8-HxCDF	8.0E-5	4.0E-4	5.8E-6	1.6E-4	6.2E-7	7.6E-8
1,2,3,6,7,8-HxCDF	8.0E-5	4.0E-4	5.8E-6	1.6E-4	6.2E-7	7.6E-8
2,3,4,6,7,8-HxCDF	8.0E-5	4.0E-4	5.8E-6	1.6E-4	6.2E-7	7.6E-8
1,2,3,7,8,9-HxCDF	8.0E-5	4.0E-4	5.8E-6	1.6E-4	6.2E-7	7.6E-8
1,2,3,4,6,7,8-HpCDF	8.0E-4	4.0E-3	5.8E-5	1.6E-3	6.2E-6	7.6E-7
1,2,3,4,7,8,9-HpCDF	8.0E-4	4.0E-3	5.8E-5	1.6E-3	6.2E-6	7.6E-7
OCDF	8.0E-2	4.0E-1	2.0E-3	5.4E-2	2.1E-4	2.5E-5
PCB Congeners						
3,3',4,4'-TCB	PCB 77	1.6E-4	8.0E-4	5.8E-3	1.6E-1	6.2E-4	7.6E-5
3,4,4',5-TCB	PCB 81	8.0E-5	4.0E-4	2.0E-3	5.4E-2	2.1E-4	2.5E-5
2,3,3',4,4'-PeCB	PCB 105	8.0E-2	4.0E-1	2.0E-2	5.4E-1	2.1E-3	2.5E-4
2,3,4,4',5-PeCB	PCB 114	8.0E-1	4.0E+0	2.0E-2	5.4E-1	2.1E-3	2.5E-4

2,3',4,4',5-PeCB	PCB 118	8.0E-1	4.0E+0	2.0E-2	5.4E-1	2.1E-3	2.5E-4
2',3,4,4',5-PeCB	PCB 123	8.0E-1	4.0E+0	2.0E-2	5.4E-1	2.1E-3	2.5E-4
3,3',4,4',5-PeCB	PCB 126	8.0E-5	4.0E-4	5.8E-6	1.6E-4	6.2E-7	7.6E-8
2,3,3',4,4',5'-HxCB	PCB 156	8.0E-2	4.0E-1	2.0E-2	5.4E-1	2.1E-3	2.5E-4
2,3,3',4,4',5-HxCB	PCB 157	8.0E-2	4.0E-1	2.0E-2	5.4E-1	2.1E-3	2.5E-4
2,3',4,4',5,5'-HxCB	PCB 167	8.0E-1	4.0E+0	2.0E-2	5.4E-1	2.1E-3	2.5E-4
3,3',4,4',5,5'-HxCB	PCB 169	8.0E-3	4.0E-2	2.0E-5	5.4E-4	2.1E-6	2.5E-7
2,3,3',4,4',5,5'-HpCB	PCB 189	8.0E-1	4.0E+0	2.0E-2	5.4E-1	2.1E-3	2.5E-4

Notes for Table A-3:

(a) Based on a fish ingestion rate of 0.0175 kg/day.
(b) (b) Based on a fish ingestion rate of 0.1424 kg/day.
(c) The Great Blue Heron was the selected receptor for protection of piscivorous birds. The eagle (individual) and the osprey (population) were the selected receptor for protection of eggs from piscivorous birds.
(d) Mink was the selected piscivorous mammal receptor.
(e) Individual ATLs are derived from a no adverse effects level.
(f) Population ATLs are derived from a low adverse effects level.
(g) Value represents safe level for eagle (individual) egg development based on methodology in Appendix C. Applies only to osprey or eagle receptors.
(h) Value represents safe level for osprey (population) egg development based on methodology in Appendix C. Applies only to osprey or eagle receptors.
(i) Ecological SLVs based on Aroclor 1254.
(j) Osprey egg value is based on DDE because it is more toxic to bird-egg development than DDT.
(k) Value taken from Columbia River Basin (USEPA 2002c)

Table A-4

Table A-4: CTLs for Chemicals in Fish, Shellfish, and Other Aquatic Organisms

CHEMICAL	CASRN	Recommended BCF *(c)* (l/Kg)	Freshwater		Marine		Note
			National Recommended WQC *(a)* (µg/l)	CTL (mg/kg) wet weight	National Recommended **WQC** *(a)* (µg/l)	CTL (mg/kg) wet weight	
Arsenic	7440-38-2	44	150	6.6	36	1.6	*(a)*
Cadmium	7440-43-9	64	0.25	0.15	8.8	0.15	*(b)(e)*
Chlordane	57-74-9	14,000	0.0043	0.06	0.004	0.056	*(d)*
4,4'-DDT	50-29-3	54,000	0.001	0.054	0.001	0.054	*(d)*
4,4'-DDE	72-55-9	54,000	0.001	0.054	0.001	0.054	*(d)*
4,4'-DDD	72-54-8	54,000	0.001	0.054	0.001	0.054	*(d)*
Dieldrin	60-57-1	4700	0.056	0.26	0.056	0.26	*(d)*
Lead	7439-92-1	49	2.5	0.12	8.1	0.40	*(b) (d)*
Pentachlorophenol	87-86-5	11	15	0.17	7.9	0.087	*(d)*
PCBs (Total as Aroclors)	1336-36-3	31,000	0.014	0.43	0.03	0.93	*(d)*
PCB Congeners (see 2,3,7,8-TCDD TEQs)	*(f)*	*(f)*	*(f)*	*(f)*	*(f)*	*(f)*	*(f)*
Pyrene	129-00-0	30	300 *(g)*	1.0	300 *(g)*	1.0	*(d) (g)*
Selenium	7782-49-2	4.8	5.0	0.024	71	0.34	*(d)*
Tributyltin	56573-85-4	866	0.063	0.055	0.010	0.0087	*(d)*
Dioxins and Furan Congeners (as 2,3,7,8-TCDD TEQs)	1746-01-6	*(f)*	*(f)*	6.4E-6	*(f)*	6.4E-6	*(e)*
Fluoranthene	206-44-0	1200	16	19	16	19	*(d) (g)*
Hexachlorobenzene	118-74-1	8700	3.68	32	3.68	32	*(d) (g)*
Mercury, inorganic (mercuric chloride)	33631-63-9	7,342	0.012	0.088	0.025	0.18	*(d)*
Mercury, organic (methyl mercury)	22967-92-6	*(f)*	*(f)*	*(f)*	*(f)*	*(f)*	*(f)*

Notes for Table A-4:

(a) National Recommended Water Quality Criteria (WQC) (USEPA, 2004).
(b) Cadmium and lead criteria are hardness dependent and were calculated using a hardness of 100 milligrams per liter.
(c) See Appendix C for a discussion on how the recommended bioconcentration factor (BCF) was chosen.
(d) The recommended tissue screening levels were calculated by multiplying the National Recommended Water Quality Criteria by the recommended BCFs
(e) See Appendix C for discussion on how species sensitivity distributions values were calculated. Values presented are based on a species protection level of 95%.
(f) Not available or not applicable.
(g) WQC developed by USEPA are not available for these chemicals. DEQ developed their own values, as presented in Appendix C. Pyrene value includes an adjustment using an acute/chronic ratio of 9.

Table A-5

Table A-5a: Default Uptake Values for Estimating Concentrations in Fish Tissue

CHEMICAL	CASRN	Kd (unitless)	Log_{10} Kow (unitless) *(a)*	Biota-Sediment Accumulation Factor (BSAF) (kg oc/kg lipid) *(b)*	BMFegg Eagle *(c)*	BMFegg Osprey *(d)*
Arsenic	7440-38-2	29	NA	NA	NA	NA
Cadmium	7440-43-9	6.7	NA	NA	NA	NA
Chlordane	12789-03-6	NA	6.32	24	NA	NA
4,4'-DDD	72-54-8	NA	6.10	24	NA	NA
4,4'-DDE	72-55-9	NA	6.76	28	75	87
4,4'-DDT	50-29-3	NA	6.53	24	NA	NA
DDT (Total)	NA	NA	NA	24	NA	NA
Dieldrin	60-57-1	NA	5.37	24	NA	NA
Dioxin and Furans (as 2,3,7,8-TCDD)	NA	NA	See Table A-5b	See Table A-5b	16	10
Fluoranthene	206-44-0	NA	5.12	0.105	NA	NA
Hexachlorobenzene	118-74-1	NA	5.89	0.105	NA	NA
Lead	7439-92-1	900	NA	NA	NA	NA
Mercury	7439-97-6	NA	NA	NA	2.8	2.8 (f)
Pentachlorophenol	87-86-5	NA	5.09	0.105	NA	NA
PCBs (congeners as 2,3,7,8-TCDD TEQs)	NA	NA	See Table A-5b	See Table A-5b	NA	NA
PCBs (total as aroclors)	1336363	NA	4.53 - 6.79 *(e)*	4*(h)*	113	11
Pyrene	129-00-0	NA	5.11	0.105	NA	NA
Selenium	7782-49-2	5	NA	NA	NA	NA
Tributyltin (oxide)	56-35-9	NA	3.84 (e)	4.70 *(g)*	NA	NA

Notes for Table A-5a:

(a) Taken from EPA's Soil Screening Guidance (USEPA 1996) except as noted.
(b) (WDOH 1995), 75th percentile (except for tributyltin oxide). Developed using logKow values that may not match values in USEPA 1996.
(c) Used as representative of threatened and endangered species. Taken from Buck, 2004, Table 23.
(d) Used a representative of non-threatened and endangered species. Taken from Henny et al., 2003, Table XI.
(e) Oak Ridge National Laboratory, Risk Assessment Information System (http://rais.ornl.gov/), May 2006.
(f) BMF is for bald eagle eggs because osprey data are not available.
(g) Linear interpolation of USACE 2007 data. Only invertebrate data are available.
(h) Value for Aroclors 1242, 1248, and 1254 taken as representative of most PCB Aroclors in sediment. Rounded from 3.962 (WDOH 1995).

Table A-5b: Default Uptake Values for Values for Designated Congeners

CHEMICAL		logKow (b)	Toxic Equivalency Factor (TEF) (unit less) *(a)*			Biota-Sediment Accumulation Factor (BSAF) *(b)* (kg oc/kg lipid)
			Bird	Fish	Mammal and Human	
Dioxin/Furan Congeners						
2,3,7,8-TCDD		7.02	1	1	1	2.268
1,2,3,7,8-PeCDD		7.5	1	1	1	0.076
1,2,3,4,7,8-HxCDD		7.8	0.05	0.5	0.1	0.076
1,2,3,6,7,8-HxCDD		7.8	0.01	0.01	0.1	0.076
1,2,3,7,8,9-HxCDD		7.8	0.1	0.01	0.1	0.076
1,2,3,4,6,7,8-HpCDD		8.2	<0.001	0.001	0.01	0.003
OCDD		8.6	0.0001	<0.0001	0.0003	0.003
2,3,7,8-TCDF		5.8	1	0.05	0.1	0.27
1,2,3,7,8-PeCDF		6.5	0.1	0.05	0.03	0.27
2,3,4,7,8-PeCDF		7	1	0.5	0.3	2.268
1,2,3,4,7,8-HxCDF		7.5	0.1	0.1	0.1	0.076
1,2,3,6,7,8-HxCDF		7.5	0.1	0.1	0.1	0.076
2,3,4,6,7,8-HxCDF		7.5	0.1	0.1	0.1	0.076
1,2,3,7,8,9-HxCDF		7.5	0.1	0.1	0.1	0.076
1,2,3,4,6,7,8-HpCDF		8	0.01	0.01	0.01	0.003
1,2,3,4,7,8,9-HpCDF		8	0.01	0.01	0.01	0.003
OCDF		8.8	0.0001	<0.0001	0.0003	0.003
PCB Congeners						
3,3',4,4'-TCB	PCB 77		0.05	0.0001	0.0001	3.962
3,4,4',5-TCB	PCB 81		0.1	0.0005	0.0003	3.962
2,3,3',4,4'-PeCB	PCB 105			<0.000005	0.00003	4.134
2,3,4,4',5-PeCB	PCB 114			<0.000005	0.00003	3.962
2,3',4,4',5-PeCB	PCB 118			<0.000005	0.00003	3.26
2',3,4,4',5-PeCB	PCB 123			<0.000005	0.00003	3.26
3,3',4,4',5-PeCB	PCB 126		0.1	0.005	0.1	4.134
2,3,3',4,4',5'-HxCB	PCB 156			<0.000005	0.00003	3.26
2,3,3',4,4',5-HxCB	PCB 157			<0.000005	0.00003	3.26
2,3',4,4',5,5'-HxCB	PCB 167			<0.000005	0.00003	3.26
3,3',4,4',5,5'-HxCB	PCB 169		0.001	<0.000005	0.03	3.26
2,3,3',4,4',5,5'-HpCB	PCB 189			<0.000005	0.00003	0.59

Notes for Table A-5b:

(a) Van den Berg et al., 1998 and 2006.

(b) WDOH 1995. The BSAF is based on the 75th percentile (WDOH 1995). LogKow values for Aroclors ranged from 5.88 to 6.91.

Table A-6.

Table A-6a: Table: Toxicity Reference Values (TRVs)

CHEMICAL	CASRN	Birds (mg/kg/day)				Mammals (mg/kg/day)			
		Individual		Population		Individual		Population	
Arsenic	7440-38-2	2.24	*(a)*	11.2	*(a) (b)*	1.04	*(a)*	5.2	*(a) (b)*
Cadmium	7440-43-9	1.47	*(a)*	7.35	*(a) (b)*	0.77	*(a)*	3.85	*(a) (b)*
Chlordane	12789-03-6	0.214	*(c) (d)*	1.07	*(c) (d)*	0.458	*(c) (d)*	0.915	*(c) (d)*
DDT (Total)	NA	0.009	*(e) (f)*	0.027	*(e)*	0.08	*(c) (e) (d)*	0.4	*(c) (e) (b)*
Bird egg	NA	1	*(g)*	4.2	*(h)*	NA	NA	NA	NA
Dieldrin	60-57-1	0.0077	*(d)*	0.039	*(i) (d)*	0.02	*(d)*	0.1	*(d)*
Dioxin/Furan Congeners (as 2,3,7,8-TCDD TEQs)	NA	1.4E-06	*(e)*	7E-06	*(e)*	8.0E-08	*(j)*	2.2E-06	*(j)*
Bird egg	NA	0.00030	*(k)*	0.00040	*(g) (l)*	NA	NA	NA	NA
Fluoranthene	206-44-0	NA	NA	NA	NA	26	*(m) (n)*	130	*(m) (b) (n)*
Hexachlorobenzene	118-74-1	NA	NA	NA	NA	NA	NA	NA	NA
Lead	7439-92-1	1.63	*(a) (o)*	8.5	*(a) (b)*	4.7	*(a)*	23.5	*(a) (b)*
Mercury (methyl)	7439-97-6	0.013	*(a)*	0.026	*(a)*	0.016	*(e)*	0.027	*(e)*
Bird egg	7439-97-6	0.5	*(p)*	2.5	*(i)*	NA	NA	NA	NA
Pentachlorophenol	87-86-5	NA	NA	NA	NA	0.024	*(c) (d)*	0.24	*(c) (d)*
PCBs (total as 2,3,7,8-TCDD TEQs)	NA	1.4E-06	*(e)*	7E-06	*(e)*	8.0E-08	*(j)*	2.2E-06	*(j)*
PCBs (as Aroclor 1254)	NA	0.2	*(e)*	0.6	*(e)*	0.12	*(q)*	0.23	*(q)*
Bird egg	NA	4	*(r)*	20	*(s) (i)*	NA	NA	NA	NA
Pyrene	129-00-0	NA	NA	NA	NA	1,300	*(m) (n)*	6,500	*(m) (b) (n)*
Selenium	7782-49-2	0.04	*(c) (d)*	0.08	*(c) (d)*	0.005	*(m) (d)*	0.121	*(m) (d)*
Tributyltin	56-35-9	6.8	*(c)*	16.9	*(c)*	2.34	*(c) (d)*	3.5	*(c) (d)*

NA = not applicable or not available
Footnotes follow Table A-6b below

Table A-6b: Toxicity Reference Values for Designated Congeners

CHEMICAL	CASRN	Birds *(t)* (mg/kg/day)		Mammals *(t)* (mg/kg/day)	
		Individual	Population	Individual	Population
Dioxin/Furan Congeners					
2,3,7,8-TCDD		0.0000014 *(e)*	0.000007 *(e)*	0.00000008 *(j)*	0.0000022 *(j)*
1,2,3,7,8-PeCDD		0.0000014	0.000007	0.00000008	0.0000022
1,2,3,4,7,8-HxCDD		0.000028	0.00014	0.0000008	0.000022
1,2,3,6,7,8-HxCDD		0.00014	0.0007	0.0000008	0.000022
1,2,3,7,8,9-HxCDD		0.000014	0.00007	0.0000008	0.000022
1,2,3,4,6,7,8-HpCDD		0.0014	0.007	0.000008	0.00022
OCDD		0.014	0.07	0.000266667	0.0073333
2,3,7,8-TCDF		0.0000014	0.000007	0.0000008	0.000022
1,2,3,7,8-PeCDF		0.000014	0.00007	2.66667E-06	7.333E-05
2,3,4,7,8-PeCDF		0.0000014	0.000007	2.66667E-07	7.333E-06
1,2,3,4,7,8-HxCDF		0.000014	0.00007	0.0000008	0.000022
1,2,3,6,7,8-HxCDF		0.000014	0.00007	0.0000008	0.000022
2,3,4,6,7,8-HxCDF		0.000014	0.00007	0.0000008	0.000022
1,2,3,7,8,9-HxCDF		0.000014	0.00007	0.0000008	0.000022
1,2,3,4,6,7,8-HpCDF		0.00014	0.0007	0.000008	0.00022
1,2,3,4,7,8,9-HpCDF		0.00014	0.0007	0.000008	0.00022
OCDF		0.014	0.07	0.000266667	0.0073333
PCB Congeners *(r)*					
3,3',4,4'-TCB	PCB 77	0.000028	0.00014	0.0008	0.022
3,4,4',5-TCB	PCB 81	0.000014	0.00007	0.000266667	0.0073333
2,3,3',4,4'-PeCB	PCB 105	0.014	0.07	0.002666667	0.0733333
2,3,4,4',5-PeCB	PCB 114	0.14	0.7	0.002666667	0.0733333
2,3',4,4',5-PeCB	PCB 118	0.14	0.7	0.002666667	0.0733333
2',3,4,4',5-PeCB	PCB 123	0.14	0.7	0.002666667	0.0733333
3,3',4,4',5-PeCB	PCB 126	0.000014	0.00007	0.0000008	0.000022
2,3,3',4,4',5'-HxCB	PCB 156	0.014	0.07	0.002666667	0.0733333
2,3,3',4,4',5-HxCB	PCB 157	0.014	0.07	0.002666667	0.0733333
2,3',4,4',5,5'-HxCB	PCB 167	0.14	0.7	0.002666667	0.0733333
3,3',4,4',5,5'-HxCB	PCB 169	0.0014	0.007	2.66667E-06	7.33E-05
2,3,3',4,4',5,5'-HpCB	PCB 189	0.14	0.7	0.002666667	0.0733333

Notes for Table A-6:

(a) TRV from USEPA 2006.
(b) A LOAEL was extrapolated from a NOAEL by multiplying the NOAEL x 5.
(c) Sample, B.W., Opresko, D.M., and Suter II, G.W. ,1996.
(d) An interspecies uncertainty factor of 10 was used.
(e) USEPA 1995.
(f) Extrapolated NOAEL/LOAELs were performed according to the recommended methodology in the reference.
(g) Eagle NOAEL or LOAEL taken from Wiemeyer et al., 1984; Kubiak, T.J. and D.A. Best, 1991; Elliot, J.E. and M.L. Harris, 2001/2002.
(h) DDE LOAEL for the osprey was taken from Wiemeyer et al., 1988.
(i) Population (LOAEL) TRVs were extrapolated from an individual (NOAEL) TRV by multiplying the individual TRV x 5.
(j) Tillitt, D. E., et al. 1996.
(k) Bald Eagle NOAEL and osprey NOAEL and LOAEL taken from Elliot, J.E. and M.L Harris, 2001/2002; Elliot J.E. et al., 1996.
(l) The eagle NOAEL or LOAEL was used as a surrogate for the osprey.
(m) California Department of Toxic Substances Control, 2000.
(n) Calculated Pyrene TRVs from Benzo(a)pyrene TRVs by applying a TEF of 0.001; calculated Fluoranthene TRVs from Benzo(a)pyrene TRVs by applying a TEF of 0.05.
(o) A NOAEL was extrapolated from a LOAEL by multiplying the LOAEL by 0.1.
(p) Mercury NOAEL taken from Wiemeyer et al., 1993.
(q) Total PCB TRVs for mink taken from Millsap et al. 2004.
(r) The PCB NOAEL for bald eagle was taken from Wiemeyer et al., 1984.
(s) 20 mg/kg was also suggested by Elliot, J.E. and M.L. Harris, 2001/2002 for a LOAEL for bald eagles, confirming the relevancy of this number for an osprey LOAEL.
(t) Calculated Dioxin/PCB Congener TRVs from 2,3,7,8 TCDD TRV by applying TEFs from Van den Berg et al., 1998 and 2006.

Table A-7

Table A-7: Analytical Methods and Reporting Limits

CHEMICAL	CASRN	Analytical Method	Method Reporting Limit Sediment *(a)*	Method Reporting Limit Tissue *(b)*
METALS				
Arsenic	7440-38-2	6010C or 7060A	1.0 mg/Kg	100 µg/kg
Cadmium	7440-43-9	6010C or 7131A	1.0 mg/Kg	100 µg/kg
Lead	7439-92-1	6010C	1.0 mg/Kg	500 µg/kg
Mercury	7439-97-6	7471B	2.0 µg/Kg	10 µg/kg
Selenium	7782-49-2	6010C or 7740	2.0 – 10 mg/Kg	100 µg/kg
ORGANICS				
Chlordane	12789-03-6	8081A	5.0 µg/Kg	2 µg/kg
4,4'-DDD	72-54-8	8081A	1.0 µg/Kg	2 µg/kg
4,4'-DDE	72-55-9	8081A	1.0 µg/Kg	2 µg/kg
4,4'-DDT	50-29-3	8081A	1.0 µg/Kg	2 µg/kg
Dieldrin	60-57-1	8081A	1.0 µg/Kg	2 µg/kg
Dioxin and Furans (as 2,3,7,8-TCDD TEQs)	NA	8280, 8290, or 1613B	1-5 ng/Kg	2 ng/kg (ppt)
Fluoranthene	206-44-0	8310 or 8270C	100 µg/Kg	100 µg/kg
Hexachlorobenzene	118-74-1	8081A	660 µg/Kg	100 µg/kg
Pentachlorophenol	87-86-5	8181A or 8270C	1.0 µg/Kg	600 µg/kg
PCBs (individual congeners)	NA	8082 or 1668A	1-5 µg/Kg *(c)*	20 ng/kg (ppt)
PCBs (individual Aroclors)	NA	8081A or 8082	1-10 µg/Kg *(c)*	1-10 µg/Kg *(c)*
Pyrene	129-00-0	8310	100 µg/Kg	100 µg/Kg
Tributyltin	56-35-9	130.00 (NOAA)	10 µg/Kg	10 µg/Kg

Notes for Table A-7:

(a) Method reporting limit (MRL) on a dry-weight basis.
(b) Method reporting limit (MRL) on a wet-weight basis
(c) Method reporting limits for PCBs may require sample extract concentration step and other sample extract cleanup procedures.

Appendix B.

Regional Default Background Concentrations for Soil/Sediment

Regional Default Background Concentrations for Soil/Sediment

When selecting metal background levels for a specific site, the preference for a source of such values is, in order: (1) those calculated from site-specific data (assuming the sampling and analysis were adequate, etc.), (2) local default values (e.g., those for SW Oregon), and (3) the regional default values for the Pacific Northwest listed in the table below. Background values are based on the 90th or 95th percentile of regional soil data.

The regional default values given below can be used (1) to make an initial assessment of a site (before site-specific data are available), (2) if local default values are unavailable, or (3) to check the credibility of site-specific values. They are to be used at the discretion of the DEQ cleanup project manager, can be ignored, and should not be seen as constituting a background "standard" or "criteria". Other sources of background information can be researched from the references section listed in this Appendix.

To determine if site concentrations are greater than background, compare the 90 percent upper confidence limit on the arithmetic mean, or the maximum concentration, whichever is less, to the background value shown in Table B-1.

Table B-1: Oregon DEQ Suggested Default Background Concentrations for Inorganic Contaminants in Soil/Sediment

CHEMICAL	Soil/Sediment (mg/kg, dw)
Arsenic	7 *(a)*
Cadmium	1 *(b)*
Lead	17 *(c)*
Mercury	0.07 *(d)*
Selenium	2 *(e)*

Notes for Table B-1:

(a) State-wide 90th percentile value from WDOE (1994). 95th percentile British Columbia regional soil background estimate for As is 10 mg/kg (BCE, 1999).

(b) State-wide 90th percentile value from WDOE (1994).

(c) State-wide 90th percentile value for Washington (WDOE, 1994). United States geometric mean value is 16 mg/kg (Fuhrer, 1986; Table 7). Lead range in Oregon soils reported as 1.2 to 18 mg/kg (Fuhrer, 1989; Table 8).

(d) 95th percentile British Columbia regional soil background value (BCE, 1999).

(e) State-wide 90th percentile value from WDOE (1994). 95th percentile British Columbia regional soil background estimate for As is 10 mg/kg (BCE, 1999).

References for Appendix B

The following guidance should be considered for developing estimates of background for soil or sediments:

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2. EPA, 2002a. *Role of Background in the CERCLA Cleanup Program.* OSWER 9285.6-07P. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington DC.
3. EPA, 2002b. **Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites, Appendix B: Policy Considerations for the Application of Background Data in Risk Assessment and Remedy Selection.** EPA 540/R-01/003, OSWER 9285.7-41. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington DC.
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10. Nagpal, N. K. and Howell, K., 2001. **Water Quality Guidelines for Selenium, Technical Appendix**. British Columbia Ministry of Water, Land, and Air Protection. Victoria, British Columbia, Canada.
11. Nozaki, Y., 1997. **A fresh look at element distribution in the North Pacific.** EOS electronic supplement, posted May 27, 1997. [www.agu.org/eos_elec/]
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13. Quinby-Hunt, M.S. and Wilde, P., 1986/87. **Modeling of dissolved elements in sea water.** Ocean Science and Engineering, 11:3,4, p. 153-251.
14. Rickert, D.A., Kennedy, V.C., McKenzie, S.W., and Hines, W.G., 1977. **A Synoptic Survey of Trace Metals in Bottom Sediments of the Willamette River, Oregon**. Geological Survey Circular 715-F. U.S. Geological Survey, Arlington, Virginia.
15. WDOE, 1994. **Natural Background Soil Metal Concentrations in Washington State**. Publication #94-115. Washington Department of Ecology, Olympia, WA.

Appendix C.

Calculating Acceptable Tissue Levels

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Critical Tissue Levels

C.1 Acceptable Tissue Levels for Humans

For human consumption, acceptable tissue levels for carcinogens (ATLhC) and noncarcinogens (ATLhN) are back-calculated from acceptable risk levels in accordance with federal guidance for establishing fish consumption limits and for conducting human health risk assessments (USEPA, 1989, 1997). Calculated ATLh values are provided for your use in Appendix A, Table A-3. Separate levels were not calculated for men and women, as differences in consumption rates relative to body weight are minor.

Acceptable fish tissue levels for humans are calculated using the following equations.

For carcinogens:

$$ATLh_C = \frac{ARL_C \cdot BW \cdot AT}{SF_O \cdot IR_P \cdot ED} \qquad [C\text{-}1]$$

and for noncarcinogens:

$$ATLh_N = \frac{RfD \cdot BW \cdot ARL_N}{IR_P} \qquad [C\text{-}2]$$

where:

$ATLh_C$ = Acceptable tissue level (carcinogen) in diet for human receptors (mg/kg);

$ATLh_N$ = Acceptable tissue level (noncarcinogen) in diet for human receptors (mg/kg);

ARL_C = Acceptable risk level for carcinogens (unitless; 1×10^{-6});

ARL_N = Acceptable risk level for noncarcinogens (unitless; 1);

AT = Averaging time (years);

ED = Exposure duration (years);

SFo = Oral slope factor $(mg/kg \cdot d)^{-1}$;

RfD = Reference dose (mg/kg·d);

BW = Body weight (kg); and

IR_P = Fish and/or shellfish ingestion rate for the exposed population (mean daily rate over a year in kg/day).

The default calculations of ATLh do not take into consideration (1) the feeding range of a fish species relative to the area of sediment contaminated by releases from the site, or (2) the fraction of total fish consumed by humans that comes from the site. These factors can be considered in a

site-specific ATLh calculation. If you are considering development of site specific ATLh values, be sure to discuss them with the DEQ project manager and get approval prior to making them.

The ATL values in Table A-3 represent the maximum concentration of a given chemical in fish tissue that will NOT:

1. Generate a risk greater than the maximum acceptable risk level (ARL) used for carcinogens; or
2. Cause adverse noncarcinogenic health effects based on a lifetime of daily consumption at an exposure scenario-specific ingestion rate (IR, see Table A-2).

Therefore, the ATLh values permit a specific population of humans to consume safely any combination of fish and/or shellfish for an extended period, provided that the combined daily consumption rate remains below the value of IR used to calculate ATLh.

EPA has not developed a slope factor or reference dose for lead. The absence of toxicity factors makes evaluation of acceptable tissue levles difficult. EPA addressed this issue during the evaluation of data from the Columbia River basin fish contamination survey (USEPA 2002(c)). They modeled lead exposure using the Integrated Exposure Uptake Biokinetic (IEUBK) model and the Adult Lead Model (ALM). These models take into account lead exposure from a variety of sources (including site sources, and in this case dietary fish sources), and calculate blood lead levels. EPA determined that at a lead concentration of 500 µg/kg in fish, there was a less than 5 percent chance that blood lead levels would exceed the acceptable level of 10 µg/dl in children. EPA also found that a lead concentration of 700 µg/kg in fish tissue consumed by a mother results in less than a 5 percent chance that blood lead levels in a fetus will exceed acceptable levels. The calculations included high fish consumption rates typical of Columbia River tribes. Based on these results using regional data, DEQ is using 500 µg/kg (= 0.5 mg/kg) as an acceptable concentration of lead in fish tissue to protect humans. Given the uncertainties, this value will be applied to both typical and higher fish ingestion rates.

C.2 Acceptable Tissue Levels for Wildlife

An acceptable tissue level for wildlife (ATLw) is the concentration of a contaminant that an animal could consume in its prey that would result in a dose equal to a given toxicity reference value (TRV) without harming the individual animal or the population. This assumes that the animal receives no additional exposure to that contaminant through other environmental media. Calculated ATLw values are provided for your use in Table A-3. An ATLw can be calculated from a TRV for a chemical either at a lowest-observable-effect-level (LOAEL), as a surrogate for populations, or a no-observable-effect-level (NOAEL), as a surrogate for individuals, by assuming a receptor's total diet contains that chemical concentration (Sample et al., 1996).

Values in the "Population" columns of Table A-3 for birds and mammals represent chemical concentrations in sediment at and below which chemicals are not expected to accumulate in the

tissues of prey items (e.g., fish) above LOAEL-based acceptable levels. These values imply the possibility of adverse effects in individuals within a local population but not to the local population as a whole. When the chemical concentration in all food items is constant, the relationship between dose and the concentration in food items can be represented by the following equation:

$$ATLw = \frac{TRV_W}{(IR/BW)} \qquad [C\text{-}3]$$

where:

ATL_W = Acceptable tissue level in diet for wildlife receptors (mg/kg, wet weight diet);

TRV_W = Toxicity reference value for wildlife (mg/kg·body weight day, dry weight; NOAEL-based for individuals, LOAEL-based for populations);

BW = Body weight (kg) (Heron = 2.39 kg and Mink = 1 kg); and

IR = Daily food ingestion rate (kg wet weight/day) (Heron = 0.42 kg/d and Mink = 0.137 kg/d).

Mink and great blue heron were chosen as representative fish-eating receptors for mammals and birds, respectively. Osprey was chosen as the representative fish-eating bird species for the egg pathway when evaluating risk to populations, and eagle was chosen to evaluate risk to individuals of threatened and endangered species. Their diets were assumed to consist entirely of fish. Toxicological information on bird and mammal responses to various chemicals was based on a number of sources listed in Table A-7. Different wildlife species may be evaluated when mink and great blue heron are not present or when other species are more appropriate.

Several extrapolations were made to complete the ATLs if the desired toxicity threshold was not provided. NOAELs were extrapolated to LOAELs by multiplying the NOAEL by 5. LOAELs were extrapolated to NOAELs by multiplying the LOAEL by 0.1. Additionally, dioxin/PCB toxicity equivalency factors (TEFs) were based on Van den Berg (1998 and 2006).

The default calculations of ATLw do not take into consideration:

The entire feeding range of the mammal relative to the part of the range where fish can be found that have been contaminated from sediment at the site, or

The fraction of the total fish consumed by the mammal that comes from the site.

In other words, the default area-use factor for mammals and birds is set at one. This includes the assumption that the receptors are present year-round and that they obtain all of their food from the specific habitat area. While this may not be true for all potential receptors, these assumptions

were used to ensure that the species that do meet the criteria are afforded adequate protection. Both of these factors may be considered if a site-specific ATLw is calculated.

An ecological receptor is generally selected to represent a class of organisms. For this reason you should use risk assessment parameters that represent the other organisms in the class and not just the individual receptor. Values of ATLw should also consider this factor. The feeding range of a particular ecoreceptor may not be confined to the site in question but another member of the same receptor class may use the entire site. The receptor classes could also be changed if the ones that were used to calculate the generic ATLw values are not appropriate for the site. If you are considering making changes, be sure to discuss them with the DEQ project manager and get approval prior to making them.

When data are available for higher trophic level species, they should be incorporated into a food web model or ecological risk assessment. Although these species generally have greater ranges than the area within smaller cleanup sites, their addition can greatly improve confidence in a food web model or when estimating risk. These are often the organisms we are trying to protect, especially in cases where contaminants bioaccumulate in organisms lower in the food chain but not to levels that adversely affect them.

For some chemicals, such as PCBs, DDTs, chlorinated dibenzo-p-dioxins and chlorinated dibenzofurans, the most important and most sensitive effects on birds are to the developing embryos. In this case, an ATLw-egg (in mg-chemical/kg-egg) is developed using NOAELs or LOAELs available from EPA or other sources (e.g., US EPA, April 2003; Henny 2003; and Buck 2004). ATLs for bird eggs are calculated with the following equation:

$$ATL_{W-egg} = \frac{TRV_w}{BMF_{egg}} \qquad [C\text{-}4]$$

where:

ATLW-egg = Acceptable tissue level in fish for protection of eggs of fish-eating birds (mg/kg);

TRVw = Toxicity reference value for bird egg (mg/kg; NOAEL-based for individual eagles, LOAEL-based for osprey populations) (Table A-6).

BMFegg = Biomagnification factor, fish tissue to bird eggs (Table A-5).

C.3 Critical Tissue Levels for Fish

Critical tissue levels (CTLs) represent concentrations in tissue at or below which approximately 95 percent of aquatic organisms bearing this residue would be highly unlikely (less than 5 percent chance) to experience adverse health effects. A CTL is one tool for evaluating the risk to aquatic organisms from internal exposure to chemicals capable of bioaccumulation or biomagnification. A CTL is not species specific, as benthic and pelagic biota appear to have

similar sensitivity to tissue residues, and should therefore meet the protectiveness standard (i.e., avoidance of "significant adverse impacts") under ORS 465.315, and the administrative rules promulgated thereto, for a variety of aquatic ecological receptors.

The two methods used to derive CTLs are presented below.

- The ambient water quality criteria and bioconcentration factor method (AWQC x BCF Method) from Shephard, *et al.* (1998); and
- The species sensitivity distribution method (SSD method), which employs empirical-effects data.

Table C-1, below, summarizes the two databases that were used to select no-observed-effects residue and lowest-observed-effects residue (NOER/LOER) data pairs, and also identifies the chemicals for which CTLs were calculated using the AWQC x BCF method.

C.3.1 WQC x BCF Method

We initially calculated CTLs for chemicals with available WQC in US Environmental Protection Agency's (EPA) "National Recommended Water Quality Criteria" (EPA, 2002a and 2006). WQC were not available for dioxins and furans (as 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxicity equivalents), fluoranthene, hexachlorobenzene, and pyrene. We identified alternative WQC for fluoranthene, hexachlorobenzene, and pyrene following a search of alternative federal, regional, state, and international WQC. A WQC was not identified for dioxins and furans. They were addressed using the SSD method described below.

Table C-1 presents the WQC (chronic unless noted, freshwater and saltwater), recommended BCFs, and WQC x BCF CTLs. Table C-2 presents BCFs that were obtained from the sources described below.

C.3.1.1 WATER QUALITY CRITERIA

WQC were obtained from EPA's "National Recommended Water Quality Criteria" (EPA, 2002a and 2006), with the exception of fluoranthene, hexachlorobenzene, and pyrene.

We compiled water quality criteria from Canadian, Australian, European, and other sources inside or outside the U.S for fluoranthene, hexachlorobenzene, and pyrene. Federal and international water quality criteria were obtained from the following sources (Table C-3):

- EPA Region IV Surface Water Screening Values (EPA, 2001);
- EPA Region V Ecological Screening Levels (ESL) (EPA, 2003);
- EPA Region VI Ecological Benchmarks for Water. According to the Oak Ridge National Laboratories (ORNL) Risk Assessment Information System, "EPA Region 6 recommends

use of surface water benchmarks developed for the Texas Natural Resource Conservation Commission" (http://risk.lsd.ornl.gov/homepage/eco_foot.shtml#80; TNRCC, 2001). Therefore, these state-developed criteria are included in the table of federal and international water quality criteria (Table 3);

- National Oceanic and Atmospheric Administration (NOAA) Screening Quick Reference Tables (SQuiRTs) (NOAA, 1999);
- EPA Ecotox Thresholds (EPA, 1996);
- ORNL Toxicological Benchmarks (Suter and Tsao, 1996);
- Canadian Environmental Quality Guidelines (CEQ, 2005); and
- European Economic Community (EEC) Water Quality Objectives (WQO; Bro-Rasmussen et al., 1994).

State water quality criteria were obtained from the following sources (Table C-4):

- Ohio EPA Water Quality Standards for the Ohio River and Lake Erie Basis. (Ohio EPA, 2005);
- Michigan DEQ Quality Rule 57 Water Quality Values (Michigan DEQ, 2006);
- Minnesota Pollution Control Agency (MPCA) Water Quality Standards; Minnesota Rules Chapter 7050.0222 (MPCA, 2005);
- Colorado Department of Public Health and Environment (DPHE) Basic Standards for Organic Chemicals (Colorado DPHE, 2005);
- Rhode Island Department of Environmental Management (RIDEM) Water Quality Regulations (RIDEM, 2000);
- Nebraska DEQ Chapter 4 – Standards for Water Quality (Nebraska DEQ, 2002);
- Kansas Department of Health and Environment (DHE) Surface Water Quality Standards (Kansas DHE, 2004); and
- Hawaii Department of Health (DOH) Water Quality Standards (Hawaii DOH, 2004).

After reviewing the water quality criteria from these state, federal, and international sources, we decided on using the following water quality criteria:

Fluoranthene. Water quality criteria were identified for fluoranthene that range from 0.04 to 39.8 µg/L. We used the NOAA marine chronic value of 16 µg/L to calculate a CTL for fluoranthene (NOAA, 1999). The value of 16 µg/L is the marine chronic toxicity effect level identified in EPA's Gold Book (EPA, 1986b).

Hexachlorobenzene. Water quality criteria were identified for hexachlorobenzene that range from 0.0003 to 129 µg/L. We used the NOAA freshwater chronic value of 3.68 µg/L to calculate a CTL for hexachlorobenzene (NOAA, 1999). Kansas DEQ also recommends this value as a

chronic aquatic life criterion. The only identified water quality criteria we identified that were lower than 3.68 µg/L are the EPA Region V ESL of 0.0003 µg/L (EPA, 2003) and the EEC WQO of 0.01 µg/L (Bro-Rasmussen et al., 1994). The EPA Region V ESL is equal to the Michigan DEQ Wildlife Value and is considered protective of aquatic life, but was developed in order to protect non aquatic wildlife (Michigan DEQ, 2006). The EEC WQO may be set at the detection limit for hexachlorobenzene.

Pyrene. Water quality criteria were identified for pyrene that range from 0.025 to 300 µg/L. We used the NOAA marine acute value of 300 µg/L to calculate a CTL for pyrene (NOAA, 1999). The value of 300 µg/L is the marine acute toxicity effect level identified in EPA's Gold Book (EPA, 1986b). Because this is an acute value, we divided the 300 µg/L by an acute-to-chronic ratio (ACR) of 9, which was recommended by Burt Shepard at EPA Region 10 (personal communication between Burt Shepard, Toxicologist, EPA Region 10, and Neil Morton, Senior Environmental Scientist, GeoEngineers, on June 9, 2006). The ACR of 9 is the 50th percentile value from a data set of 72 ACR values for 72 chemicals (Fawell and Hedgecott, 1996). The resulting estimated marine chronic water quality criterion is 33.3 µg/L.

C.3.1.2 Bioconcentration Factors

BCFs were obtained from the following sources:

- BCFs were developed using a bilinear model (Bintein, Devillers, and Karcher, 1993) and the octanol-water partition coefficients (Log K_{ow}) for each chemical. The primary and secondary sources for Log K_{ow}s are on-line database developed by Sangster Research Laboratories (SRL, 2006) and Syracuse Research Corporation (SRC, 2005), respectively.
- EPA's Ambient Water Quality Criteria (AWQC) Reports (referenced in Table 2);
- EPA Region 6 guidance: Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities (EPA, 1999) and Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities (EPA, 2005);
- Washington State Department of Ecology (Ecology) Cleanup Level and Risk Calculations (CLARC) on-line database (Ecology, 2005);
- EPA's National Recommended Water Quality Criteria: 2002, Human Health Criteria Calculation Matrix (EPA, 2002b); and
- EPA's Superfund Public Health Evaluation Manual (EPA, 1986a).

We reviewed the BCFs from these sources and decided to use the BCFs from Washington State Department of Ecology's CLARC on-line database for the following reasons:

- The BCFs have been approved by Washington DOE;
- The BCFs were obtained from a 1992 update of EPA's 1986 "Quality Criteria for Water" report (otherwise known as the Gold Book; EPA, 1986b); and

- The BCFs are consistent with those recommended in EPA's National Recommended Water Quality Criteria: 2002, Human Health Criteria Calculation Matrix (EPA, 2002b) and EPA's Superfund Public Health Evaluation Manual (EPA, 1986a). We also recommend using these two documents as secondary sources of BCFs.

Note that the ranges of freshwater and saltwater BCFs from EPA's AWQC documents are included in Table C-2.

C.3.2 SSD Method Data Compilation

We searched two databases to identify studies that concurrently report biological effects and whole-body residues in aquatic organisms. The two databases are the U.S. Army Corps of Engineers Environmental Residue Effects Database (ERED; USACE, 2005) and the EPA Office of Research and Development's effects residue database (Jarvinen and Ankley, 1999; referred to in this report and associated tables as the Society of Environmental Toxicology and Chemistry (SETAC) database).

C.3.2.1 Primary Data Screening Criteria

For each database, the number of data points for each of the chemicals is included in Table C-5. The approach to identifying useable data points followed the approach recommended by Steevens et al. (2005) that included screening studies using the seven primary criteria below. Studies that did not meet these criteria were removed from further consideration.

- No-observed effect residue (NOER)/lowest-observed effect residue (LOER) concentrations had to be reported in the same study;
- Ecologically significant endpoints (growth, survival/mortality, and reproduction) that can be most confidently associated with ecological consequences at the population level. Endpoints included in ERED that were eliminated from consideration included behavior, biochemical, cellular, development, metabolism, morphology, and physiological effects. The SETAC database was limited to endpoints "that consist of, or are directly related to, survival, growth, and reproduction;"
- Whole body residues;
- Laboratory studies with single chemical exposures;
- Exposure route (dietary, waterborne, or maternal exposures) and duration (sufficient to equilibrate within organism);
- Measured data versus modeled; and
- Dose-dependent response demonstrated.

C.3.2.2 Secondary Screening Criteria

A secondary database screen was used to identify matched pairs of data (NOER/LOER) from individual studies that was not initially apparent from the information available in either database. In other words, because individual studies were not obtained and reviewed and some studies reported several NOER and LOER data points, it was difficult to identify which data points represented pairs from the same test. We developed and followed the secondary screening criteria as shown below to facilitate the identification of matched pairs under this scenario. The criteria listed below represent variables that were evaluated in some or all of the tests. NOER/LOER pairs were considered as matched pairs if they came from studies where the variables were the same (e.g., the NOER and LOER were both measured in a test of 60 days using water with a pH of 7.0).

- Chemical (e.g., arsenic trioxide, disodium arsenate);
- Species;
- Life stage (e.g., adult, juvenile);
- Exposure route (e.g., ingestion, absorption);
- Review paper. Some references reported results from multiple studies;
- Study length;
- Temperature;
- Hardness of water;
- pH;
- Salinity; and
- Endpoint (e.g., prenatal mortality versus increased biomass).

A list of NOER/LOER pairs was identified from each database following the secondary screen. Tables that present the NOER/LOER pairs for the 18 chemicals of interest are presented in Appendix A of GeoEngineers 2006.

C.3.2.3 Tertiary Screening Criteria

The NOER/LOER pairs from each database that passed the primary and secondary screening steps were evaluated a final time in a tertiary screening step as shown below. Those NOER/LOER pairs that remained after the third screening were then used as the data set from which SSDs were generated.

- Duplicate NOER/LOER pairs were removed. The ERED and SETAC databases often both reported the same study and results.

- NOER/LOER pairs that overlapped were removed. Some of the NOER/LOER data points were reported in the SETAC database as ranges, rather than individual values. Database pairs were removed when the highest NOER was greater than lowest LOER because unique studies were not obtained and reviewed. In cases where ranges did not overlap, the high end of the NOER range was used as the NOER and the low end of the LOER range was used as the LOER.
- The NOER/LOER pairs remaining after the first two steps of the tertiary screen are shown in the second to last column of Table C-5 as "Acceptable NOER/LOER Pairs."
- Finally, as presented in Steevens et al. (2005), the NOER/LOER pairs associated with a unique species were used or, if multiple NOER/LOER pairs were presented for a single species, the geometric mean for each NOER/LOER pair was calculated and the lowest calculated geometric mean was retained.

The NOER/LOER pairs remaining after the tertiary screen are shown in the last column of Table C-5 as "Acceptable NOER/LOER Pairs (Unique Species)."

C.3.3 SSD Method Calculations

SSDs for cadmium, chlordane, lead, pentachlorophenol, polychlorinated biphenyls (PCBs) as Aroclors, selenium, dioxins and furans (as 2,3,7,8-TCDD), mercury, and 4,4'-dichlorodiphenyltrichloroethane (DDT) were successfully calculated. SSD calculations and associated real space and natural log (ln) space graphs are included in Appendix B of GeoEngineers 2006 for chemicals where there were at least four acceptable NOER/LOER pairs available based on unique species. SSDs were not calculated for arsenic, total PCBs (as 2,3,7,8-TCDD toxicity equivalents), pyrene, organic selenium tributyltin, fluoranthene, hexachlorobenzene, organic mercury, 4,4'- dichlorodiphenyldichloroethylene (DDE), and 4,4'-dichlorodiphenyldichloroethane (DDD) because these chemicals did not have a least four acceptable NOER/LOER pairs.

The NOER/LOER datasets were fit to the following logistic distribution model to calculate SSDs for each chemical:

$$P = \exp[\alpha + \beta*\ln(GM)]/[1 + \exp[\alpha + \beta*\ln(GM)]] \qquad [C\text{-}5]$$

Where,

- P is the cumulative proportion;
- GM is the geometric mean of the NOER and LOER; and
- Alpha (α) and beta (β) are parameters to be estimated. SYSTAT® Version 10 was used to estimate α and β for each chemical. The SYSTAT® model output is included in Appendix C. SYSTAT® was unable to estimate α and β for selenium. α and β were calculated for selenium using an alternate approach described below.

The cumulative proportion was estimated by the following equation:

$$P = i/(n+1) \qquad [C\text{-}6]$$

Where,

- i = the rank of the GM within the data set when GMs are ordered from smallest to largest
- n = the number of data points in the data set

The linear regression form of the logistic distribution model is as follows:

$$\text{logit}(P) = \ln[P/(1-P)] = \alpha + \beta * \ln(GM) \qquad [C\text{-}7]$$

Selenium. Equation 3 was used to estimate α and β, the intercept and slope, respectively, of the line estimated by plotting logit(P) and ln(GM) for the selenium data set. In this case, P is the cumulative proportion estimated for each data point using Equation 2 and the GM is the corresponding geometric mean. Microsoft Excel® was used to estimate α and β for selenium. The results are presented in Appendix B of GeoEngineers 2006.

C.3.3.1 Mean and Confidence Bound Concentrations

Mean concentrations were calculated by rearranging Equation 3 as follows:

$$\text{(Mean = average) } GM = \exp((\text{logit}(P)-\alpha)/\beta) \qquad [C\text{-}8]$$

Where,

- logit(P) = ln[P/(1-P)] where P is a chosen probability, and
- α and β were estimated as discussed above.

Confidence bound concentrations (CBCs) were calculated using the following equations as presented in Species Sensitivity Distributions in Ecotoxicology" (Posthuma et al., 2002). The confidence bounds on the Mean GM (in natural log space) were estimated by solving the following equation for x (lnGM) at a chosen y (P):

$$y = \alpha + \beta * x +/- t * s * (1 + (1/n) + (x\text{-}x\text{bar})^2 / d)^{1/2} \qquad [C\text{-}9]$$

Where,

- α = estimate of the intercept;
- β = estimate of the slope;
- t = critical t-value at level (1-alpha/2) with (n-2) degrees of freedom. 1-alpha is the prediction level;
- s = root mean square error from the regression model;

- n = number of NOER/LOER data points;
- $x$bar = average of lnGM values used for fitting the regression model;
- $d = \text{sum}(x_i\text{-xbar})^2$; and
- y = logit(P) = ln[P/(1-P)].

Upper and lower confidence bounds of the GM (based on a 95% level of significance) were then calculated using the following equation:

$$GM = \exp[(-B +/- (B^2 - 4A*C)^{1/2}) / (2A)] \qquad [C\text{-}10]$$

Where,

- $A = t^2*s^2*n - n*d*\beta^2$;
- $B = 2*\beta*n*d*(y-\alpha) - 2*t^2*s^2*n*x\text{bar}$; and
- $C = t^2*s^2*(d+ n*x\text{bar}^2) - n*d*(y-\alpha)^2$.

C.3.3.2 SSD Method Critical Tissue Levels

After calculating SSDs, we derived CTLs based on a specific species protection level represented by (1-P), which is chosen based on regulatory or other requirements. As discussed in Steevens et al. (2005) and other literature, a level of 95 percent was selected as a representative species protective concentration. This upper bound is meant to protect 95 percent of all aquatic organisms that contact the chemical at this concentration. In other words, 95 percent of all species that contact a chemical at this concentration will show no adverse effects. The 95 percent species protection level corresponds to a P of 0.05.

Table C-1 summarizes the CTLs that we calculated using the WQC x BCF method and the SSD method as discussed above. For the SSD CTLs, the lower and upper confidence bounds are referred to as 95% LCL (95% lower confidence limit) and 95% UCL (95% upper confidence limit) in Table C-1.

C.3.4 CTL Comparison

Table C-6 presents a comparison of the CTLs calculated using the WQC x BCF Method and the SSD Method versus NOER and LOER concentrations from the ERED and SETAC tissue residue databases. The purpose of this comparison was to see whether the CTLs calculated using the WQC x BCF Method are realistic based a comparison to actual tissue residue data. The NOER and LOER concentrations from the ERED and SETAC databases are presented two ways:

- The range of geometric means (NOER/LOER pairs) for each chemical using data from both databases; and

- The range of LOER concentrations for each chemical using data from the ERED database. The ERED database was used for this comparison because it is available electronically and the LOER ranges was readily obtained.

The CTLs calculated using the SSD Method are, by definition, at the low end of these tissue residue ranges. Table C-6 shows that the freshwater CTL for arsenic and the freshwater and saltwater CTLs for hexachlorobenzene calculated using the WQC x BCF Method are either higher than or in the middle of the tissue residue ranges. The freshwater CTL for arsenic is 6,600 µg/kg, while the range of geometric means is 870 µg/kg to 12,550 µg/kg (the range of LOER concentrations is similar). The freshwater and marine CTLs for hexachlorobenzene are 32,000 µg/kg, while the range of geometric means is 7,300 µg/kg to 16,400 µg/kg and the range of LOER concentrations is 63 µg/kg to 27,000 µg/kg.

An alternative for the freshwater arsenic CTL is the use of the saltwater arsenic CTL for both freshwater and saltwater. The saltwater CTL for arsenic is 1,600 µg/kg, which is at the low end of the ranges of geometric means and LOER concentrations.

An alternative WQC for hexachlorobenzene is the EEC Water Quality Objective of 0.01 µg/L. Using this alternative hexachlorobenzene WQC and the BCF presented in Table C-1 results in a hexachlorobenzene CTL of 87µg/kg, which is lower than the range of geometric means and at the low end of the range of LOER concentrations.

C.4 References for Appendix C

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Table C-1: Sources of Data for CTL Calculations

		SETAC Database (Jarvinen and Ankley, 1998)	**ERED Database** (COE, 2005)	**Combined Databases**	
Analyte	**CTLs via BCF Approach?**[1]	**Data Points**[2]	**Data Points**[2]	**Acceptable NOER/LOER Pairs**[3]	**Acceptable NOER/LOER Pairs** (unique species)[4]
Arsenic	Yes	47	154	11	2
Cadmium	Yes	488	1,149	52	**29**
Chlordane	Yes	0	60	4	**4**
Lead	Yes	42	406	7	**4**
Pentachlorophenol	Yes	33	237	9	**4**
Total PCBs (as 2,3,7,8-TCDD TEQs)	Yes	104	188	4	3
Total PCBs (as Aroclors)	Yes	101	233	17	**8**
Pyrene[5]	No	17	35	1	1
Selenium - Inorganic	Yes	136	451	26	**5**
Selenium - Organic		11	0	4	2
Tributyltin	Yes	66	350	3	2
Dioxins and Furans (as 2,3,7,8-TCDD TEQs)	No	94	466	16	**4**
Fluoranthene[6]	No	9	139	3	2
Hexachlorobenzene[7]	No	27	89	2	2
Mercury - Inorganic	Yes	134	366	16	**7**
Mercury - Organic	Yes	105	180	2	2
Total DDT	Yes	102	154	16	**9**
4,4'-DDT	Yes	102	154	16	**9**
4,4'-DDE	Yes	4	131	0	0
4,4'-DDD	Yes	2	15	0	0

Notes for Table :

[1] Critical tissue levels calculated using the BCF x AWQC approach.

[2] Number of studies that simultaneously report both endpoints.

[3] Duplicate NOER/LOER pairs were removed from the combined database.

[4] Only one NOER/LOER pair for each species was used to calculate the species sensitivity distribution for each analyte.

[5] ERED database had one additional LOER data point, while pyrene studies in SETAC database all used the same test species. Only one unique test species for LOER data points.

[6] ERED database had three additional LOER data points, while fluoranthene LOER data points in SETAC database were all determined using the same test species. Four unique test species for LOER data points. However, species are two species of copepods (*Coullana* sp and *Schizopere knabeni*), amphipod (*Diporeia* sp.), and mussel (*Mytilus edulis*).

[7] ERED database had two additional LOER data points, while hexachlorobenzene LOER data points in SETAC database were all determined using the same test species. Only three unique test species for LOER data points.

NOER = No observed effect residue

LOER = Lowest observed effect residue

Shading indicates that there are at least four acceptable NOER/LOER pairs.

TABLE C-2
BIOCONCENTRATION FACTORS
WQC x BCF METHOD
AQUATIC ORGANISM CRITICAL TISSUE LEVEL DEVELOPMENT
OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

			BCFs Calculated from Log(Kow)[1]				BCFs from EPA Ambient Water Quality Criteria Reports (1980s)									EPA Region 6 Ecological Risk Assessment BCFs[3]			EPA Region 6 Human Health Risk Assessment BCFs[4]				MTCA CLARC[5]		NRWQC HH Matrix[6]		EPA SPHEM BCFs[7]	
							Aquatic Organisms						Human Health																
							Freshwater			Saltwater																			
			Sangster Research Laboratories[2]		Syracuse Research Corporation[10]			BCF Range			BCF Range																		
Chemical	CASRN	Recommended BCF	Log(K_{ow})	BCF (L/kg)	Log(K_{ow})[2]	BCF (L/kg)	Recommended Freshwater BCF	Whole Body Tests (animals only)	Other Tests	Recommended Saltwater BCF	Whole Body Tests (animals only)	Other Tests	Recommended BCF	Comment	Source	BCF (l/kg)	Method of BCF Calculation	Species Tested	Fish BCF (L/kg)	Methodology Reference	Surrogate	Surrogate Source	BCF (l/kg)	Source	BCF (l/kg)	Source	BCF (l/kg)	Source
Arsenic	7440-38-2	44	--	--	--	--	-- --	0 to 10 0 to 17	-- --	-- --	-- --	350 350	44 --	WAvg (1 & 350)	EPA 440/5-80-021 EPA 440/5-84-033	114	Geometric mean of 3 lab values	Not reported	114	A	--	--	44	H	44	57 FR60848	44	F
Cadmium	7440-43-9	64	--	--	--	--	766 678.6 --	22 to 12,400 33 to 4,190 33 to 4,190	3 to 7,100 3 to 960 3 to 1,256	3,080 225.7 --	57 to 3,160 22 to 3,160 22 to 3,160	5 to 3,650 5 to 2,040 5 to 2,150	64 -- --	WAvg (11 & 444)	EPA 440/5-80-025 EPA 440/5-84-032 EPA 822-R-01-001	907	Geometric mean of 4 field values	*Catostomus occidentalis, Gasterosteus aculeatus, Ptychocheilus grandis, Oncorhynchus mykiss, Micropterus salmoides*	907	A	--	--	64	H	--	--	81	F
Chlordane	57-74-9	14,000	5.80	15,338	6.16	17,078	4,702	5,200 to 37,800	--	4,702	6,600 to 16,000	--	14,100	Ecological BCF multiplied by 3 to account for 3% lipid content of consumed fish and shellfish	EPA 440/5-80-027	NA	--	--	3,427	B	Log K_{ow} (5.5)	C	14,000	H	14,100	IRIS 02/07/98	14,000	F
Lead	7439-92-1	49	--	--	--	--	331[9]	42 to 1,700	--	458[9]	933 to 1,050	17.5 to 2,570	49	WAvg (3.8 and 375)	EPA 440/5-80-057	0.09	1 field value	*Lepomis macrochiras*	0.09	A	--	--	--	--	--	--	49	F
Pentachlorophenol	87-86-5	11	5.18	6,979	5.12	6,303	-- --	1,000 163 to 1,066	13 7.3 to 406	-- --	13 to 3,830 10.75 to 64	41 to 390 34 to 82	11 --	BCF of 13 adjusted for lipids --	EPA 440/5-80-065 EPA 440/5-86-009	109	Geometric mean of 20 lab values	Not reported, *Morone saxatilis, Carassius auratus, Zeucisens idus melanotus, Cyprinodon variegatus, Funidulus similis, Mugil cephalus, Jordanella floridae, Pimephales promelas*	671	B	Log K_{ow} (5.1)	C	11	H	11	IRIS 07/01/93	770	F
Total PCBs (as Aroclors)	1336-36-3	31,000	--	--	7.1	5,477	10,400	2,700 - 270,000	--	10,400	800 to >670,000	13,000 to >100,000	31,200	Ecological BCF multiplied by 3 to account for 3% lipid content of consumed fish and shellfish	EPA 440/5-80-068	--	--	--	--	--	--	--	31,000	H	31,200	IRIS 06/01/97	100,000	F
Aroclor 1016	12674-11-2	--	--	--	5.69	13,974	--	--	--	--	--	--	--	--	--	22,649	Geometric mean of 4 field values	*Cyprinodon variegatus, Lagodon rhomboides*	20,000	B	Log K_{ow} (5.69)	D	31,000	H	--	--	--	F
Aroclor 1221	11104-28-2	--	--	--	4.65	2,629	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
Aroclor 1232	11141-16-5	--	--	--	4.4	1,598	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
Aroclor 1242	53469-21-9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
Aroclor 1248	12672-29-6	--	--	--	6.2	16,934	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
Aroclor 1254	11097-69-1	--	--	--	6.5	13,955	--	--	--	--	--	--	--	--	--	281,588 (Document states that BCF is 230,394)	Geometric mean of 7 field values	*Pimephales promeles, Sculpins (bottom fish), Pelagic fish, Cynoscion nebulosus,* not reported	84,100	B	Log K_{ow} (6.5)	D	31,000	H	--	--	--	F
Aroclor 1260	11096-82-5	--	--	--	7.55	2,086	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
Total PCBs (as 2,3,7,8-TCDD toxicity equivalents)	1336-36-3	31,000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 77	32598-13-3	--	6.11	17,158	6.63	12,017	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 81	70362-50-4	--	6.53	13,526	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 114	74472-37-0	--	6.72	10,620	6.98	6,890	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 105	32598-14-4	--	6.79	9,549	6.79	9,549	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 118	31508-00-6	--	6.57	12,933	7.12	5,264	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 123	65510-44-3	--	6.64	11,862	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 126	57465-28-8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 156	38380-08-4	--	7.11	5,369	7.6	1,861	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 157	69782-90-7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 167	52663-72-6	--	7.29	3,703	7.5	2,335	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 169	32774-16-6	--	7.55	2,086	7.41	2,854	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
PCB 189	39635-31-9	--	7.24	4,116	8.27	381	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	F
Pyrene	129-00-0	30	5	5,100	4.88	4,089	--	--	--	--	--	--	--	--	--	--	--	--	1180	A	Log Kow (4.9)	B	30	H	30	IRIS 07/01/93	--	
Selenium	7782-49-2	4.8	--	--	--	--	-- --	8 to 78 8 to 470	15 to 18 2 to 11.6	-- --	-- 0 to 11.78	-- 2.88 to 800	16 --	Wavg (15 and 18)	EPA 440/5-80-070 EPA 440/5-87-006	129	Geometric mean of 12 lab values	Not reported, *Leomis reinhardtii, Lepomis macrochirus, Pimephales promelas, Oncorhynchus mykiss, Micropterus salmoides*	129	A	--	--	4.8	H	4.8	1988 Addendum	16	F
Tributyltin	56573-85-4 688-73-3	866	--	--	4.1	866	1,040[8]	240 to 2,250	312 - 17,413	6,073[8]	--	192.3 to 60,000	--	--	EPA 822-R-03-031	--	--	--	--	--	--	--	--	--	--	--	--	--
Dioxins and Furans (as 2,3,7,8-TCDD)	1746-01-6	--					--	--	--	--	--	--	--	--	--				--	--	--	--	--	--	--	--	--	--
Fluoranthene	206-44-0	1,200	5.2	7,215	5.16	6,748	--	--	--	--	--	--	--	--	--	--	--	--	1,410	A	Log Kow (5)	B	1,200	H	1,150	IRIS 07/01/93	1,150	C
Hexachlorobenzene	118-74-1	8,700	5.31	8,602	5.73	14,498	--	--	--	--	--	--	--	--	--	2.53	1 field value	*Freshwater fish*	2,400	A	Log Kow (5.3)	B	8,700	H	8,690	IRIS 11/01/96	8,690	C
Mercury	7439-97-6	7,342.6	--	--	--	--	--	--	--	--	--	--	3,750 4,700 13,000	Probable BCFs for freshwater, estuarine or coastal, and ocean species	EPA 440/5-80-058	--	--	--	NA	--	--	--	--	--	7,342.6	Weighted Average 62 FR42160	5,500 (inorganic) 3,750 (alkyl)	F F
Mercury, inorganic (mercuric chloride)	33631-63-9	--	--	--	--	--	-- 4,994	-- 1,800 to 4,994	-- --	-- 10,000	-- --	3.5 to 10,000 129 to 10,000	-- --	-- --	EPA 440/5-80-058 EPA 440/5-84-026	3,530	Geometric mean of 3 lab values	*Oncorhynchus mykiss, Pimephales promelas*	--	--	--	--	--	--	--	--	--	--
Mercury, organic (methyl mercury)	22967-92-6	--	--	--	--	--	23,000 81,700	-- 10,000 to 85,700	12,000 to 63,000 11,000 to 33,000	40,000 40,000	--	40,000 40,000	-- --	-- --	EPA 440/5-80-058 EPA 440/5-84-026	11,168	Geometric mean of 3 lab values	*Oncorhynchus mykiss, Salvelinus fontinalis*	--	--	--	--	--	--	--	--	--	--
Total DDT	--	54,000	--	--			--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4,4'-DDT	50-29-3	54,000	6.36	15,706	6.91	7,816	17,870	1,200 - 4,426,666	623 - 458,259	17,870	1,200 - 46,500	--	53,600	Ecological BCF multiplied by 3 to account for 3% lipid content of consumed fish and shellfish	EPA 440/5-80-038	--	--	--	16,904	B	Log Kow (6.4)	C	54,000	H	53,600	IRIS 05/01/91	54,000	F
4,4'-DDE	72-55-9	54,000	6.96	7,148	6.51	13,814	--	--	--	--	--	--	--	--	--	26,512 (document states that BCF is 25,512)	Geo mean of 12 lab values (document states that 11 values were used)	Not reported, *Lepomis macrochirus, Oncorhynchus mykiss, Gambusia affinis, Pimephales promelas*	4,886	B	Log Kow (5.7)	C	54,000	H	53,600	IRIS 08/22/88	51,000	F
4,4'-DDD	72-54-8	54,000	6.02	17,022	6.02	17,022	--	--	--	--	--	--	--	--	--	--	--	--	8,317	B	Log Kow (6)	C	54,000	H	53,600	IRIS 08/22/88	--	--

Notes:
[1] Bintein, S. and J. Devillers, 1993. BCF is calculated from Log(Kow) using the bilinear equation log BCF = 0.910 log P - 1.975 log (6.8x10^{-7} P + 1) - 0.786
[2] SRL, 2006. Sangster Research Laboratories. LOGKOW® On-line database (http://logkow.cisti.nrc.ca/logkowIndex.jsp). Last updated May 2, 2006.
[3] EPA, 1999
[4] EPA, 2005
[5] Ecology, 2006
[6] EPA, 2002b
[7] EPA, 1986a
[8] Freshwater and Saltwater BCFs are the geometric mean of the freshwater and saltwater species BCFs included in Table 5 of the referenced 2003 AWQC report for tributyltin.
[9] Freshwater and Saltwater BCFs are the geometric mean of the freshwater and saltwater species BCFs included in Table 5 of the referenced 1980 AWQC report for lead. The recommended BCF is the geometric mean of the freshwater and saltwater BCFs.
[10] SRC, 2005
A = EPA, 1999. Volume III, Appendix C: Media-To-Receptor BCF Values.
B = Meylan et al., 1999.
C = EPA, 2004
D = SRC, 2005
E = Lyman et al., 1982
F = OWRS, U.S. EPA, 1980. Ambient Water Quality Criteria Documents for [Specific Chemical].
G = Total PCBs BCF is based on Aroclor 1254. Lyman et al., 1982 also includes BCFs for Aroclor 1016 (42,500), Aroclor 1248 (70,500), and Aroclor 1260 (194,000).
H = EPA, 1992
l/kg = liters (water) per kilogram (tissue)
BCF = Bioconcentration factor
Shading indicates source of recommended BCFs

TABLE C-3
WATER QUALITY CRITERIA - FEDERAL AND INTERNATIONAL
FLUORANTHENE, HEXACHLOROBENZENE, AND PYRENE
AQUATIC ORGANISM CRITICAL TISSUE LEVEL DEVELOPMENT
OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

All values are in µg/L

		EPA Region IV Surface Water Screening Values (2001)[a]				EPA Region V - Ecological Screening Levels (2003)[b]		EPA Region VI Ecological Benchmarks for Water (2001)[g]				NOAA Screening Quick Reference Tables (1999)[j]								Ecotox Thresholds[n]						ORNL Toxicological Benchmarks (1996)[p]										Canadian Environmental Quality Guidelines[q]				EEC Water Quality Objectives[t]	
Chemical	CASRN	Acute - FW	Chronic - FW	Acute - M	Chronic - M	Water	Notes	Freshwater	Notes	Marine	Notes	Acute - FW	Notes	Chronic - FW	Notes	Acute - M	Notes	Chronic - M	Notes	FW: FCV	Notes	Tier II	Notes	M: FCV	Notes	NAWQ - Acute		NAWQ - Chronic		Fish	Daphnids	Invertebrates	Aquatic Plants	All Organisms	FW	Notes	M	Notes	WQO	Note
Fluoranthene	206-44-0	398	39.8	4	1.6	1.9	c,d	6.16	h	2.96	h	3,980	k	--	--	40	k	16	k	8.1	o	--	--	11	o	33.6	o	6.16	o	30	15	--	54,400	15	0.04	s	--	r	--	--
Hexachlorobenzene	118-74-1	--	--	--	--	0.0003	e	--	--	--	--	6	l	3.68	l	160	k,m	129	k,m	--	--	--	--	--	--	--		--		--	--	--	--	--	--	r	--	r	0.01	u
Pyrene	129-00-0	--	--	--	--	0.3	f	7	i	0.24	i	--		--		300	k,m	--		--	--	--	--	--	--	--		--		--	--	--	--	--	0.025	s	--	r	--	--

Notes:
[a] EPA, 2001
[b] EPA, 2003
[c] Minnesota PCA, 2005. Minnesota Water Quality Standards; "Chronic Standard" = concentration to which aquatic organisms can be exposed indefinitely with no harmful effects.
[d] New ESL data is lower than previous table
[e] Michigan DEQ, 2006. Michigan Water Quality Standards; Value is a "Wildlife Value" and is considered protective of aquatic life.
[f] Region 5, RCRA Interim Criteria (based on Aquire database with acceptable review codes and endpoints (life cycle). Must have eight or more acceptable studies (i.e., chronic and/or acute). http://www.epa.gov/reg5rcra/ca/edql.htm
[g] TNRCC, 2001
[h] These numbers are FCVs calculated by the EPA for use in the derivation of the sediment quality criteria (EPA, 1993).
[i] TNRCC water quality chronic values based on LC50 values in accordance with methodology defined in the TSWQS.
[j] NOAA, 1999
[k] Lowest Observable Effect Level
[l] Proposed
[m] Value is for chemical class and is not chemical-specific
[n] EPA, 1996
[o] Final chronic value derived for EPA Sediment Quality Criteria documeents (EPA, 1993).
[p] Suter and Tsao, 1996
[q] CEQ, 2005
[r] Insufficient data.
[s] Interim guideline.
[t] Bro-Rassmussen et al., 1994
[u] Value appears to be set at detection limit and a note in Table 2 describes a specific reference to persistence and bioaccumulation data
FW = Freshwater
M = Marine
FCV = Final chronic value
NOAA = National oceanic and atmospheric administration
NAWQ = National ambient water quality
WQO = Water Quality Objective

Table C-3: Water Quality Criteria – Federal and International

Table C-4: Water Quality Criteria for Fluoranthene, Hexachlorobenzene and Pyrene by State

All values are in µg/L		Chemical		
		Fluoranthene	**Hexachlorobenzene**	**Pyrene**
	CASRN	206-44-0	118-74-1	129-00-0
Ohio[a]	**IMZM**	7.4	NA	83
	OMZM	3.7	NA	42
	OMZA	0.8	NA	4.6
Michigan[b]	**FCV**	1.6	NA	NA
	AMV	14	NA	NA
	FAV	28	NA	NA
Minnesota[c]	**CS**	1.9	0.061	NA
	MS	3.5	NA	NA
	FAV	6.9	NA	NA
Colorado[d]	**Acute**	3,980	NA	NA
	Chronic	NA	NA	NA
Rhode Island[e]	**FW – Acute**	199	NA	NA
	FW – Chronic	4.4	NA	NA
Nebraska[f]	**Acute**	3,980	6	NA
	Notes	g	g	
	Chronic	370	0.0077	11,000
	Notes	*(h,i)*	*(h,j)*	*(h,i)*
Kansas[k]	**Acute**	3,980	6.0	NA
	Chronic	NA	3.7	NA
Hawaii[l]	**FW – Acute**	1,300	NA	NA
	FW – Chronic	NA	NA	NA

Notes:

(a) Ohio EPA, 2005

(b) Michigan DEQ, 2006

(c) Minnesota PCA, 2005. Hexachlorobenzene value is based on protection of human health.

(d) Colorado DPHE, 2005

(e) RIDEM, 2000

(f) Nebraska DEQ, 2002

(g) Concentration not to be exceeded at any time

(h) Twenty-four hour average concentration

(i) Human health criteria based on the consumption of fish and other aquatic organisms

(j) Human health criteria at the 10-5 risk level for carcinogens based on the consumption of fish and other aquatic organisms

(k) Kansas DEQ, 2004

(l) Hawaii DOH, 2004

IMZM = Inside mixing zone maximum

OMZM = Outside mixing zone maximum

OMZA = Outside mixing zone average

FCV = Final chronic value

AMV = Aquatic maximum value

FAV = Final acute value

CS = Chronic standard (highest concentration of a toxicant to which aquatic organisms can be exposed indefinitely with no harmful effects)

MS = Maximum standard (concentration that protects aquatic organisms from potential lethal effects of a short-term "spike" in toxicant concentrations. O
FW = Freshwater

TABLE C-5: NOER/LOER Database Summary

	Phase 1[1]	Phase 2[2]			
Analyte	**Tissue Screening Level via BCF Approach?**	**SETAC Database** (Jarvinen and Ankley, 1998) **Data Points**[3]	**ERED Database** (COE, 2005) **Data Points**[3]	**Combined Databases Acceptable NOER/LOER Pairs**[4]	**Acceptable NOER/LOER Pairs** (unique species)[5]
Arsenic	Yes	47	154	11	2
Cadmium	Yes	488	1,149	52	29
Chlordane	Yes	0	60	4	4
Lead	Yes	42	406	7	4
Pentachlorophenol	Yes	33	237	9	4
Total PCBs (as 2,3,7,8-TCDD toxicity equivalents)	Yes	104	188	4	3
Total PCBs (as Aroclors)	Yes	101	233	17	8
Pyrene[6]	No	17	35	1	1
Selenium - Inorganic	Yes	136	451	26	5
Selenium - Organic		11	0	4	2
Tributyltin	Yes	66	350	3	2
Dioxins and Furans (as 2,3,7,8-TCDD toxicity equivalents)	No	94	466	16	4
Fluoranthene[7]	No	9	139	3	2
Hexachlorobenzene[8]	No	27	89	2	2
Mercury - Inorganic	Yes	134	366	16	7
Mercury - Organic	Yes	105	180	2	2
Total DDT	Yes	102	154	16	9
4,4'-DDT	Yes	102	154	16	9
4,4'-DDE	Yes	4	131	0	0
4,4'-DDD	Yes	2	15	0	0

Notes:

[1] Tissue screening levels calculated in Phase 1 using the WQC x BCF Method.

[2] Endpoint selection criteria for Phase 2 followed the Stevens et al. (2005) approach.

[3] Number of studies that simultaneously report both endpoints

[4] Duplicate NOER/LOER pairs were removed from the combined database.

[5] Only one NOER/LOER pair for each species will be used to calculate the species sensitivity distrubution for each analyte.

[6] ERED database had one additional LOER data point, while pyrene studies in SETAC database all used the same test species. Only one unique test Species for LOER data points.

[7] ERED database had three additional LOER data points, while fluoranthene LOER data points in SETAC database were all determined using the same test species. Four unique test species for LOER data points. However, species are two species of copepods (*Coullana* sp and *Schizopere knabeni*), amphipod (*Diporeia* sp.), and mussel (*Mytilus edulis*).

[8] ERED database had two additional LOER data points, while hexachlorobenzene LOER datapoints in SETAC database were all determined using the same test species. Only three unique test species for LOER data points.

NOER = No observed effect residue

LOER = Lowest observed effect residue

TABLE C-6: Critical Tissue Levels Check (All Species) WQC X BCF Method and SSD Method

		Water Quality Criteria x BCF Critical Tissue Levels[1]		Species Sensitivity Distribution (95% Species Protection Level) Critical Tissue Levels[2]			ERED and SETAC Databases		ERED Database	
							Number of Values	Range of Tissue Concentrations (Geometric Mean of NOER & LOER)	Number of Values	Range of Tissue Concentrations (LOER Only)
Chemical	**CASRN**	**Freshwater** (µg/kg)	**Saltwater** (µg/kg)	**LCL** (µg/kg)	**Mean** (µg/kg)	**UCL** (µg/kg)	(unitless)	(µg/kg)	(unitless)	(µg/kg)
Arsenic	7440-38-2	6,600	1,600	--	--	--	11	870 - 12,550	7	1,500 - 11,600
Cadmium	7440-43-9	16	560	110	150	180	52	85 - 106,000	58	32 - 3,620,000
Chlordane	57-74-9	60	56	9.8	190	540	4	1,100 - 17,200	8	1,700 - 281,000
Lead	7439-92-1	120	400	1.8E-23	13	400	7	370 - 104,000	8	4,000 - 200,000
Pentachlorophenol	87-86-5	170	87	6.3E+16	8,200	21,000	9	16,700 - 81,000	11	10,800 - 662,000
PCBs (total as Aroclors)	1336-36-3	430	930	21	170	570	17	2,120 - 503,000	8	1,300 - 956,000
PCB Congeners (see 2,3,7,8-TCDD TEQs)	1336-36-3	--	--	--	--	--	4	3,780 - 168,000	3	5,770 - 112,000
Pyrene	129-00-0	1,000	1,000	--	--	--	1	420,000	1	465,000
Selenium	7782-49-2	24	340	4.6	65	150	26	160 - 31,500	30	180 - 29,600
Tributyltin	56573-85-4	55	8.7	--	--	--	3	230 - 2,100	13	13 - 1,170
Dioxins and Furans (as 2,3,7,8-TCDD)	1746-01-6	--	--	2.3E-83	0.0064	0.048	16	0.024 - 524	19	0.04 - 1,380
Fluoranthene	206-44-0	19,000	19,000	--	--	--	3	69,900 - 179,000	7	220 - 789,000
Hexachlorobenzene	118-74-1	32,000	32,000	--	--	--	2	7,300 - 16,400	4	63 - 27,000
Mercury	7439-97-6	88	180	--	--	--	--	--	--	--
Mercury, inorganic (mercuric chloride)	33631-63-9	--	--	3.4	47	170	16	660 - 62,800	15	40 - 73,100
Mercury, organic (methyl mercury)	22967-92-6	--	--	--	--	--	2	5,650 - 5,840	3	700 - 10,000
Total DDT	--	54	54	68	120	170	16	360 - 47,800	17	820 - 68,900
4,4'-DDT	50-29-3	54	54	68	120	170	16	360 - 47,800	17	820 - 68,900
4,4'-DDE	72-55-9	54	54	--	--	-	--	--	3	290 - 2,480
4,4'-DDD	72-54-8	54	54	--	--	--	--	--	1	600

Notes:

[1] The recommended tissue screening levels were calculated by multiplying the National Recommended Water Quality Criteria by the recommended BCFs.

[2] See text for discussion on how species sensitivity distributions values were calculated. Values presented are based on a species protection level of 95%.

-- = Not available or not applicable

CASRN = Chemical Abstracts Service Registry Number

µg/l = micrograms per liter

l/kg = liters (water) per kilogram (tissue)

µg/kg = micrograms per kilogram

LCL = 95% lower confidence limit

Red shading indicates that the critical tissue levels are elevated relative to tissue residue concentrations in the ERED and/or SETAC databases

Green shading indicates that the values presented are questionable.

UCL = 95% upper confidence limit

Appendix D.

Deriving Bioaccumulation Screening Level Values

D. Deriving Bioaccumulation Screening Level Values

Bioaccumulation SLVs represent COI concentrations in sediment which are not expected to result in tissue residue levels that could adversely affect the health of humans or wildlife that consume fish, shellfish, and other aquatic organisms. The details of their derivation are discussed below.

D.1 Wildlife Receptors

Values in the "Individual" columns of Table A-1 for birds and mammals represent chemical concentrations in sediment at and below which chemicals would not be expected to accumulate in the tissues of prey items (*i.e.*, fish) above NOAEL-based acceptable levels. They are the lowest and most protective type of sediment bioaccumulation SLVs. These values should be used in circumstances where fish-eating T&E species are currently or reasonably likely to exist.

Values in the "Population" columns of Table A-1 for birds and mammals represent chemical concentrations in sediment at and below which chemicals would not be expected to accumulate in the tissues of prey items (*i.e.*, fish) above LOAEL-based acceptable levels. These values imply the possibility of adverse effects in individuals within a local population but not to the local population as a whole. They are appropriate at sites where:

- No T&E or sensitive species reside or are likely to reside;
- Critical habitat values are not expected to be a concern;
- Protection is extended only at the population level per OAR 340-122-084(1)(h)(B)(ii); and
- The intent is consistency with the point before significant adverse impacts language of ORS 465.315(1)(b)(A).

"Individual" values should be used if there is doubt as to compliance with these criteria. Bioaccumulation SLVs were calculated as follows:

D.1.1 Organic Chemicals

$$SLV_{BW} = f_{oc} \cdot \left(\frac{ATLw}{BSAF \cdot f_L} \right) \qquad [D\text{-}1]$$

where:

SLV_W = Sediment bioaccumulation screening level value for fish-eating bird or mammal receptors (mg/kg);

ATL_W = Acceptable tissue levels in diet for bird or mammal receptors (mg/kg); NOAEL-based for individuals, LOAEL-based for populations (Table A-3);

BSAF = Biota-sediment accumulation factor for organic COIs (kg sediment organic carbon / kg organism lipid) (Table A-5);

f_{oc} = Fraction of total organic carbon in surface sediment (unitless; default = 0.01); and

f_L = Fraction of organism lipid content of whole-body wet weight (unitless; the default = 0.05).

As shown in equation D-2, BSAF is the ratio of the concentration of a bioaccumulating nonpolar organic chemical in the total extractable lipids of an organism normalized on the lipid fraction, to the concentration in sediment normalized on the organic carbon content of sediment. Note that fish concentrations in the BSAFs are in wet weight and the sediment concentrations are in dry weight.

$$BSAF = \left[\frac{\frac{C_{fish}\,(ug/kg)}{F_L}}{\frac{C_{sed}\,(ug/kg)}{F_{oc}}} \right] \qquad [D\text{-}2]$$

where:

C_{sed} = concentration of contaminant in sediment, dry weight;

C_{fish} = concentration of contaminant in the fish, wet weight;

F_{oc} = organic carbon fraction in sediment, dry weight; and

F_L = lipid fraction in the fish, wet weight.

If you decide to develop site-specific BSAFs, you need to consider the following:

- Organisms with small home-ranges should be selected for BSAF development, as they will be more representative of the study site.
- Sediment samples reflective of the species' home-range should be collected.
- Sediment samples should represent the most recent exposure surface. For fish, this depth should be the shallow surficial depth (e.g. 0 to 2 cm). For deeper burrowing invertebrates, a deeper surficial depth may be more appropriate (e.g. 0 to 5 cm).
- Adequate numbers of tissue and sediment samples should be collected to derive unbiased estimates of the mean concentrations in both media.
- The tissue and sediment collections should be spatially and temporally coordinated such that recent loadings of the chemicals to the ecosystem are relatively unchanged.
- If compositing tissue samples, they should be done by size or age classes due to dietary differences. The mixing of fishes of different species, or size or age class is not recommended.
- Where multiple sediment/tissue pairs are available, regression and other approaches can be used to estimate a BSAF.

For more information on BSAF calculations, you should refer to Burkhard (2003), Burkhard *et al*. (2003), and Burkhard (2006).

For PCBs, we selected a representative BSAF value for the PCBs typically encountered at cleanup sites. The PCBs most frequently encountered at sites include Aroclors 1242, 1248, 1254, and 1260. In WDOH (1995), Table 6 shows the 75th percentile based on chemical class and logKow. For Aroclors 1242, 1248, and 1254 (with logKow values from 6 to 6.48), the BSAF value is 3.962, which rounds to 4.0. For Aroclor 1260 (logKow = 6.91), the BSAF value is 4.134, which rounds to 4.1. We consider a BSAF value of 4.0 appropriate for these PCBs. It is also a conservative value for other PCBs, such as Aroclor 1016, with lower BSAFs.

When using BSAFs, the assumptions are that the sediment is the only source of the BCOIs available to the fish in the habitat, the chemicals in the fish are in equilibrium with those in the sediment, and the chemicals are not transformed when moving from the sediment to the organism. BSAF values are provided inTable A-5. Chemicals that cannot be screened out using these parameters should be evaluated using site-specific sampling of residues in the target receptors.

If total organic carbon (TOC) data are not available for the site, assume that f_{oc} is 1% (0.01). If measured fish lipid data are not available for the site, assume that f_L is 3% (0.03) for human health risk assessments based on consumption of fillets only and 5% (0.05)[11] for human health risk assessments based on consumption of whole fish and for all wildlife risk assessments.

Concentrations greater than the table values indicate that bioaccumulation could be a threat to humans or wildlife that consume fish, shellfish, and other aquatic organisms.

D.1.2 Inorganic Chemicals

Given the difficulties and uncertainties of associating biota concentrations with sediment concentrations of inorganic chemicals, at this time we have decided to not include SLVs for bioaccumulating inorganic chemicals (those listed in Table A-1). Instead, regional background levels will be used as screening values. DEQ will continue to evaluate methods for modeling biota-to-sediment accumulation factors for inorganics. In the interim, if the sediment levels of site-related bioaccumulating inorganics exceed background levels at your site, biota tissue testing will likely be necessary.

[11] Arnot and Gobas (unpublished 2007) use a median value of 5% in their assessment of BCF and BAF values. This value is also supported by Henny et al. (2003) and USEPA (2002c). We recognize that there may be site-specific circumstances where fish are present that have higher lipid contents.

D.2 Human Receptors

Values for humans in Table A-1 represent chemical concentrations in sediment at and below which chemicals would not be expected to accumulate in tissues of fish above levels acceptable for human consumption. These values were calculated as follows:

D.2.1 Organic Chemicals

$$SLV_{BH} = f_{oc} \cdot \left(\frac{ATLh}{BSAF \cdot f_L} \right) \qquad [D\text{-}3]$$

where:

SLV_{BH} = Sediment bioaccumulation screening level value for human population (mg/kg);

BSAF = Biota-sediment accumulation factor for organic COIs (kg sediment organic carbon / kg organism lipid) (Table A-5);

ATLh = The acceptable tissue level for carcinogens or noncarcinogens, whichever is smaller (mg/kg) (Table A-3)

f_{oc} = Fraction of total organic carbon in surface sediment (unitless; default = 0.01); and

f_L = Fraction of organism lipid content of fillet (unitless; default = 0.03).

D.2.2 Inorganic Chemicals

For the same reasons discussed for wildlife receptors in Section D.1.2, SLVs are not provided for inorganic chemicals at this time. If the sediment levels of site-related bioaccumulating inorganics exceed background levels at your site, biota tissue testing will likely be required.

D.2.3 SLVs for Populations Other Than the General Population

The human bioaccumulation SLVs shown in the "General" column of Table A-1 are based on the lower of the carcinogen or non-carcinogen acceptable tissue levels for the general population, default (75^{th} percentile) BSAF values, and an assumption that only fillets are consumed. These SLVs are therefore protective of general and recreational populations but may not be protective for subsistence, Native American populations engaged in traditional fish consumption practices, or for populations consistently consuming whole fish, for example in soups, stews or bullion. At sites where there is a current or reasonably likely future use by these other populations, SLVs based on acceptable tissue levels for these populations (the "Subsistence" column of Table A-1) should be used.

D.3 Fish and Other Aquatic Receptors

The SLVs in Table A-1 represent chemical concentrations in sediment at and below which chemicals would not be expected to accumulate in tissues of fish or other aquatic organisms above levels acceptable to the organisms. These values were calculated as follows:

D.3.1 Organic Chemicals

$$SLV_{BF} = f_{oc} \cdot \left(\frac{CTL}{BSAF \cdot f_L} \right) \qquad [D\text{-}4]$$

where:

SLV_{BF} = Sediment bioaccumulation screening level value for fish and other aquatic organisms (mg/kg);

BSAF = Biota-sediment accumulation factor for organic COIs (kg sediment organic carbon / kg organism lipid) (Table A-5);

CTL = Critical tissue level for fish and other aquatic organisms (mg/kg) (Table A-3)

f_{oc} = Fraction of total organic carbon in surface sediment (unitless; default = 0.01); and

f_L = Fraction of organism lipid content (unitless; default = 0.05).

D.3.2 Inorganic Chemicals

For the same reasons discussed for wildlife receptors in Section D.1.2, SLVs are not provided for inorganic chemicals at this time. If the sediment levels of site-related bioaccumulating inorganics exceed background levels at your site, biota tissue testing will likely be necessary.

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Appendix E.

Bioaccumulation Test Methods

E.1 Using Standard Test Organisms

Laboratory bioaccumulation tests provide an estimate of contaminant uptake by benthic organisms. In addition, data from such tests can be used to evaluate the potential for transfer of contaminants to higher organisms. In general, all laboratory bioaccumulation tests involve exposing test organisms to sediment for a 28-day period without providing any supplemental food.[12] The test duration of 28 days is generally required for most chemicals to approach a steady-state[13] between the sediment and the test organisms. It also reflects the practical limitations of test organism health and survival associated with longer test periods.

Two species from two different niches (suspension-/filter-feeding and burrowing, deposit-feeding) should be exposed to sediment collected from the site. Different test animals are used for freshwater and marine sediments. Test animals are also exposed to a control sediment to establish that contaminants were not introduced during the course of testing via laboratory water, glassware, or some other source unrelated to the sediment being tested and that the test animals are in good health. A reference sediment is not used because resulting tissue residue levels will be compared to acceptable tissue levels.

E.1.1 Freshwater Tests

Adult Oligochaete (*Lumbriculus variegatus*): The oligochaete worm *Lumbriculus variegates* (*L. variegates*) is a burrowing/deposit-feeder and is perhaps the most commonly used test species for evaluating bioaccumulation in freshwater sediments and the only freshwater bioaccumulation test species for which the EPA has a published test method (USEPA, 2000). In general, most bioaccumulation test species are selected because they are not easily killed by the contaminants thereby ensuring that a sufficient number of animals will survive to the end of the test for subsequent tissue analysis. *L. variegatus* is actually quite sensitive and has been used as a toxicity test species. Consequently, a 96-hour toxicity-screening test should be performed to ensure that the sample is not overly toxic prior to expending the resources to set-up the bioaccumulation study. Conduct the bioaccumulation test with *L. variegatus* using either EPA Method 100.4 (USEPA (2000) or ASTM Method E 1688-97a (1998). Use EPA Method 100.3 (USEPA (2000) for the 96-hour toxicity screening.

Adult Bivalve (*Corbicula fluminea*): *Corbicula fluminea* (*C. fluminea*) is a suspension/filter-feeder. Though there are no standard methods currently available for testing with *C. fluminea*, researchers have used it in other studies because mollusks represent a potentially important vector for the transfer of contaminants to higher organisms. Test methods described below

[12] The presence of food may alter bioavailability of the compound and/or alter its rate of uptake.

[13] Certain chemicals, such as DDT, require longer periods to approach steady-state and an adjustment factor may be required to account for this.

represent a compilation of generic guidance (Lee *et al.*, 1993) and published studies where *C. fluminea* has been used (Baudrimont *et al.*, 1997; Mac *et al.*, 1990).

Obtain test animals with soft tissue weights of approximately 1 gram wet weight through commercial suppliers. Use 20 to 30 animals in each of five replicate test chambers per sediment treatment. Ask the suppliers to document the sources of the organisms and provide control sediment from the areas where the animals were collected.

Conduct the test in 39-liter (L) glass aquaria or similar containers with 5-cm layers of sediment (approximately 2-3 L of sediment is required per container). Place sediment into the aquaria and add water twenty-four hours prior to adding test animals. Place the aquaria in a flow-through system with a flow rate of 0.1 L/min. Acclimate the animals to the test conditions by allowing them to live under those conditions for 1 to 2 days before testing.

Conduct the test using a 12-hours of light/12-hours of dark photoperiod at a temperature of 20 ± 1°C. Don't aerate the system unless dissolved oxygen falls below 40% and don't feed the animals for the duration of the experiment. Monitor water quality hardness, alkalinity, conductivity, pH, and total ammonia at the beginning and the end of the test, and check the temperature, dissolved oxygen and flow rate daily. Examine the test chambers daily to evaluate survival and remove dead animals.

When the test is over, remove the animals by gently sieving the sediment through a 1-mm mesh sieve. You should assume that any gaping animals that are unresponsive to gentle prodding are dead and exclude them from subsequent tissue analysis. Transfer all surviving organisms from an individual replicate to an aquarium containing clean water and leave them there for 24 hours to purge the contents of their gut. After this 24-hour period, place the animals in clean containers and freeze them. Submit the frozen samples for analysis for bioaccumulative COPCs.

E.1.2 Marine / Estuarine Tests

Conduct marine and estuarine bioaccumulation tests with appropriate benthic marine organisms. Our current recommendation is that you test both a burrowing polychaete (*Nereis virens*, *Nepthys*, or *Arenicola marina*) and a deposit-feeding bivalve mollusk (*Macoma nasuta*). Many species can metabolize PAHs and give a misleading indication of bioaccumulation potential. Therefore, it is essential that you include in the tests one or more species with very low ability to metabolize PAHs. Bivalve mollusks like *M. nasuta* are widely accepted as meeting this requirement. Methods for performing marine bioaccumulation tests are fully described in ASTM Method E 1688-97a (1998), Lee *et al.* (1993), and USEPA/USACE (1994).

E.2 Using Caged Test Organisms

Laboratory testing has the advantage of removing doubt that an organism is being exposed to site-related sediment but has the disadvantage of accounting for few, if any, additional site-

specific factors. *In situ* tests are thus useful in that they can provide more realistic measures of exposure accounting for the influence of site-specific conditions on contaminant uptake. Like laboratory bioassays, *in situ* tests can be confounded by factors unrelated to sediment exposure (*e.g.*, short-term changes in turbidity, current flow, *etc.*). Unlike laboratory bioassays, which are conducted in a controlled setting, there is a greater potential for such factors to go undetected. *In situ* tests have been conducted successfully and there are many examples in the published literature where such tests have helped to elucidate environmental effects (Rice and White, 1987; Gale *et al.*, 1997). Methods for conducting *in situ* exposures are determined largely by the site characteristics and species being evaluated.

Appendix F.

Data and Graph for Example 2

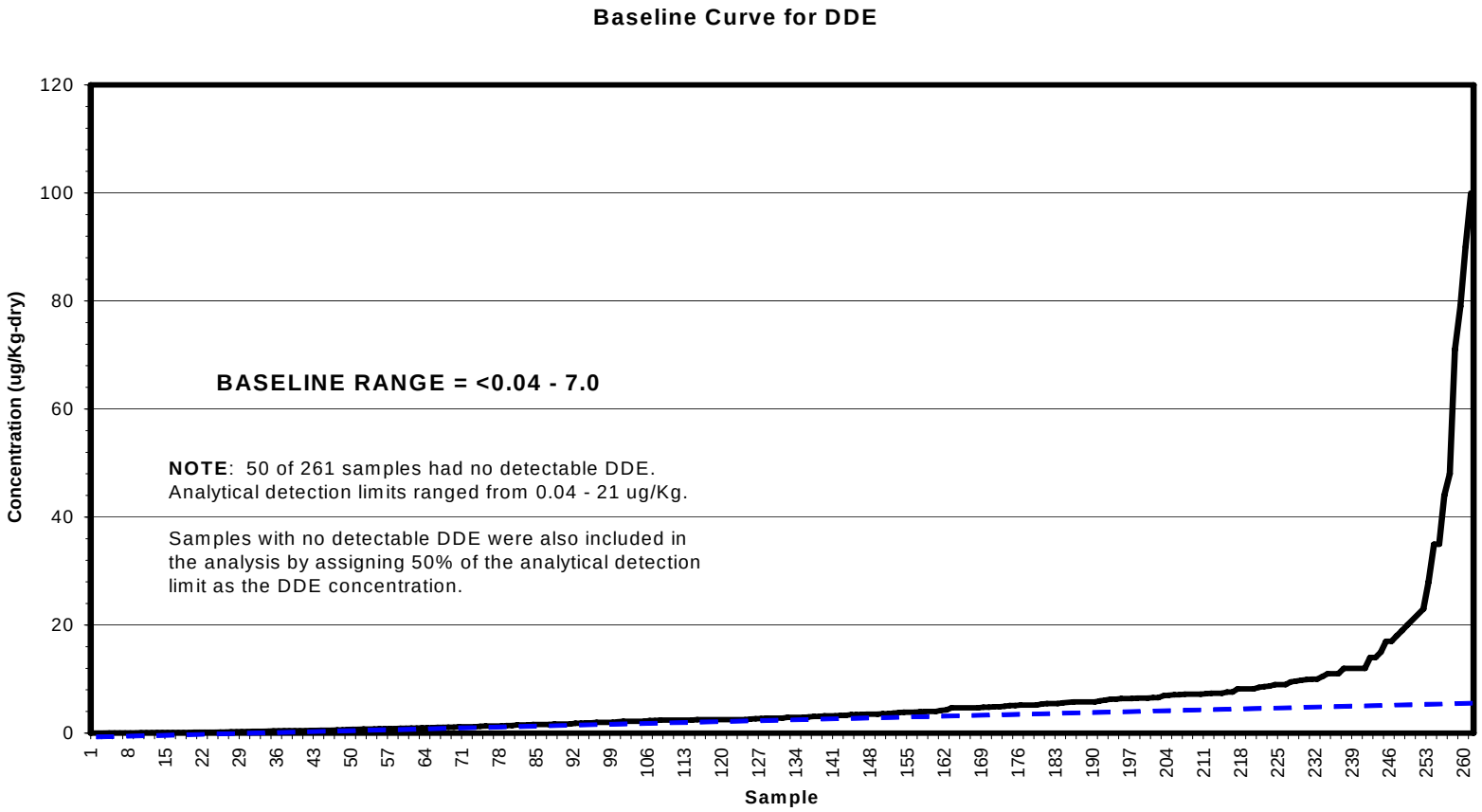

Figure F-1. Using a Graph to Determine Ambient/Baseline Concentrations

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Table F-1. Calculating Ambient/Baseline Concentrations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Calculated Ambient Concentration	Toxicity Screening Level (a)	Bioaccum Screening Level (a)
Semivol Organics (µg/kg)																					
Naphthalene	NT	NT	**3.3** J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**3** J	**3** J	2.51 U	**2.68**	2.1 U	2.3 U	1.64 U	**3.3**	200	none
Acenaphthylene	NT	NT	**3.2** J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	10 U	10 U	**4.08**	**6.28** J	**2.68**	**3.71**	1.64 U	**6.28**	40	13577000
Acenaphthene	NT	NT	16 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	10 U	10 U	2.51 U	1.89 U	2.1 U	2.3 U	1.64 U	**2**	60	140000
Fluorene	NT	NT	16 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	10 U	10 U	2.51 U	1.89 U	2.1 U	2.3 U	1.64 U	**2**	20	94000
Phenanthrene	NT	NT	**4.3** J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**60**	**10** J	**7** J	2.51 U	1.89 U	2.1 U	2.3 U	**4.96**	60	**40**	13577000
Anthracene	NT	NT	16 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**1** J	**1** J	2.51 U	1.89 U	2.1 U	2.3 U	1.64 U	**2**	60	4100000
2-Methylnaphthalene	NT	NT	NT	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**2** J	**1** J	2.51 U	1.89 U	2.1 U	2.3 U	1.64 U	**2**	20	none
Fluoranthene	NT	NT	**5.6** J	50 U	**69**	50 U	50 U	50 U	50 U	50 U	**98**	**17**	**14**	**4.79**	**7.16** J	**5.4**	**5.23**	**12.2**	**98**	100	70000
Pyrene	NT	NT	**10** J	50 U	**67**	50 U	50 U	50 U	50 U	50 U	**89**	**20**	**16**	**7.86**	**8.16**	**8.37**	**6.05**	**9.32**	89	**50**	53000
Benzo(a)anthracene	NT	NT	**4.8** J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**7** J	**6** J	5.02 U	3.78 U	4.2 U	4.59 U	3.28 U	7	30	**5**
Chrysene	NT	NT	**5.1** J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**9** J	**8** J	5.02 U	3.78 U	4.2 U	4.59 U	3.28 U	**9**	60	500
Benzofluoranthenes	NT	NT	**11.7**	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**13** J	**13** J	**13.8**	3.78 UJ	4.2 U	**8.85**	**8.57**	**13.8**	30	50
Benzo(a)pyrene	NT	NT	**13** J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**8** J	**6**	**5.08**	1.89 UJ	2.1 U	**2.68**	**5.17**	13	30	**1**
Indeno(1,2,3-cd)pyrene	NT	NT	**12** J	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**7**	**6** J	2.51 U	1.89 U	2.1 U	2.3 U	1.64 U	12	20	**5**
Dibenzo(a,h)anthracene	NT	NT	16 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	5 U	5 U	2.51 U	1.89 U	2.1 U	2.3 U	1.64 U	2	60	**1**
Benzo(g,h,i)perylene	NT	NT	**45**	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	**7**	**8**	2.51 U	1.89 U	2.1 U	2.3 U	1.64 U	**45**	60	1018000
Dibenzofuran	NT	NT	16 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	50 U	5 U	5 U	25.1 U	18.9 U	21 U	23 U	16.4 U	**20**	1000	4400
Bis(2-ethylhexyl)phthalate	NT	NT	310 U	**350**	**420**	100 U	100 U	100 U	100 U	**120**	100 U	200 U	**120**	33 U	54 U	48.5 U	30.2 U	46.2 U	420	**20**	none
Phenol	NT	NT	46 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	100 U	50 U	50 U	25.1 U	18.9 U	21 U	23 U	16.4 U	20	**10**	none
PCBs (µg/kg)																					
Aroclor 1248	14 U	15 U	16 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	19.2 U	14.3 U	16 U	16 U	11.8 U	**10**	30	**10**
Aroclor 1254	14 U	15 U	16 U	10 U	**12**	10 U	10 U	10 U	10 U	10 U	10 U	**8** J	**5** J	19.2 U	14.3 U	16 U	16 U	11.8 U	12	600	**10**
Aroclor 1260	14 U	15 U	16 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	10 U	19.2 U	14.3 U	16 U	16 U	11.8 U	**10**	**10**	**10**
Total PCBs	28 U	29 U	31 U	20 U	**12**	20 U	20 U	20 U	20 U	20 U	20 U	**8** **J**	**5** **J**	38.4 U	28.6 U	32 U	32 U	23.7 U	**20**	30	none
Pesticides (µg/kg)																					
p,p'-DDE	1.4 U	1.5 U	1.6 U	2.3 U	2.3 U	2.3 U	2.3 U	2.3 U	2.3 U	2.3 U	2.3 U	**0.8** J	**0.6** J	3.84 U	2.86 U	3.2 U	3.2 U	2.37 U	**2**	**2**	**2**
p,p'-DDD	1.4 U	1.5 U	1.6 U	3.3 U	3.3 U	3.3 U	3.3 U	3.3 U	3.3 U	3.3 U	3.3 U	**0.5** J	**0.5** J	3.84 U	2.86 U	3.2 U	3.2 U	2.37 U	**2**	4	**2**
p,p'-DDT	1.4 U	1.5 U	**0.73** J	6.7 U	6.7 U	6.7 U	6.7 U	6.7 U	6.7 U	6.7 U	6.7 U	**1** J	**0.6** J	3.84 U	2.86 U	3.2 U	3.2 U	2.37 U	**2**	4	**2**
Aldrin	1.4 U	1.5 U	1.6 U	NT	NT	NT	NT	NT	NT	NT	NT	2 U	2 U	1.92 U	1.43 U	1.6 U	1.6 U	1.18 U	2	8	**1**
Chlordane	1.4 U	1.5 U	1.6 U	NT	NT	NT	NT	NT	NT	NT	NT	2 U	2 U	19.2 U	14.3 U	16 U	16 U	11.8 U	**2**	10	10
Dieldrin	1.4 U	1.5 U	1.6 U	NT	NT	NT	NT	NT	NT	NT	NT	**0.3** J	2 U	3.84 U	2.86 U	3.2 U	3.2 U	2.37 U	**2**	3	**2**
Heptachlor	1.4 U	1.5 U	1.6 U	NT	NT	NT	NT	NT	NT	NT	NT	2 U	2 U	1.92 U	1.43 U	1.6 U	1.6 U	1.18 U	2	2	**1**
Tributyltin (pore water) (µg/L)	NT	NT	**0.07**	0.02 UJ	0.02 UJ	0.05 UJ	0.04 UJ	0.02 UJ	0.04 U	0.05 U	0.05 U	NT	NT	0.00816 U	0.0149 UJ	0.0102 U	0.00879 U	0.0175 U	0.07	**0.064**	800
Metals (mg/kg)																					
Antimony	NT	NT	**0.47** J	2.28 UJ	2.46 UJ	2.49 UJ	2.49 UJ	2.5 UJ	2.49 UJ	2.52 UJ	2.39 UJ	**0.12** J	**0.08** J	**0.904**	0.651 U	0.837 U	0.814 U	0.645 U	**0.90**	4.00	none
Arsenic	NT	NT	**2.7**	2.28 U	2.46 U	2.49 U	2.49 U	2.5 U	2.49 U	2.52 U	2.39 U	**3.09**	**3**	**3.69**	**2.78**	**3.31**	**3.24**	**2.19**	**2.80**	10.00	10.00
Cadmium	NT	NT	**0.07**	0.27 UJ	0.3 UJ	0.3 U	0.3 U	0.3 UJ	0.3 UJ	0.3 UJ	0.29 UJ	**0.16**	0.08 U	0.339 U	0.261 U	0.335 U	0.325 U	0.258 U	**0.16**	0.60	0.60
Copper	NT	NT	**15.4**	**24.2**	**26.8**	**16.6** J	**17.3**	15 U	**16.2**	**21**	**15**	**24.8**	**25.8**	**32**	**19.4**	**21.6**	**27.9**	**18.8**	23.00	36.00	**18.00**
Chromium	NT	NT	**16.8**	NT	NT	NT	NT	NT	NT	NT	NT	**23.1**	**20.1**	**24.5**	**19**	**21.3**	**25.1**	**13.9**	**25.10**	86.00	86.00
Lead	NT	NT	**5.24**	**11.2**	**17.9**	**5.1**	**5.53**	**4.56**	**5.43**	**9.69**	**5.77**	**12.1**	**11.8**	**9.86**	**7.13**	**8.4**	**9.28**	**8**	10.00	35.00	**8.90**
Mercury	NT	NT	**0.02**	0.19 U	0.19 U	0.2 U	0.19 U	0.19 U	0.19 U	0.19 U	0.19 U	**0.04**	**0.06**	**0.0606**	**0.0328** J	**0.0461**	**0.0516**	**0.031** J	**0.061**	0.200	0.180
Nickel	NT	NT	**18.5**	**21.2** J	**20.1** J	**17.1** J	**21.4** J	**14.3** J	**21.6** J	**18.2** J	**17.6** J	**23.6**	**20.2**	**19.9**	**19.4**	**18.4**	**21**	**14**	**20.00**	**20.00**	42.70
Silver	NT	NT	**0.1**	**0.26**	**0.38**	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.19 U	**0.16**	**0.28**	0.846 U	0.651 U	0.837 U	0.814 U	0.645 U	**0.38**	1.00	**0.38**
Zinc	NT	NT	**49.7**	**71.1** J	**76.9** J	**43.8** J	**58** J	**49.8** J	**61.7** J	**60.5** J	**48.6** J	**80.7**	**78.7**	**69.3**	**57.5**	**64.8**	**72.3**	**57.8**	**68.00**	129.00	129.00
PETROLEUM HYDROCARBONS (mg/kg)																					
Gasoline (b)	14 U	14 U	NT	10 UJ	20 U	10 U	10 U	10 U	10 U	10 U	10 U	NT	NT	NT	NT	NT	NT	NT	**10.00**	80.00	none
Diesel (b)	14 U	14 U	NT	10 U	20 U	10 U	10 U	10 U	10 U	10 U	10 U	NT	NT	46.2 U	35.1 U	38.8 UJ	40.1 U	31.9 U	**10.00**	80.00	none
Heavy Oil (b)	34 U	35 U	NT	25 U	50 U	25 U	25 U	25 U	25 U	25 U	25 U	NT	NT	**154**	**70.7**	**93.7** J	**93.7**	63.7 U	154.00	**80.00**	none

Notes: 1.) Detected constituents are indicated by bold-face type.
2.) Bold-face type/boxed values indicate the lowest concentration among the calculated ambient concentration, and screening levels.

(a) Toxicity and bioaccumulation screening levels from DEQ Ross Island Fill Evaluation Fact Sheet received on January 16, 2003.
(b) As of January 20, 2003, DEQ is still in the process of deciding whether the 80 ppm toxicity screening level applies to each type of petroleum or the sum of all three types.

NT = Not tested.
U = Nondetect.
J = Estimated value.

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Appendix G.

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G. References

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