APPENDIX C

Human Health and Ecological Risk Assessment Work Plan

PUBLIC REVIEW DRAFT HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT WORK PLAN

Oakland Bay in Shelton, Washington

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Acronyms/Abbreviations

ATSDR	Agency for Toxic Substances and Disease Registry
BaP	benzo(a)pyrene
BSAF	biota-to-sediment accumulation factor
BW	body weight
CalEPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPCs	chemicals of potential concern
cPAHs	carcinogenic polycyclic aromatic hydrocarbons
CPF	cancer potency factor
CSF	cancer slope factor
CSL	Cleanup Screening Level
CSM	conceptual site model
CT	central tendency
E & E	Ecology and Environment, Inc.
Ecology	Washington State Department of Ecology
ED	exposure duration
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
HHRA	human health risk assessment
HH/ERA	human health and ecological risk assessment
HI	hazard index
HPAHs	high molecular weight PAHs
HQ	hazard quotient
IHSs	indicator hazardous substances
IR	ingestion rate
IRIS	Integrated Risk Information System
LOAEL	lowest observed adverse effect level
M m^3	million cubic meters
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg-day	milligram per kilogram per day
µg/kg	micrograms per kilogram
MDL	method detection limit
mL	milliliters
MTCA	(State of Washington) Model Toxics Control Act
NCEA	National Center for Environmental Assessment
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NSSP	National Shellfish Sanitation Program
NWFSC	Northwest Fisheries Science Center

Acronyms/Abbreviations (Continued)

ORNL	Oak Ridge National Laboratory
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCDDs	polychlorinated dibenzo-p-dioxins
PCDFs	polychlorinated dibenzofurans
PCP	pentachlorophenol
PPRTVs	EPA’s Provisional Peer-Reviewed Toxicity Values
PSEP	Puget Sound Estuary Program
QA/QC	Quality assurance / quality control
RfD	reference dose
RME	reasonable maximum exposure
SAP	Sampling and Analysis Plan
SF	slope factor
SMCJ	*Shelton-Mason County Journal*
SQS	Sediment Quality Standards
STSC	The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center
SUF	site use factor
TEF	toxic equivalency factor
TRVs	toxicity reference values
TEC	toxicity equivalent concentration
TTEC	total toxicity equivalent concentration
UCL	upper confidence limit
USFWS	United States Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDOH	Washington Department of Health
WOE	weight-of-evidence
WRCC	Western Region Climate Center

1.0 Introduction

Oakland Bay is one of seven bays identified as a priority for environmental restoration by the Washington State Department of Ecology (Ecology) as part of the Toxics Cleanup Program's Puget Sound Initiative. Ecology has identified Oakland Bay for source control actions, sediment cleanup, and focused restoration efforts, if necessary. Earlier environmental investigations throughout the bay, including the Shelton Harbor area, have indicated that chemicals of concern have been released by historical and current industrial and commercial activities around the bay. Previous sediment sampling in the area has indicated that chemicals in Bay sediments and biota may pose a risk to the environment, with contaminant concentrations that exceed the *Sediment Management Standards*, Chapter 173-204 Washington Administrative Code (WAC) and other established thresholds of environmental concern (EPA 1998; Long and Morgan 1991; and Long et al. 1995).

As part of the effort to restore and clean up Oakland Bay, there is a need to characterize marine sediment throughout the bay as related to current and historic contaminant sources. Ecology has tasked Ecology and Environment, Inc. (E & E) with conducting a sediment investigation and human health and ecological risk assessments (HH/ERAs), focusing on the marine sediment environment associated with terrestrial and aquatic sources. This work will be performed with assistance from Herrera Environmental Consultants (Herrera).

The purpose of the RA for Oakland Bay sediment is to evaluate risks that contaminants in sediment and benthic biota may pose to human and ecological receptors.

1.1 Risk Assessment Approach and Applicable Guidance

1.1.1 Human Health Risk Assessment

The Human Health Risk Assessment (HHRA) will be performed in accordance with the U.S. Environmental Protection Agency's (EPA's) *Risk Assessment Guidance for Superfund* and other associated guidance (EPA 1989 et seq.) – see Section 4.1 of this Work Plan for further information. Additional policies and guidance developed by the Washington State Departments of Ecology and Health, and the Squaxin Island Tribe also will be taken into consideration.

1.1.2 Ecological Risk Assessment

An ecological risk assessment (ERA) also will be prepared for Oakland Bay. The purpose of the ERA is to determine whether or not sediment contamination from historic and ongoing municipal, commercial, and industrial sources poses a risk to ecological receptors at the site, including threatened and endangered species. The results of the ERA will be used to help determine whether or not remedial measures are necessary to protect and/or restore the natural environment and, if so, to aid in the selection of appropriate remedial goals. The methodology used to perform the ERA will be consistent with Ecology and EPA guidance including *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting*

Ecological Risk Assessments (EPA 1997b); *Guidelines for Ecological Risk Assessment* (EPA 1998); and *Wildlife Exposure Factors Handbook* (EPA 1993)— see Section 5.1 of this Work Plan for further information.

1.2 Document Structure

The risk assessment deliverable will begin with an executive summary of the entire document. The main body of the document will begin with a general description and history of Oakland Bay. Two main sections will follow, presenting the HH/ERAs, respectively.

The major sections of the HHRA will be:

1. **Data Evaluation:** An evaluation of the data available characterizing any chemical contamination that may be present at the site. The data will be compared with available information about background levels of chemicals that are naturally present in environmental media, and health risk-based screening levels. Generally, chemicals present in environmental media at concentrations greater than background and risk-based concentrations are selected as chemicals of potential concern (COPCs) or indicator hazardous substances (IHSs). Potential exposure pathways and receptors are identified, and a conceptual site model is developed.

2. **Exposure Assessment:** The extent of exposure to site-related contaminants each receptor group may experience is estimated. Site-specific exposure factor values will be used where possible; otherwise, standard EPA, Ecology, or tribal exposure factor values will be used.

3. **Toxicity Assessment:** There are two elements to the toxicity of a substance: the nature of the adverse effect(s) caused by exposure to a substance and the strength of the substance's ability to cause the effect. For carcinogenic effects, the quantitative toxicity estimate for a substance is its slope factor (SF) or cancer potency factor (CPF); for noncarcinogenic effects, it is the substance's reference dose (RfD). Information on the toxicity of substances identified as COPCs or IHSs will be gathered from EPA's hierarchy of sources.

4. **Risk Characterization:** In this section the information developed in the exposure and toxicity assessments is combined to obtain quantitative risk estimates. The potential for the site-specific exposures estimated to produce adverse health effects in the potentially exposed populations is estimated; the potential adverse effects, and the factors leading to the estimated risks and hazards, are described.

5. **Uncertainty Analysis:** There are numerous uncertainties throughout the risk assessment process that can lead to under- or overestimating the true risks posed by potential exposures to environmental contaminants. The sources of these uncertainties and their potential effects on the risk estimates are discussed in this section.

6. **Summary and Conclusions:** In this section the risk assessment is summarized and conclusions are drawn.

The major sections of the ERA will be:

1. **Ecological Characterization:** An ecological characterization of Oakland Bay will be prepared based on site-specific information contained in previous site reports, general information on the ecology of southern Puget Sound, and observations made by personnel during site investigation activities. The marine environment of Oakland Bay and the plant, invertebrate, fish, and wildlife species found there will be described. The United States Fish and Wildlife Service (USFWS) and Washington Department of Fish and Wildlife (WDFW) will be contacted for current information on threatened and endangered species in the site vicinity.

2. **Problem Formulation:** A refined problem formulation will be included in the ERA. This step of the risk assessment process identifies site-related contaminants, receptors, and exposure pathways. A refined ecological conceptual site model (CSM) will then be developed to summarize the relationship between stressors and receptors. The refined ecological CSM will be based on the preliminary CSM (presented below in Chapter 2).

3. **Risk Assessment:** The three main components of the risk assessment will be exposure assessment, toxicity assessment, and risk characterization, as described above for the HHRA.

4. **Uncertainty Analysis:** There are numerous uncertainties intrinsic to any ERA process that can lead to under- or overestimating the actual risks posed by potential exposures to environmental contaminants. The sources of these uncertainties and their potential effects on the risk estimates will be discussed.

5. **Summary and Conclusions:** In this section the risk assessment is summarized and conclusions are drawn.

2.0 Background and Scope

2.1 Site Location and Description

Oakland Bay is located in southern Puget Sound approximately 20 miles northwest of Olympia, Washington. Oakland Bay is a small, relatively broad, and shallow estuary approximately 4 miles long and 0.75 miles wide with water depths averaging 10 to 35 feet with a tidal range of 10 to 15 feet or more. A large area of the foreshore is exposed to the atmosphere at low tides. This intertidal zone is mainly mud flats with narrow, deeper channels. Due to the restrictive nature of Hammersley Inlet, the long narrow waterway linking the bay to the Puget Sound Basin, the water in Oakland Bay has high refluxing, low flushing, and high retention rates. There are eight major creeks that discharge to Oakland Bay: Deer, Cranberry, Campbell, Johns, Uncle John, Malaney, Shelton, and Goldsborough (Kenny 2007). The City of Shelton and Shelton Harbor are located at the southwest end of Oakland Bay (see Figure 2-1).

2.1.1 History

Historically, Mason County and the Oakland Bay area were inhabited by the Skokomish and Squaxin Island Tribes. Europeans first arrived in the area in 1839. Much of the of the area's economic structure was built upon the logging industry. Commercial logging and lumber production began in the area in the 1850s and lumber mills soon followed. Lumber mills have operated in Shelton since about 1853. Rail lines were soon built to facilitate transportation of logs to the mills and Oakland Bay. The logs were dumped into the bay to be sorted, stored, formed into rafts and booms, and floated down to the mouth of Hammersley Inlet, where they could be loaded on ships for transport to remote markets (SMCJ 2007, NWFSC 2008).

Farming, fishing, and the oyster industry were also beginning in other areas of the county at that time. Oysters were a valuable local commodity, so much so that local oyster beds were all but depleted by 1887. By 1902, hundreds of acres of Mason County waters were under cultivation, annually producing more than 25,000 sacks of oysters (NWFSC 2008).

In 1927 a pulp and paper mill commenced operations on the Shelton waterfront. The pulping process produces sulfite liquor, a waste product that was released into the bay with catastrophic effects on the oyster beds. In 1930 the oyster growers sued the mill owners for damages to their harvest. The mill's industrial processes were improved, reducing, but not eliminating, its impact on the bay. The pulp and paper mill continued to operate until 1957, after which significant environmental recovery of the bay began to occur (Kenny 2007, SMCJ 2007).

Currently, Oakland Bay is one of the most productive commercial shellfish growing areas in the country. Much of the nation's manila clam harvest is grown here, as well as high-value oysters. Approximately 3 million pounds of clams and 1.8 million pounds of oysters are harvested yearly. There are 21 shellfish growers in Oakland Bay in addition to the Squaxin Island Tribe. Some of the public and private beaches in the area support recreational shellfish harvesting.

Approximately 2000 recreational harvesting licenses are obtained for the area each year (Kenny 2007).

Over the years the importance of the forest products industries in the area has decreased while the value of the recreation, tourism, retail, and private and governmental service industries has increased (NWFSC 2008, SMCJ 2007).

2.1.2 Demographics and Land Use

By 2007 the population of Mason County had grown to over 50,000 and that of the City of Shelton had increased to 8,700. According to the 2000 U.S. Census, the median age in 2000 was 35.8, which is comparable to the national median of 35.3 for the same year. According to the same data, 22 percent of the population was 14 years of age or younger and 37.6 percent was between the ages of 25 and 54. For the population 18 years and over, 75.6 percent had a high school education or higher, 11.6 percent had attained a Bachelor’s degree or higher, and 3.0 percent earned a graduate or professional degree; as compared to the national averages of 79.9 percent, 22.3 percent, and 7.8 percent, respectively. The 2000 U.S. Census shows that the racial composition was predominantly White (85.8 percent), followed by American Indian and Alaskan Native (2.7 percent), and Asian (1.2 percent). A total of 10.9 percent identified themselves as Hispanic or Latino (SMCJ 2007, NWFSC 2008).

Oakland Bay is used mainly for cultivation and harvesting of shellfish. Currently, Oakland Bay has approximately 1,434 acres classified as Conditionally Approved by the WDOH for shellfish harvesting. Fifty- five acres at the north end of the bay are classified as Restricted. In addition, 774 acres to the south are classified as Prohibited due to Shelton Wastewater Treatment Plant discharge. The Shelton Water Treatment Plant receives both sanitary sewage and stormwater; due to the risk of a discharge of inadequately treated or raw sewage into the bay as a result of a storm event, rainfall of 1 inch or more in 24 hours triggers a five-day shellfish harvesting closure throughout the Conditionally Approved area. Figure 2-2 shows the shellfish harvesting approval status of the Oakland Bay Growing Area. The outfall from the water treatment plant is located in the bay north of Eagle Point (see Figure 2-1).

Upland areas around Oakland Bay are primarily residential, with some agricultural, commercial, and industrial uses. Development on the shoreline and upland areas of Oakland Bay is gradually expanding. Most development in the area is residential with some industry and commercial activity, especially along the west and south sides of the bay.

Shelton Harbor continues to be used for a variety of wood handling activities as shown in Figure 2-3. Shore-side activities around the harbor include a marina, a tank farm, wood handling and processing facilities, and a sewage treatment plant.

2.1.3 Climate

Shelton has a moderate and moist climate. Average daily temperatures range from approximately 40°F in January to 68°F in August. Average daily high temperatures reach 80°F in August, while average daily low temperatures fall to about 32°F in January. Precipitation averages 65.7 inches per year; snowfall averages approximately 8 inches per year (WRCC 2008).

2.1.4 Geology and Sediment

The natural sediments of Oakland Bay outside of Shelton Harbor consist mainly of silt, with 10 – 15 percent sand and gravel and 0 – 20 percent clay. Within Shelton Harbor, which has been substantially impacted by wood handling and other anthropogenic activities, the sediments contain substantially greater quantities of sand and gravel (25 – 85 percent); sediments in the southwest corner of the harbor contain about 40 percent clay (Ecology 2000).

2.1.5 Hydrology

Oakland Bay is a broad, shallow estuary connected by the narrow channel of Hammersley Inlet to the Puget Sound Basin (Figure 2-1). The HH/ERAs described in this document will only address Oakland Bay and the portion of Hammersley Inlet west of Miller's Point. Creeks discharging to the bay include Goldsborough, Johns, Cranberry, Shelton, Deer, Uncle Johns, Mill, Malaney, and Campbell. The tidal range in Oakland Bay is 10 to 15 feet or more. During a typical flood tide, 79 million cubic meters (M m^3) of water enters Oakland Bay, which has a volume of only about 87 M m^3 (Oakland Bay and Hammersley Inlet combined have a volume of about 148 M m^3). A simple tidal prism calculation results in a flushing time of slightly over a day. However, this gives a very poor estimate of the actual flushing time because much of the same water that leaves the bay during the ebb tide returns (refluxes) on each subsequent flood tide. The results of dye trace and hydrodynamic model studies conducted by Ecology indicated that the time required to flush half of the contents of the bay was about 4 days, based on the dye test, and about 6.2 days, based on the results of the hydrodynamic model (Ecology 2004a).

2.1.6 Ecology

Species

Oakland Bay is part of the Puget Sound ecosystem, which is the second largest estuary in the United States. The waters of Puget Sound support more than 200 species of fish, 26 marine mammals, 100 seabirds, and thousands of species of plants and marine invertebrates. Coastal wetlands in Puget Sound provide habitat for more than 175 species, including 63 salt marsh plant species. As part of the Puget Sound ecosystem, the Oakland Bay estuary supports a wide variety of organisms at all trophic levels, including phytoplankton and other marine plants, zooplankton, shellfish (crabs and clams), fish (including salmonids and bottom fish), birds, and mammals. The organisms present in the Oakland Bay estuary are described below.

Phytoplankton and Other Marine Plants

This category includes phytoplankton, benthic and macroalgae, and seagrasses. Phytoplankton species include green algae, blue-green algae, euglenoids, diatoms, dinoflagellates, and microflagellates. These species are the primary producers that support the higher organisms in the food web. These organisms are abundant in Oakland Bay.

Zooplankton

Zooplankton are small, primary consumers that feed mainly on phytoplankton. These small animals float and drift in the water, providing a major food source for higher trophic-level animals such as baitfish, sportfish, and commercially fished species. Three types of zooplankton, icthyoplankton (eggs and larval forms of fish and shellfish), microzooplankton (microscopic organisms), and macrozooplankton (very small, but visible, marine animals), occur in Oakland Bay.

Shellfish

Shellfish include clams, crabs, and shrimp. Clams are bottom feeders, while shrimp and crabs consume living or dead organic material. Oakland Bay is one of the most productive commercial shellfish growing areas in the country. Approximately 3 million pounds of manila clams and 1.8 million pounds of oysters are harvested yearly from Oakland Bay (Kenny 2007). Geoducks, horseneck clams, and littleneck clams also are harvested in the area (NWFSC 2004); other species, including butter clams and softshell clams, are taken occasionally (WDFW 2008a).

Fish

Chum, coho, and chinook salmon are found in several of the creeks flowing into Oakland Bay, including Mill, Cranberry, and Johns Creeks (Ecology 2006). An obsolete dam on Goldsborough Creek was removed in 2002, opening up approximately 25 miles of upstream fish habitat that had been nearly inaccessible to salmon since 1885 (*The Olympian* 2007). Removal of the dam has facilitated movement of coho salmon between the saltwater environment of Oakland Bay to spawning and rearing habitat above the former dam site. According to a report by the Squaxin Island Tribe, more than 41,200 of the 42,729 young coho salmon entering Oakland Bay saltwater originated from above the former dam site (*The Olympian* 2007).

A detailed study of the fish species present in marine waters, 65 miles to the north, identified lingcod, copper rockfish, quillback rockfish, black rockfish, English sole, Dover sole, rock sole, starry flounder, sand dabs, and perch (Malcolm Pirnie 2005). Forage fish found in Port Angeles include herring, smelt, anchovies, and sand lance. It is expected that the same fish exist in Oakland Bay. Commercial and sport fishing businesses operating out of Puget Sound include those fishing for Chinook, Coho, and chum salmon (NWFSC 2004).

Birds

Birds that may use the Oakland Bay estuary include shorebirds (e.g., plovers, sandpipers, rails), waterfowl (e.g., dabbling ducks, geese, diving ducks), wading birds (e.g., herons, egrets), gulls, loons, grebes, and kingfishers. Intertidal and shallow tidal submerged grasses such as eelgrass and associated benthic invertebrates provide food for many species (Malcolm Pirnie 2005). For example, eelgrass (found in nearshore beds) is a principal dietary component for brant and other herbivorous birds. Dabbling ducks consume invertebrates and floating plants. Diving ducks, cormorants, grebes, herons, hawks, gulls, terns, kingfishers, and alcids all forage for fish. Two bald eagle nests have been monitored in the Oakland Bay area since 1986 (WDFW 2008b).

Mammals

Marine mammals that could occur in Oakland Bay include harbor seal (*Phoca vitulina*), minke whale (*Balaenoptera acutorostrata*), orca (*Orcinus orca*), harbor porpoise (*Phocoena phocoena*), and river otter (*Lutra canadensis*).

Threatened and Endangered Species

More than one-third of Washington's threatened or endangered species require near-shore habitat (e.g., estuarine, mudflat, tidal wetland) to survive. Species of concern that inhabit southern Puget Sound include the Orca whale (*Orcinus orca*), brown pelican (*Pelecanus occidentalis*), marbled murrelet (*Brachyramphus marmoratus*), Puget Sound chinook salmon (*Oncorhynchus tshawytscha*), and bull trout (*Salvelinus confluentus*).

2.2 Chemicals of Potential Concern

Several types of contamination are of concern in Oakland Bay and Shelton Harbor. The greatest concern to the shellfishing industry is fecal coliform contamination. Known or suspected sources of fecal coliform releases to Oakland Bay include discharges of effluent from the Shelton Wastewater Treatment Plant, on-site sewage systems, stormwater, livestock, pets, and wildlife. The WDOH sets standards and is responsible for approving or restricting shellfish harvesting in growing areas based on these standards. The current harvest approval status for areas within Oakland Bay and Hammersley Inlet are shown in Figure 2-2. While fecal coliform affects shellfish harvesting in the bay, fecal coliform will not be evaluated as a chemical of potential concern in the HHRA or ERA.

A second major source of contamination in Oakland Bay is the wood handling and processing industry. As wood debris decays in marine waters, it depletes oxygen from the sediment and releases to the sediment and water column various degradation products, including phenols, benzoic acid, retenes, and other compounds. The physical presence of the wood debris, its degradation products, and anoxic conditions all are detrimental to benthic organisms. The distribution of wood debris in Shelton Harbor sediments is shown in Figure 2-4.

Numerous chemical wastes released by the forest products industry and other local industries also are of potential concern. These compounds include the following:

- Sulfite- and mercury-containing wastes released from the pulp and paper mills (historically, mercury compounds were used as slimicides in pulp and paper making processes);
- Dioxin (polychlorinated dibenzo-p-dioxins [PCDDs] and polychlorinated dibenzofurans [PCDFs]) containing wastes generated by bleaching pulp with chlorine, hypochlorite and chlorine dioxide;

- Wood-preserving materials including creosote, which contains polycyclic aromatic hydrocarbon (PAH) compounds, and pentachlorophenol (PCP), which can contain dioxins (PCDDs and PCDFs) as contaminants;
- Deposition of air emissions from hog fuel boilers and wood-fired power plants, and the burn plant used to incinerate the sulfite liquor. Hog fuel consisted of bark removed from logs, rejected wood chips and debris generated from the sawmills, some of which was laden with salt. Combustion of organic materials typically produces PAHs. In addition, baghouse residues from the wood-fired power plants have been found to contain dioxins.
- Marine industry wastes including copper and organotin compounds, which currently or formerly were used as active ingredients in antifouling bottom paints. Many of these paints were intended to function, in part, by sloughing off of boat hulls, thereby shedding marine growth and exposing fresh antifouling surfaces. Antifouling paints are also scraped from hulls that are being reconditioned or refurbished. Materials released in these ways are often deposited in marina sediments and in boat yards, where they can be transported to the adjacent waters by surface runoff; and
- Polychlorinated biphenyls (PCBs) associated with transformers located near the bay.

A Reconnaissance Survey of Inner Shelton Harbor Sediments was conducted by Ecology (Ecology 2000) to assess the physical and chemical condition of harbor sediments. Sediment samples from 10 monitoring stations in and near the harbor, and one from a nearby reference area, were analyzed for metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc), semivolatile organic compounds, PCBs, and butyltins. Results were compared to Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSL) established by Ecology to protect biological resources (Chapter 173-204 WAC). Chemicals that exceeded these criteria in one or more samples included copper, mercury, benzoic acid, phenol, 4-methylphenol, 2,4-dimethylphenol, high molecular weight PAHs (HPAHs), bis(2-ethylhexyl)-phthalate, chrysene, fluoranthene, and PCP. These chemicals would be considered COPCs or IHSs.

2.3 Preliminary Conceptual Site Model

In general terms, a conceptual site model depicts media that may contain site-related constituents, potential human and ecological receptors, and potential routes of exposure of receptors to site-related constituents. A complete pathway requires the presence of site-related chemical constituents in an environmental medium that receptors are likely to contact.

The sections below present the preliminary conceptual site models for human and ecological receptors in Oakland Bay. The receptor groups evaluated may change after sampling is conducted in Oakland Bay. Potential risk to these receptor groups from exposure to Bay constituents will be evaluated if sufficient media (e.g., sediment, plant, animal) concentration data are available.

2.3.1 Human Exposure Scenarios and Pathways

Historical information indicates that greatest sources of contaminants released to Oakland Bay are or were located in and around Shelton Harbor. These include the former pulp and paper mill, lumber mills, log and lumber storage, handling and processing facilities, the boat yard and marina, and the Shelton Wastewater Treatment Plant. In addition, *The Shelton Inner Harbor Reconnaissance Survey* (Ecology 2000) found wood debris to be widespread in Shelton Harbor (Figure 2-4). The decay of this material also releases contaminants to the waters and sediment of the bay. Stormwater runoff and releases from on-site septic systems can enter the bay at numerous locations along the shoreline as can releases from other facilities in the Oakland Bay watershed. Tidal currents and wind-generated turbulence have the potential to transport contaminants throughout the bay.

Human populations at greatest risk of exposure to Oakland Bay contaminants include those who use the bay and its shoreline for recreational, commercial, or subsistence purposes and/or consume seafood caught or harvested from the bay or its tributaries. These groups include:

- Beach and shoreline users – individuals who swim, wade, walk, or lounge, etc., on Bay beaches or shoreline;
- Commercial fishers – engaged in catching or harvesting seafood from the bay for market. These individuals are assumed to contact Bay water and sediment occupationally, but are not assumed to eat their catch;
- Recreational fishers – individuals assumed to contact Bay water and sediment while fishing or gathering shellfish and who eat their catch; and
- Subsistence fishers – individuals assumed to contact Bay water and sediment while fishing or gathering shellfish and who eat their catch. Subsistence fishers are assumed to have higher water and sediment contact rates, and to consume greater quantifies of the fish and shellfish they catch than do recreational fishers.

A conceptual model of potential human exposures to Oakland Bay contaminants is presented graphically in Figure 2-5.

2.3.2 Ecological Exposure Scenarios and Pathways

The ecology of Oakland Bay indicates that five principal groups of ecological receptors have a high potential to be exposed to contaminants that accumulate in sediment and/or the food chain – seagrasses and macroalgae, benthic invertebrates, fish, birds, and mammals. Figure 2-6 provides a preliminary ecological conceptual site exposure model for Oakland Bay featuring these receptor groups:

- Seagrasses and macroalgae may be exposed to site-related chemicals through direct contact with and uptake from sediment.
- Benthic invertebrates and fish may be exposed to site-related chemicals through direct contact with sediment and ingestion of biota (plant and animal) that has accumulated contaminants. Benthic invertebrates and fish may, in turn, bioaccumulate contaminants.

- Aquatic vegetation, benthos, and fish also may be exposed to chemicals in water, but this means of exposure is likely to be minor when compared to containment levels in the sediment.
- Birds and mammals may be exposed to site-related chemicals through incidental ingestion of sediment and consumption of biota (plant and animal) that has accumulated contaminants. Dermal exposure of birds and mammals to chemicals in sediment is considered a negligible route of exposure due to protection provided by external coverings (i.e., fur, feathers, and scales). Exposure through incidental ingestion of surface water also is considered negligible for wildlife because chemicals typically occur at much lower concentrations in water compared with sediment or biota.

3.0 Assessment of Data Quality

All available chemical data for Shelton Harbor and Oakland Bay collected within the previous 10 years will be evaluated to determine usability according to the data quality criteria discussed below, including data collected during the 2008 field event. Results from benthic toxicity tests will be evaluated for data quality according to criteria provided in the Sampling and Analysis Plan (SAP). The rules for data treatment described below will be implemented once a complete project dataset is compiled.

3.1 Data Usability Criteria

Relevant data that meet the established quality criteria outlined in the project SAP will be considered for use in the risk evaluation. Data also will be evaluated according to *Guidance for Data Usability for Risk Assessment* (EPA 1992), which provides minimum data requirements to ensure that data will be appropriate for risk evaluation use. The guidance addresses the following issues relevant to assessing data quality for risk evaluation:

- Data sources—Consider the type of data collected (e.g., field screening data, fixed laboratory data) and determine whether data meet quality assurance/quality control (QA/QC) objectives outlined in the project SAP.
- Consistency of data collection methods—Review sample collection methods for appropriateness relative to the target analytes, media, and laboratory analytical methods; review field logs to identify sample collection quality issues; and identify differences in sample collection methods, if any, for different field investigations.
- Analytical methods and detection limits—Evaluate methods for appropriateness for the target analytes and media and determine if detection limits are low enough for risk-based evaluation.
- Data quality indicators—Review data validation reports for data quality issues.

3.2 Data Treatment

Data determined to be acceptable for use in the risk evaluation may be treated or modified according to the rules listed below. Treatment may relate to detected or non-detected analytes, data qualifiers, and duplicate sample results. Other treatment rules may relate to specific classes of chemicals, such as PCDDs and PCDFs, PCBs, and carcinogenic polycyclic aromatic hydrocarbons (cPAHs).

3.2.1 Qualified Data

At times, problems are identified in laboratory analytical results and in such cases, detected analytes may be assigned a data qualifier. A detailed discussion of the data validation process and data qualification is provided in the project SAP. It is not uncommon to identify problems with analytical data associated with the chemical concentration, chemical identity, interference from other analytes, and/or matrix interferences (EPA 1989).

The four dominant data qualifiers used in environmental investigations are “R,” “U,” “J,” and “B.” Validated data will be reviewed, and any results that are flagged with “R” qualifiers, indicating the result was rejected by the data validator, will not be included in the risk evaluation dataset. Results flagged with a “U” qualifier indicate that the analyte was not detected. Treatment of “U”-qualified data is discussed in the following section. Data flagged with a “J” qualifier indicate that the chemical identity is certain and that the chemical was detected, but the concentration is estimated. These results will be included in the risk evaluation dataset. “J” qualifiers may be a result of interference with the sample analysis or when contamination was detected in the blank samples. In the latter case, the result also may be flagged with a “B” qualifier. Positive hits for common laboratory contaminants (including acetone, 2-butanone, methylene chloride, and toluene) that are flagged with a "B" qualifier are assumed to be present in the sample due to laboratory contamination if the concentration is less than five times the detection limit. Such “B”-qualified data will be assumed to be present at the detection limit.

3.2.2 Non-Detect Data

Results that are flagged with a “U” qualifier indicate that the analyte was not detected at the method detection limit (MDL). The MDL is the lowest concentration that can be reliably measured above the “noise” associated with the analytical method (EPA 1989). If an analyte is not detected in any samples for a particular medium, then it will be assumed that the chemical is not present, and it will not be considered further in the risk evaluation.

In most cases, results flagged with a “U” qualifier will be assumed to be present at a concentration equal to one-half of the MDL. In some cases, substitution of the MDL with a concentration of one-half of the MDL may not be an acceptable approach to evaluating “U”-qualified data. Exceptions to this substitution method will be based on the frequency of detection of the analyte and the distribution and skewness of the data. When data are censored, or are skewed due to a high frequency of non-detect results, statistical methods may be used to substitute surrogate concentrations to non-detect results (e.g., bootstrapping). EPA guidance (Singh and Singh 2007) and Ecology will be consulted to determine an appropriate approach to treatment of censored datasets, and an explanation of treatment of all non-detect concentrations will be provided in the risk evaluation report.

An additional consideration for treatment of non-detect results pertains to PCDDs/PCDFs; co-planar, dioxin-like PCBs; and PAHs. For these chemical classes, two approaches will be followed to describe concentrations of these compounds. One approach will involve using one-half of the MDL for non-detected congeners or cPAH constituents when calculating the total toxic equivalent concentration (TTEC) for each sample. The second approach will involve assuming a value of zero for non-detected congeners or cPAH constituents when calculating the TTEC. Results using both approaches will be presented in the risk evaluation.

3.2.3 Application of Toxic Equivalency Factors and Calculation of Total Toxicity Equivalence Concentrations

Chemical concentrations for carcinogenic PCDDs/PCDFs; co-planar, dioxin-like PCBs; and PAHs are usually expressed as the total toxic equivalent concentration of a reference compound. The measured concentrations of PCDDs/PCDFs; co-planar, dioxin-like PCBs; and PAHs (milligrams per kilogram [mg/kg] or micrograms per kilogram [µg/kg]) are converted to TEQs by multiplying the measured concentrations of these compounds, or similar groups of compounds, by a chemical-specific toxic equivalency factor (TEF). The TEF is an estimate of the relative toxicity of a chemical compared to the reference chemical. Then, the toxic equivalent concentrations (TEC) for each chemical or class of chemicals are summed to obtain a TTEC (total toxicity equivalent concentration). The TTEC provides a measure of the total toxicity of the individual congeners of PCDDs/PCDFs, PCBs, and/or cPAHs present in a sample. A list of TEFs and a more complete discussion of this methodology is provided in *Evaluating the Toxicity and Assessing the Carcinogenic Risk of Environmental Mixtures Using Toxicity Equivalency Factors* (Ecology 2006b).

The TTEC for PCDDs/PCDFs and co-planar, dioxin-like PCBs is expressed in terms of the toxicity of the reference chemical, 2,3,7,8-TCDD. Separate TECs will be calculated for PCDDs/PCDFs and for co-planar, dioxin-like PCBs to determine the relative contribution of each group of congeners to the TTEC for 2,3,7,8-TCDD. The TTEC for cPAHs is expressed in terms of the toxicity of the reference chemical, benzo(a)pyrene (BaP).

The TEFs developed by the World Health Organization (Van den Berg et al. 1998, 2006) will be used to calculate the TTECs for PCDDs/PCDFs and dioxin-like PCBs for mammals, birds, and fish. Ecology has adopted the TEFs recommended by the California Environmental Protection Agency (CalEPA 2005) for evaluation of cPAHs (Ecology 2006b). A list of TEFs and a discussion of the toxicological basis for their use will be provided in the toxicity assessment section of the risk evaluation report.

3.3 Selection of Indicator Hazardous Substances

The State of Washington Model Toxics Control Act (MTCA) acknowledges that at some sites where a large number of chemicals are present, it can be useful to eliminate from further consideration those chemicals that contribute only a small portion of the overall threat to human health and the environment. Chemicals that are not eliminated are referred to as indicator hazardous substances (IHSs) under MTCA (Chapter 173-340-703 WAC). The IHS selection process, described below for the HH/ERAs, will be completed following further consultation with Ecology and receipt of the validated data. The selected IHSs and the process for their selection will be described in *Technical Memorandum #1, IHS Selection and Revised CSM*, which will be developed prior to completion of the risk evaluation. *Technical Memorandum #1* also will include a revised CSM.

3.3.1 Human Health Screening Process

Ecology considers several parameters in the selection of IHSs, including frequency of detection, evaluation of essential nutrients, toxicological and physical characteristics of each chemical, and natural background concentrations. These parameters are consistent with EPA human health risk evaluation guidance (EPA 1989).

Frequency of Detection

The first step in selecting IHSs involves assessing the frequency of detection for all analytes. Analytes that were not detected in any sample will not be evaluated in the risk evaluation. Analytes with a low frequency of detection (for example, 5 percent) in a medium also may be eliminated from further consideration because they could be attributable to laboratory contamination, may be an artifact of the sampling methodology, or may not be site-related. Chemicals that are known to be site-related or that cluster in specific areas of the harbor (indicating a potential hot spot) should not be excluded.

Evaluation of Essential Nutrients

EPA (1989) recommends removing chemicals from further consideration if they are generally considered “essential nutrients” because some naturally occurring chemicals are beneficial to human life. These are chemicals that are toxic only at very high doses, are essential human nutrients, and are present at concentrations that would not be due to sources identified in the summary of chemical sources for Oakland Bay. The essential nutrients that will not be included in the list of IHSs include magnesium, calcium, sodium, and potassium.

Selection of Screening Values

Screening values are typically selected from a variety of sources for media that could be primary sources of exposure and are usually based on either residential or worker exposure scenarios. As noted in the discussion of the preliminary CSM, people who may have contact with media in Oakland Bay include subsistence, recreational, and commercial fishers, and recreational users of area beaches. The primary pathway for human contact with contaminated sediments is through contact with marine surface sediments while fishing or gathering shellfish. However, there are no marine SQS numerical concentration criteria for the protection of human health (Chapter 173-204-320 WAC). Discussions will be held with Ecology risk assessors to select appropriate screening values. As mentioned above, a separate technical memorandum will be developed that will outline the selected screening levels and the basis for their selection.

Evaluation of Background

Substances in the environment that are not related to an unplanned release and that may be either naturally occurring or anthropogenic are referred to as “background” substances (EPA 2002). Naturally occurring substances are found in forms that have not been influenced by human activity. Anthropogenic substances are those chemicals, natural (e.g., metals) or man-made (e.g., PCBs), that are present in the environment as a result of globally distributed human activities but are not specifically related to the sources of contamination under investigation.

Background samples are usually collected from a “reference” area, which is a relatively uncontaminated area that is suitable for sampling to evaluate background chemical concentrations. These reference areas are identified as “background reference areas” (EPA 2002).

Site-specific background samples, if available, as well as published regional background levels will be used to make comparisons between background reference and site investigation data, as appropriate. Additional discussion of the use of any reference data will be provided in the risk evaluation report.

3.3.2 Ecological Screening Process

Chemicals to be included in the ERA will be selected by comparing maximum chemical concentrations in sediment with sediment benchmarks. Washington State *Sediment Management Standards* (Chapter 173-204 WAC) will be used preferentially as screening benchmarks, as described in Section 5.5. In addition, all detected chemicals in sediment, fish, or shellfish samples with a log K_{ow} greater than 3.5 will be included in the ERA. Such chemicals may pose a hazard to wildlife that feed on biota from Oakland Bay. Chemicals that appear to be associated with toxicity in bioassays, and that may be associated with wood waste decomposition, will also be included, such as ammonia, sulfides, and total organic carbon. Finally, selection of chemicals to be included in the ERA will follow the general guidelines described above regarding frequency of detection, essentiality, and background concentrations.

3.4 Exposure Areas

Data will be grouped into appropriate exposure areas, which will allow for calculation of risks associated with each area to facilitate further site investigation planning as well as the risk management and land use decision-making process. Generally, data will be grouped into areas where people or ecological receptors are expected to contact exposure media over the duration of exposure.

3.5 Calculation of Exposure Point Concentrations

An exposure point concentration (EPC) is used to estimate the magnitude of exposure for each receptor, or person, who may contact IHSs present in Oakland Bay media. EPCs are estimates of the average concentration in a medium that a receptor may contact over time (EPA 1989). To account for uncertainty in estimating a true average concentration, EPA recommends using the 95 percent upper confidence limit (UCL) of the arithmetic mean concentration for each exposure area (EPA 1992, 2002c). Typically, the lesser of the UCL or the maximum detected concentration for each IHS is used as the EPC.

UCLs will be calculated according to EPA guidance (1992, 2002c), using EPA's EPC calculation software, ProUCL Version 4.0 (Singh and Singh 2007, Singh et al. 2007)[1]. For exposure areas containing fewer than 10 data points, the maximum value will be used as the EPC. For exposure areas containing greater than 10 data points, ProUCL will be used to determine the statistical distribution of the data. The method for calculating the UCL will depend on the distribution of the dataset. After evaluating a dataset, ProUCL 4.0 provides a recommendation for what it deems to be the most appropriate statistical method for calculating the UCL for that dataset. The UCL calculation methods recommended by ProUCL version 4.0 will be used.

When direct measurement of the exposure medium of interest is not possible or data are not available, EPCs may be estimated indirectly through the use of models. For example, concentrations of IHSs in fish tissue may be estimated by applying a biota-to-sediment accumulation factor (BSAF) to the measured sediment concentration. These models include inherent uncertainties and must be applied carefully to avoid significant over- or underestimation of exposure media concentrations. Calculation of EPCs using modeling approaches will be discussed with Ecology and the technical basis for model selection will be discussed in the risk evaluation report.

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[1] ProUCL Version 4.0 and the User's Guide (Singh et al. 2007) can be downloaded for free at: http://www.epa.gov/esd/tsc/software.htm.

4.0 Human Health Risk Assessment Methodology

4.1 Overview

The following section outlines the methodology for the human health risk evaluation. This section consists of methods for the exposure assessment (Section 4.2), toxicity assessment (Section 4.3), risk characterization (Section 4.4), and the uncertainty evaluation (Section 4.5).

The exposure assessment describes how exposures to receptors will be quantified for each anticipated exposure pathway while the toxicity assessment explains how the toxicity of carcinogenic and noncarcinogenic IHSs is estimated. The information from the exposure and toxicity assessments is then combined to generate quantitative estimates of risk. The risk evaluation report will provide a detailed discussion of uncertainty associated with each step of the risk evaluation and will indicate how each issue may impact the overall risk estimates.

The risk evaluation will draw upon federal and state guidance, in addition to information presented in peer-reviewed publications, including but not limited to the following documents:

- *Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Part A* (EPA 1989);
- *Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Part B, Development of Risk-Based Preliminary Remediation Goals* (EPA 1991);
- *Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment. Final.* (EPA 2004);
- *Exposure Factors Handbook* (EPA 1997a); and
- *Evaluating the Toxicity and Assessing the Carcinogenic Risk of Environmental Mixtures Using Toxicity Equivalency Factors* (Ecology 2006b).

4.2 Exposure Assessment

An exposure assessment estimates the type and magnitude of human exposure to IHSs. A complete exposure pathway must exist for exposure and subsequent risks to occur. A complete pathway must include the following elements (EPA 1989):

- A source and mechanism for release of constituents;
- A transport or retention medium;
- A point of potential human contact (exposure point) with the affected medium; and
- An exposure route at the exposure point.

The exposure pathway is not considered complete if any one of these elements is missing. The preliminary human health CSM (Figure 2-5) illustrates each of the possible exposure pathways relevant to receptors present at Oakland Bay.

Exposures are quantified using an algorithm that represents exposure. Inputs to this algorithm are assumptions based on site-specific and other applicable information. EPA (1989) provides a generalized exposure algorithm used in risk assessment, which is modified for each exposure pathway:

$$I = \frac{EPC \times CR \times EF \times ED \times F \times ABS}{BW \times AT}$$

where

I = Intake, the amount of chemical taken in by the receptor (mg chemical/kg body weight-day)

EPC = Exposure point concentration, the chemical concentration contacted over the exposure period at the exposure point (e.g., mg chemical/kg sediment)

CR = Contact rate, the amount of the exposure medium contacted per unit time or event (e.g., sediment ingestion rate (milligrams per day [mg/day]))

EF = Exposure frequency, describes how often exposure occurs (days/year)

ED = Exposure duration, describes how long exposure occurs (year)

F = Intake fraction, fraction of media contacted that is assumed to be from the contaminated source (unitless)

ABS = Absorption factor, an adjustment factor to account for relative absorption of a chemical from the medium of interest compared to absorption from the exposure medium in the toxicity study(ies) used to derive the toxicity value (unitless)

BW = Body weight, the average body weight of the receptor over the exposure period (kilograms)

AT = Averaging time, period over which exposure is averaged (days)

The variables shown in the exposure algorithm above are called exposure factors and vary depending on the population being evaluated. Each population (i.e., beach and shoreline users, commercial fishers, recreational fishers, and subsistence fishers) will be characterized by exposure factors assumptions regarding the frequency of contact with exposure media, duration of exposure, and other parameters unique to each population. Exposure factors will be obtained from several regulatory agency and literature sources, including the EPA (1989, 1997a, 2002d, 2004), and any Ecology, tribal, and local exposure information that may be available.

Exposure factors specific to each exposure scenario will be selected following consultation with Ecology and will be presented in a separate *Technical Memorandum #2, Exposure Assessment*. The memorandum will include factors for a reasonable maximum exposure (RME) scenario and a central tendency (CT) scenario for each receptor population, as defined by EPA (EPA 1989). The CT scenario is based on average estimates of exposure. The RME scenario provides a health-protective estimate of exposure that is reasonable. The reasonable maximum exposure is defined here as the highest exposure that is reasonably expected to occur at a site but is still well above the average exposure level, while the CT scenario provides an estimate of exposure for most individuals within a population.

4.2.1 Identification of Exposure Scenarios

Section 2.3 describes the preliminary CSM, including potential exposure pathways and receptors of concern for Oakland Bay. As shown in Figure 2-5, relevant exposure media include surface water, sediment (accessible at the shoreline), beach soil/sand, bottom sediment, and aquatic biota. Populations that might encounter these exposure media are identified as current and future adult and child receptors of the following populations: subsistence, recreational, and commercial fishers, and recreational users of Oakland Bay beaches.

The preliminary CSM identifies potentially complete exposure routes but does not attempt to classify routes as "major" or "minor" routes. The risk evaluation will discuss the significance of each route and include a revised CSM that will note those routes evaluated quantitatively versus qualitatively. The scenarios proposed for evaluation in this risk evaluation include:

- Current/future subsistence fisher, adult and child;
- Current/future recreational fisher, adult and child;
- Current/future commercial fisher, adult; and
- Current/future recreational user, adult and child.

The exposure pathways for the subsistence and recreational fisher populations and the recreational user populations are expected to be similar, but will differ from each other in the frequency and magnitude of exposure. Complete and more detailed descriptions of each exposure scenario, including exposure factors for each receptor population and exposure areas relevant to each scenario, will be provided to Ecology in a separate document, *Technical Memorandum #2, Exposure Assessment*, which will be developed following consultation with Ecology and completion of *Technical Memorandum #1, IHS Selection and Revised CSM*.

4.3 Toxicity Assessment

The toxicity assessment compiles information on adverse health effects that the IHSs could cause and provides an estimate of the dose-response relationship for each IHS, i.e., the relationship between the extent of exposure and increased likelihood and/or severity of adverse effects. The dose-response relationship provides the basis for the development of toxicity values used in the risk evaluation. Toxicity values and a brief narrative describing the toxicity of each IHS will be provided in the risk evaluation report.

Toxicity values for the IHSs will be presented in the risk evaluation report according to the following hierarchy recommended in EPA's *Human Health Toxicity Values in Superfund Risk Evaluations* (2003):

- *Integrated Risk Information System* (IRIS) Computer Database (EPA 2008). IRIS is the preferred source of information because this database contains the most recent toxicity values that have been reviewed extensively by EPA.
- EPA's Provisional Peer-Reviewed Toxicity Values (PPRTVs). The Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC) develops PPRTVs on a chemical-specific basis. These values will be consulted if a toxicity value is not available on IRIS.
- Other Values. In the absence of established values from IRIS or PPRTVs, toxicity values from several sources (e.g., CalEPA toxicity values, EPA regional toxicologists, Agency for Toxic Substances and Disease Registry [ATSDR] toxicological profiles, Health Effects Assessment Summary Tables [HEAST], and National Center for Environmental Assessment [NCEA]) may be used.

When no other values are available, surrogate values may be used in consultation with Ecology risk assessors. Surrogates are selected based on similar structure, mechanism of action, and toxicity.

The approach for assessing the toxicity of carcinogenic and noncarcinogenic IHSs is presented in the following sections. Special subpopulations may be more susceptible to the toxic effects of exposure to IHSs. These subpopulations include the elderly, infants and children, people with pre-existing illnesses, and the fetuses of pregnant women. As described in the following sections, uncertainty factors are used to provide additional protection for sensitive subpopulations.

4.3.1 Assessment of Carcinogens

EPA (2005a) uses a weight-of-evidence (WOE) approach to evaluate the likelihood that a substance is a carcinogen. Data derived from human and animal studies are reviewed and then the carcinogenicity of a chemical is characterized as: (1) known human carcinogens (WOE Class A); (2) probable human carcinogens (WOE Class B1 or B2); (3) possible human carcinogens (WOE Class C); or (4) not classifiable as to human carcinogenicity (WOE Class D). If an evaluation reveals that a substance is not a carcinogen, it is classified as WOE Class E (EPA 2005a). The WOE classifications for each IHS will be presented in the risk evaluation report.

The toxicity of a chemical at low doses is estimated from high-dose cancer bioassays. Consistent with one of the current theories of carcinogenesis, EPA (1989) has selected the linearized multistage model to estimate toxicity values. In this model, EPA uses the 95 percent UCL of the slope of the dose-response curve, or slope factor, to estimate carcinogenicity. Using these procedures, the regulatory agencies are unlikely to underestimate the actual carcinogenic potency of an IHS. The carcinogenic potency is represented by an IHS's cancer slope factor (CSF) and is expressed as risk per milligram per kilogram per day [$(mg/kg\text{-}day)^{-1}$].

EPA (2004) has not developed CSFs for dermal exposure to all chemicals, but has provided a method for extrapolated dermal CSFs from oral CSFs. This route-to-route extrapolation has a scientific basis because once a chemical is absorbed, its distribution, metabolism, and elimination patterns are usually similar, regardless of exposure route. However, dermal toxicity values typically are based on absorbed dose, whereas oral exposures usually are expressed in terms of administered dose. Consequently, if adequate data regarding the gastrointestinal absorption of an IHS are available, then dermal CSFs may be derived by applying a gastrointestinal absorbance factor to the oral toxicity value (EPA 2004). For chemicals lacking a gastrointestinal absorbance value, absorbance is assumed to be 100 percent, and the oral CSF will be used to estimate toxicity via dermal absorption.

4.3.2 Assessment of Noncarcinogens

To evaluate noncarcinogenic effects, EPA (1989) defines acceptable exposure levels as those to which the human population, including sensitive subgroups, may be exposed without adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety. The potential for adverse health effects associated with noncarcinogens (e.g., organ damage, immunological effects, birth defects, and skin irritation) usually is assessed by comparing the estimated average daily intake (i.e., exposure dose) to an RfD.

EPA develops the RfD by identifying the no observed adverse effect level (NOAEL) or lowest observed adverse effect level (LOAEL) in the scientific literature. NOAELs and LOAELs may be derived from either human epidemiological studies or animal studies; however, because human data are often lacking, these levels are usually derived from laboratory animal studies in which relatively high doses are administered. Uncertainty factors then are applied to the NOAELs and LOAELs to compensate for the data limitations inherent in the experiments, in addition to uncertainties associated with extrapolating high-dose animal data to the relatively low-dose environmental exposure situations in humans.

RfDs are expressed in units of mg/kg-day. The RfD is an estimate (with uncertainty possibly spanning an order of magnitude) of the daily intake to humans (including sensitive subgroups) that should not result in an appreciable risk of deleterious effects. EPA assigns a qualitative level of confidence (i.e., low, medium, or high) to the study used to derive the toxicity value, database, and RfD. The relative degree of uncertainty associated with the RfDs and the level of confidence that EPA assigns to the data and the toxicity value are considered when evaluating the quantitative results of the risk evaluation.

RfDs are developed for specific exposure routes (i.e., oral, dermal, and inhalation). The extrapolation of inhalation and dermal RfDs from oral RfDs will be discussed in the risk evaluation report if such RfDs are used. RfDs for all IHSs will be presented in the risk evaluation report.

4.4 Risk Characterization

The risk characterization is the calculation of upper-bound excess lifetime cancer risks and noncarcinogenic hazards for each scenario described in the refined CSM that will be provided in the risk evaluation report. The exposure parameters described in Section 4.2 will be integrated with the toxicity information provided in Section 4.3 to obtain risk and hazard estimates for each scenario. Risks and hazards will be summed for each person across all pathways to obtain an estimate of total potential risk and hazard.

4.4.1 Risks for Carcinogens

The potential for someone to develop cancer as a result of exposure to Oakland Bay media will be estimated using the exposure and toxicity assumptions. The estimated intake will be multiplied by the chemical-specific CSF to determine the cancer risk, as shown below:

$$Risk = Intake \times CSF$$

where:

Intake = Lifetime average daily intake (mg/kg-day)
CSF = Cancer slope factor (mg/kg-day)-1

This linear relationship is valid only at cancer risk levels less than 1 × 10^{-2}. The calculated risk is an upper-bound estimate of the excess risk of an individual developing cancer over a lifetime from exposure to site-related contaminants. The actual risk is likely to be no more than, and probably less than, the calculated risk.

Cancer risks will be determined separately for exposure to each chemical through each exposure pathway. People may be exposed to IHSs through multiple pathways; for that reason, cancer risks then will be summed across the exposure pathways representative of each exposure scenario to obtain the total potential excess lifetime cancer risk for each scenario.

Federal and state environmental laws and regulations recognize that estimates of very small levels of risk are insignificant. The concept of *de minimis* risk refers to a specific level below which risks are so small that they are not of potential regulatory concern. In risk evaluation, government agencies recognize that excess lifetime cancer risks less than 1 × 10^{-6} are generally *de minimis*. For the purposes of risk evaluation, Ecology has determined an acceptable target level will be 1 × 10^{-5} and the risk for an individual IHS shall not exceed 1 × 10^{-6}.

4.4.2 Risks for Noncarcinogens

The potential for adverse effects resulting from exposure to noncarcinogens will be assessed by comparing the chemical-specific intake to its RfD, yielding a hazard quotient (HQ) as follows:

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

where:

HQ = Hazard quotient (unitless)
Intake = Average daily intake (mg/kg-day)
RfD = Reference dose (mg/kg-day)

The reference exposure level, the RfD, is calculated using exposure parameters similar to those in the intake equation described in Section 4.2. The RfD represents an exposure level at which no adverse effects are expected to occur, although the absence of all risks cannot be ensured (EPA 1989). An adequate margin of safety is incorporated into the reference dose to ensure protection of sensitive populations (EPA 1989). As mentioned in Section 4.3.2, the reference dose is considered a "soft" estimate, with bounds of uncertainty that can span an order of magnitude.

HQs will be provided for exposure to individual chemicals through each exposure pathway, for each person. HQs for individual chemicals will be summed to yield a hazard index (HI). A person could be exposed to multiple IHSs through various pathways. Therefore, the HIs will be summed across all exposure pathways for each scenario. The IHS-specific HQs will be summed according to the major health effects and target organs affected, because the effects of exposure may not be additive for all IHSs and may lead to an overestimation of the potential for adverse health effects.

4.5 Uncertainty Assessment

Uncertainty is inherent in every step of the process and will be discussed in relation to its impact on the risk evaluation results. For example, uncertainty will be associated with the estimating the intake of each IHS for each receptor due to the use of assumptions for exposure factors such as contact rate, frequency of exposure, and duration of exposure. Similarly, the uncertainty underlying a toxicity estimate for a particular IHS may be great or small, depending on the confidence EPA provides in the toxicity database or critical study on which the toxicity estimate is based. The risk evaluation report will include an evaluation of the uncertainty associated with each step of the risk evaluation process.

5.0 Ecological Risk Assessment Methodology

5.1 Overview

The purpose of the ERA is to determine whether or not sediment contamination from historic and ongoing municipal, commercial, and industrial sources poses a risk to ecological receptors at the site, including threatened and endangered species. The results of the ERA will be used to help determine whether or not remedial measures are necessary to protect and/or restore the natural environment and, if so, to aid in the selection of appropriate remedial goals.

The methodology used in the ERA will be consistent with state and federal guidance, including, but not limited to:

- Washington State *Sediment Management Standards, Chapter 173-204 WAC*;
- *Model Toxics Control Act Chapter 173-340 WAC*;
- *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (EPA 1997b);
- *Guidelines for Ecological Risk Assessment* (EPA 1998); and
- *Wildlife Exposure Factors Handbook* (EPA 1993).

In addition to the above-mentioned state and federal guidance documents, publications from Oak Ridge National Laboratory (ORNL) and articles from the peer-reviewed literature will be used, as appropriate.

The ERA will include an ecological characterization, final list of assessment and measurement endpoints, wildlife exposure analysis, ecological effects assessment, risk characterization, and uncertainty evaluation. These components of the ERA are discussed in turn below.

5.2 Ecological Characterization

An ecological characterization of Oakland Bay will be prepared based on site-specific information contained in previous site reports, general information on the ecology of southern Puget Sound, and observations made during site investigation activities. The marine environment of Oakland Bay and the plant, invertebrate, fish, and wildlife species found there will be described. The USFWS and the WDFW will be contacted for current information on threatened and endangered species in the site vicinity.

5.3 Assessment and Measurement Endpoints

In an ERA, assessment endpoints are expressions of the ecological resources that are to be protected (EPA 1997b). An assessment endpoint consists of an ecological entity and a characteristic of the entity that is important to protect. According to EPA (1998), assessment endpoints do not represent a desired achievement or goal, and should not contain words such as *protect* or *restore*, or indicate a direction for change such as loss or increase. Assessment endpoints are distinguished from management goals by their neutrality (EPA 1998).

Measurements used to evaluate risks to the assessment endpoints are termed "measures" and may include measures of effect (e.g., results of sediment toxicity tests), measures of exposure (e.g., chemical concentrations in sediment), and/or measures of ecosystem and receptor characteristics (e.g., habitat characteristics) (EPA 1998). Based on the site ecology, site-related contaminants, and preliminary ecological conceptual site model, the ecological resources most at risk from sediment contamination at Oakland Bay include aquatic vegetation, benthic invertebrates, fish, mammals, and birds. The assessment endpoints and measures for these receptors are listed in Table 5-1.

Table 5-1 Summary of Assessment Endpoints and Measures for the Ecological Risk Assessment for the Oakland Bay Sediment Investigation

Assessment Endpoint[a]	Representative Species	Measure
Seagrasses and Macroalgae	Eelgrass, Kelp	Sediment habitat quality as affected by wood waste distribution in sediment.
Benthos	Clams, Polychaetes, Crabs	Sediment chemical concentrations compared with marine sediment standards and benchmarks.
		Sediment bioassay results.
		Sediment habitat quality as affected by wood waste distribution in sediment.
Fish	Rock Sole, Starry Flounder	Fish tissue chemical concentrations compared with tissue standards and benchmarks.
Carnivorous Birds	Cormorant, Bald Eagle	HQ method based on concentration of site-related chemicals in sediment and fish.
Omnivorous Birds	Scaup	HQ method based on concentration of site-related chemicals in sediment, seagrass or macroalgae, and marine invertebrates.
Herbivorous Birds	Black Brant	HQ method based on concentration of site-related chemicals in sediment and seagrass or macroalgae.
Carnivorous Mammals	Harbor Seal	HQ method based on concentration of site-related chemicals in sediment, fish, and benthic invertebrates.
Omnivorous Mammals	Raccoon	HQ method based on concentration of site-related chemicals in sediment, fish, and benthic invertebrates.

[a] Sustainability (growth, survival, and reproduction) of the listed communities and wildlife populations in Oakland Bay.

Key: HQ = hazard quotient.

5.4 Wildlife Exposure Analysis

Exposure analysis is the first step in the wildlife risk assessment process. In this step, wildlife exposure to site-related chemicals is estimated using measured concentrations of chemicals in environmental media and exposure parameters for the chosen receptor species. Because potential impacts to aquatic life and benthos will be examined using direct measurements of effects, comparison of media concentrations to published guidelines, and/or evaluation of effects, comparison of media concentrations to published guidelines, and/or evaluation of sediment habitat quality, the exposure assessment will apply only to the wildlife species being evaluated.

Potential wildlife receptors and exposure pathways were generally discussed in Section 2.3 and identified in the preliminary conceptual site model. This section identifies specific wildlife exposure scenarios that will be evaluated in the assessment and discusses how wildlife exposure to chemicals in the environment will be quantified.

5.4.1 Wildlife Receptor Species

Six wildlife species representing different functional groups will be evaluated:

- Brant (*Branta bernicla*);
- Double-Crested Cormorant (*Phalacrocorax auritus*);
- Greater Scaup (*Aythya marila*);
- Harbor seal (*Phoca vitulina*);
- Raccoon (*Procyon lotor*); and
- Bald Eagle (*Haliaeetus leucocephalus).*

The cormorant, harbor seal, and bald eagle are piscivorous and therefore may be highly exposed to bioaccumulative contaminants. The raccoon is an omnivorous mammal that is known to forage in the intertidal zone and thus may be exposed to contaminants in water, sediment, and prey. The brant and scaup are waterfowl that often forage in shallow water habitats and thus may be exposed to contaminants in water, sediment, and prey in the littoral zone of Oakland Bay.

For these six wildlife receptors, exposure from incidental ingestion of contaminated sediment and consumption of contaminated prey will be evaluated. Exposure through drinking will not be quantitatively evaluated because Oakland Bay is a saltwater system. Although wildlife may consume small amounts of surface water while feeding, such consumption is likely to account for only a small faction of total chemical exposure. This is due to the fact that chemicals typically occur at much greater concentrations in sediment and biota than in surface water. Lastly, direct contact with contaminated water and sediment is assumed to be a minor route of exposure for wildlife due to the protection provided by fur and feathers and will not be quantitatively evaluated. A summary of important life-history characteristics of the chosen receptor species is provided below.

Brant

The brant is a small goose that breeds in the Arctic, winters from Alaska south to Baja California, and remains near saltwater throughout the year (Kaufman 1996). The brant feeds almost exclusively on plants. During the winter, it feeds predominantly on eelgrass, salt marsh plants, and green algae. During the breeding season, it feeds on Arctic grasses and sedges, forbs, and moss. The brant forages on exposed vegetation and rooted plants in shallow water but does not dive; at high tide, it feeds on dislodged leaves floating at the surface.

Double-Crested Cormorant

The double-crested cormorant is the most widely distributed cormorant in North America (Kauffman 1996). It is very adaptable and will use almost any aquatic habitat, including rocky northern coasts, mangrove swamps, large reservoirs, and small ponds. The double-crested cormorant nests in trees near water, on sea cliffs, or on ground on islands. The diet of this species varies with the season and place and includes a very wide variety of fish, crabs, shrimp, crayfish, frogs, salamanders, eels, and sometimes snakes, mollusks, and plant material. It forages mostly by diving from the surface and swimming under water, propelled by its feet. The double-crested cormorant may forage in clear or muddy water. It usually forages at mid to upper levels more often than near the bottom.

Greater Scaup

The greater scaup breeds in Alaska and northern Canada and spends the winter on either the Pacific or Atlantic coast (Kaufman 1996). During summer, this species occurs on lakes and bogs in semi-open country near the northern limits of the boreal forest, and out onto the tundra. In winter, the greater scaup occurs mainly on coastal bays, lagoons, and estuaries. In winter, the diet includes mainly mussels, clams, oysters, snails, and other mollusks. In summer, the diet of the greater scaup includes plants such as pondweeds, wild celery, sedges, and grasses, as well as insects and crustaceans. The greater scaup usually forages by diving and swimming under water; larger food items are brought to the surface to be eaten. Occasionally, the greater scaup will forage by dabbling or upending in shallow water.

Harbor Seal

Harbor seals range from Alaska to Baja California along the Pacific coast (EPA 1993). Harbor seals inhabit a wide variety of environments and are able to tolerate a wide range of temperatures and water salinities. In western North America, the harbor seal inhabits tidal mudflats, sand bars, shoals, river deltas, estuaries, bays, coastal rocks, and off-shore islets, even ranging up rivers into freshwater areas in search of food (EPA 1993). Habitats used for haulouts include cobble and sand beaches, tidal mud flats, off-shore rocks and reefs, and man-made objects such as piers and log booms. The diet of the harbor seal varies seasonally and includes bottom-dwelling fishes (e.g., sole, flounder), invertebrates (e.g., octopus, crabs, and clams), and pelagic species that can be caught in periodic aggregations (e.g., herring, squid). Harbor seals are opportunistic, consuming different prey in relation to their availability and ease of capture. They hunt alone or in small groups.

Raccoon

The raccoon is the most abundant and widespread medium-sized omnivore in North America. Raccoons are found near most aquatic habitats (EPA 1993) and are common in suburban areas, residential areas, and cultivated and abandoned farmland. The raccoon is an omnivore and opportunistic feeder. They feed on fruits, nuts, acorns, corn and other grains, insects, frogs, shellfish, crayfish, eggs, and many other types of animal and vegetable matter. Diet composition for raccoons depends on location and season. Plants usually are a larger component of the diet than animals, except in the summer. When available, raccoons preferentially consume aquatic animals, including clams, crayfish, frogs, fish, and snails (WDFW 2008c). Raccoons also will dunk or wash food in water prior to consumption. Raccoons normally are active from sunset to sunrise but will change their activity pattern to accommodate food availability. For example, salt marsh raccoons may be active during the day in order to forage during low tide.

Bald Eagle

The bald eagle is a top predator in many aquatic ecosystems in North America and the second largest raptor (bird of prey) in North America (Peterson 1980). Bald eagles are found throughout North America, and extensive breeding populations are found in Alaska, northern Canada, and along the Atlantic Coast from Florida to Maine and up through the Maritime Provinces of Canada (Buehler 2000). Bald eagles are opportunistic foragers that frequently scavenge for dead or dying fish, waterfowl, and mammals, or steal prey from other birds. They are typically found in coastal areas or along the margins of rivers and lakes. Bald eagles are known to occur in the northern portion of the South Puget Sound and may use Oakland Bay and nearby coastal areas for foraging. Because the bald eagle consumes larger and presumably older fishes than the cormorant, its exposure to bioaccumulative chemicals may be greater.

5.4.2 Quantification of Exposure

Chemical exposure for wildlife will be calculated as the sum of exposures from diet and incidental sediment ingestion. Dietary exposure will be calculated by multiplying the chemical concentration in each food item by its fraction of the total diet, and summing the contribution from each item. This sum is then multiplied by the receptor's site use factor (SUF), exposure duration (ED), and ingestion rate (IR), and divided by the receptor's body weight (BW), as shown in the following equation:

$$EE_{diet} = ([(C_1 \text{ x } F_1) + (C_2 \text{ x } F_2) + \ldots (C_n \text{ x } F_n)] \text{ x SUF x ED x IR})/BW$$

where:

EE_{diet} = Estimated exposure from diet (mg/kg-day);
C_n = Chemical concentration in food item *n* (mg/kg dry weight);
F_n = Fraction of diet represented by food item *n*;
SUF = Site use factor (unitless);
ED = Exposure duration (unitless);
IR = Ingestion rate of receptor (kg/day dry weight); and
BW = Body weight of receptor (kg fresh weight).

The SUF indicates the portion of an animal's home range represented by the site. If the home range is larger than the site, the SUF equals the site area divided by the home range area. If the site area is greater than or equal to the home range, the SUF is equal to 1. ED is the percentage of the year spent in the site area by the receptor species. Home-range size, IR, diet composition, and BW for the brant, double-crested cormorant, greater scaup, harbor seal, and raccoon will be taken from EPA (1993), Sample and Suter (1994), Sample et al. (1996), Kaufman (1996), and/or other applicable references.

Wildlife exposure to chemicals through incidental sediment ingestion will be estimated in a manner similar to dietary exposure. Specifically, the sediment chemical concentration will be multiplied by the sediment IR and then multiplied by the SUF and ED and divided by BW. Sediment ingestion estimates for the receptor species will be taken from Sample and Suter (1994), Sample et al. (1996), Beyer et al. (1994), and/or other applicable references.

The total exposure for a receptor will be calculated as the sum of the exposure from diet and incidental sediment ingestion, as represented by the following equation:

$$EE_{total} = EE_{diet} + EE_{sediment}$$

where:

EE_{total} = Total exposure (mg/kg-day);
EE_{diet} = Estimated exposure from diet (mg/kg-day);
$EE_{sediment}$ = Estimated exposure from sediment ingestion (mg/kg-day).

5.4.3 Exposure Point Concentrations

EPCs – exposure point concentrations – for site-related chemicals in sediment and biota will be developed as described below.

Sediment

As described in Section 3.5, ProUCL version 4.0 may be used to calculate the 95 percent UCL on the arithmetic average concentration for chemicals in sediment. If so, the sediment EPCs will be area-weighted as appropriate based on the wildlife receptor being evaluated. For example, for the raccoon, only intertidal and splash-zone sediment samples will be used. Alternatively, sediment EPCs may be established on a point-by-point basis for some exposure areas if the numbers of sediment samples that are available are too few to allow calculation of a meaningful UCL. The sediment EPCs will be used to estimate exposure from incidental sediment ingestion, as described in Section 5.4.2. In addition, the sediment EPCs may be used to model uptake of sediment contaminants into wildlife prey if site-specific data on contaminant levels in wildlife prey are lacking.

Seagrass and Macroalgae

The brant and greater scaup consume aquatic vegetation. If available, site-specific data on chemical concentrations in seagrasses or macroalgae from Oakland Bay will be used to evaluate exposure for the brant and greater scaup. If such site-specific data are not available, modeling will be used to estimate chemical levels in aquatic vegetation. The models will be selected in consultation with Ecology.

Benthic Invertebrates

Benthic invertebrates are readily consumed by the scaup, raccoon, and harbor seal. If available, site-specific data on chemical concentrations in invertebrates (shrimp, snails, crabs, clam, etc.) from Oakland Bay will be used to evaluate exposure to the scaup, raccoon, and harbor seal. If such site-specific data are not available or cannot be collected as part of the present investigation, modeling will be used to estimate chemical levels in benthic invertebrates. The models will be selected in consultation with Ecology.

Fish

Fish are the preferred prey of the harbor seal, cormorant, and Bald Eagle. If available, site-specific data on chemical concentrations in fish from Oakland Bay will be used to evaluate exposure to the harbor seal and cormorant. If such site-specific data are not available, modeling will be used to estimate chemical levels in fish. The models will be selected in consultation with Ecology.

5.5 Ecological Effects Assessment

The ecological effects assessment establishes concentrations and doses of chemicals that are associated with toxicity. For benthic life, appropriate sediment quality benchmarks are selected. For fish, critical tissue concentrations associated with effects on fish can be selected. For wildlife, reference doses are selected. Lastly, for some receptor groups, ecological effects can be measured directly using bioassay methods. This section describes the selection of media benchmarks, wildlife references doses, and bioassays for the Oakland Bay ERA.

5.5.1 Sediment Quality Benchmarks

Sediment quality benchmarks will be taken from the following sources:

- Washington State *Sediment Management Standards* (Chapter 173-204 WAC);
- *A Compendium of Environmental Quality Benchmarks* (MacDonald et al. 2000);
- *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Sediment-Associated Biota: 1997 Revision* (Jones, Suter, and Hull 1997); and
- *NOAA Screening Quick Reference Tables* (Buchman 1999).

Other sources also may be used if those listed above do not provide benchmarks for all chemicals of interest in sediment at the site.

5.5.2 Fish Tissue Benchmarks

Critical fish-tissue concentrations associated with adverse effects on fish will be taken from the following sources:

- *Lower Duwamish Waterway. Quality Assurance Project Plan: Fish and Crab Tissue Collection and Chemical Analysis. Appendices A to E* (Windward 2004);
- *A Compendium of Environmental Quality Benchmarks* (MacDonald et al. 2000);
- *Linkage of Effects to Tissue Residues: Development of a Comprehensive Database for Aquatic Organisms Exposed to Inorganic and Organic Chemicals* (Jarvenin and Ankley 1999);
- *Phase 1 Fish Tissue Sampling Data Evaluation, Upper Columbia River Site CERCLA RI/FS* (CH2M HILL 2006); and
- *Assessments of Chemical Mixtures via Toxicity Reference Values Overpredict Hazard to Ohio River Fish Communities* (Dyer et al. 2000).

Other sources also may be used if those listed above do not provide benchmarks for all chemicals of interest in fish at the site.

5.5.3 Wildlife Toxicity Analysis

NOAELs and LOAELs based on chronic effects on reproduction and/or growth will be the preferred toxicity reference values (TRVs) for the wildlife risk assessment. Chronic NOAELs and LOAELs will be taken from the following sources:

- EPA (2005b-j; 2006a,b; and 2007a-d) for metals;
- *Review of Navy–EPA Region 9 BTAG Toxicity Reference Values for Wildlife* (CH2M HILL 2000); and
- *Toxicological Benchmarks for Wildlife: 1996 Revision* (Sample et al. 1996).

Other sources also may be used if those listed above do not provide TRVs for all chemicals of interest at the site. If necessary, chronic NOAELs and LOAELs will be developed from subchronic or acute toxicity data using uncertainty factors recommended by Sample et al. (1996).

5.5.4 Bioassay Methods

Three different sediment bioassays will be conducted at selected sediment sampling stations to directly measure sediment toxicity, or the lack thereof, in Oakland Bay:

- 10-day amphipod (*Rhepoxynius abronius* or *Eohaustorius estuarius*) test (survival endpoint);
- 48-hour bivalve (*Mytilus galloprovincialis* or *Dendraster excentricus*) larval development test (normal development endpoint); and
- 20-day juvenile polychaete (*Neanthes arenaceodentata*) test (survival and growth endpoints).

These tests directly measure the combined effect of all sediment contaminants on benthos (PSEP 1995).

5.6 Risk Characterization

The risk characterization section of the ERA will provide a summary of potential risks to the assessment endpoints listed in Table 5-1. The significance of the risks will be discussed.

Potential risks to wildlife receptors posed by site-related chemicals will be evaluated by calculating an HQ for each contaminant for each endpoint species. The HQ will be determined by dividing the total exposure (EE_{total}) by the appropriate TRV, as shown in the following equation:

$$HQ = EE_{total}/TRV$$

To estimate the range of potential risks, HQs for each receptor will be calculated based on both the NOAEL and LOAEL (abbreviated as HQ-NOAEL and HQ-LOAEL, respectively). For a given receptor and chemical, an HQ-NOAEL greater than 1 indicates that the estimated exposure exceeds the highest dose at which no adverse effect was observed. Such a result does not necessarily imply that the receptor is at risk, especially if the HQ-NOAEL is only marginally above 1. An HQ-LOAEL greater than 1 suggests that a chronic adverse effect is possible to an individual receptor, assuming that the estimated exposure for that receptor is accurate.

Similarly, HQs for risks to benthic life and fish will be calculated by dividing chemical concentrations in sediment and tissue, respectively, by the appropriate benchmarks. If a resultant HQ is greater than 1, a potential risk exists for adverse effects from exposure to that chemical.

Lastly, the growth and survival results for the sediment bioassays listed in Section 5.5.5 will be examined to identify locations of potential toxic effects. Bioassay results will be weighted more heavily than predictions of chemical toxicity to benthos based on calculated HQs.

The ecological significance of HQs greater than 1 will be discussed from the perspective of the weight-of-evidence of the chemical and biological data. Factors entering into this discussion could include bioavailability of contaminants, geographic extent of contaminated areas, and uncertainties in the toxicology of the chemicals.

5.7 Uncertainty Assessment

The final analysis in the risk assessment will be a discussion of uncertainties in the analysis and possible effects these uncertainties could have on the interpretation of the results. Because modeling techniques will be used in the assessment of wildlife risks, uncertainties are associated with most portions of the risk calculations. However, the use of conservative assumptions throughout the analysis will ensure that risks are unlikely to be underestimated.

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