PORTLAND HARBOR RI/FS
PROGRAMMATIC WORK PLAN

APPENDIX B:
ECOLOGICAL RISK ASSESSMENT APPROACH

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LIST OF ACRONYMS

AOC	Administrative Order on Consent
AWQC	Aquatic Ambient Water Quality Criteria
BERA	Baseline Ecological Risk Assessment
COI	Chemical of Interest
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
CRD	Columbia River Datum
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
ESA	Endangered Species Act
ft	feet
ISA	Initial Study Area
LWR	Lower Willamette River
LWG	Lower Willamette Group
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
m	meter
mm	millimeter
mg/kg	milligrams per kilogram, dry weight
mg/L	milligrams per liter
NMFS	National Marine Fisheries Service
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
ONHP	Oregon Natural History Program
PCB	polychlorinated biphenyl
PRE	Preliminary Risk Evaluation
PRG	Preliminary Remediation Goal
QA/QC	Quality Assurance/Quality Control
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RM	River Mile
ROD	Record of Decision
SOW	Statement of Work
SMA	Sediment Management Area
TRV	Toxicity Reference Value
USFWS	U.S. Fish and Wildlife Service
yr	year

1.0 INTRODUCTION

1.1 PROJECT AND SITE DESCRIPTION

This document presents the Ecological Risk Assessment Approach for the Portland Harbor Superfund site. This approach is prepared based on the requirements of the scope of work (SOW) and Administrative Order on Consent (AOC) (EPA 2001) entered into with the U.S. Environmental Protection Agency (EPA) for conducting the Remedial Investigation/Feasibility Study (RI/FS). This ecological risk assessment approach was developed according to EPA guidance for conducting ecological risk assessments (ERAs) (EPA 1997, 1998).

The Portland Harbor Superfund site focuses on the lower Willamette River (LWR) in the vicinity of the City of Portland. Although the boundaries of the site have yet to be defined (and will be defined as a result of the RI/FS process), EPA has defined an initial study area (ISA) as the LWR from river mile (RM) 3.5 to 9.2 (Figure 1-2, RI/FS Work Plan).

1.2 DOCUMENT DESCRIPTION

The remainder of this document is organized into 9 sections. Section 2 presents the problem formulation including assessment endpoints and measures, representative species, and exposure pathways. Existing data are summarized in Section 3. The process of identifying chemicals of potential concern (COPCs) is discussed in Section 4. Section 5 includes steps of the analysis for each assessment endpoint: the exposure characterization, effects characterization, and risk estimation. Section 6 discusses risk description and Section 7 addresses uncertainties. References are given in Section 8.

1.3 ECOLOGICAL RISK ASSESSMENT PROCESS

This appendix presents the information and processes critical to completing the preliminary risk evaluation (PRE), Comprehensive Round 2 site characterization and data gaps analysis report, and baseline ecological risk assessment (BERA) for the Portland Harbor Superfund Site, including processes for intermediate decisions. This appendix presents the compilation of background information used to help guide the ecological risk assessment process at this Superfund site, and presents the rationale and tasks necessary to complete the ecological risk assessment. It is anticipated that the risk assessment will be an iterative process, with production of a PRE at an intermediate stage of data collection, a Comprehensive Round 2 site characterization and data gaps analysis report following further data collection, and a BERA after Round 3 data collection concludes. LWG has engaged in continuous discussions with EPA and its partners regarding the ERA approach. Agreements have been reached on some methods and issues and these are reflected in this appendix. Discussions will continue as the ERA process progresses.

An ERA is an integral part of the RI/FS process. This process is designed to facilitate risk management decisions for Superfund sites. Ecological risk assessment draws on many fields of science, such as environmental toxicology, ecology, and environmental chemistry, to characterize potential adverse effects caused by exposure to site-related chemicals. According to EPA guidance, the ERA is "a qualitative and/or quantitative appraisal of the actual or potential impacts of chemicals from a hazardous waste site on plants and animals other than humans and domesticated species (EPA 1997)." Using the results of this process, it is possible to determine if actual or potential ecological risks exist at a site, identify which chemicals present at a site pose an ecological risk, and generate data to be used in evaluating cleanup options (EPA 1997). Figure 1-1 presents the ecological risk assessment framework, as presented in EPA (1998). The Portland Harbor Superfund Site ERA process will be consistent within this framework.

An ERA, conducted under EPA guidance (EPA 1997, 1998), has three major components:

- Problem Formulation: The information needed to focus the analysis phase of the ERA
- Analysis: The characterization of effects and characterization of exposure
- Risk Characterization: The calculation of risk estimates and discussion of uncertainties

The problem formulation considers the historical background and conditions of the site, the ecological management goals and important aspects to be protected (assessment endpoints), the means by which the assessment endpoints will be evaluated (measures), and the habitats and ecological receptors (EPA 1998). The end product of the problem formulation process is the conceptual site model (CSM), which describes the potential chemical sources and transport mechanisms, evaluates potential exposure pathways, and identifies the receptors that will be assessed.

A clear picture of the site conditions and ecological resources potentially at risk is important in preparing and conducting the risk assessment. The problem formulation is the tool used to do this, thus framing the scope and scale of the risk assessment. The problem formulation is also used to prepare for the analysis phase of the ERA. The analysis phase of the risk assessment includes the characterization of exposure and the characterization of effects. The risk characterization is the final phase of the risk assessment, where risk assessors use the results of the analysis phase to estimate risk, describe the risk (using multiple lines of evidence), and finally to identify and summarize the uncertainties, assumptions, and qualifiers in the risk assessment (EPA 1998). Following the risk characterization, an evaluation of background chemical concentrations will be conducted, consistent with EPA guidance on background (EPA 2002). This information will be used to help in making risk management decisions for the site.

Consistent with EPA guidance (1989), the goal of the ERA process is not to eliminate uncertainties, but to reduce them to a level that can support sound risk management decisions. This process will result in the identification of those pathways and areas of the site that warrant evaluation for possible remedial action. To assist in this process, risk management decision points (e.g., COPC selection for fish) will be considered at various intervals in the Portland Harbor Superfund Site remedial process. Additional field sampling plans will be developed as the project proceeds through each round of data collection.

To evaluate ecological risks at the site, the following overall process has been established:

- Compile and review existing data and information about the LWR
- Develop, using the problem formulation process, a CSM and identify assessment endpoints, representative species, risk questions, and measures for the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA
- Develop a work plan that presents an analysis approach for assessing risks and identify data needed to assess risk
- Collect and analyze data as required to complete a PRE
- Identify data gaps
- Collect additional data
- Conduct PRE and prepare report
- Refine CSM and identify additional data gaps
- Fill data gaps (e.g., collect site-specific ecological information on selected receptors)
- Prepare the Comprehensive Round 2 site characterization and data gaps analysis report for the site
- Identify remaining data gaps
- Collect remaining data
- Prepare BERA report.

In this process, data needs will be identified through an iterative process of data analysis and field work. In this document, existing ecological data are used to determine data needs for field sampling events through a problem formulation approach. Using this approach, representative species for the site were selected and data needed to further evaluate risks to these species were identified. The first data collection efforts occurred before issuance of the AOC in 2000 and 2001 (Round 0). Since the AOC, a single round of data collection has occurred — Round 1 in 2002. Additional sampling rounds will begin in 2004. To design the 2004 Round 2 sampling, the spatial coverage of the Round 1 and historical data will be reviewed with regard to known contaminant sources and representation of receptor habitat and home ranges. In addition, co-located sample analyte concentrations will be reviewed to evaluate the relationship between tissue and sediment concentrations. If no correlation is seen between the tissue and sediment chemistry, various hypotheses will be evaluated with EPA and EPA's Partners and additional sampling may be conducted. Additional sampling needs may be identified for subsequent rounds, as needed, based on this review of Round 1 and Round 2 data.

Existing data and data from the 2002 sampling events will be analyzed in an upcoming PRE document to determine remaining data needs that will be addressed either in the remainder of the Round 2 sampling season or in subsequent rounds if needed. The PRE is used as an interim tool to assist in the risk assessment process. The intent of the PRE is to facilitate a better understanding of the CSM and to assist in future discussions regarding uncertainty in making risk management decisions. Because ERA sampling in Round 1 targeted mainly fish and invertebrate (crayfish) tissues and sediments, the PRE will focus on assessing risk to fish and wildlife receptors. The PRE will include data presentation and an evaluation of the potential ecological risk based on data collected as part of the Round 1 data collection effort. The PRE will be conducted using conservative exposure assumptions, with the purposes of identifying key exposure pathways on which to focus more detailed analyses and identifying potential data gaps. The PRE results will be used to identify preliminary COPCs for fish tissue and possibly some of the wildlife receptors (e.g., those with lower sediment ingestion rates; COPCs for the sandpiper, with it's high sediment ingestion rate, could not be identified) for which additional evaluation is necessary in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA to answer risk assessment questions and risk management decisions. Specifically, the PRE will be used to help facilitate discussions at the site, but not to limit pathways or receptors. Any future limitations of COPCs, receptors, and/or pathways will be discussed with EPA and EPA's Partners prior to that decision.

Following Round 2 sampling, the database will be evaluated for any remaining data gaps and additional sampling will be conducted where necessary to complete the risk assessment. A Comprehensive Round 2 Site Characterization and Data Gaps Analysis report will be prepared following Round 2 sampling. Following any additional sampling rounds completed to fill data gaps identified in the Comprehensive Round 2 site characterization and data gaps analysis report, a BERA will be prepared to assess ecological risks at the site and to aid in the remedial decision-making process for the Portland Harbor Superfund Site using the RI/FS process.

1.4 INTEGRATION WITH RI/FS WORKPLAN

The ERA process outlined in this document will augment and support the RI/FS data collection effort and analysis that is described in the Programmatic RI/FS Work Plan. The ERA and the RI/FS approach have been developed in concert to meet project requirements and to facilitate combined data collection and evaluation efforts. The RI/FS Work Plan is organized into the following major sections:

Section 1. Introduction
Section 2. Physical Setting
Section 3. Chemical Sources
Section 4. Summary of Previous Investigations
Section 5. Preliminary CSM
Section 6. Overview of Portland Harbor RI/FS Process
Section 7. Site Characterization Approach
Section 8. Feasibility Study Approach
Section 9. Project Management Plan

The information presented in the RI/FS Work Plan Section 2 was used in the development of the ERA CSM. The information provided in Sections 3 and 4 of the RI/FS Work Plan was used to further refine and develop the ERA CSM. A summary of the ecological CSM is provided in Section 5 of the RI/FS Work Plan. A summary of the ecological risk assessment approach, ERA data quality objectives (DQOs), and the approach for evaluation of the groundwater pathway is provided in Section 7 of the RI/FS Work Plan.

1.5 UTILIZATION OF ERA PROCESS IN PROJECT DECISION-MAKING

The ERA process is a tool to help managers make informed risk management decisions about site remedial actions. The EPA-prescribed iterative process for ERAs (e.g., moving from conservative assumptions, such as 100 percent site use, to more realistic and accurate site-specific assumptions, such as actual site use (which may be less than 100 percent) helps to better understand the assessment on those critical pathways, receptors, and exposure scenarios that warrant further action (EPA 1992, 1998).

The PRE will provide data and evaluations for the following:

- Refinement/better understanding of the CSM
- Identification of data gaps to reduce uncertainty in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA
- Preliminary COPC list for fish tissue and possibly wildlife receptors (following discussion and agreement with EPA)

The PRE will not be used to limit the benthic assessment or to prematurely limit or focus Round 2 sampling for the wildlife assessment. In addition, the PRE will not be used to limit COPCs for pathways that have not been evaluated (e.g., surface water for fish). All COPCs will be carried forward for evaluation and discussion in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA.

The Comprehensive Round 2 site characterization and data gaps analysis report will provide data and evaluations for the following:

- Refinement of the CSM
- Preliminary COPC list for all ecological receptors
- Identification of any additional data gaps to reduce uncertainty in the BERA
- Refinement of the PRE based on results of Round 2 sampling

The BERA will provide data and evaluations for the following:

- Refinement of the CSM
- Final COPC and COC list for ecological receptors
- Preliminary Remediation Goals (PRGs) for ecological receptors
- Maps of SMAs based on unacceptable ecological risk
- Technical basis for identification of potential remedial alternative
- Potential identification of data gaps to reduce uncertainty in risk management decisions

1.6 DELIVERABLES

A data report will be produced and delivered within 120 days of receipt of the validated analytical results for Round 1. In addition, the PRE will be developed. The target date for a draft of this document is fall 2004. This report will summarize the information gathered from Round 1 and present a preliminary ERA. The PRE report will summarize the data collection effort, evaluate the data in a risk assessment framework using conservative assumptions (e.g., 100 percent site use), and identify data gaps to reduce uncertainties as the ERA process moves through the EPA tiered process. These conservative assumptions are used at this initial stage in the ERA process to ensure no pathways, COPCs, receptors, or exposure scenarios are missed in the evaluation process (for those pathways that can adequately be assessed in the PRE). Following the PRE, more realistic, site-specific assumptions will be used to more accurately characterize risk. This iterative process, as prescribed by EPA (EPA

1997, 1998) will ultimately (following the Comprehensive Round 2 site characterization and data gaps analysis report and BERA) result in a focus on only those problem areas, media, COPCs, or pathways that may warrant remedial action (i.e., an accurate depiction of true risk, based on site-specific considerations).

The PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA will contain the following information and evaluations:

- Introduction
- Summary of data collection effort (ecological field summary, ecological habitat/habitat characteristics summary, analytical data summary)
- Summary of data evaluation process
- Problem Formulation
- Exposure and Effects Analysis
- Risk Characterization
- Identification of Uncertainties and Data Gaps
- Recommendations for additional information/data to reduce uncertainties and fill data gaps
- Conclusions.
- Risk Management Recommendations

Risk management recommendations will be presented in a separate section (or separate document) after the conclusion of risk characterization and the identification of uncertainties. The target date for delivery of a draft PRE Report is fall 2004. Following Round 2 sampling, the Comprehensive Round 2 site characterization and data gaps analysis report will be completed. Although there is no predetermined number of sampling rounds, it is anticipated that additional rounds of sampling may be required for the BERA. The Comprehensive Round 2 site characterization and data gaps analysis and BERA Report will include results from multiple iterations of the ERA process, from the conservative assumptions used in the PRE (e.g., 100 percent bioavailability and/or site use) to more realistic assumptions (e.g., actual bioavailability and/or site use) and estimates of risk based on site-specific information. The Comprehensive Round 2 site characterization and data gaps analysis report may also identify additional data needs. Such data needs will be addressed in the BERA following subsequent rounds of sampling.

2.0 PROBLEM FORMULATION

This problem formulation defines assessment endpoints and examines historical and ecological information pertaining to the site to develop a CSM. A CSM is a depiction of the transport of COPCs from sources through exposure pathways to receptors. The CSM is important in providing a framework for the ecological risk assessment. Section 2.1 discusses selection of assessment endpoints and measures to be used during the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA. Sections 2.2 and 2.3 characterize the ecological receptors in the site and the habitats they utilize. Special status species are considered in Section 2.4. Section 2.5 uses all the previous information to identify receptors for the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA. Section 2.6 identifies potential exposure pathways for these receptors.

It is assumed that any unacceptable ecological risk that may exist is primarily derived from chemicals in sediment. The chemicals may have reached the sediment through groundwater, seeps, upstream sources via surface water transport, upstream sources via sediment transport, or local sources via storm drains, overland flow, bank erosion. The assessment endpoints were selected to evaluate potential impact from the sediments as the primary medium of concern, with potential secondary (contributing sources) media being groundwater and surface water. Potential chemical contaminants include a wide range of organic and inorganic chemicals.

2.1 SELECTION OF ASSESSMENT ENDPOINTS AND MEASURES

The identification of assessment endpoints and measures is essential to the preliminary risk evaluation process. These components are used to focus the ecological risk assessment and ensure that the various attributes of the site are considered from an ecological standpoint when making risk management decisions.

The overall objective for the ecological risk assessment is to identify the risks to ecological receptors from site-related chemicals. If unacceptable risk to ecological receptors is present at the site, the chemicals causing the risk and their pathways to ecological receptors will be identified and become input to risk management decisions about the site.

2.1.1 Assessment Endpoints

The selection of assessment endpoints is an important component of the ERA because the endpoints define the important ecological values that are to be protected (EPA 1998). Assessment endpoints describe both the ecological entity to be protected (i.e., a species, ecological resource, or habitat type) and the characteristics of the entity to be protected (e.g., reproductive success). They are developed based on known information concerning the chemicals present, the environment, and the risk management goals. The development of assessment endpoints aids in clearly defining the goal of the risk assessment and helps to focus efforts.

The assessment endpoints for the ERA were selected based on the following criteria (EPA 1998) and consistency with the AOC:

- Ecological relevance
- Political, societal, and cultural relevance
- Susceptibility to known or potential chemical stressors at the site
- The concepts of habitat viability and functioning of the system
- Consistency with ecological management goals for the site

Assessment endpoints will be evaluated at one of the following levels:

- Individual level
- Population level
- Community level.

These levels are defined according to the values to be protected in the ERA. Species of special status (i.e. federally listed threatened, endangered, candidate, and proposed species, and state listed species) are the only receptors that will be assessed at the individual level, as mandated by EPA guidance (EPA 1997, 1998). In an individual level assessment, the receptor is assessed with the objective of protecting every individual of the population as opposed to accepting adverse effects on some portion of the population.

If a population-level endpoint is selected, it is generally accepted that adverse effects on individuals may be acceptable as long as the overall viability of the population is not significantly affected. Often, single species are selected as a surrogate for populations of other species that have similar exposure pathways (e.g., feeding guilds). Population-level analysis is often an extrapolation from exposure and effects analyses at individual levels. This is usually done because the most precise information on toxicity is often available for the individuals in laboratory tests

A community-level assessment values the community as a whole, and assumes that adverse effects on some species in the community may be acceptable as long as the overall functional structure of the community is not adversely affected. Most ecological communities contain multiple species that occupy similar niches and serve similar ecological function (e.g., shredders and grazers in benthic communities). Therefore, adverse effects on one species may not affect the overall function. However, significant effects on multiple species with similar function could affect the community to levels at are ecologically meaningful. Community-level assessment does not evaluate a single species as a receptor. Instead, risk assessment tools focus on multiple species in the community, often drawing on whatever relevant toxicological information is available.

Fish, birds, and mammals will be evaluated at the population level. Aquatic plants, amphibians, and reptiles will also be evaluated on population level. However, because very little exposure and toxicity information is available that allows assessment of any single species of plants, amphibians and reptiles, the assessment may be performed collectively as a community. Benthic invertebrates and aquatic plants are typically evaluated at the community level because many species are co-located in a localized "community" with little to no movement occurring within the habitat. A community-level assessment of benthic invertebrates will therefore be conducted in Portland Harbor. A population level assessment will also be conducted, as feasible. However, due to practical limitations and the available exposure and toxicity information, the population assessment will likely be more qualitative for benthic invertebrates. Remedial decisions will be based on a community assessment. These levels of assessment were developed based on the SOW and are the levels at which the Lower Willamette Group (LWG), in collaboration with EPA and EPA's Partners, expects to make risk management decisions.

The following assessment endpoints were selected for the Portland Harbor Superfund site. Specific receptor species were selected for assessment to meet the goals set by the assessment endpoints and are identified in Section 2.5.

Assessment Endpoint No. 1: Survival, growth, and reproduction of aquatic plant populations

Aquatic plant communities play an important role in river ecosystems. Diverse and complex aquatic plant communities provide important resources for other aquatic species that inhabit the river ecosystem (Figure 2-1). Many birds, aquatic mammals, amphibians, fish, and invertebrate species rely on aquatic plant communities for nesting and breeding habitat. In addition, these communities provide food for herbivores as well as refuge for higher-trophic-level organisms and habitat for their prey. The physical presence of aquatic plants reduces the velocity and volume of water flowing close to river banks, decreasing erosion and protecting adjacent upland areas from flooding. Plants are also an important source of energy in the river ecosystem. Through photosynthesis, plants utilize light energy to produce biomass for higher trophic organisms. Plants also play an important role in the cycling of nutrients throughout the system. Nutrients in the soil and the water column are taken up and stored in plant tissues. These stored nutrients are further cycled through the system as herbivorous aquatic fauna consume plant tissues and pass these nutrients up the food web. Decomposing plant litter is consumed by detritivorous organisms that return organic matter and nutrients to the soil.

Chemicals in the ecosystem may impact the survival and growth of plant species and adversely affect plant communities. In addition, chemicals can be taken up by plants and transferred through the food web through consumption by higher-trophic-level species.

Assessment Endpoint No. 2: Survival, growth, and reproduction of benthic invertebrate and shellfish populations

Benthic invertebrates serve various functions in large river ecosystems. Both infaunal and epifaunal benthic invertebrates often comprise a significant portion of the biomass and serve as a principal food resource for higher-trophic-level consumers (i.e., fish and wildlife). The benthic invertebrate community plays a vital role in nutrient cycling. This community acts as the link between detrital material deposited on the river bed and the higher trophic levels. Chemicals within the ecosystem can directly impact the survival, growth, and reproduction of the benthic community and can also be transferred through the food web through prey consumption by higher trophic level aquatic fauna.

The infaunal community occurs in the surface sediments, generally the uppermost 10–15 cm, feeding on decaying vegetation, decaying animal biomass, and feces. The epifaunal community occurs either on the surface of the river sediment or attached to hard substrates (e.g., rip-rap, pilings, bulkheads) and is the most diverse benthic invertebrate community in the ISA. This community plays an important role in nutrient cycling and also comprises a major portion of fish and aquatic bird diets. Large benthic invertebrates in the ISA, such as shellfish and crayfish, provide a valuable food resource for fish and avian species. Alteration in the community structure can result in the loss of forage species, which may result in a loss of the functionality of the system. For example, shorebirds, juvenile salmonids, and other carnivorous fish rely heavily on the invertebrate community for their prey base. Therefore, adverse impacts to the benthic community may result in adverse effects on these bird and invertivorous fish populations. In addition, higher trophic level animals that depend on these bird and fish populations can subsequently be affected.

Assessment Endpoint No. 3: Survival, growth, and reproduction of fish

Several different feeding guilds of fish comprise the fish community in the ISA. Each feeding guild plays a distinct role in the dynamics of the river ecosystem. Detritivorous fish feed predominantly on detritus, and are frequent prey of higher-trophic-level fish and birds (Figure 2-2). Omnivorous/herbivorous fish feed upon both vegetation and invertebrates, and also may serve as prey for piscivorous fish, birds, and mammals. Invertivorous fish feed predominantly on benthic and pelagic invertebrates. Both omnivores and invertivores impact invertebrate community composition and size, and also transfer energy and nutrients to higher-trophic-level fish, birds, and mammals. Piscivorous fish feed predominantly on smaller fish species and serve as top fish predators. Chemicals within the ecosystem can have potentially adverse effects on the fish populations by directly impact the survival, growth, and reproduction of fish species. The specific assessment endpoints are as follows:

- Survival, growth, and/or reproduction of herbivorous fish
- Survival, growth, and/or reproduction of detritivorous fish
- Survival, growth, and/or reproduction of invertivorous fish
- Survival, growth, and/or reproduction of picivorous fish

The feeding guilds of fish represented in the ISA are important pathways of nutrients and energy throughout the food chain and the ecosystem. Many bird and aquatic mammal species rely on fish for food. Fish of all feeding guilds are important in the maintenance of a balanced ecosystem and in the nutrient and energy cycles between aquatic primary producers and higher levels in the food chain, both aquatic and terrestrial. Alteration in the fish community structure can result in a loss of the functionality of the system. Chemicals within the system can directly impact the survival, growth, and reproduction of the fish species and adversely affect fish populations. Special concern fish species (i.e. federally or state listed threatened, endangered, candidate or proposed species) will be assessed at the individual level and all other fish species at the population level.

Assessment Endpoint No. 4: Survival, growth, and reproduction of amphibian and reptile populations

Amphibian and reptilian communities play an important role in energy flow in aquatic systems. They feed on aquatic invertebrates and small fish and are prey items for birds, mammals, and fish (Figure 2-1). Many fish species consume tadpoles both as juveniles and as adults. Adult amphibians are preyed on by fish. Birds and mammals also consume adult and juvenile amphibians. In some aquatic systems, amphibians and reptiles provide an important pathway by which nutrients and energy are transferred between the aquatic and terrestrial ecosystems. The survival, growth, and reproduction of amphibian and reptilian populations can be adversely affected by chemicals in the aquatic ecosystem.

Assessment Endpoint No. 5: Survival, growth, and reproduction of birds

Birds utilizing the ISA are from several different feeding guilds, each filling a distinct ecological role in the ecosystem (Figure 2-1). Herbivorous birds feed predominantly on aquatic plants and provide a direct pathway of energy and nutrients from primary producers in the aquatic environment to higher levels in the food chain, both aquatic and terrestrial. They also influence aquatic plant community composition, population size, and structure and serve as prey for organisms higher in the food chain. Invertivorous birds feed on insects and other benthic invertebrates and provide a pathway of energy and nutrients to higher levels in the food chain. Omnivores and invertivores help regulate insect community composition, population size, and structure and serve as prey for organisms higher in the food chain. Piscivorous birds feed on fish and may serve as the top predators in the ISA. They provide another pathway for energy and nutrients to be transferred from the aquatic to the terrestrial ecosystem, and regulate fish community composition and population size and structure. Because most piscivorous birds are in higher trophic levels, they are potentially exposed to greater levels of contamination due to biomagnification of certain chemicals up the food chain. Chemicals present in the food chain may adversely affect bird populations by impacting the survival, growth, and reproduction of avian species. The specific assessment endpoints are as follows:

- Survival, growth, and/or reproduction of invertivorous/omnivorous birds
- Survival, growth, and/or reproduction of carnivorous/omnivorous birds
- Survival, growth, and/or reproduction of picivorous birds

Birds are an important component of the ecosystem and are highly valued by society. They transfer energy and nutrients throughout the food chain and between ecosystems (aquatic and terrestrial), and regulate populations up and down the food chain. Special concern bird species (i.e. federally or state listed threatened, endangered, candidate or proposed species) will be assessed at the individual level and all other bird species at the population level.

Assessment Endpoint No. 6: Survival, growth, and reproduction of mammals
Mammals utilizing the ISA are predominantly piscivorous (Section 2.3.4); however, their diet may include amphibians and aquatic invertebrates (Figure 2-1). Piscivorous mammals provide a pathway for energy and nutrients to be transferred from the aquatic to the terrestrial ecosystem and may serve as prey for other predators. By feeding on fish and invertebrates, they influence fish and invertebrate community composition, population size, and structure. They are relatively high on the food chain and may be exposed to greater levels of chemicals due to biomagnification of chemicals up the food chain. Mammals are valued highly by society. Chemicals present in the food chain may adversely affect their populations by impacting their survival, growth, and reproduction. Mammals will be assessed at the population level. The specific assessment endpoints are as follows:

- Survival, growth, and/or reproduction of piscivorous mammals

2.1.2 Testable Hypotheses

Following selection of assessment endpoints, testable hypotheses and measures of effect must be developed to determine whether or not a potential risk to the assessment endpoint exists (EPA 1997). A testable hypothesis is an operational statement of an investigator's research assumption made in order to evaluate logical or empirical consequences (EPA 1997, 1998). For the purpose of this risk assessment, the testable hypotheses are presented as risk questions about the relationship between the assessment endpoints and the responses of receptors when exposed to chemicals at the site. The general risk question: "are the chemical concentrations in media in the ISA sufficient to cause adverse effects on the survival, growth, or reproduction"? applies to the following assessment endpoints (Section 2.1.1):

- Aquatic plants
- Benthic invertebrates
- Shellfish
- Herbivorous fish
- Detritivorous fish
- Invertivorous fish
- Picivorous fish
- Amphibians
- Reptiles
- Invertivorous/omnivorous birds
- Carnivorous/omnivorous birds
- Picivorous birds
- Piscivorous mammals

Habitat and receptors, where appropriate, will be considered outside of the ISA if there is a potential for exposure to site-related contamination. More specific questions are addressed for each assessment endpoint. These questions and the proposed approach are presented in Sections 4 and 5. Development of risk questions correspond to the "Identify the Decisions" step in EPA's DQO process.

2.1.3 Measures

Three categories of measures that are, in combination, predictive of the assessment endpoints (EPA 1998) will be evaluated in the Portland Harbor ERA:

- Measures of exposure
- Measures of ecological effects
- Measures of ecosystem and receptor characteristics.

Criteria considered in the selection of measures include (EPA 1998):

- Corresponds to or is predictive of an assessment endpoint
- Can be readily measured or evaluated
- Is appropriate to the exposure pathway
- Is associated with low natural variability
- Is not disruptive to the ecological community and species variability
- Is appropriate to the scale of the ISA.

The scale of the ISA may be larger or smaller that the home range of a receptor of interest. Therefore, the scale will be defined in ecological terms. Localized effects will be evaluated based on exposure to the receptors of interest.

2.1.3.1 Measures of Exposure

Measures of exposure are measures of the contact or co-occurrence of the stressor and the receptor (EPA 1998), and include concentrations of COPCs in sediments, surface water, groundwater, and biota. Section 5.0 provides a discussion of the process that will be used to identify COPCs in the various media in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA.

2.1.3.2 Measures of Ecological Effects

Measures of ecological effects are used to evaluate the response of the assessment endpoint receptors when they are exposed to the stressor (EPA 1998). Measures of effect are measurable changes in an attribute of an assessment endpoint or its surrogate in response to a stressor to which it is exposed (EPA 1998). In practice, measurable changes can be based on site-specific measurements of effects, or extrapolation from empirical measurements at other site (e.g., application of TRVs to predict effects). Measures of ecological effects on an individual level will be performed by comparison to a NOAEL and on a population level by comparison to a LOAEL. For completeness, a comparison to both a NOAEL and LOAEL at each level will be made. Identification of measures is also dependent on the level of biological organization being protected in the assessment endpoint.

Individual-level measures:
Effects on survival, growth, or reproduction for individuals of special-status species (see Table 2-8)

Population-level measures:
Effects on survival, growth, or reproduction for aquatic plants, benthic invertebrates, shellfish, amphibian, reptile, fish, bird, and mammalian populations

Community-level measures:
Effects on survival, growth, or reproduction for benthic invertebrate communities

2.1.3.3 Measures of Ecosystem and Receptor Characteristics

Stressors other than chemical toxicity affect the assessment endpoints and can be important in interpreting risks and making decisions. In addition, such factors may modify exposure, such as the frequency and duration of exposure and, therefore, are important considerations in estimating risks. Factors that may modify the potential for adverse effects include predation, habitat alterations, temperature and dissolved oxygen. These measures of ecosystem and receptor characteristics that may have an adverse effect on the ecological community or population will be identified and discussed qualitatively in the context of the chemical-specific risk estimates, the ultimate goal being to estimate those risks attributable to site-related COPCs.

2.2 HABITAT TYPES IN THE LOWER WILLAMETTE RIVER

The majority of the ISA is industrialized, with modified shoreline and nearshore areas. Wharves and piers extend out toward the channel, and bulkheads and riprap revetments armor the riverbank. Active dredging has produced a uniform channel with little habitat diversity. However, some segments of the ISA, as well as areas upstream and downstream of the ISA, are more complex with side channels, shallow water areas, and less shoreline development, providing habitat for a suite of local fauna. This section describes the general types of habitat in the LWR available to ecological species.

2.2.1 Open-water Habitat

The lower main stem of the Willamette River, i.e., Willamette Falls to the confluence with the Columbia River, is characterized by a developed navigation channel and shoreline. Most open-water habitat in the ISA is in the main river channel, but also includes several shallower backwater sites (e.g., Willamette Cove, Swan Island Lagoon, and slips). The deep, open water provides foraging habitat for fish and wildlife that feed in the water column. Shallow-water habitats provide refuge for juvenile salmonids as well as greater foraging opportunities for birds and mammals. Aside from Willamette Cove and Swan Island Lagoon, shallow-water habitats are largely limited to the narrow strip between the shoreline and the navigation channel.

There are three types of benthic habitats in the open water of the LWR: 1) unconsolidated sediments (sands and silts) in the deeper water (greater than approximately 20 ft Columbia River Datum [CRD]) of the navigation channel and lower channel slopes, 2) unconsolidated sediments (sands and silts) in water depths less than 20 ft CRD in gently sloping nearshore areas (e.g., beaches and benches) and on the upper channel slopes, and 3) developed shoreline (e.g., rock riprap, sheet pile, bulkheads). The navigation channel habitat is subject to variable (seasonal and annual) hydrodynamic forces, the impacts of navigation, natural sediment deposition, erosion, and bedload transport, and periodic navigational dredging. These forces vary spatially through the system largely as a function of the channel cross-sectional area and this results in both relatively stable and unstable sedimentary environments that likely support heterogeneous infaunal communities controlled by the local physical regime. In the relatively shallow, nearshore areas, natural hydrodynamic forces are likely less temporally variable. The physical sedimentary regimes are a function of the local riverbank morphologies, and sheltered areas away from anthropogenic disturbance factors should support well-developed infaunal invertebrate communities. Conversely, exposed nearshore areas, particularly around berths, docks, and boat ramps, likely have limited benthic communities controlled by physical disturbance factors. The hard surfaces of the developed shoreline should provide habitat for an epibenthic community. Benthic surveys and maps have been done using sediment profile imaging (SCT 2002f and Work Plan Figure 2-14).

2.2.2 Bank and Riparian Habitat

The Portland Bureau of Planning mapped the banks of the Willamette River from the confluence with the Columbia River to Ross Island at RM 15 (Greenworks et al. 2001). They calculated the percentage of the banks in seven categories ranging from river beach to sea wall. Riprap and unclassified fill combined make up about half of the shoreline in this 15-mile section of the LWR (Figure 2-3).

The type of river bank is expected to influence the species of fish utilizing a given area. The Oregon Department of Fish and Wildlife (ODFW) has conducted several studies addressing this issue (see Section 2.3.2.2). A common factor associated with beneficial habitat for juvenile salmonids is the presence of large woody debris along river banks, which generates small shallow pools and provides cover (Sedell and Froggatt 1984; Bjornn and Reiser 1991). However, no comprehensive survey of large woody debris has been conducted for the LWR, and little opportunity currently exists for large woody debris recruitment to the river banks due to the general absence of mature trees along much of the shoreline.

The upland environment near the LWR is primarily urban, with fragmented areas of riparian forest, wetlands, and associated upland forests. Historical development and filling of channels and wetlands has left only small strips or isolated pockets of riparian wildlife habitat. Therefore, isolated wildlife habitat areas along the LWR corridor exist, but linkages to the larger landscape are limited.

The City of Portland's natural resource inventory of the Willamette River corridor classified the habitat based on characteristics such as connectivity to other areas, access to water, and other factors in order to determine their overall habitat value (Adolfson et al. 2000). Ten distinct habitat classes were identified along the 16-mile stretch of the Willamette River from Sellwood to the Columbia River, including bottomland forest, foothill savanna, conifer forest, scrub/shrub, meadow, emergent wetland, beach, rock outcrop, open water, and unvegetated/disturbed. Fifteen sites of significant habitat value were designated as "habitat sites" for fish and wildlife. The habitat sites identified in the ISA were the South Rivergate corridor at the north end of the ISA, the Harborton forest and wetlands, Willamette Cove, the railroad corridor, and the Swan Island beaches and lagoon on the southern end (Adolfson et al. 2000). The available wildlife habitat in the ISA is shown in Figure 2-3. Other important habitat sites identified in the general area were Kelley Point at the confluence with the Columbia River, and Ross Island and Oaks Bottom Complex around RM 16. The habitat sites listed are known to be utilized by numerous aquatic birds and aquatic and semi-aquatic mammals (Adolfson et al. 2000).

2.3 HABITAT UTILIZATION AND POTENTIAL ECOLOGICAL RECEPTORS

2.3.1 Benthic Invertebrate Community

Benthic invertebrates serve various functions in large river ecosystems. Both infaunal and epifaunal benthic invertebrates often comprise a significant portion of the heterotrophic biomass in a river system (Jahn and Anderson 1986), and therefore, serve as a principal food resource for higher-trophic-level consumers. Invertebrates also control energy flow by acting as the principal processor of organic matter (Merritt et al. 1984).

Benthic invertebrates utilize various habitat types within a large river ecosystem. These habitats can generally be divided into soft and hard substrates, with soft substrates supporting an infaunal community and hard substrates an epifaunal community. These habitats are typically quite different in their community structure and function.

The structure and function of invertebrate communities within portions of the Willamette basin have been extensively investigated. However, few studies have focused on the lower main stem. Tetra Tech (1994) reported benthic invertebrate community structure at six stations as part of the Willamette River basin water quality study. Dames & Moore (1998) sampled 16 stations in the Portland Harbor area, and Landau (2000) collected samples at 10 locations near Ross and Hardtack Islands. Other limited investigations have been conducted by Hjort et al. (1984) and Ward et al. (1988). Table 2-1 contains a list of all the invertebrate taxa collected in the LWR.

2.3.1.1 Infaunal Community Structure and Function

Limited site-specific data exist on the infaunal invertebrate community of the lower main stem of the Willamette River. Tetra Tech (1994), Dames & Moore (1998), and Landau (2000) sampled the infaunal invertebrate community in the LWR. The infaunal community was reported to be dominated by oligochaetes (segmented worms) and chironomids (midge larvae) that are considered gatherers consuming organic material associated with the sediments. Other infaunal species documented include the burrowing mayfly (*Hexagenia* sp.), nematodes, fingernail clams, and freshwater mussels.

Dames & Moore (1998) collected 16 benthic infaunal samples in the Portland Harbor area, and about a third of the sampling stations were located near the Portland Shipyard and in Swan Island Lagoon. They found the abundance of oligochaetes and chironomids at the Portland Shipyard stations to be approximately 50% less than in other sampled areas of the mainstem Willamette River.

Oligochaetes feed on bacteria, diatoms, detritus, and other microorganisms by ingesting large quantities of substrate and extracting organic material. Some species live from 1 to 3 cm below the sediment surface, while others live in tubes attached to filamentous algae, submerged plants, and terrestrial debris (Brusca and Brusca 1990). Most oligochaetes are found in waters less than 1 m deep; however, Tubificidae species can be found in the very deep waters of large lakes and rivers (Pennak 1978).

Chironomids are the only infaunal dipterans occurring in the LWR. Chironomids possess a juvenile aquatic life stage and become terrestrial after their metamorphosis into adult form. Chironomid larvae are herbivorous, feeding primarily on algae, aquatic plants, and detritus. Some species are solitary and free-living, while others are found in large congregations. Infaunal chironomids are burrowers. They are primarily algae collector/gatherers and detritus shredders. Chironomid larvae make up an important component of freshwater fish diets and comprise the most diverse family of infaunal organisms found in the LWR (Pennak 1978).

Burrowing mayflies are primitive winged insects in which the aquatic nymph stage has come to dominate the life cycle. Larvae hatch in fresh water and are long-lived, passing through many instars. Mayfly nymphs are an important food source for many fishes (Brusca and Brusca 1990).

Nematodes are also found in the LWR. They are free-living and parasitic roundworms generally found in freshwater substrates. In natural freshwater habitats, most specimens are confined to the uppermost 5 cm of the substrate (Pennak 1978). Many infaunal nematodes are direct deposit feeders. Others are detritivores or microscavengers, living in or on dead organisms. Some of the free-living nematodes are predatory carnivores. Others are herbivorous, feeding on diatoms, algae, and bacteria (Brusca and Brusca 1990).

The LWG collected van Veen (0.1 m^2) grab samples from 22 locations within the ISA in the fall of 2002 as part of the Round 1 assessment of Portland Harbor. As in the previous studies, the community was dominated by oligochaete worms and chironomid larvae. Bivalves (*Corbicula* sp.) and amphipods (*Corophium* sp.) were also relatively common. A complete review of the data collected in this survey is included in Attachment B1.

2.3.1.2 Epibenthic Community Structure and Function

Hjort et al. (1984) and Ward et al. (1988) conducted limited investigations of the benthic invertebrate community associated with shoreline habitats in the lower main stem of the Willamette River as well as similar sites in more upstream reaches. Landau (2000) collected shallow water benthic samples from hard substrates around Ross Island. Hjort et al. (1984) found high densities of benthic invertebrates associated with revetted shorelines in more upstream reaches. The solid substrate supported a taxonomically and functionally diverse community consisting of scrapers, grazers, filter feeders, and gatherers (Table 2-1). The epibenthic community in the LWR was represented by the following epibenthic invertebrates: ephemeropterans (i.e., mayflies), trichopterans (caddis flies), dipterans (true flies), crustaceans (both amphipods and crayfish), annelids, platyhelminthans, and mollusks.

During the summer of 2002, the LWG conducted a survey of the epibenthic community present in the LWR by deploying artificial substrates in the water column at ten locations in the ISA and two reference locations just upstream. Multiplate samplers were used as artificial substrates. After six weeks, the multiplate samplers were retrieved and all organisms that colonized the available substrate were identified. Chironomid larvae, oligochaete worms, and amphipods (*Corophium* sp.) dominated the epibenthic community collected on the multiplate samplers. *Corophium* sp. were present at all sampling locations from RM 4 through RM 13.5. The highest abundances were seen around RM 4.5, 5.5, 6.5, 9 and 13.5. The lowest abundances were seen in Swan Island Lagoon. A complete review of results from the multiplate sampler survey is included in Attachment B.1.

Most organisms collected during the infaunal and epibenthic surveys conducted by the LWG were consistent with the type of species expected for a deep river like the LWR. According to the River Continuum Concept, the invertebrate community in deep rivers is expected to be dominated by the feeding group called collectors (Vannote et al. 1980). Collectors are composed of both gatherers—organisms that forage for organic matter in the sediments—and filterers, organisms that filter organic matter out of the water column (Cummins and Klug 1979). The dominant taxa in the infaunal and epibenthic communities collected in the LWR all belong to the collector feeding group.

The following invertebrate taxa may be locally abundant in areas of the LWR that provide suitable habitats:

Oligochaeta

Oligochaetes feed on bacteria, diatoms, detritus, and other microorganisms by ingesting large quantities of substrate and extracting organic material. Some species live from 1 to 3 cm below the sediment surface, while others live in tubes attached to filamentous algae, submerged plants, and terrestrial debris (Brusca and Brusca 1990). Most oligochaetes are found in waters less than 1 m deep; however, Tubificidae species can be found in the very deep waters of large lakes and rivers (Pennak 1978).

Diptera

Four families of true flies are found in the LWR: Chaoboridae, Empididae, Simuliidae, and Chironomidae. All of the LWR dipterans are aquatic as juveniles and become terrestrial after they metamorphose into their adult form. *Chaoborus* larvae, also known as phantom midges, are predatory, feeding on small crustaceans and insect larvae. This genus is found throughout the water column, spending most of their time in the bottom waters and on the mud during the day and migrating to the surface water at night. Empididae larvae are sprawlers found on the substrate surface. They are collector/gatherers. The larvae of *Simiulumus,* also known as black flies, attach themselves to rocks and vegetation in shallow areas with swift current and feed on plankton and organic debris by straining prey items from the water with anterior fans. Chironomid larvae are herbivorous, feeding primarily on algae, aquatic plants, and detritus. Some are sprawlers and clingers, attaching themselves to or lying flat against rocks and other substrate. Others are infaunal burrowers, gathering organic matter in and on the sediments. They can be collector/gatherers, detritus shredders, or engulfing predators. Chironomid larvae make up an important component of freshwater fish diets and comprise most diverse and one of the most abundance families of benthic organisms found in the LWR (Pennak 1978).

Amphipoda

Amphipods are scavenging omnivores, feeding on various kinds of plant and animal material. They rarely feed on live animals, but they will consume freshly killed animals. During the daytime, amphipods are found in vegetation and in the crevices of and under debris and rocks. Amphipods, such as *Gammarus* spp., generally occur in water depths no greater than 1 m, and in large rivers such as the Willamette they are mainly found in shallow backwater and overflow pond areas (Voshell 2002). However, estuarine amphipods, such as *Corophium* spp., are locally abundant in the LWR and are commonly found in fine sediments over many depths (McCabe et al. 1997).

Decapoda

Two species of decapods occur in the LWR: Western freshwater crayfish (*Pacifastacus leniusculus*) and the Siberian prawn (*Exopalaemon modestus*). Crayfish have been collected throughout the LWR (Salmon 1972; ODEQ 1994; PTI 1992). Crayfish are omnivores with a diet composed mainly of aquatic vegetation, but they will eat fish, aquatic insects, and detritus when aquatic vegetation is less available (Pennak 1978). Adult crayfish remain in burrows, under stones or debris, or half-buried in substrate during the day and more actively feed between dusk and dawn. Juveniles, however, can be active during the day. Crayfish usually prefer shallow habitats but can be found in depths greater than 1 m. Most stream-dwelling crayfish have home ranges of less than 30 m (Pennak 1978). *Pacifastacus* sp. can live up to eight yr (Hobbs 2001). The Siberian prawn (*Exopalaemon modestus*) is an introduced decapod species in the LWR and the lower Columbia River that may have become well established (Emmett et al. in press). There are no native freshwater shrimp in the Pacific Northwest.

Mollusca

Two classes of mollusks occur in the LWR: Gastropoda and Bivalvia. The five genera of gastropods that may occur in the LWR are all freshwater snails. These gastropods are generally herbivorous, ingesting algae that coats submerged surfaces and other dead plant material by scraping the surfaces with a sclerotized jaw. On occasion they will also ingest dead animal material. Gastropods generally occur in water from 0-3 m deep. Hydrobiidae species generally occur in areas with aquatic vegetation. The barren juga (*Juga hemphilli hemphilli*) and Columbia pebblesnail (*Fluminicola fuscus*) are generally found in creeks and rivers with gravel-boulder substrate and that lack aquatic macrophytes and epiphytic algae (Frest and Johannes 1995). Little is known about the ecology of the rotund physa (*Physella columbiana*). It is thought that they occur in large rivers in relatively deep, well-oxygenated waters and prefer gravel-boulder substrates (Frest and Johannes 1995). Distribution of freshwater snails in the Willamette River is not well understood. Tetra Tech (1995) found *Fluminicola* species and *Juga* species at RM 25.5 in 1994, but no snails were found farther downstream. No snails were found at any stations sampled in 1993. No snails were reported in the benthic grab samples collected by Dames & Moore (1998) or Landau (2000).

Two species of epibenthic bivalves may be found in the LWR. They include the Asiatic clam (*Corbicula fluminea*) and Western pearlshell (*Margaritifer falcata*). These species feed on zooplankton, phytoplankton, and organic detritus. They can occur in water up to 30 m deep, but are predominantly found in water depths from 0-2 m. They prefer stable sand and gravel substrates and are not generally found in areas of high turbidity or clay or rock substrate (Pennak 1978).

The introduced Asiatic clam is the most abundant bivalve in the LWR (Tetra Tech 1995; Dames & Moore 1998; Landau 2000). Tetra Tech (1995) found the highest densities of Asiatic clams between RM 1 and RM 6. Dames & Moore (1998) collected *C. fluminea* at 3 of 14 sampling stations, located at RM 9, RM 10.6, and in the Swan Island channel. Landau (2000) found *C. fluminea* in both deep water and shallow water locations around Ross and Hardtack Islands. The pearlshell mussel is common in the lower Clackamas River (Ellis 1998). However, benthic invertebrate surveys conducted in the LWR during the last seven years have not collected freshwater mussels (Tetra Tech 1995, Dames & Moore 1998, Landau 2000, Frest and Johannes 1995).

Nematoda
Nematodes are also found in the LWR. They are free-living and parasitic roundworms generally found in freshwater substrates. In natural fresh-water habitats, most specimens are confined to the uppermost 5 cm of the substrate (Pennak 1978). Many infaunal nematodes are direct deposit feeders. Others are detritivores or microscavengers, living in or on dead organisms. Some of the free-living nematodes are predatory carnivores. Others are herbivorous, feeding on diatoms, algae, and bacteria (Brusca and Brusca 1990).

Isopoda
Isopods in the LWR generally occur in water no deeper than 1 m. They are found under rocks, vegetation, and debris where they scavenge for food, preying on items such as dead and injured aquatic animals and aquatic vegetation.

Trichoptera
Caddis fly larvae are often found in shallow-water habitats where there is an adequate supply of oxygen. They can occur on all types of substrate, including rock, gravel, sand, mud, debris, and vegetation. There are three families of caddis flies in the LWR: Polycentropodidae, Hydropsychidae, and Leptoceridae. Polycentropodidae and Hydropsychidae are net filter feeders. They collect prey items by constructing a fine net that strains particulate material from the water. They feed either by eating the entire net and its contents or by removing the particulate matter they have collected from the nets. Leptoceridae are grazers. They feed on algae, fungi, detritus, and small invertebrates found on the river bottom.

Ephemeroptera
Mayflies are aquatic as juveniles and terrestrial as adults. Mayfly nymphs in the LWR are opportunistic feeders, consuming primarily aquatic plants and detritus. There are two genera of epibenthic Ephemeroptera in the LWR. *Baetis* nymphs tend to be free-ranging. When at rest they attach themselves to pebbles on the river bottom. *Stenonema* nymphs cling to rocks and other substrates and are found in highest abundance in crevices and under rocks (Pennak 1978). Burrowing mayfly nymphs, e.g., *Hexagenia* spp., are typically found in sandy or silty sediments (Hilsenhoff 2001). Mayfly nymphs are an important food source for many fishes (Brusca and Brusca 1990).

Eucopepoda
Eucopepods found in the LWR are classified in the suborder Calanoida. These copepods filter-feed on plankton and can be found in both littoral and benthic regions of rivers (Pennak 1978). Calanoids can comprise a major part of fish diets.

Heteroptera
The primary heteropterans in this system are the Corixidae, commonly known as water boatmen. These species can move throughout the water column and even fly to other areas in response to overcrowding, high temperatures, or unfavorable conditions. They spend most of their time anchored to the river bottom where they

gather food by sweeping flocculent material into their mouths. They feed primarily on debris, algae, Protozoa, and microscopic Metazoa. Nymphs and adults may spend winters hibernating in the substrate, although they can also be active during the cold season (Pennak 1978).

Other Invertebrate Taxa

Annelids (Nereidae and Hirudinidae families) and Platyhelminthes (Tricladida family) are also found in the LWR epibenthic community. Most of the freshwater species in the family Hirudinidae (leeches) are common inhabitants of ponds, marshes, lakes and slow streams. Leeches prefer protected shallows, where there is little wave action and plants, stones, and debris provide protection. The great majority of specimens are collected in water depths of 0-2 m (Pennak 1978). Leeches prefer substrates to which they can adhere and consequently are uncommon on pure mud or clay bottoms. Nereidae are hunting predators, feeding mostly on small invertebrates. They are predominantly epibenthic, preferring protected habitats in mussel communities, algae, crevices, and under rocks (Brusca and Brusca 1990).

Animals in the phylum Platyhelminthes are free-living and parasitic flatworms. They are particularly successful as parasites and commensals. Most are carnivorous predators or scavengers, feeding on available animal matter (mostly small, living invertebrates). A few are herbivorous, feeding on macroalgae; some switch from herbivory to carnivory as they mature. Freshwater flatworms are found virtually everywhere, usually on or closely related to a substrate. Most species are photonegative and are found under objects during the daytime. Flatworms thrive on any kind of substrate where there is an appropriate food supply (Pennak 1978).

Three species of freshwater mussels may occur in the LWR infaunal community. They are the California floater (*Anodonta californiensis*), Willamette floater (*Anodonta wahlametensis*), and western ridgemussel (*Gonidea angulata)* (Frest and Johannes 1995; Ingram 1948). The California floater and Willamette floater live buried in the soft substrates of large streams and lakes. They prefer relatively slow currents and are filter-feeders, as are the other freshwater mussel species (Frest and Johannes 1995). Ingram (1948) states that the California floater and Willamette floater were present at the mouth of the Willamette River; however, benthic invertebrate surveys conducted in the LWR during the last seven years have not found freshwater mussels (Tetra Tech 1995; Dames & Moore 1998; Landau 2000; Frest and Johannes 1995).

Fingernail clams (Sphaeriidae) are the only native clams reported in the LWR. Tetra Tech (1995) collected Sphaeriidae from the LWR in 1993 and 1994 at two sites located at RM1 and RM 25.5, with an average of 11.1 individuals per sample at RM 1 and 72.1 individuals per sample at RM 25.5. Fingernail clams can reach high densities, up to 10,000 individuals/m^2 in large rivers and can be the major food source for benthivorous fish and wildlife (Jahn and Anderson 1986).

2.3.2 Fish Species

Ellis (2000) conducted a comprehensive review of published and unpublished literature containing information pertinent to fish use of Portland Harbor. This review was conducted through searching ODFW, Oregon Department of Environmental Quality (ODEQ), Columbia River Intertribal Fish Commission, Bonneville Power Administration, U.S. Army Corps of Engineers, and the Northwest Power Planning holdings, published scientific journal articles, agency and private research reports, permit applications, biological assessments and biological opinions, and meetings with agency biologists familiar with the work that has been conducted on the river. In total, 36 documents were reviewed. Based on this review, 64 fish species that have been reported to occur or potentially occur in the LWR, were identified and are presented in Table 2-2. In addition to these reports, ODFW has completed the first year of a four-year study that addresses the diversity and abundance of fish in the LWR, their habitat use, migration patterns and rates, and food habits. Data from the first year of this study (North et al. 2001) are reviewed in Section 2.3.2.2.

Farr and Ward's (1993) sampling of the LWR from RM 0 through RM 17 in 1987 and 1988 using six different sampling methods provides the most recent and complete accounting of the fish of the LWR. In this study, 39 species of fish from 17 families were captured. Nineteen of these species from 7 families were exotic species. Species not reported in previous studies included mountain whitefish (*Prosopium williamsoni*), redside shiner (*Richarsonius balteatus*), longnose dace (*Phinichthys cataractae*), mountain sucker (*Catostomus playrhynchus*), channel catfish (*Ictalurus punctatus*), three-spined stickleback (*Gasterosteus aculeatus*), sand roller (*Percopsis transmontana*), banded killifish (*Fundulus diaphanus*), smallmouth bass (*Micropterus dolomieui*), pumpkinseed sunfish (*Lepomis gibbosus*), walleye (*Stizostedion vitreum*), and starry flounder (*Platichthys stellatus*). They reported two additional fishes captured by anglers, pirapatinga (*Piaractus brachypomus*) and hybrid bass. The diversity of species from this study was higher than any previous study, possibly due to the wide variety of sampling methods and sampling over a longer timeframe. Several fish species that were not captured in this study but have been reported to be present in the LWR include the Pacific brook lamprey (*Lampreta pacifica*), speckled dace (*Rhinichthys osculus*), and tench (*Tinca tinca*), and several other fishes are suspected to occur due to their presence in adjacent waterways (Bond 1973; Wydoski and Whitney 1979).

Since the Farr and Ward (1993) study, several studies have sampled fish species over extended periods of time at specific locations within the harbor (Fishman 1999; Beak 2000). However, no additional fish species have been documented.

2.3.2.1 Fish Habitat Association

Several studies have addressed habitat association of both resident and migratory fish species in the LWR. Farr and Ward (1993) characterized the fish community in terms of bank preference up to RM 17 from 1987 to 1990. Results from this study suggested that non-indigenous species are more associated with moderately developed banks than indigenous species (Table 2-3). Migratory fishes, generally salmonids and American shad (*Alosa sapidissima*), are more evenly distributed between developed and undeveloped shorelines within Portland Harbor (Farr and Ward 1993).

Habitat use by juvenile salmonids in the LWR has been addressed in several studies. Ward et al. (1994) found no pattern to the horizontal distribution (distance from shore) of yearling chinook salmon (*Oncorhynchus tshawytscha*) or juvenile steelhead (*Oncorhynchus mykiss gairdneri)* in Portland Harbor. Sub-yearling chinook salmon were found closer to shore at developed sites than at undeveloped sites.

In 2000, ODFW mapped the banks of the LWR up to Willamette Falls (RM 26) and sampled the fish community using several different gear types to determine habitat preference (North et al. 2001). Mean electrofishing catch rates of juvenile salmonids, in the first year of this four year study, were highest at beach and rock sites in the LWR (North et al. 2001). However, these results were not significantly different from those in other areas, and data from radiotelemetry of subyearling and yearling chinook suggested that rock outcrops were the most preferred habitat (North et al. 2001). Electrofishing catch rates of minnows, suckers, and sunfish were highest adjacent to riprapped banks (North et al. 2001). Additional data in the next three years of this four-year study will provide more information on the habitat associations of resident and migratory fish species in the LWR.

2.3.2.2 Resident and Migratory Fish Species

This section describes resident and migratory fish species that are known to be present, or that could occur based on life history characteristics in the LWR (Altman et al. 1997; Hughes and Gammon 1987; Friesen and Ward 1996; Farr and Ward 1992; Tetra Tech 1995; Beak 2000; Wydoski and Whitney 1979). Fish species were separated into feeding guilds based on the feeding preference of each species as an adult. The four feeding guilds are defined as omnivore/ herbivore (feeds on vegetation and invertebrates or solely vegetation); invertivore (feeds primarily on invertebrates including insects and benthic organisms); piscivore (feeds mostly on fish); and detritivore (feeds mostly on detritus). The diets of fish species in the ISA are somewhat flexible, with a great deal of overlap in diet among groups. For example, a study of piscivorous fish diets in Portland Harbor revealed that piscivorous fish are at least occasionally eating mainly insects and crayfish (Fishman 1999). Similar flexibility is expected in fishes from the other feeding groups. The abundance, feeding guild, habitat, food preferences, lifespan, and age of reproductive maturity of each fish species reported or expected to be found in the LWR, based on collection in the LWR or adjacent water bodies, are presented in Table 2-2.

The majority of fish species found in the LWR are resident species; thus, all life stages may be present within the LWR. These fishes may move upstream and downstream or offshore and inshore in response to water temperatures, food availability, and river flow, but do not have seasonal mass migrations for spawning or feeding. In addition, several species of migratory fishes use the LWR for juvenile rearing and as a migration corridor for both adult and juvenile fishes (Table 2-2). Although spawning habitat for many of these resident and migratory species may occur in the LWR, no studies to date have documented specific spawning locations for any fish species within the LWR.

Omnivores /Herbivores

Thirteen omnivorous fish may occur in the LWR (Table 2-2). The largescale sucker (*Catostomus macrocheilus*), white sturgeon (*Acipenser transmontana*), common carp (*Cyprinus carpio*), brown bullhead (*Ameiurus nebulosus*), and yellow bullhead (*Ameiurus natalis*) are a few examples of common omnivorous species.

The largescale sucker, a member of the Catostomidae family, is native to the LWR. It has a long life span (up to 15 yr) and reaches reproductive maturity at age 3-5 yr (males) and 4-6 yr (females) (Wydoski and Whitney 1979). The largescale sucker generally inhabits large riverine and estuarine waters; however, it prefers to remain close to the bottom in shallow waters both as a juvenile and as an adult. It consumes insect larvae as a juvenile, and diatoms, detritus, crustaceans, and snails as an adult (CBFWA 1996). This native fish is known to consume large amounts of sediment during feeding as an adult (CBFWA 1996). The largescale sucker is a common resident species of LWR (Beak 2000; Farr and Ward 1992; Hughes and Gammon 1987; Tetra Tech 1995). The general habitat of this species is included in Figure 2-6.

The white sturgeon is another common omnivore in the LWR. Sturgeon rely on large, complex river systems for many of their life stages and can feed opportunistically on prey ranging from benthos to large fish (Beamesderfer and Farr 1997). Juvenile white sturgeon are slow to mature, reaching reproductive maturity at 9 yr for males and 13 yr for females (McCabe and Tracy 1993). In addition, white sturgeon is a native species with a very long lifespan (some more than 100 yr) and is highly sought after by anglers (Dees 1961).

White sturgeon are found in the lower Willamette River, including in Portland Harbor. They are highly valued by tribes as a food source and for cultural uses. They are also highly valued as sport fish. The annual harvest of sturgeon from the lower Willamette River has been estimated to be from 1000 to 2000 fish (ODFW 2002). White sturgeon is the largest freshwater fish in North America and has a long life span. Some studies suggest that sturgeon can show strong site fidelity (Veinott et al. 1999) while other studies indicate individual sturgeon can have large ranges (Devore and Grimes 1993). Farr and Ward (1992) found that white sturgeon were more abundant in undeveloped areas than developed areas.

Another sturgeon species, which may be present in the Lower Willamette River, is the green sturgeon (*Acipenser medirostris*).

The common carp is an exotic species to the LWR with a long lifespan (more than 20 yr). Juvenile carp are primarily pelagic feeders; however, the adult fish are largely benthic feeders and consume copepods along with algae and plant fragments (Wydoski and Whitney 1979). The common carp is a common resident species (Hughes and Gammon 1987) and has been found to be evenly distributed throughout the LWR, with populations increasing as the water temperature increases (Farr and Ward 1992; Tetra Tech 1995). The general habitat of this species is included in Figure 2-6.

Brown bullhead and yellow bullhead are two members of the Ictaluridae family present in the LWR. Both of these species are residents and were introduced to the LWR. These species are both bottom feeders with similar life spans (approximately 5 yr) and habitat preferences. However, the preferred range of depth of yellow bullhead (0-10 m) is shallower than that of brown bullhead (0-40 m) (Scott and Crossman 1973). In addition, brown bullhead are tolerant of low dissolved oxygen levels and high temperatures, whereas yellow bullhead prefer clear water of streams or ponds with aquatic vegetation (Wydoski and Whitney 1979). Yellow bullhead have been the most common catch from this family in several studies (Hughes and Gammon 1987; Farr and Ward 1992; Beak 2000); however, yellow bullhead catch numbers were relatively low in other studies (4 fish in Beak [2000], 1 fish in Hughes and Gammon [1987]). In addition, only a few brown bullhead were caught by Farr and Ward (1992).

The eulachon (*Thaleichthys pacificus*) is a native pelagic species that may be present in LWR during a short period of the year. Eulachon inhabit predominately marine waters, migrating to estuaries and coastal rivers to spawn. It is estimated that eulachon spend less than six weeks in freshwater a year.

Other omnivores that are possibly present in the LWR include the fathead minnow (*Pimephales promelas*), oriental weatherfish (*Misgurnus anguillicaudatus*), pumpkinseed sunfish, bluegill (*Lepomis macrochirus*), black bullhead (*Ameiurus melas*), and goldfish (*Carassius auratus*) (Table 2-2). All of these species have been introduced to the LWR. Pumpkinseed prefer quiet vegetated pools in low-velocity areas of rivers (Wydoski and Whitney 1979). Bluegill have similar habitat preferences as the pumpkinseed, preferring low gradient, low velocity areas with abundant pools and aquatic vegetation (Stuber et al. 1982a). Pumpkinseed and bluegill are both benthopelagic species from the Centrarchidae family and are not as common as other members of this family (black and white crappie, smallmouth and largemouth bass), but have been caught in several studies (Farr and Ward 1992; Tetra Tech 1995; Beak 2000).

The goldfish is a benthic feeder with a long life span (up to 25 yr) from the Cyprinidae family and prefers low-velocity, stagnant water of ponds, lakes, and slow-moving rivers (Wydoski and Whitney 1979). Local goldfish populations are subject to frequent fluctuations due to the release of aquarium goldfish into local rivers and ponds (Wydoski and Whitney 1979).

The black bullhead is also a benthic feeder whose presence is rare in the LWR and can live up to 10 yr (Scott and Crossman 1973). Black bullhead prefer soft substrate habitat in pools, backwater and slow current areas in small to large rivers, impoundments, oxbows and ponds.

The oriental weatherfish prefers shallow waters (0-5 m) and muddy substrates (Page and Burr 1991). The fathead minnow prefers pools of headwaters, creeks, and small rivers and can tolerate low dissolved oxygen levels and high water temperatures (Page and Burr 1991). Oriental weatherfish and fathead minnow have not been documented in any of the studies to date.

Only two fish species are classified as herbivores in the LWR: the chiselmouth (*Arocheilus alutaceus*) and the mountain sucker (Table 2-2). Both of these fish are native to the region and resident species.

The chiselmouth is a member of the Cyprinidae family. Chiselmouth can live up to 6 yr and usually reach maturity at age 3-4 yr (Wydoski and Whitney 1979). The chiselmouth is a benthic feeder and consumes a diet of diatoms and algae as an adult, and insects and algae as a juvenile (Wydoski and Whitney 1979). This fish inhabits moderate-to-fast moving pools, creeks, rivers, and lake margins over sandy or gravel substrate (Page and Burr 1991; Wydoski and Whitney 1979). Several fish studies have captured chiselmouth in the LWR (Hughes and Gammon 1987; Farr and Ward 1992; Tetra Tech 1995; Beak 2000).

The mountain sucker is a member of the Catostomidae family and shares similar life history characteristics with the chiselmouth. The mountain sucker inhabits shallow waters of mountain streams over sandy to rocky substrate (Wydoski and Whitney 1979; Scott and Crossman 1973). As adults, mountain suckers prefer diatoms, algae, insects, and plants (Wydoski and Whitney 1979). Studies conducted by Farr and Ward (1992) and Beak (2000) both reported capturing mountain sucker in the LWR. Tetra Tech (1995) collected mountain sucker upstream from Willamette Falls.

Invertivores (benthopelagic)

Several species of benthopelagic invertivorous fish (primarily feeding on invertebrates) may occur in the LWR (Table 2-2). The peamouth (*Mylocheilus caurinus*), redside shiner, and American shad are a few common benthopelagic invertivores occurring in the LWR. All of these species are residents except the American shad, which is anadromous.

The peamouth is a member of the Cyprinidae family and is native to the LWR. It predominantly feeds on benthic invertebrates, crustaceans, and small fish as an adult and can live up to 13 yr (Wydoski and Whitney 1979). The peamouth prefers shallow areas of lakes and slow-moving rivers, remaining nearshore during winter months and moving to deeper waters in the summer months (Wydoski and Whitney 1979). The peamouth has been caught in several studies in the LWR (Farr and Ward 1992; Tetra Tech 1995; Beak 2000).

The redside shiner is a member of the Cyprinidae family and a native resident of the LWR with a short life span (less than 5 yr). The redside shiner prefers to eat zooplankton and algae as a juvenile, and as an adult consumes aquatic and terrestrial insects, zooplankton, and fish eggs. It resides in shallow areas of ponds, lakes, and streams, and prefers gravel-bottomed streams for spawning (Wydoski and Whitney 1979). Farr and Ward (1992) reported catching redside shiner throughout the LWR, but not with the high frequency of other members of the Cyprinidae family.

The American shad is an introduced member of the Clupeidae family. The American shad is anadromous and a repeat spawner, migrating to freshwater after spending 2-6 yr in the ocean (Stier and Crance 1985). The shad is long-lived (approximately 11 yr) and reaches reproductive maturity at 4 yr for males and 5 yr for females (Stier and Crance 1985). It prefers to spawn in broad flats or shallow water of large rivers, and juvenile shad remain in fresh water for their first summer, moving to marine waters in the fall (Stier and Crance 1985). While in freshwater, juveniles consume insects, crustaceans, zooplankton and benthic invertebrates (Wydoski and Whitney 1979). Several studies have observed both adult and juvenile American shad in the LWR (Farr and Ward 1992; Tetra Tech 1995; Beak 2000). Farr and Ward (1992) reported capturing adult and juvenile shad in their May and June collections.

Other benthopelagic invertivores that may be present in the LWR through their introduction to the region include the mosquitofish (*Gambusia affinis*), the banded killifish, the brook trout (*Salvelinus fontinalis*), and the lake trout (*Salvelinus namaycush)*.

The mosquitofish and the banded killifish are resident species and both inhabit shallow water of ponds or backwaters with aquatic vegetation present. The mosquitofish has a very short lifespan (approximately 1 yr). Both species consume benthic invertebrates and insects (Wydoski and Whitney 1979; Page and Burr 1991). Banded killifish were observed in studies conducted by Farr and Ward (1992) and Beak (2000).

Brook trout and lake trout are both salmonids. Brook trout is a benthopelagic feeder, consuming fish, insect larvae, shrimp and snails. It has a lifespan of approximately 4 yr and inhabits cold, headwater ponds and spring-fed streams (Wydoski and Whitney 1979). The lake trout has a longer lifespan (approximately 10 yr) and prefers deep waters of lakes and streams (Marcus et al. 1984).

Invertivores (benthic)

Several benthic invertivores reside in the LWR, including seven sculpin species (*Cottus* spp.), starry flounder, redear sunfish (*Lepomis microphus*), channel catfish, warmouth (*Lepomis gulosus*), and threespine stickleback (Table 2-2). All of these species are residents and are introduced except the sculpin, the starry flounder, and the threespine stickleback, which are native.

The prickly sculpin (*Cottus asper*) is one of seven members of the Cottidae family present in the LWR. The prickly sculpin is short-lived (approximately 4-5 yr) and reaches maturity in 2-4 yr (Wydoski and Whitney 1979). As a juvenile, it feeds in the pelagic zone for the first 30 days, consuming mostly plankton and aquatic insect larvae. The prickly sculpin is a benthic feeder as an adult and consumes crustaceans, aquatic insect larvae, fish, and mollusks (Wydoski and Whitney 1979). It prefers shallow water with sand, gravel, or rubble bottoms and abundant aquatic vegetation (Wydoski and Whitney 1979). It is also tolerant of salinity. Several studies suggested that the prickly sculpin is the most common sculpin in the LWR (Hughes and Gammon 1987; Farr and Ward 1992; Tetra Tech 1995). General sculpin habitat is shown in Figure 2-7.

Other sculpins reported to occur in the Willamette River are the reticulate sculpin (*Cottus perplexus*), mottled sculpin (*C. bairdi*), paiute sculpin (*C. beldingi*), shorthead sculpin (*C. confuscus*), riffle sculpin (*C. gulosus*), and torrent sculpin (*C. rhotheus*) (Hughes and Gammon 1987; Farr and Ward 1992; Tetra Tech 1995). These species are similar in life span (approximately 5-7 yr) and prefer to consume aquatic insects, crustaceans, snails, and fish eggs as adults and aquatic insect larvae as juveniles (Wydoski and Whitney 1979). The reticulate sculpin is reported to have the longest life span (up to 7 yr). It prefers pools and riffles of small streams, and can burrow up to 36 cm into gravel to forage (Wydoski and Whitney 1979). The mottled sculpin, paiute sculpin, shorthead sculpin, and riffle sculpin prefer moderate- to fast-moving, shallow water with rubble or gravel substrates (Wydoski and Whitney 1979).

The starry flounder inhabits shallow to deep estuarine waters, although it can travel far upstream rivers for foraging (Orcutt 1950). It is a benthic feeder and consumes crabs, mollusks, and small fish (Orcutt 1950). Starry flounder were observed in studies conducted by Tetra Tech (1995), Farr and Ward (1992) and Beak (2000).

Redear sunfish is in the Centrarchidae family and is introduced to the LWR. The redear sunfish lives up to 8 yr. Both juveniles and adults are bottom feeders, consuming bottom insects, crustaceans, algae, snails and insect larvae (Twomey et al. 1984). The preferred habitat of the redear sunfish is warm, slow-moving water with little turbidity, although adults can also be found in deeper, open waters (Twomey et al. 1984). The redear sunfish has not been documented in any of the studies of the LWR.

The channel catfish is in the Ictaluridae family and was introduced to the region. This species can live over 14 yr (Wydoski and Whitney 1979), and juveniles take a relatively long time to reach reproductive maturity (approximately 6-7 yr) (McMahon and Terrell 1982). The channel catfish prefers warm water with moderate to swift currents; it forages in shallow water among vegetation, and takes cover in deeper waters (Wydoski and Whitney 1979). Juveniles forage for aquatic insect larvae and plankton, whereas adults consume more crayfish, fish, fish eggs, and aquatic insects (Scott and Crossman 1973; Wydoski and Whitney 1979). Farr and Ward (1992) collected one channel catfish in their 1987–1990 study.

The warmouth is a member of the Centrarchidae family and is also exotic to the region. It has a lifespan of about 7 yr (Wydoski and Whitney 1979) and reaches reproductive maturity at 2 yr (McMahon et al. 1984a). The warmouth prefers backwater habitats with slow-moving water and dense vegetation and is known to be adversely affected by channelization (McMahon et al. 1984a). Juvenile warmouth feed on protozoa, bacteria, and zooplankton, and adults feed on aquatic insect larvae, crayfish, and small fish (Wydoski and Whitney 1979). Farr and Ward (1992) collected warmouth in their 1987-1990 study.

The threespine stickleback is a member of the Gasterosteidae family and is native to the LWR. The threespine stickleback can live in both freshwater and marine systems, but spawns in freshwater habitats. It is a benthic feeder in fresh water, and consumes small crustaceans, insects, and fish eggs (Wydoski and Whitney 1979). The threespine stickleback is short-lived (up to 3 yr) and is found close to the bottom of streams and lakes near aquatic vegetation (Wydoski and Whitney 1979). The threespine stickleback has been observed in the LWR in several studies (Farr and Ward 1992; Tetra Tech 1995; Beak 2000).

Other benthic invertivores that may be present in the LWR include Oregon chub (*Oregonichthys crameri*), longnose dace, leopard dace (*Rhinichthys falcatus*), speckled dace, white catfish (*Ameiurus catus*), tench, green sunfish (*Lepomis cyanellus*), and sand roller.

The Oregon chub, longnose dace, leopard dace, speckled dace, and the tench are in the Cyprinidae family and are all native to the region except the tench. The Oregon chub is endemic to the Willamette Basin (Altman et al. 1997) and is classified as a federally endangered species. According to historic records, Oregon chub have never been recorded north of the Clackamas River and are unlikely to be found in the ISA. They are traditionally found in backwater areas with plentiful aquatic vegetation, little or no flow, and silty organic substrate such as flooded marshes, beaver ponds, or oxbos lakes (Scheerer 1999). The exotic tench prefers warm lakes and pools with mud bottom and abundant weeds, and feeds mostly on algae as a juvenile and on bottom invertebrates and aquatic insects as an adult (Wydoski and Whitney 1979). The three dace species prefer flowing pools and rocky riffles (Page and Burr 1991; Wydoski and Whitney 1979). Longnose and leopard dace live approximately 5 yr, whereas the speckled dace has a lifespan of approximately 3 yr (Wydoski and Whitney 1979). As adults, all three species consume insects, algae, fish eggs, and plant material, whereas juveniles prefer plankton and aquatic insects (Wydoski and Whitney 1979). Farr and Ward (1992) collected one longnose dace in their 1987–

1990 LWR study, and Hughes and Gammon (1987) and Tetra Tech (1995) caught all three dace species upstream from Willamette Falls.

The white catfish has habitat and food requirements similar to the channel catfish; however, the white catfish prefers pools and backwater habitats and can tolerate brackish water (Turner 1966a). The green sunfish and the sand roller also prefer habitat with abundant pools and vegetative or woody debris cover (Stuber et al. 1982b; Wydoski and Whitney 1979). All of these species are benthic feeders and feed on crustaceans, larval insects, and some fish (Wydoski and Whitney 1979). Farr and Ward (1992) reported collecting sand rollers in the LWR. Beak (2000) observed sand rollers in the LWR.

Invertivores (salmonid): Ten species of salmonids are known to occur in this region: chinook salmon (*Oncorhynchus tshawytscha)*, steelhead trout (*O. mykiss gairdneri)*, rainbow trout (*O. mykiss*), chum salmon (*O. keta*), coho salmon (*O. kisutch*), sockeye salmon (*O. nerka nerka*), kokanee (*O. nerka kennerlyi*), coastal cutthroat trout (*O. clarki clarki*), brown trout (*Salmo trutta*), and mountain whitefish (*Prosopium williamsoni*) (Table 2-2). In general, many of these species are anadromous, spawning in freshwater and then spending part of their lifecycle in saltwater before returning again to freshwater. Rainbow trout, kokanee, mountain whitefish, and brown trout are resident species, and are not anadromous. Sockeye salmon, kokanee, and brown trout are exotic to the region; the rest of the salmonids are native. The larger salmon species may be piscivorous as adults in the ocean, but these species are grouped with invertivores because their juvenile stages prey primarily on invertebrates during their residence in rivers. Piscivorous adult salmon returning upriver during their spring migrations feed relatively little.

There are two life history patterns that chinook salmon follow in the Willamette River, a stream type and an ocean type. The stream type generally comprise the spring runs and spend one or more yr in fresh water before migrating to the ocean. The ocean type generally comprise the summer and fall runs and usually migrate to the ocean about three months after emergence (Healy 1991). Chinook spawn in gravel runs, and their eggs require high oxygen concentrations. Juveniles reside in marginal areas of rivers and find cover near woody debris and tree roots (Healy 1991). While in fresh water, juvenile chinook salmon feed on aquatic insect larvae and terrestrial insects (Wydoski and Whitney 1979; Healy 1991).

Steelhead trout share similar life history traits with chinook. Winter runs of steelhead enter fresh water in March or April and spawn in May and June (NMFS 1996). The majority of steelhead in Washington and Oregon smolt after two years in freshwater; however, some juveniles can spend up to seven years in fresh water before migrating to the ocean (NMFS 1996). Steelhead are iteroparous, being able to spawn multiple times, although most steelhead in this region spawn only once (NMFS 1996). Juvenile steelhead feed on aquatic insects and insect larvae while in fresh water (Wydoski and Whitney 1979).

Rainbow trout, the freshwater resident form of steelhead trout, has a lifespan of 3–8 yr. It consumes aquatic insects and insect larvae, worms, and fish eggs as a juvenile, and aquatic insects and fish as an adult (Wydoski and Whitney 1979; Raleigh et al. 1984). Rainbow trout inhabit clear, cold water of stream riffles and pools, with abundant vegetation present (Raleigh et al. 1984).

Chum salmon are semelparous, spawning only once, and anadromous (Salo 1991). Spawning habitat for chum salmon is usually located in the lowermost reaches of rivers and streams, in close proximity to marine waters. After emergence, fry do not remain in fresh water, but immediately begin to migrate to estuarine waters. Migration usually takes approximately 30 days in short streams (Salo 1991).

Coho salmon are also semelparous and anadromous (Sandercock 1991). Coho prefer to spawn in gravel located at the head of stream riffles (Wydoski and Whitney 1979; Sandercock 1991). After emergence, fry remain in freshwater habitat for 1–2 yr before migrating to marine waters. Juvenile coho inhabit shallow waters (10–20 ft) in backwater areas, side channels, and small creeks with overhanging vegetation (Sandercock 1991). Like other salmonid species, juvenile coho are insectivores and consume mostly insects, insect larvae, worms, and fish eggs (Wydoski and Whitney 1979).

Sockeye salmon spawn in gravel riffles of streams and tributaries to lakes. Upon emergence, juvenile sockeye spend 1–2 yr in freshwater habitats, usually the pelagic zone of lakes (Wydoski and Whitney 1979). Juvenile sockeye consume zooplankton while in fresh water. Kokanee are the resident form of sockeye salmon and share similar food and habitat preferences. After emergence, juvenile kokanee migrate to lake environs to mature and reside as adults in the pelagic zone of the lake (Wydoski and Whitney 1979).

Coastal cutthroat trout have variable life history patterns. Some are anadromous, migrating to marine waters and returning to freshwater to spawn; some are potamodromous, spending most of their lives in streams and lakes and migrating to tributaries to spawn; and some are nonmigratory, remaining in small streams and headwater tributaries (Trotter 1997). Coastal cutthroat trout are known to spawn in the smallest headwater streams (Wydoski and Whitney 1979). Upon emergence, juveniles prefer low-velocity backwater areas until large enough to move into riffles and overwinter in pools with logs and vegetation for cover (Trotter 1997). Anadromous juveniles remain in fresh water habitats for 2–4 yr before migrating to marine waters. While in fresh water, juveniles are pelagic feeders and consume fish, insect larvae, and sand shrimp (Trotter 1997).

Brown trout are tolerant of high turbidity, low oxygen levels, and warm temperatures, and tend to fare well in recently disturbed areas, out-competing other trout species (Wydoski and Whitney 1979). This species tends to rely on deep pools for cover during the day. As juveniles, brown trout prefer insects such as mayflies and stoneflies, crustaceans, and shrimp; as adults, brown trout consume fish, crustaceans, and aquatic insect larvae (Wydoski and Whitney 1979). Brown trout reach reproductive maturity in 3-5 yr (Raleigh et al. 1986).

The mountain whitefish is a native salmonid and prefers riffle areas and large pools of cold streams (Wydoski and Whitney 1979). This species feeds on crustaceans, larval insects, and some fish (Wydoski and Whitney 1979). Farr and Ward (1992) reported collecting a few mountain whitefish in the LWR. Studies conducted by Hughes and Gammon (1987) and Tetra Tech (1995) captured mountain whitefish in areas above Willamette Falls.

The LWR is considered critical habitat for several of these salmonid species (Table 2-2). Chinook salmon, steelhead, and coho salmon appear to use this area for juvenile rearing and adult holding more extensively than other salmonid species (Ward 2001; Foster 2001a). Chinook were the most prevalent species caught using both electrofishing and beach seine gear in the 2001 ODFW study. In the beach seine catch, sub-yearling chinook was the highest catch overall (94.7%), followed by coho (0.6%), steelhead (0.0%), and unidentified salmonids (4.7%). Electrofishing catch was comprised of chinook (47.1%), coho (11.5%), steelhead (3.0%), and unidentified salmonids (38.4%) (North et al. 2001). It appears that some seasonal variation in relative abundance occurs among these species: the relative abundance from most to least fish caught per unit effort by beach seine in the LWR, was coho, chinook, steelhead in spring; chinook, coho, steelhead in summer; and chinook, steelhead, coho in fall (North et al. 2001). This information contrasts with what was previously believed based on Portland General Electric out-migrant counts at Willamette Falls and at the Clackamas hydroelectric dam, which found these salmonid species to be abundant only for a short period of time (Domina 1997). This discrepancy is probably due to the different locations sampled and different methods used to observe the fish.

Salmonids, both adult and juvenile, are common in the LWR during various times of the year. Timing of downstream movements of juvenile salmonids has been documented by monitoring yearling chinook movement patterns downstream to Willamette Falls (Schreck et al. 1994), seasonal fish trapping at Willamette Falls (Massey 1967; Domina 1997), and sequential seasonal sampling within the harbor (Beak 2000; Fishman 1999; Farr and Ward 1993; Ward and Farr 1989, 1990; Ward and Knutsen 1991; Ward et al. 1988; Ward et al. 1994). Juvenile salmon can be found in the LWR year-round (various life stages), but peak periods of downstream movement appear to be March through mid-June and November.

Based on telemetry data, juvenile chinook salmon appear to have a longer residence time in Portland Harbor than steelhead or coho salmon (Ward et al. 1992, North et al. 2001). Average migration rates were 15.5 km/d, 13.8 km/d, 11.0 km/d, and 7.2 km/d for steelhead, coho, yearling chinook, and subyearling chinook respectively (North et al. 2001). Migration rates for juvenile chinook salmon through the LWR from Willamette Falls to the mouth of the Columbia River ranged from two days to two months, based on calendar year 2001 ODFW studies (North et al. 2001). Beach seining data collected in 2001 shows that the migration rate of sub-yearling fall chinook salmon is slower than that of yearling spring chinook salmon. Preliminary radio telemetry studies found that the range of residence times for sub-yearling fall chinook was 1.2 to 6.8 days from RM 9.5 to RM 3.5 and 1.6 to 26.8 days from RM 18.5 to RM 3.5 (Ellis 2001). Residence time of smaller juvenile salmon (less than 108 mm) has not been measured and may vary somewhat from those reported here. Periods of adult salmonid migration through Portland Harbor are not as well documented as downstream movements (Ellis 2001). Timing of salmonid migration through the LWR is shown in Figure 2-4.

Piscivores: Northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieui)*, largemouth bass (*Micropterus salmoides*), black crappie (*Pomoxis nigromaculatus*), white crappie (*Pomoxis annularis)*, walleye (*Stizostedion vitrem*), yellow perch (*Perca flavescens*), and bull trout (*Salvelinus confluentus*) are piscivorous fish species known to inhabit the region (Table 2-2). Both smallmouth and largemouth bass are introduced species, and northern pikeminnow and bull trout are native. Bull trout is classified as a federally threatened species. All four species are residents.

The northern pikeminnow is a member of the Cyprinidae family. It has a long life span, up to 19 yr, and reaches reproductive maturity at 3 yr (males) and 4 yr (females) (Wydoski and Whitney 1979). Northern pikeminnow is benthopelagic and inhabits large riverine systems, remaining nearshore in summer and occupying deeper waters in the winter (Wydoski and Whitney 1979). Juvenile northern pikeminnow forage for aquatic and terrestrial insects and small fish, whereas adults consume predominantly fish and some insects (Jeppson and Platts 1959; Buchanan et al. 1981). Northern pikeminnow was the most abundant catch out of six common species in the LWR in a study conducted by Ward and Nigro (1992). Farr and Ward (1992), Tetra Tech (1995), and Beak (2000) also captured northern pikeminnow.

Smallmouth bass, largemouth bass, and black and white crappie are members of the Centrarchidae family. All four species are benthopelagic, consuming fish, crayfish and other crustaceans, mollusks, and worms as adults and insect larvae and zooplankton as juveniles (Wydoski and Whitney 1979; Turner 1966b; George and Hadley 1979). The largemouth bass has a longer life span (12–16 yr) than smallmouth bass (approximately 10 yr), but both species mature around the same age (1–4 yr) (Wydoski and Whitney 1979). Smallmouth bass prefer riverine systems with a moderate current and rocky substrate (Wydoski and Whitney 1979), and reportedly use riprap for cover (Farr and Ward 1992). Largemouth bass inhabit warm shallow waters with abundant plants and woody debris available for cover (Wydoski and Whitney 1979). Largemouth and smallmouth bass are reported to be common throughout the LWR (Ward and Nigro 1992; Farr and Ward 1992; Beak 2000). Tetra Tech (1995) reported smallmouth bass to be the most abundant catch of the centrarchid species.

The black crappie is an introduced resident of the LWR. The black crappie has a relatively long life span (approximately 13 yr), becoming reproductively mature at 2–3 yr (Wydoski and Whitney 1979). As a juvenile, the black crappie prefers plankton, crustaceans, and larvae, and consumes fish as it matures (Scott and Crossman 1973), and commonly forages in open, deep waters (Edwards et al. 1982a). Black crappie prefer areas of low velocity and turbidity with abundant vegetative cover, nesting in soft mud (Edwards et al. 1982a). Several studies have shown that black crappie is an abundant centrarchid species in the LWR (Ward and Nigro 1992; Farr and Ward 1992; Beak 2000).

White crappie is another introduced fish to the LWR. The white crappie lives 7–9 yr and reaches reproductive maturity at 1–3 yr (Edwards et al. 1982b). Juvenile white crappie prefer zooplankton, aquatic insects, and algae, whereas adults consume fish, insects, fish eggs, and crustaceans (Muoneke et al. 1992; Edwards et al. 1982b). The white crappie inhabits low-gradient, low-turbidity, slow-moving riverine systems with abundant vegetative cover and shallow areas for nesting (Edwards et al. 1982b). Several studies have observed white crappie throughout the LWR (Ward and Nigro 1992; Farr and Ward 1992; Beak 2000).

The walleye is another introduced resident of the LWR with a long life span (17 yr), becoming reproductively mature at 2–4 yr for males and 3–8 yr for females (McMahon et al. 1984b). A member of the Percidae family, the juvenile walleye prefers a diet of zooplankton and aquatic insects, and consumes fish and crustaceans as an adult (McMahon et al. 1984b; Wydoski and Whitney 1979). Walleye require moderate to large riverine systems with abundant shallow vegetated areas for all life stages and prefer to spawn in rocky areas in rivers or below falls (McMahon et al. 1984b; Scott and Crossman 1973; Wydoski and Whitney 1979). Walleye have been captured in several studies in the LWR (Hughes and Gammon 1987; Tetra Tech 1995; Beak 2000), and Farr and Ward (1992) suggested that walleye prefer less developed areas of the LWR.

The yellow perch is in the Percidae family and is exotic to the LWR. Yellow perch can live up to 9–10 yr, but most live to 7 yr and reach maturity at 2-3 yr (males) and 3–4 yr (females) (Krieger et al. 1983). The yellow perch prefers shoreline habitat with pools and vegetation present in freshwater systems, although it can tolerate brackish water (Krieger et al. 1983). Some local populations are reported to have a small home range and do not travel far (Wydoski and Whitney 1979). Juvenile yellow perch consume insect larvae and zooplankton, and adults consume fish, crayfish, fish eggs, and aquatic insects (Krieger et al. 1983; Wydoski and Whitney 1979). Yellow perch appear to be common throughout the LWR (Hughes and Gammon 1987; Tetra Tech 1995; Beak 2000) and evenly distributed among developed and undeveloped sites (Farr and Ward 1992).

The bull trout is a salmonid but is not anadromous in Oregon (Buchanan et al. 1997). The bull trout is benthopelagic and consumes mostly fish and zooplankton. It inhabits deep or shaded pools in large, cold rivers with abundant woody debris (Buchanan et al. 1997; Page and Burr 1991). Historically, they were probably found throughout most of the Willamette River basin, but, currently, there are no known populations in the mainstem Willamette or any of the tributaries below Willamette Falls. The historic populations in the Clackamas and Santiam rivers are believed to be extinct (Buchanan et al. 1997).

Detritivores: Four species of detrivorous lamprey are native to the Willamette River: the Pacific lamprey (*Lampreta tridentata*), the river lamprey (*Lampreta ayresi)*, the western brook lamprey (*Lampreta richardsoni)*, and the Pacific brook lamprey (Table 2-2). The Pacific brook and western brook lampreys are resident species, whereas the Pacific lamprey and river lamprey are anadromous and migrate to the ocean as adults.

The Pacific lamprey and river lamprey share many similar life history traits. Both are filter-feeders as juveniles, consuming phytoplankton and detritus while burrowed in the freshwater sediment (Kostow 2002; Moore and Mallatt 1980). The Pacific lamprey has a longer life span (up to 12 yr) than the river lamprey (up to 8 yr) and also takes longer to mature (5-7 yr and 4-6 yr, respectively) (Kostow 2002). Farr and Ward (1992) and Beak (2000) reported collecting a few Pacific lamprey in the LWR.

The two resident lamprey, western brook and Pacific brook, are similar to the anadromous species in that juveniles remain burrowed in mud until maturity, feeding on diatoms and detritus (Kostow 2002). Both the western brook and Pacific brook lamprey live less than 6 yr and reach maturity in 4-6 yr. As adults, these two species remain in fresh water, migrating downstream from the spawning grounds. However, unlike the anadromous species, which become ectoparasitic as adults, the two resident species do not feed as adults (Kostow 2002). As soon as they become adults, they spawn and die. Friesen and Ward (1996) reported collecting western brook lamprey in streams of the Tualatin Basin in the Willamette River basin. General lamprey habitat for the ISA is shown in Figure 2-6.

2.3.3 Birds

Numerous species of aquatic or semi-aquatic birds use the Willamette River in the ISA. Table 2-4 presents the aquatic and semi-aquatic bird species that may breed along the LWR, and Table 2-5 presents a list of bird species that may overwinter or only partially utilize the LWR.

Of the fifteen sites in the ISA with significant habitat identified by Adolfson et al. (2000), the Oaks Bottom Complex contains the greatest abundance and diversity of birds. Within this site is the Oaks Bottom Wildlife Refuge, a diverse habitat closely associated with Ross Island. More than 200 bird species have been reported in this area, including nesting raptors and river birds such as green-backed herons, northern shovelers, pintails, mallards, wood ducks, coots, wigeons, gulls, and cormorants (Adolfson et al. 2000).

This section discusses birds that may reside in the ISA according to four feeding guilds that are based on common feeding strategies and diet composition (Table 2-4). These guilds are:

- Herbivores (birds feeding predominantly on plant material)
- Diving carnivores and omnivores (birds that usually swim on the surface and feed on invertebrates or mix of invertebrates, fish, and occasionally plants)
- Sediment-probing invertivores and omnivores (birds probing in the sediments for invertebrates in shallow water and along the shoreline)
- Piscivores (birds feeding almost exclusively on fish).

2.3.3.1 Herbivorous Birds

Two common herbivores may use the ISA: Canada geese (*Branta canadensis*) and mallards (*Anas platyrhynchos*). Canada geese are common in the vicinity of the ISA throughout the year (Puchy and Marshall 1993). Some are present year-round while others merely overwinter in the area. Canada geese typically nest on the ground near open water, often in vegetated marshes (Csuti et al. 1997). These geese preferentially feed on the shoots of terrestrial and aquatic plants but will also eat aquatic invertebrates (Ehrlich et al. 1988). Mallards are also very common in the area. Some are present in the summer during breeding season, while others overwinter along the Willamette River (Puchy and Marshall 1993). Mallards are “dabbling ducks” that forage in open water areas on aquatic plants (Csuti et al. 1997), and nest on the ground near water (Ehrlich et al. 1988).

2.3.3.2 Carnivorous and Omnivorous Birds

Within the group of carnivorous and omnivorous birds, three species feed more heavily on plants (omnivores) and four rely primarily on invertebrate prey and small fish (carnivores). The omnivores are cinnamon teal (*Anas cyanoptera*), wood duck (*Aix sponsa*), and American coot (*Fulica americana*). The cinnamon teal is a fairly common breeding duck found throughout Oregon (Puchy and Marshall 1993). They typically overwinter south of Oregon, but some are known to remain throughout the year (Csuti et al. 1997). Cinnamon teals are described as dabbling ducks and forage near vegetative cover along shorelines on a mix of aquatic plants and aquatic invertebrates such as mollusks, midges, and larvae (Ehrlich et al. 1988). They typically nest on the ground in marshes, meadows, or other low vegetation habitats near open water (Puchy and Marshall 1993).

The wood duck is relatively uncommon in the Willamette Valley but some are year-round residents (Puchy and Marshall 1993). They are described as perching ducks and, as their name suggests, they prefer to nest in woodland habitats, often in trees and snags near water (Ehrlich et al. 1988). They feed in shallow water, mainly foraging on seeds and aquatic plants, but they are also known to eat aquatic insects (Csuti et al. 1997).

Unlike the other two omnivores, the American coot is a rail rather than a duck. It is locally abundant in the Willamette Valley and is usually a year-round resident (Puchy and Marshall 1993). American coots build floating nests usually under vegetative cover; therefore, marshes are a common nesting location (Ehrlich et al. 1988). They are described as a diving species (as opposed to dabbling avian species that feed in shallower water) and feed mostly on aquatic plants, but also eat aquatic insects, crustaceans, worms and other invertebrates especially when they are young (Csuti et al. 1997).

The four species of diving carnivores that may use the ISA are the American dipper (*Cinclus mexicanus*), common merganser (*Mergus merganser*), hooded merganser (*Lophodytes cucullatus*), and pied-billed grebe (*Podilymbus podiceps*). American dippers are mostly year-round residents (Puchy and Marshall 1993). They generally prefer smaller, fast-flowing streams, but are occasionally found along larger rivers, ponds, and lakes (Csuti et al. 1997). They usually nest in stream banks or cliffs along flowing water, and feed mostly on aquatic insects and larvae (Ehrlich et al. 1988).

Common and hooded mergansers are both locally common breeders in the Willamette Valley with some year-round residents (Csuti et al. 1997; Nebeker 2001; Davis 2002). Both prefer to nest in tree cavities in close proximity to open water (Kitchen and Hunt 1969; Ehrlich et al. 1988). Common mergansers feed primarily by diving for whatever small fish are abundant, but they will also eat aquatic invertebrates, especially as hatchlings (Csuti et al. 1997). Hooded mergansers are smaller, and therefore eat more aquatic invertebrates than do common mergansers (Csuti et al. 1997). They are known to feed on crustaceans, aquatic insects, and small fish (Bendell and McNicol 1995).

Pied-billed grebes are range from uncommon-to-common breeders in the Willamette Valley, but many individuals overwinter in the area (Puchy and Marshall 1993; Csuti et al. 1997). They forage in open water for aquatic insects, crayfish, small fish, and other aquatic invertebrates (Csuti et al. 1997). Pied-billed grebes typically build floating nests in quiet waters, usually under the cover of emergent vegetation (Ehrlich et al. 1988).

2.3.3.3 Sediment-probing Invertivorous and Omnivorous Birds

Spotted sandpipers (*Actitis macularia*) are locally common breeders in the Willamette Valley and some are present year-round (Puchy and Marshall 1993). They build ground nests amid herbaceous vegetation and usually feed nearby along shallow gravel shorelines and beaches (Ehrlich et al. 1988). They feed on insects and benthic invertebrates such as crustaceans, mollusks, and worms (Csuti et al. 1997). Some sandpipers are known to ingest relatively large amounts of sediment while feeding (Beyer et al. 1994). Spotted sandpiper habitat is shown in Figure 2-9.

The common snipe (*Gallinago gallinago*) is a common breeder in the Willamette Valley and most are present year-round (Puchy and Marshall 1993). They usually nest on the ground in grassy areas near water (Ehrlich et al. 1988). Common snipes feed by probing into saturated soils in wetlands and very shallow water, feeding largely on insect larvae and worms.

Killdeer (*Charadrius vociferus*) are locally abundant in the Willamette Valley and most are year-round residents (Puchy and Marshall 1993). They feed mostly on flying insects, such as beetles, dragonflies, and grasshoppers, but may also eat crayfish and other benthic invertebrates (Csuti et al. 1997). Killdeer nest on the ground in a variety of habitats near open water (Ehrlich et al. 1988).

Soras (*Porzana carolina*) are common breeders along the Willamette, but are usually present during the summer only (Puchy and Marshall 1993). They build floating nests in emergent vegetation along lakes and streams and are more omnivorous than the other species in this guild (Csuti et al. 1997). They feed on seeds, insects, and aquatic invertebrates (Ehrlich et al. 1988).

Finally, the Virginia rail (*Rallus limicola*) is a locally common breeder in the Willamette Valley and some are year-round residents (Puchy and Marshall 1993). They nest on the ground, usually in marshes with cover from emergent vegetation (Ehrlich et al. 1988). Virginia rails' diets consist of insects, aquatic invertebrates, and some seeds (Csuti et al. 1997).

2.3.3.4 Piscivorous Birds

Few species from this guild feed solely on fish, but fish make up the majority of the diets for all eight species of piscivorous birds discussed below. Osprey (*Pandion haliaetus*) tend to feed solely on fish. Several breeding pairs are present in the ISA from March until September (Henny 2002). In addition to the five pairs nesting between RM 0 and 7.1, osprey also nest in Oaks Bottom Wildlife Refuge at RM 15.4 (Henny 2002). Each fall, they migrate south to western Mexico and Central America (Martell et al. 2001). They generally feed on slow-moving prey that swim near the water surface (Csuti et al. 1997).

Belted kingfishers (*Ceryle alcyon*) also tend to feed solely on fish. They are uncommon breeders in the Willamette Valley, but tend to be year-round residents (Puchy and Marshall 1993). They usually nest in horizontal burrows dug into sandy stream and river banks (Ehrlich et al. 1988). Kingfishers feed anywhere they can find small fish (3-4 in.); they may also eat crayfish, amphibians, and insects (Csuti et al. 1997).

American bittern (*Botaurus lentiginosus*) are uncommon breeders in the Willamette Valley but are present year-round (Puchy and Marshall 1993). They have a more varied diet than most other species in this guild as they feed on fish, amphibians, crayfish, and insects (Csuti et al. 1997). American bitterns build ground nests amid emergent vegetation, usually in marshes (Ehrlich et al. 1988).

Double-crested cormorants (*Phalacrocorax auritus*) are common breeding birds along the coast and the lower Columbia River, and it is possible that some breed in the vicinity of the LWR (Puchy and Marshall 1993; Csuti et al. 1997). They are present year-round and many overwinter in the area (Puchy and Marshall 1993). Double-crested cormorants nest in cliffs, trees, and marshes near open water (Csuti et al. 1997). They feed mostly on fish by diving in relatively deep water; they sometimes also feed on aquatic invertebrates such as crayfish and mollusks (Ehrlich et al. 1988).

The green heron (also called the green-backed heron) (*Butorides virescens*) is an uncommon year-round resident in the LWR (Puchy and Marshall 1993). They usually nest in trees in riparian woodlands, often in willows (Csuti et al. 1997). Green herons also have a varied diet consisting mainly of small fish and aquatic invertebrates such as crustaceans and snails. They will also take frogs and terrestrial invertebrates (Ehrlich et al. 1988).

The great blue heron (*Ardea herodias*) is more common and widespread than the green heron and is resident year-round in the LWR (Puchy and Marshall 1993). Ross Island is the site of an active heronry containing up to 30 nests. They are colonial nesters and usually build their nests in trees near water. They can utilize many different habitats and often travel great distances (Csuti et al. 1997). Great blue herons feed mainly on fish, but can also take crustaceans, amphibians, and some upland vertebrates (Ehrlich et al. 1988).

Finally, bald eagles (*Haliaeetus leucocephalus*) are known to nest up and down the Willamette River. The closest known nest is on Ross Island at RM 15, while two old nests are located on Sauvie Island (Isaacs and Anthony 2001). Eagles are year-round residents in western Oregon, with some eagles from further north overwintering in the area (Puchy and Marshall 1993). They nest in treetops or cliffs near large bodies of water (Csuti et al. 1997). Bald eagles feed mainly on fish but are also opportunistic, as they will scavenge on mammals and birds (Ehrlich et al. 1988).

2.3.4 Mammals

Aquatic or semi-aquatic mammals using the LWR include beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), raccoon (*Procyon lotor*), river otter (*Lutra* *canadensis*), mink (*Mustela vison*), nutria (*Myocastor coypus*), and California sea lion (*Zalophus californianus*) (Table 2-6). Nutria was introduced to the area and is considered a nuisance species. Potential foraging areas for beaver, muskrat, raccoon, river otter, mink, and nutria are present at many of the 15 habitat sites identified as part of the Adolfson et al. (2000) natural resource inventory. California sea lions may use the ISA, primarily from March to mid-May, to forage on runs of spring chinook and summer and winter steelhead (Foster 2001b). California sea lions are protected under the Marine Mammals Act; however, they are considered a nuisance in the LWR because they prey on salmonids. They are known to congregate at the Willamette Falls fish ladder and may use Portland Harbor for migrating upstream to their preferred feeding areas. Mink have also been observed near Ross Island (per EPA comment).

Beaver and nutria are herbivores, although nutria may occasionally eat mollusks. Muskrats are aquatic mammals that dig burrows in banks and feed on vegetation, but may also consume crayfish, fish, turtles, snails, and salamanders (Csuti et al. 1997). Mink and river otter feed on fish, frogs, crayfish, and small mammals and birds (Csuti et al. 1997). Raccoons are omnivorous, ingesting small mammals, fish, amphibians, birds, aquatic invertebrates, fruits, berries, nuts, and seeds (Csuti et al. 1997). Potential mink habitat in the ISA is shown in Figure 2-10.

2.3.5 Amphibians and Reptiles

Conditions within the ISA are likely to provide a limited amount of suitable habitat for amphibians and reptiles. Amphibians and reptiles require off-channel, low-flow aquatic habitat with a substantial presence of riparian vegetation. They can utilize either permanent or ephemeral aquatic habitat, provided the hydro-period is long enough to allow eggs to hatch and larvae to develop. Emergent vegetation is required during the breeding season for ovipositing of eggs. Areas that also contain tree-dominated riparian vegetation provide the most suitable habitat (Hayes 2002). Amphibians generally avoid large lakes and rivers due to predation by large fish (Corkran 2002). Potential habitat for amphibians is shown for the ISA in Figure 2-11. Habitat requirements for reptiles are not met within the ISA, although the painted turtle (Chrysemys picta) has been observed in nearby ponds and wetlands.

There is a paucity of scientific information concerning the occurrence of amphibians and reptiles in the LWR. Table 2-7 lists the amphibians and reptiles that may occur in or near the ISA as well as their associated life history characteristics. Reptile species that are possibly present at or near the ISA are the painted turtle (*Chrysemys picta*) and the Western pond turtle (*Clemmys marmorata marmorata*). Breeding populations of painted turtles have been documented in wetland habitats with some access to the LWR (Adolfson et al. 2000), but these species generally prefer the more quiet backwaters of lakes, ponds, and marshes. Amphibians using the aquatic environment for portions of their life history that may be present in the vicinity of the ISA include northern red-legged frog (*Rana aurora aurora*), northwest salamander

(*Ambystoma gracile*), long-toed salamander (*Ambystoma macrodactylum*), rough skin newt (*Taricha granulosa),* Western toad *(Bufo boreas*), Pacific chorus frog (*Pseudacris regilla*), Cope's giant salamander (*Dicamptodon copei*), Pacific giant salamander (*Dicamptodon tenebrosus*), tailed frog (*Ascaphus truei*), and the bullfrog (*Rana catesbeiana*). The Pacific chorus frog and the long-toed salamander are the most likely amphibian species found in the area (Hayes 2002). The northern red-legged frog, tailed frog, and the northwestern pond turtle are federal species of concern and state-listed sensitive species.

The aquatic portion of amphibian diets may include aquatic plants, detritus, small invertebrates, tadpoles, fish eggs, zooplankton, and small fish. Amphibian adults may prey on terrestrial insects, earthworms, and in some species small birds and mammals (Csuti et al. 1997). Juvenile amphibians rely more heavily on the aquatic environment for their diet and development than do adults. Reptiles have a similar aquatic diet as amphibians, including aquatic plants, mollusks, crayfish, fish and tadpoles. Additionally, reptiles may feed on earthworms and terrestrial insects.

2.3.6 Aquatic Plants

The current conditions of the LWR prevent the successful establishment of a dense, submerged and emergent plant community along the river banks. Turbidity is too high in the LWR for the establishment and growth of many plant species (Sytsma 2002). In addition, riprap and other bank stabilization efforts have resulted in little area for plant establishment on the banks and shoreline areas. Riprap also separates the shoreline plant community from upland plant communities. The disturbance of bank stabilization and channelization efforts often promotes the successful invasion of exotic plant species such as Himalayan blackberry (*Rubus discolor*) and reed canary grass (*Phalaris arundinaceae*). These exotic, pioneer species flourish in disturbed areas and further prevent native plant species from establishing along the banks of the LWR.

Currently, no comprehensive vegetation surveys have been conducted to quantify and describe the plant community in the LWR. However, Adolfson et al. (2000) recently conducted an inventory of fish and wildlife habitat along the shoreline of the LWR. This inventory resulted in general descriptions of plant community types occurring along the LWR and identified 10 distinct habitat classes: bottomland forest, foothill savanna, conifer forest, scrub, meadow, shrub, emergent wetland, beach, rock outcrop, open water, and unvegetated/disturbed. Although all of these plant communities occur in the vicinity of the LWR, bottomland forest, emergent wetlands, rock outcrop, beach, and open water communities are likely the most common community types occurring along the shoreline within the ISA. The following is a brief description of the plant species commonly found within these communities.

Black cottonwood (*Populus balsamifera*) is usually a dominant species in bottomland forest communities, along with Pacific willow (*Salix lucida*), red osier dogwood

(*Cornus sericea*), snowberry (*Symphoricarpos alba*), Oregon ash (*Fraxinus latifolia*), and Himalayan blackberry (Adolfson et al. 2000). Historically, this plant community was an important component of the Willamette River floodplain system (Sedell and Froggatt 1984), and exists today at a small percentage of its former extent (Adolfson et al. 2000).

Emergent wetlands make up a small percentage of habitat type on the shoreline of the LWR. This community type exists in a few small remnant patches in areas adjacent to the shoreline. These areas are usually dominated by reed canary grass with Douglas spiraea (*Spiraea douglasii*), red osier dogwood, and other sedge and rush species (Adolfson et al. 2000).

Basalt rock outcrops are not common throughout the LWR, perhaps due to the local geology and bank stabilization and channelization efforts in the area. Where they exist, these areas provide substrate for plant communities consisting of ferns, mosses, liverworts, and lichens (Adolfson et al. 2000).

Beach habitats throughout the LWR typically consist of narrow shoreline areas, with sand substrate, and are dominated by a variety of annual grasses and perennial shrubs. Willow communities often establish in these areas and can include Pacific willow, Columbia River willow (*Salix fluviatilis*), and Piper's willow (*Salix piperii*) (Adolfson et al. 2000).

Open water habitats occur throughout the LWR in tributaries, sloughs, and side channels and are often dominated by aquatic plant species from bottomland forest, emergent wetland, and scrub/shrub communities (Adolfson et al. 2000).

2.4 SPECIAL-STATUS SPECIES

Special-status species include federal and state proposed and candidate species, federal species of concern, and state sensitive species. Table 2-8 identifies the special-status species likely to occur in the ISA.

2.4.1 Invertebrates

The Columbia pebblesnail (also known as the Columbia spire snail) is a freshwater mollusk that may occur in the LWR. They are listed as a species of concern by the U.S. Fish and Wildlife Service (USFWS).

2.4.2 Fish

Of the seven salmonid species reported to use the LWR, five are listed as threatened or proposed threatened (Table 2-8). Coastal cutthroat trout, steelhead, and chum and chinook salmon are also all considered sensitive species by ODFW. Bull trout are federally threatened species but there is no known population in the LWR (Buchanan et al. 1997). Historic populations from the Clackamas and Santiam rivers are now thought to be extinct, and the only known remaining populations in the Willamette basin are found in the McKenzie and Middle Fork Willamette River (Buchanan et al. 1997).

Pacific lamprey and river lamprey are recognized as species of concern at the federal level (USFWS) and are currently under consideration for threatened or endangered status. Pacific lamprey is recognized as a sensitive species at the state level (ODFW). Pacific lamprey is an anadromous species that occurs in Portland Harbor. Pacific lamprey populations have significantly declined in the last 30 to 50 years. At the Bonneville Dam on the Columbia River, Pacific lamprey have declined from peak returns of about 380,000 in the 1930s and 1940 down to returns of about 10,000 recently. Reasons for declines are unclear, but lamprey ammocoetes require spawning habitats similar to those for Pacific salmon, and declines may be related to dams and habitat degradation (Kostow 2002). Little is known about the presence of river lamprey in the Lower Columbia Basin and the Willamette River. River lamprey have not been observed in these areas in recent years, but they are a rare species and difficult to find in fresh water. They have been collected in the Lower Columbia River in the vicinity of the LWR, but their presence in the LWR is unknown (Kostow 2002).

2.4.3 Birds

The status of sensitive aquatic or semi-aquatic bird species is listed in Table 2-8. Aleutian Canada geese (*Branta canadensis leucopareia*) are rare but may be observed occasionally along the LWR in winter and are considered a threatened species (USFWS). Both Aleutian Canada geese and the American peregrine falcon (*Falco peregrinus annatum*) are protected as state endangered species (ODFW). Black terns (*Childonias niger*), a federal listed species of concern, are generally rare in the area, but were common during the summer of 2001 due to the drought in the eastern part of the state (Nebeker 2001). Bald eagles are known to use habitat along the Willamette River and are recognized as a threatened species both by USFWS and ODFW. Harlequin duck (*Histrionicus histrionicus*) is considered a federal species of concern, but is uncommon in the Lower Willamette Valley. On rare occasions these ducks may be observed migrating through the area, but would not use the area as a foraging ground (Nebeker 2001). Bald eagles tend to forage near the nesting site during the breeding season. Garrett et al. (1993) determined home ranges in bald eagles in the lower Columbia River estuary averaged 21.7 km^2 (13.4 $miles^2$; range= 5.9 - 47.3 km^2) in breeding eagles. Average shoreline range of these home ranges in breeding eagles was 5.6 km (3.5 miles).

Breeding populations of several species that are present in the LWR only during the winter have been given special status by ODFW or are considered sensitive by the Oregon Natural Heritage Program (ONHP). These species include Barrow’s goldeneye (*Bucephala islandica*), bufflehead (*Bucephala albeola*), horned grebe (*Podiceps auritus*), red-necked grebe (*Podiceps grisegena*), long-billed curlew (*Numenius americanus*), and greater sandhill crane (*Grus canadensis*) (ONHP 2001).

2.4.4 Amphibians and Reptiles

Western toad, Cope's giant salamander, tailed frog, northern red-legged frog, northwestern pond turtle, and painted turtle are all considered sensitive species by ODFW. In addition, northwestern pond turtle, tailed frog, and red-legged frog are listed as species of concern by USFWS.

2.4.5 Aquatic Plants

Nine wetland plants that occur in the Willamette Valley and may occur in the ISA are special-status species (Table 2-8). Howell's bentgrass (*Agrostis howellii*), white-topped aster (*Aster curtus*), wayside aster (*Aster vialis*), Peacock larkspur (*Delphinium pavonaceum*), and Hitchcock's blue-eyed grass (*Sisyrinchium hitchcockii*) are all species of concern by USFWS. Howellia (*Howellia aquatilis*) and Nelson's sidalcea (*Sidalcea nelsonia*) are federally threatened species, and the Willamette daisy (*Erigeron decumbens*), Bradshaw's lomatium (*Lomatium bradshawii*) are protected federal endangered species. All of these plant species have threatened or endangered state status as well, with the exception of Howell's bentgrass, howellia and Hitchcock's blue-eyed grass.

Additional habitats may be developed along the river banks as part of future restoration projects. Future enhancement will be taken into account under future use of the area.

2.5 IDENTIFICATION OF REPRESENTATIVE SPECIES

A systematic process was followed to select representative species. Representative species were selected for fish, birds and mammals.

Based on the available information for the resources and on EPA guidance (EPA 1997, 1998) for fish, birds, and mammals, representative species were selected based on the following steps:

- Key direct and indirect exposure routes were identified.
- Groups of organisms that may be exposed via these pathways were identified.

- Species from within these groups of organisms were then selected based on:
  - Their societal and cultural significance (i.e., species valued by society or that have special regulatory status—threatened or endangered)
  - Their ecological significance (i.e., species that serve a unique ecological function)
  - Their level of exposure to likely COPCs at the site (i.e., site usage)
  - Their relative ability to bioaccumulate likely COPCs at the site
  - Their sensitivity to likely COPCs at the site
  - Availability of sufficient data on behaviors that determine exposure and potential sensitivity of the species to COPCs to allow meaningful assessment of risks.

In Sections 2.3 and 2.4, fish, birds, and mammals confirmed as or likely to be present in the ISA were discussed as a function of their feeding guild, ecological significance, and societal significance. This information was used to determine which species could be exposed to contaminants in the ISA. Final selection of receptors was based on the sensitivity and relative ability of the species to bioaccumulate COPCs, based on available bioaccumulation and toxicity studies, including historical site data and available information on site usage which affects exposure. By selecting the most sensitive species, other less sensitive species that experience similar exposure conditions, will also be protected. Species that occupy the LWR during a large part of the year or during sensitive periods, such as nesting, were preferentially selected as receptors.

Finally, data availability regarding both exposure and effects was assessed. Species for which there are related site-specific data, such as COPC concentrations in food, site usage, and feeding, and toxicological data, such as toxicity reference values (TRVs), were preferred. A TRV is a value (e.g., dose, medium concentration, or tissue residue) that represents a toxicity threshold and can be defined by either no-effect data or low-effect data or both. For some species, toxicological information from surrogate species will be required because species-specific data are not available.

This section presents a discussion of species selected as receptors (i.e., the representative species). A representative species was chosen from each of the feeding guilds for fish, birds, and mammals.

2.5.1 Aquatic Plants

Various wetland plant species were identified in the Aquatic Plant and Amphibian/Reptile Reconnaissance Survey (see Attachment B.2). Native wetland plant species were identified, including common wetland asters (*Aster* spp.), sedges (*Carex* spp.), horsetail (*Equisetum avense*), rushes (*Juncus* spp.), smartweed (*Polygonum* spp.), black cottonwood (*Populus balsamifera*), Columbia river willow (*Salix fluviatilis*), Douglas' spiraea and cattail (*Typha latifolia*). Fifteen non-native species were also found and no submerged aquatic plants were found (See Attachment B.2). Wapato (*Sagittaria latifolia*) is a wetland plant of particular interest to Native Americans. Aquatic plants will be assessed by evaluating multiple species, dependent on the scientific information available.

2.5.2 Benthic Invertebrates

2.5.2.1 Epibenthic and Infaunal Invertebrates

Lower-trophic-level benthic invertebrates are generally evaluated as a community in ERAs. Benthic invertebrates in the ISA are in direct contact with sediment and therefore have a high exposure potential. They are present in the ecosystem year-round. Benthic invertebrates are an important food source for other invertebrates, fish, birds, and mammals, and provide essential nutrient cycling to the LWR ecosystem. Both infaunal and epibenthic macroinvertebrates often comprise a significant portion of the heterotrophic biomass in a river system (Jahn and Anderson 1986), and therefore serve as a principal food resource for higher trophic-level consumers (i.e., fish and wildlife). Macroinvertebrates also control energy flow by acting as principal processors of organic matter (Merritt et al. 1984). In large, deep rivers, such as the LWR, particles suspended in the water column are a significant source of organic matter for the ecosystem. Bivalves are important filter feeders that capture this energy source and serve as potential food resources for higher trophic-level consumers. In addition, benthic organisms have been shown to be susceptible to sediment-associated chemicals and data are available to assess their exposure and predict potential effects.

The potential effects to shellfish will be assessed separately from the epibenthic and infaunal invertebrate evaluation. The assessment will be performed on the population level.

2.5.2.2 Epibenthic Macrofauna

In addition to the community assessment, crayfish were selected as an important prey species. The effects to crayfish will be assessed by comparing whole body concentrations with tissue TRVs. Crayfish have small home ranges, and therefore may be susceptible to localized concentrations of chemicals. They are also highly exposed because of direct contact with sediment and have a relatively long life span, up to eight yr, compared to other invertebrates (Hobbs 2001). Some toxicological data are available to evaluate potential effects.

2.5.3 Fish Species

Representative species of fish were selected based on the criteria presented in Section 2.5. First, all fish that may occur in the LWR were identified through literature reviews (Table 2-2). Fish were then classified into four feeding guilds: omnivores/herbivores (eating vegetation, or vegetation and invertebrates), invertivores (primarily eating invertebrates), piscivores (primarily eating fishes), and detritivores (primarily eating detritus).

Information on origin (native versus introduced), abundance, feeding guild, prey items, home range, location in water column, preferred habitat, spawning time, and lifespan was compiled for each fish (Table 2-2). Using this information and the criteria presented above, representative species of fish that are likely to be more highly exposed to COPCs in the ISA were selected for each feeding guild. These representative species were chosen from each feeding guild to represent the fish community as a whole, and the risk evaluation for these species should be representative of risks to all fish species in the ISA. The choice of representative species from each of these feeding groups is discussed in the sections below.

2.5.3.1 Omnivores/herbivores

Omnivorous and herbivorous fish in the LWR are exposed to chemicals primarily through their diet and incidental ingestion of sediments (Section 2.6). Omnivores are predominately bottom feeders. The common omnivores in the ISA are largescale sucker, common carp, and white sturgeon (Table 2-2). These species are benthic-feeders that ingest sediment along with a variety of animal, plant, and detrital material. All of these species are long-lived, with life expectancies of 15, 20, and 100 yr for largescale sucker, carp, and white sturgeon, respectively. Largescale sucker is one of the most abundant species in the LWR. Farr and Ward (1993) reported that they were common in all habitats in the LWR**.** However, largescale sucker have a large home range that may extend outside of the LWR into the adjacent segments of the Clackamas and Columbia Rivers, and largescale sucker have not been observed to spawn in the ISA. They spawn in sand or gravel shoals in cold water lakes or streams at temperatures of 7.8 to 8.9°C (Scott and Crossman 1973).

White sturgeon are also common in the LWR and were captured by Farr and Ward (1993) throughout the LWR. White sturgeon were captured most frequently near sandy beach shorelines with no structures (Farr and Ward 1993). White sturgeon in the LWR are considered to be part of the lower Columbia River population. Some studies suggest that sturgeon can show strong site fidelity (Veinott et al. 1999) while other studies indicate individual sturgeon can have large ranges (Devore and Grimes 1993). White sturgeon have not been reported to spawn in the ISA. They spawn in cobble habitat that is not present in the ISA. They may spawn upstream of Portland

Harbor below Willamette Falls. Eggs and larval stages of white sturgeon have been found dozens of miles downstream from spawning locations (Devore and Grimes 1993). Thus, early life-stages of white sturgeon are likely to be present in the ISA if spawning takes place below Willamette Falls. White sturgeon are extremely long-lived and slow to mature. They are anadromous and rear in freshwater for up to 11 yr.

Carp are a benthopelagic species frequently associated with bottom sediments. Farr and Ward (1993) report that carp are common in the LWR, though not as common as largescale sucker or white sturgeon. Carp in the LWR did not appear to be associated with any particular habitat (Farr and Ward 1993). Carp have not been reported to spawn in the LWR. They prefer to spawn in backwater areas at temperatures greater than 17°C with some vegetation present (Scott and Crossman 1973).

Based on the criteria above, largescale sucker and common carp are suitable representative species, though largescale sucker is preferred because it is more highly associated with the benthic environment. Hence, largescale sucker is selected rather than carp to represent omnivorous and herbivorous fish in the ISA because of their close association with sediments. Largescale sucker have a higher trophic status than the only two herbivorous fish (chiselmouth and mountain suckers), and thus should have higher exposure to biomagnifying chemicals. Because the herbivorous fish are not known to be more sensitive, the more highly exposed largescale sucker is an appropriate representative species. However, carp will be assessed as a surrogate receptor of concern for dioxin-like chemicals including PCB congener analysis. Per EPA's request white sturgeon were also added as a representative of omnivorous or herbivorous fish within the ISA in March 2004. Some uncertainty exists in selecting this species because they have a home range extending beyond the ISA. Mark and recapture studies with white sturgeon have documented migrations of greater than 500 miles (Chadwick 1959; Kohlhurst et al. 1991; Devore and Grimes 1993). The maximum documented movement of white sturgeon in the Columbia River was an order of magnitude greater (~40 mi) than for largescale sucker (Dauble 1986) (Figure 2-5).

2.5.3.2 Invertivores

Many species of invertivorous fish inhabit the LWR (Table 2-2). Carnivorous fish are potentially exposed to biomagnifying chemicals through their prey, and to chemicals through direct and indirect exposure to water and sediments. Within this feeding guild, two resident fish species were selected, along with an anadromous salmonid species. Of all the fish species that occur in the ISA, invertivorous salmonids are perhaps most highly valued by society. Pacific salmon contribute to recreational and commercial fisheries, and are important in both spiritual and practical terms as food and fishery to the Native American tribes of the area. Of the Pacific salmon, several species that occur in the ISA are listed under the Endangered Species Act (ESA) (Table 2-8).

Resident invertivorous fish common in the ISA include yellow perch, peamouth, threespine stickleback, reticulate sculpin, and prickly sculpin. Other invertivorous fish in the LWR (e.g., shad) are migratory or uncommon and thus do not represent this feeding guild well. As resident species, all life stages of these species are potentially exposed to chemicals in the ISA. Peamouth are a benthopelagic species that preys on both benthic and pelagic prey, whereas sculpin is a benthic species that feeds on benthic prey. The home range for the peamouth is unknown, but it is likely to be larger than that of sculpin, which are generally territorial species. Therefore, sculpin exposure is likely to be reflective of chemical concentrations near the site where fish are captured, whereas peamouth are likely to integrate exposure over a larger area. Peamouth, with a maximum lifespan of approximately 13 yr, are longer-lived than sculpin, which have a lifespan of approximately 4–7 yr. Based on their ecology, both peamouth and sculpin species may be representative of invertivorous fish in the LWR.

Sculpin were selected to represent invertivorous fish because of their close association with sediments and their small home range. The species of sculpin has not been chosen because they are difficult to distinguish; however, they all have similar feeding behavior and home ranges. As resident invertivores, all life stages of sculpin are present and exposed to chemicals in the ISA. The peamouth was also selected to represent invertivorous fish because it is a resident species with a home range potentially much larger than the sculpin, and therefore representative of exposure over a wider area in the ISA.

Both juvenile and adult life stages of several Pacific salmon, including chinook salmon, migrate through the ISA. However, adult life stages of these salmonids are exposed to chemicals in their oceanic habitat; thus, the source of chemical burdens in adult fishes found in the ISA would be difficult to ascertain. Adult life stages of most anadromous species have substantially reduced feeding during their upstream migrations, so exposure to chemicals in the ISA through this pathway is likely to be relatively low. These factors make adult salmonids an inappropriate choice for a representative species. Additionally, juveniles are generally believed to be more susceptible to toxic substances than adults.

Juvenile salmonid residence time in the LWR and ISA is a matter of ongoing investigation, and there is uncertainty in the year-to-year variation between size and age cohorts for each of the various species. However, of the juvenile Pacific salmonids, juvenile chinook salmon appear to have the longest residence in the ISA (Ward and Nigro 1992, North et al. 2001) (Figure 2-4), giving them the greatest potential exposure to chemicals. Abundant toxicological data from studies conducted with salmonid species are available to evaluate potential effects for this species. Based on the above information, juvenile chinook salmon were selected to represent juvenile salmonids in the ISA. However, some salmonids (e.g., spring chinook) may spend more time in the ISA than juvenile fall chinook. Neither spring nor fall chinook can be distinguished during sampling. Therefore, it is uncertain which seasonal chinook tissue will be collected for use in the risk assessment. As described above, peamouth inhabit similar habitats and have diets similar to juvenile salmonids utilizing the ISA. Therefore, peamouth will provide a conservative estimate of exposure for those juvenile chinook with greater residence time in the ISA. General juvenile chinook habitat is shown in Figure 2-6.

2.5.3.3 Piscivores

Several species of piscivorous fish have been observed in the LWR (Table 2-2). Northern pikeminnow, smallmouth bass, largemouth bass, bull trout, black crappie, white crappie, and walleye are common piscivores in the LWR. As top predators, all of these fish play a key role in the dynamics of the aquatic community. Because of their high trophic status, these fish have high potential exposure to biomagnifying chemicals such as polychlorinated biphenyls (PCBs), DDTs, and mercury. Of the piscivores listed in Table 2-2, northern pikeminnow is the only native species.

Habitat associations for piscivores in the LWR vary between species in ways that may affect their exposure to chemicals. Northern pikeminnow, black crappie, and white crappie are more common in the LWR than the other piscivorous fish. The northern pikeminnow is common in all habitats in Portland Harbor, especially near undeveloped natural beaches (Farr and Ward 1993). Black crappie and white crappie, though common in all habitats, are most common near developed sites, especially near quiescent rip-rapped areas (Farr and Ward 1993). Black crappie, white crappie, smallmouth bass, and largemouth bass are closely related species, all of the family Centrarchidae. These centrarchids are all believed to have home ranges that are small relative to the ISA. Northern pikeminnow have varying home ranges. In a mark-recapture study, North et al. (2001) found that most northern pikeminnow were recaptured within 1.4 km of their release site; however, one fish was captured 21 km from the release site, and several fish were not recaptured and may have moved long distances or been eaten by predators (Figure 2-5).

The diets of piscivorous fishes in the LWR have been shown to be similar (Fishman 1999). All of the piscivorous fish in the LWR are benthopelagic species, so none are likely to have greater direct sediment exposure. Northern pikeminnow have a longer expected lifespan (19 yr) than walleye (17 yr), largemouth bass (16 yr), black crappie (13 yr), smallmouth bass (10 yr), or white crappie (6–7 yr). Sufficient tissue data were not available to compare relative bioaccumulation directly (Section 3). Also, few toxicological data are available for piscivorous fish species present in the LWR. Therefore, the relative sensitivity of piscivorous fish species could not be used as a factor for selection of a receptor for this guild. The northern pikeminnow was selected as representative of piscivorous fish because it is relatively long-lived and is a top predator. Smallmouth bass were also selected as representative of piscivorous fish because of their smaller home range and similarity to other centrarchid piscivores in the LWR.

2.5.3.4 Detritivores

Lamprey ammocoetes are unique to the fish community in Portland Harbor because they live burrowed in the sediment and filter their food from sediment, ingesting sediments in the process. These are the only detritivorous fish present in the LWR. Lamprey ammocoetes reside in freshwater for up to 6 yr and potentially have extensive exposure. However, lamprey ammocoetes are reported to move progressively downstream as they mature, so exposure in the ISA is likely to be less than the maximum possible in fresh water. Pacific lamprey are also a species of concern under the ESA and an Oregon State sensitive species. Pacific lamprey are valued by Native American tribes in the region for ceremonial purposes. Additionally, toxicity data are available for lamprey because several chemicals have been tested as lampricides for use in the Great Lakes, where sea lamprey from the Atlantic Ocean are an introduced pest species.

The occurrence of lamprey ammocoetes in the ISA is largely unknown; however, they were reported to be present near RM 11 from an electrofishing survey (Fishman 1999). Three species of lamprey other than Pacific lamprey may occur in the ISA, but their presence has not been well documented (Table 2-2). Therefore, Pacific lamprey ammocoetes were selected to serve as a representative for detritivorous fish in the LWR. Extensive sampling efforts to capture this receptor within the ISA occurred in 2002, but few were captured (Attachment B.3). These results indicate that use of the ISA by lamprey ammocoetes may be more limited than expected. The opportunity to sample additional lamprey ammocoetes will be evaluated and if deemed not feasibly other fish tissue data will be used as surrogates in the evaluation of potential effects to lamprey. If lamprey are observed during sediment sampling, they should be collected and held for possible analysis.

Adult lamprey travel through the ISA while migrating to upstream spawning areas. Growth of adult lamprey occurs primarily during parasitic feeding on other fish in the ocean or estuary. Adult lamprey do not feed in fresh water. Therefore, their exposure through the dietary pathway while in the ISA is insignificant. The passage time of adult lamprey in the ISA is unknown.

2.5.3.5 Summary

Nine fish species were selected as receptors from the four feeding guilds of the LWR. They are largescale sucker, white sturgeon, carp (surrogate receptor) sculpin, peamouth, juvenile chinook salmon, northern pikeminnow, smallmouth bass, and Pacific lamprey. Collectively, these fishes represent the exposure pathways that are most likely to be significant for fish species, and they represent the range of life stages and habitat used by fishes in the ISA. Altogether, chemical risk analyses of these receptors will be protective of other fish species in the ISA. Fish in early life stages may be affected by COPCs differently from the adult stages discussed above. Methods for assessing risks to juvenile and other early-life-stage fish will be discussed in Section 5.0 of this appendix.

2.5.4 Amphibians and Reptiles

Amphibians will be evaluated at the population level and will act as a surrogate representing the reptile population. Amphibians will be a surrogate species to evaluate reptiles because little toxicity data are available on reptiles and exposure of amphibians to COPCs is greater. The suitability of using amphibians as surrogate for reptiles will be assessed by performing a comparative evaluation of toxicity based on a literature search, if appropriate reptile habitat is found in the ISA. Amphibians and reptiles will be assessed by evaluating multiple species, dependent on the scientific information available.

2.5.5 Birds

To choose avian representative species, birds at the site were evaluated using the criteria in Section 2.5, dividing them into four primary feeding guilds: herbivores (eating primarily vegetation), sediment-probing invertivores/omnivores (feeding on invertebrates), diving carnivores/omnivores (feeding on small fish, crayfish, and invertebrates), and piscivores (eating primarily fish). This section discusses the selection of representative bird species.

2.5.5.1 Herbivores

Herbivorous birds in the vicinity of the ISA that consume mostly aquatic vegetation as well as some aquatic organisms include geese, swans, American coot, and various diving and dabbling ducks. A representative from this group will not be assessed because they feed at the base of food web and thus are less exposed to contaminants than the receptors from the other feeding guilds. In addition, aquatic vegetation is limited in the ISA, so feeding probably occurs primarily in areas not associated with harbor contamination. Although dabbling ducks may ingest sediment while feeding, they are not likely to ingest as much as sandpipers. Spotted sandpiper was selected as a receptor (Section 2.5.5.3), so protection of this species will also be protective of dabbling ducks thereby acting as a surrogate for this feeding guild. The similarity of the spotted sandpiper’s and dabbling ducks’ exposure units will be evaluated through a comparison of the area usage within the ISA by the two species. The wintering population of Aleutian Canada goose is listed as threatened by the USFWS and endangered by ODFW (ONHP 2001), and may be present in the vicinity of the ISA, but is rarely observed (Nebeker 2001). Canada geese eat primarily grain and foliage in the winter (Ehrlich et al. 1988), reducing their exposure to contaminated sediment from the ISA. Herbivorous birds have limited exposure to contaminants in the LWR and estimated total exposure for sediment-probing invertivores is assumed be a conservative estimate of total exposure to herbivorous birds.

2.5.5.2 Diving Carnivore/Omnivore

Diving birds in the study area that ingest primarily invertebrates and small fish include bufflehead, hooded merganser, goldeneye, grebes, Bonaparte’s gull, California gull, and scaup. None of these species are identified as threatened or endangered. Any of these species would be good representative species for the diving birds. The hooded merganser was chosen as the representative species because it utilizes most of the aquatic habitat in the LWR to forage for crustaceans, mollusks, aquatic insects, and fish.

2.5.5.3 Sediment-probing Invertivore/Omnivore

Sediment-probing birds consume mostly sediment-associated invertebrates and may incidentally ingest a relatively large amount of sediments. In the vicinity of the ISA, these birds include sandpipers, killdeer, sora, yellowlegs, marbled godwit, long-billed curlew, Wilson's phalarope, dowitchers, common snipe, and Virginia rail. Spotted sandpiper, killdeer, sora, Virginia rail, and common snipe are species that breed in the vicinity of the ISA. Breeding populations of the long-billed curlew, which are not present in the Willamette Valley, are considered vulnerable by ODFW (ONHP 2001). None of the probing birds is listed as threatened or endangered, and species-specific laboratory toxicological data are not available for any of these species. Of the bird species evaluated for consumption of soil and sediment by EPA (1993), sandpipers were found to have the highest sediment ingestion rate. Therefore, spotted sandpiper was chosen as a representative species based on sediment exposure and presence of breeding population. Because exposure of the spotted sandpiper to sediment is expected to be relatively high, the spotted sandpiper is considered a conservative representative of omnivorous and herbivorous birds.

2.5.5.4 Piscivores

Piscivorous birds feeding from the Willamette River in the vicinity of the ISA include ospreys, cormorants, herons, terns, eagles, kingfishers, American white pelicans, and western gulls. Of these birds, the osprey and the bald eagle were chosen as representative species of piscivores at the site. The bald eagle is listed as a threatened species under the ESA and is also protected by the Bald Eagle Protection Act, and both the osprey and bald eagle are protected under the Migratory Bird treaty Act. Osprey and bald eagle nests have been observed at or close to the site, indicating that sensitive, developmental life stages of these species are potentially exposed to chemicals in the ISA. Most of the osprey's prey are fish, and bald eagles are assumed to consume primarily fish in the LWR. Consumption of secondary aquatic consumers, such as invertivorous fishes, gives bald eagle and osprey the highest potential exposure to biomagnifying chemicals. Chemical exposure in the ISA for these two species is likely to be different because the bald eagle is present year-round and osprey is a migratory species, present only from spring through fall.

Other piscivores considered for inclusion as representative species were the cormorant, great blue heron, and kingfisher, based on their presence at the site, breeding habitat, special regulatory status, or societal importance. The cormorant feeds on bottom fish, and thus may have potentially high exposure. However, the osprey and bald eagle consume secondary consumers and have more societal value, rendering them better representative species. The great blue heron nests on Ross Island, but the site affiliation may not be as strong as for the osprey because great blue heron may feed on upland species. Osprey and bald eagles are likely the most highly exposed to site-related chemicals, and protection of ospreys and eagles would therefore also protect other piscivorous birds.

2.5.5.5 Summary

Four birds were selected as representative species from three of the four feeding guilds of the LWR. They are spotted sandpiper, hooded merganser, osprey, and bald eagle. Collectively, these birds represent the exposure pathways that are most likely to be significant for bird species, and they represent the range of life stages and habitat used by birds in the ISA. Altogether, risk assessment of these receptors will be protective of other bird species in the ISA.

2.5.6 Mammals

The key exposure route for aquatic or semi-aquatic mammals is likely to be consumption of prey associated with sediment in the ISA. The mammalian species that may use the ISA and have the greatest percentage of aquatic prey in their diets are mink, river otter, raccoon, and California sea lion. None of these species is listed as threatened, endangered, or sensitive. Raccoons are omnivores that ingest significant amounts of vegetation along with a broad range of other food items. The California sea lion is generally considered a nuisance species in the Willamette River because of its predation on salmonids, and is likely to use the site only for migrating to Willamette Falls to forage at the fish ladder.

Mink were chosen as the representative species to represent wildlife consuming aquatic prey. Mink are not common in the ISA; however, mink are known to be extremely sensitive to PCBs and therefore may be sensitive to other contaminants. In addition, substantial toxicity data exists for this mammal species. By protecting mink, other less sensitive mammals such as the river otter will be protected. In addition to mink, river otter will be assessed to represent carnivorous mammals.

Table 2-9 presents a summary of the selected assessment endpoints and measures (Section 2.1) for the Portland Harbor ERA for each selected receptor of concern.

2.6 POTENTIAL EXPOSURE PATHWAYS

This section describes the potential chemical exposure pathways to species in the ISA and discusses which pathways will be evaluated for the various representative species in the ecological risk assessment. Representative species can be exposed to chemicals in water or sediment in the ISA either directly through contact with or ingestion of sediments or surface water or indirectly through the food chain. The

CSM (Figure 2-12) illustrates the pathways that chemicals may follow from primary sources to the ecological species. Exposure pathways were designated as follows:

- **Complete and Major**: Pathway is complete and expected to be a significant contributor to total exposure. This pathway will be quantitatively assessed when possible in the PRE, the Comprehensive Round 2 site characterization and data gaps analysis report, and the BERA.
- **Complete and Minor**: The pathway is complete and expected to be a minor component of total exposure. In relation to other complete pathways, chemical exposure is expected to be minimal. This pathway will not be quantitatively evaluated in the PRE, the Comprehensive Round 2 site characterization and data gaps analysis report, and the BERA unless sufficient data are available, but will be discussed qualitatively to a level of certainty dependent on available studies. If the data are insufficient, additional information will be gathered through an interim sampling process and the risk evaluated if the pathway is believed to potentially contribute to overall risk significantly.
- **Complete and Uncertain**: The pathway is complete but of undetermined significance. If there is a lack of sufficient toxicological data, this pathway will not be quantitatively evaluated in the PRE, the Comprehensive Round 2 site characterization and data gaps analysis report, and BERA, but will be discussed qualitatively to a level of certainty dependent on available studies. However, if the uncertainty is due to lack of site-specific data, appropriate information will be collected and a determination made whether the pathway is major or minor. If sufficient toxicological data exist, the pathway will be evaluated using multiple lines of evidence including sediment chemistry, bioassays and an evaluation of groundwater contribution.
- **Incomplete**: The pathway is incomplete; therefore, it will not be evaluated in the PRE, the Comprehensive Round 2 site characterization and data gaps analysis report, or BERA.

The rationale for each exposure pathway designation by receptor is discussed in the remainder of this section.

2.6.1 Aquatic Receptors

2.6.1.1 Aquatic Plants

The Aquatic Plant and Amphibian/Reptile Reconnaissance Survey (see Attachment B.2) confirmed the presence of aquatic plants in the ISA. Exposure pathways considered complete and major to aquatic plants are direct contact with surface water and sediment (Figure 2-12). Because aquatic plants actively and passively transfer chemicals from surface water and sediments, these contact pathways are considered the only complete pathways of exposure to this receptor community in the ISA.

2.6.1.2 Benthic Invertebrates

Infaunal and epifaunal invertebrates

Infaunal and epifaunal benthic invertebrates are generally in direct contact with sediment and surface waters. Therefore, direct sediment and water contact are considered complete and major pathways of exposure (Figure 2-12). Surface water ingestion is considered a complete and minor pathway of exposure for infaunal and epifaunal invertebrates. In addition, benthic invertebrates are known to routinely ingest sediment, and therefore this pathway is considered complete and major. A significant portion of benthic invertebrate diet consists of other benthic organisms, algae, and detritus. Therefore, biota ingestion for infaunal and epifaunal organisms is considered a complete and major pathway of exposure.

Benthic infauna may be exposed to chemicals associated with groundwater infiltration into sediments. This exposure may not be reflected in sediment concentrations for volatile organic compounds and some metals that do not partition into sediments. The importance of this pathway in the ISA cannot be determined at this time due to lack of information on groundwater hydrology within the ISA. Therefore, this pathway is considered complete and uncertain. The groundwater pathway will be assessed if the results of the groundwater evaluation indicate the existence of areas where porewater (i.e. transition zone) chemistry may be influenced by groundwater input creating a complete pathway to benthic infauna (see Section 7.5 of the Programmatic RI/FS Work Plan for groundwater evaluation process). The porewater (i.e. transition zone) pathway is considered complete and the significance is uncertain at this time for benthic infauna. For all other receptors, this pathway is considered incomplete.

Mollusks

Direct sediment, porewater (i.e. transition zone), and surface water contact are considered complete and major pathways of exposure for mollusks (Figure 2-12). Sediment ingestion is also considered a complete and major pathway of exposure for mollusks because they are known to routinely ingest sediment. Incidental water ingestion is considered a complete and minor pathway. Biota ingestion is considered a complete and major pathway because mollusks’ diets can consist of other benthic organisms and detritus.

Epibenthic Macrofauna
Crayfish are in direct contact with surface water, and this pathway is considered complete and major. Crayfish are also in direct contact with sediment. Thus, sediment contact is considered a complete and major pathway for crayfish. Crayfish ingest sediment both directly and indirectly, therefore this pathway is considered complete and major. Surface water ingestion is considered a complete and minor pathway of exposure. Finally, crayfish diets consist of other benthic organisms, detritus, and dead fish. Therefore, biota ingestion is considered a complete and major pathway of exposure.

2.6.1.3 Fish

Omnivore/Herbivore-largescale sucker, carp, and white sturgeon
Largescale suckers, carp, and white sturgeon live in close association with sediment and benthic invertebrates which are a primary component of this species' diet. As such, direct contact with sediment, sediment ingestion, and ingestion of benthic biota are considered to be complete and major pathways of exposure for these fish species and will be evaluated (Figure 2-12). In addition, largescale suckers, carp, and sturgeon are in direct contact with surface water, thus, this pathway is considered a complete and major pathway of exposure for this receptor. Incidental ingestion of water may occur for the largescale sucker, carp, and sturgeon, like all other fish species, however, this pathway is considered complete and minor.

Invertivore--sculpin species
Benthic invertivorous fish, such as sculpin species, are in direct contact with surface waters and sediments. Therefore, direct sediment and water contact are considered complete and major pathways of exposure for sculpin (Figure 2-12). Water ingestion is considered a complete and minor pathway. Since sculpin are benthic feeders and consume sediment-ingesting prey such as epibenthic invertebrates, sediment and biota ingestion are also considered complete and major pathways of exposure.

Invertivore—peamouth
Peamouth are in constant contact with surface water and this pathway is considered complete and major. Ingestion of surface water is a complete and minor pathway. The diet of the peamouth consists of benthic invertebrates, crustaceans and small fish which bioaccumulate chemicals. Therefore, the ingestion of biota is a complete and major pathway. While feeding, peamouth may ingest sediment directly through the mouth or indirectly through prey. The amount of sediment ingested with prey could be significant when feeding on benthic organisms. However, fish are also a portion of the peamouth diet and would constitute a minor mass of sediment. Therefore, the sediment ingestion pathway is considered complete and uncertain. Peamouth are benthopelagic species and direct contact with sediment will occur when feeding on benthic prey. However, benthic species comprise only a part of the peamouth diet and peamouth spend a significant portion of time in the pelagic zone. Therefore, direct contact with sediment is considered a complete and minor pathway.

Invertivore-juvenile chinook salmon

Juvenile chinook salmon are in constant contact with surface water. Therefore, surface water contact is considered complete and major pathway of exposure (Figure 2-12). Epibenthic invertebrates are generally a primary component of the juvenile chinook salmon diet. Therefore, ingestion of benthic biota is considered a complete and major exposure pathway. Juvenile chinook salmon may directly ingest sediment while feeding and indirectly through consumption of prey containing sediment. However, no sediment ingestion studies are available to determine its contribution to total exposure for any contaminants. Therefore, the sediment ingestion pathway is considered complete and uncertain. Direct contact between juvenile chinook salmon and sediments, and ingestion of surface water are assumed to be a complete and minor pathways.

Piscivore-smallmouth bass

The diet of piscivores such as smallmouth bass is predominantly fish, crayfish, and occasional other prey items (e.g., water column invertebrates, drift organisms). Therefore, ingestion of biota is considered a complete pathway of exposure (Figure 2-12). The ingestion of water is considered a complete and minor pathway of exposure. Smallmouth bass are in constant contact with water. Thus, direct contact with surface water is a complete and major pathway of exposure.

Smallmouth bass consume benthic prey so they are likely to incidentally consume some sediment; however, sediment ingestion is considered to be a minor pathway of exposure in comparison to the prey ingestion pathway. Though they may occasionally come into contact with sediments when foraging, they are not likely to have substantial direct contact with sediments because smallmouth bass are benthopelagic species. Therefore, direct sediment contact is considered a complete and minor pathway. Smallmouth bass habitat is shown in Figure 2-6.

Piscivore-northern pikeminnow

Northern pikeminnow are in constant contact with surface water and this pathway of exposure is considered complete and major. Juvenile northern pikeminnow feed on both insects and small fish, and adult northern pikeminnow consume primarily fish. Thus, ingestion of biota is considered a complete and major pathway of exposure. Northern pikeminnow, like smallmouth bass, are a benthopelagic species and are occasionally in direct contact with the sediment and may ingest some sediment directly and indirectly from their prey. Ingestion of surface water and sediment, and direct contact with sediment are all considered complete yet minor exposure pathways.

Detritivore-Pacific lamprey ammocoetes

Pacific lamprey ammocoetes live in direct contact with sediment and often filter food (e.g., detritus, diatoms) directly from sediment. Therefore, direct sediment contact and ingestion of sediments and biota are considered to be complete and major pathways of exposure for Pacific lamprey ammocoetes and will be evaluated in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and

BERA (Figure 2-12). In addition, Pacific lamprey ammocoetes are in direct contact with surface water; thus, surface water contact is also considered a complete and major pathway of exposure for this species. Ingestion of surface water is a complete and minor pathway.

2.6.1.4 Amphibians and Reptiles

The Aquatic Plant and Amphibian/Reptile Reconnaissance Survey (see Attachment B.2) confirmed the presence of amphibians in the ISA. Although reptiles were not observed in the qualitative two-day survey, the ISA likely provides suitable yet limited habitat for reptiles. Therefore reptiles and amphibians will all be assessed in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA. Direct contact with the surface water pathway is considered a complete and major pathway for amphibians. For reptiles direct contact with surface water is considered a complete and uncertain pathway. Because direct contact with sediment varies depending on the species and life stage, direct contact with the sediment pathway is considered complete and uncertain pathway for amphibians and reptiles. Some data are available regarding relative amounts of sediment ingested directly or indirectly by reptiles from Beyer et al. (1994) indicating that sediment is a small proportion of their total diet, approximately 4–6 % of total food ingestion. However, no comparable data are available for amphibians, which may consume more sediment. Therefore, the sediment ingestion pathway is considered complete and uncertain. The food ingestion pathway is considered complete and major for both amphibians and reptiles because some species prey on benthic invertebrates. Surface water ingestion is considered a complete but relatively minor pathway for amphibians and reptiles (Figure 2-12).

2.6.2 Wildlife Receptors

A CSM for wildlife species is presented in Figure 2-12. Pathway designations are described below.

2.6.2.1 Birds

Surface water exposure by swimming and ingestion are considered complete and minor for all birds because water ingestion does not contribute measurably to total exposure for any contaminant when included in calculation of the risk estimate and water contact is limited by insulating feathers. The insignificance of surface water exposure to birds is due in large part to the relative insolubility of many COPCs.

Diving Carnivore—hooded merganser

Hooded mergansers primarily consume benthic invertebrates and small fish. Therefore, ingestion of biota is considered a complete and major pathway of exposure (Figure 2-12). In addition, hooded mergansers are likely to ingest sediments incidentally while foraging and indirectly through their prey. Thus, sediment ingestion is considered a complete and major pathway. Surface water contact and ingestion and direct sediment contact are considered incidental occurrences and complete but relatively minor pathways of exposure.

Sediment-probing Invertivore—spotted sandpiper
Spotted sandpipers primarily consume benthic invertebrates; thus, ingestion of benthic biota is considered a complete and major pathway of exposure and will be evaluated in the PRE (Figure 2-12). In addition, spotted sandpipers are likely to consume sediments during feeding. Thus, sediment ingestion is considered a complete and major pathway of exposure. Surface water contact and ingestion are considered complete but relatively minor pathways. Because spotted sandpipers forage extensively on beaches they are likely to be in direct contact with sediments. Direct contact exposure studies have not been conducted with shorebirds; therefore, the contribution to total exposure from direct contact is uncertain. Although assumed to be a complete pathway, without sufficient toxicological data this pathway will not be quantitatively assessed in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, or BERA.

Piscivore—osprey and bald eagle
Piscivorous birds, such as osprey and bald eagle, primarily consume fish from the water column. Therefore, ingestion of fish and other biota is considered a complete and major pathway of exposure for these species and will be evaluated in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA (Figure 2-12). Bald eagles frequently consume beached fish carcasses and may incidentally consume sediments as a result. Thus, sediment ingestion is considered a complete and minor pathway of exposure for bald eagle. Since surface water contact and ingestion and direct sediment contact are likely to be minimal, these pathways are considered to be complete but minor pathways.

2.6.2.2 Mammals

Carnivore—mink and river otter
Carnivorous mammals consume a wide range of prey, but primarily consume aquatic prey such as fish and macroinvertebrates (e.g. crayfish); therefore, ingestion of fish and other biota is considered a complete and major pathway of exposure and will be evaluated in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA (Figure 2-12). Mink and river otter may ingest sediments while foraging, burrowing or digging into the sediment and while grooming their fur. Thus, sediment ingestion is considered a complete and major pathway of exposure for carnivorous mammals. Surface water contact and ingestion are considered complete but relatively minor pathways. Surface water contact by swimming and ingestion are considered complete and minor because water ingestion does not contribute measurably to total exposure for any contaminant when included in calculation of the risk estimate and water contact is limited by the insulating fur coat. The insignificance of surface water exposure to mammals is due in large part to the relative insolubility of many COPCs. Direct sediment contact may contribute to total

exposure through transdermal absorption. However, given the insulating properties of the fur of mink and other aquatic carnivorous mammals that may use the ISA, direct contact would be limited to the paws. Thus, this pathway is considered complete and minor. Because assessment methods for skin contact are unavailable, the contact pathways will be qualitatively assessed in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA.

Data will be provided by the Round 1 and later sampling programs to characterize the ecological risks associated with exposure to chemicals in sediments, water, and tissues. This information will be used to update the ecological CSM as it becomes available.

3.0 EXISTING DATA

This section summarizes the existing water, sediment,, invertebrate, tissue and toxicity testing data for samples collected within the ISA since 1990. All data were subject to a quality assurance/quality control (QA/QC) review. A complete discussion of the QA/QC review process as well as the results of the review is presented in Section 4 and Table 4-1 in the Programmatic Work Plan and Appendix F.

3.1 DATA QUALITY ASSESSMENT

Data quality and potential usability were evaluated according to criteria developed to place data into two categories (Work Plan Appendix F). Category 1 data have acceptable QA/QC, whereas Category 2 data have an unknown, incomplete, or unsatisfactory QA/QC status. Criteria for categorizing data were selected to identify basic data qualities, not to limit data to specific program uses. Criteria were developed for the following factors: traceability, comparability, sample integrity, potential measurement bias, accuracy, and precision. Placement of data into Category 1 required that all of the acceptance criteria were known or documented. If any of the factors were unmeasured or unreported, data were placed into Category 2. If the acceptance criteria for any of the factors were not satisfied, data were generally qualified and determined to have limited usefulness. Performance outside acceptance criteria did not necessarily require placement of data into Category 2.

3.2 SURFACE WATER DATA

A limited number of surface water samples have been collected and analyzed for metals or organic compounds since 1990 (Table 3-1). Data are available from a 1999 ODEQ study for Phase 3 of the McCormick & Baxter Remedial Investigation (RI), and from a 1995 study by Woodward-Clyde for the Rhone-Poulenc St. Helens Road facility. The ODEQ data are considered both Category 1 and 2 data, and the Woodward-Clyde data are Category 2. The number of samples in which each analyte was measured ranged from 4 to 11. In addition to these two investigations, surface water samples have been collected at two stations within the ISA by ODEQ as part of their ambient monitoring program, but were analyzed for trace elements only. These data are considered Category 2 because of inadequate information for data verification. Results of historic surface water sampling are provided in Table 3-2.

3.3 SEDIMENT DATA

Numerous sediment chemistry investigations have been conducted in the ISA. Sediment sampling density is the highest between RM 4 and RM 9, where facilities are undergoing remedial or other types of investigations. Table 3-3 lists investigations conducted within the ISA since 1990, along with the category of data quality. Based on the evaluation of the bathymetric survey data, the surface sediment layer at the 0-to-1-ft depth interval appears to capture the majority (97% offshore and 87% nearshore) of the elevation shifts in the riverbed. This information, combined with the fact that the biotic zone of sediments is commonly defined as 0–30 cm, supports a working definition of surface sediments for ecological risk assessment purposes as 0–1-ft. For comparison purposes, the historic sediment chemistry data is presented to full sampling depth, 0–4 ft (Category 1 and 2) and to 1 ft depth in Tables 3-4a through 3-4d for Category 1 and all historical data. Results of historic sediment sampling are presented in Section 4 of the RI/FS work plan.

3.4 INVERTEBRATE DATA

Limited site-specific data exist on the epibenthic and infaunal invertebrate communities. Since 1990 one survey of the epibenthic community (Landau 2000) and three surveys of the infaunal communities have been conducted (Tetra Tech, 1994; Dames & Moore, 1998; Landau, 2000). In 2002, LWG surveyed the infaunal communities at 22 locations and the epibenthic communities at ten locations within the ISA as part of the Round 1 assessment. The community data will not be assessed quantitatively, but will be used in the overall risk assessment as background information.

3.5 TISSUE DATA

Five studies have been conducted within the ISA since 1990 that collected fish or crayfish for chemical analysis, as summarized in Table 3-5. Several species of fish were collected, including black crappie, common carp, smallmouth bass, largemouth bass, northern pikeminnow, and largescale sucker. Table 3-6 presents detected concentrations of chemicals in fish tissue.

Thomas and Anthony (1997) measured chemicals in great blue heron eggs and their prey within the lower Columbia River basin. They examined three nest locations along the lower Columbia and two on the Willamette: one on Ross Island and one about 20 miles further upstream in Molalla State Park. In both 1994 and 1995, five eggs were chosen randomly from each site and were analyzed for DDT, DDE, PCBs, mercury, dioxins, and furans. Table 3-7 summarizes the ranges of concentrations in great blue heron eggs collected from nests on Ross Island.

Uncertainties are associated with QA/QC in all tissue studies. In general, QA/QC documentation (e.g. matrix spikes, surrogate recoveries etc.) was not available for tissue chemistry data sets. Thus all sets were assigned to Category 2 (e.g. uncertainties, unknown, suspect quality) and the data are considered useful for screening purposes only. For additional details regarding uncertainties associated with QA/QC in tissue studies see Section 4 and Table 4-1 in the Programatic Work Plan and Appendix F.

3.6 TOXICITY TESTING

Fifteen laboratory toxicity studies using benthic invertebrates have been conducted with sediment collected in the ISA since 1990. These data were generally collected for dredged material characterizations, remedial investigations, and site investigations conducted at Portland Harbor facilities. Table 3-8 summarizes the bioassay tests completed in the ISA, providing information about date of study, purpose, tests completed, number of samples, results, and data quality category. Figure 3-1 shows the location and results of each station.

In 1998, the U.S. Army Corps of Engineers, EPA, Washington State Department of Ecology, ODEQ, and Washington State Department of Natural Resources prepared the Dredged Material Evaluation Framework for the Lower Columbia River Management Area (LCRMA 1998) to provide guidelines for dredged material sampling and testing. Generally, two tests have been used to assess the suitability of dredged material, the amphipod (*Hyalella azteca*) 10-day survival, and the midge insect larvae (*Chironomus tentans*) 10-day survival and growth tests. In studies completed prior to LCRMA 1998 guidelines, bioassays were performed using *Hyalella azteca* and *Daphnia magna.* A few studies used the Microtox bioluminescence test, which is not commonly used in regulatory programs.

3.6.1 Interpretive Criteria

Amphipod and midge bioassay results were compared to LCRMA guidelines. When multiple bioassays are conducted, bioassay interpretive criteria are defined as "one-hit" and "two hit" failures. For the amphipod bioassay, a one-hit failure occurs when mean test mortality is greater than 15% when compared to mean mortality of the reference sample and statistically different from the reference ($p \leq 0.05$). For the midge survival bioassay, a 1-hit failure occurs when mean test mortality is greater than 20% when compared to mean mortality of the reference sample, and is statistically different from the reference ($p \leq 0.05$). For the midge growth bioassay, a one-hit failure occurs when the mean growth rate is less than 60% of mean growth rate of the reference sample and statistically different from the reference ($p \leq 0.05$). When any two of the three bioassay tests fails the one-hit rule, the test sample fails the two-hit rule (LCRMA 1998).

Microtox data were interpreted according to Washington State Sediment Management Standards (Chapter 173-204 WAC). A test sample fails if mean percent light reduction is greater then 20% when compared to the mean percent light reduction of the reference sample, and is statistically significantly different from the reference ($p \leq 0.05$).

3.6.2 Test Results

Results of the bioassay data are provided in Table 3-8. Organism effects, expressed as percent mortality (or survival), and measured growth as biomass varied widely between projects and often within project areas. Results showing significant adverse effects are generally associated with high chemical concentrations. Terminal 4 Slip 3 samples that failed criteria occur in the eastern half of Slip 3, in a location having elevated PAH concentrations (Hart Crowser 1999). At McCormick and Baxter, PTI (1992) noted that the sediments causing the greatest adverse effects were in the vicinity of the creosote dock and upstream of the creosote dock along the shoreline. In 1999, at the same site, investigators noted a strong statistical relationship between LPAH concentrations and *Hyalella* mortality (Ecology and Environment 2001). In a dredged material characterization performed at Tosco, significant mortalities were noted in one composite sample but not the other. The reason for the observed toxicity was not known (Exponent 1999). Exceedances of LRCMA criteria occur at the northeastern end of Terminal 4, Slip 3, McCormick & Baxter, Swan Island Lagoon, Portland Shipyard, the Pipeline Terminals, and the shoreline across from Terminals 1 and 2 (Cargill and Goldendale Alumina). It should also be noted that test samples located within these same areas passed LRCMA criteria.

3.7 SUMMARY

Overall, the existing data collected within the ISA that qualify as Category 1 data are principally associated with sediment chemistry and toxicity studies using benthic organisms. Almost all other types of environmental data collected have been determined to be Category 2 data, and therefore may be of limited use in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and the BERA.

4.0 COPC SELECTION PROCESS

At the request of regulatory agencies, a very large number of chemicals were identified for analysis in RI and FS samples. The large analyte list was due, in part, to the diversity of *potential* contaminants among the many distinct sources in the Portland Harbor. However, it is likely that only a small portion of the analytes will be important "risk drivers," and/or important in risk management decisions. The analytes will be evaluated both as harbor-wide and site-specific risk drivers. Furthermore, most individual sites along the ISA are associated with a limited scope of potential contaminants. It is impractical to expend LWG and government resources on analyzing risk from all analytes. Therefore, a process is needed to narrow the scope of COPCs for which detailed risk analysis is to be conducted.

Following the completion of the Round 1 field sampling events, a preliminary list of COPCs will be selected for fish tissue and possibly wildlife that do not ingest sediment (or ingest minimal amounts). It should be noted that toxicity data for many COPCs may be inadequate to make useful judgments of risk. Analytes for which no toxicity values are obtained will be retained as COPCs for the risk assessment but will not be quantitatively assessed. These compounds will be discussed in the uncertainty section of the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA. The potential effects of excluding such compounds on risk characterization conclusions will be discussed.

COPCs will not be developed for the benthic invertebrate community, amphibians, reptiles, some of the wildlife species, or aquatic plants based on the PRE either because data gaps critical to the evaluation of these receptor groups will remain at the time of the PRE, or because the group will be evaluated qualitatively due to lack of toxicity data. The Comprehensive Round 2 site characterization and data gaps analysis report and BERA will assess all receptors and provide an identification of COPCs. The Comprehensive Round 2 site characterization and data gaps analysis report and BERA will include all the data collected by the LWG during Rounds 1 and 2 (and any subsequent rounds needed). The COPCs presented in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA will be for all pathways and receptors that have toxicity information available. The COPCs presented in the BERA will be used to develop a final list of chemicals of concern (COC) based on probable risk, using area-weighted averages and other spatial tools and knowledge of receptor foraging characteristics. If needed, information will be collected on area-specific foraging characteristics. A fish food web model may also be used to help identify COPCs and COCs in pathways that contribute to unacceptable risk. Data gaps following Round 2 may be identified; these data gaps will be filled in subsequent rounds and presented in the BERA.

COPC identification will be presented in the comprehensive ERA approach memorandum prior to the PRE. The methods for COPC identification will rely on maximum concentrations of site media. The specific methods for each assessment endpoint are presented below.

4.1 AQUATIC PLANTS

Risk to aquatic plants will not be assessed quantitatively. A qualitative assessment will be included in the risk characterization that will consider all detected analytes in sediment and surface water as COPCs.

4.2 BENTHIC INVERTEBRATES

COPCs for sediment will not be derived for benthic invertebrates from the PRE. A benthic assessment interpretive approach will be presented in a technical memorandum prior to the Round 2 toxicity testing.

Maximum surface water analyte concentrations will be compared to the corresponding chronic ambient water quality criteria (AWQC) values or other effects-based toxicity values for sensitive species to identify COPCs for aquatic invertebrates, including mollusks and crayfish. A literature search will be conducted to locate appropriate toxicity values for analytes that do not have corresponding AWQC values. Analytes measured in surface water at concentrations greater than the corresponding AWQC or other relevant toxicity value will be retained as aqueous COPCs for aquatic invertebrates. Aqueous COPCs will be developed only after surface water data collection is completed (and the groundwater pathway has been evaluated).

In the PRE, maximum crayfish and clam tissue concentrations for each analyte will be compared to the respective tissue residue effects concentrations for crayfish and clams. Analytes with tissue concentrations above the corresponding residue effects concentrations will be retained as tissue COPCs for aquatic invertebrates. Due to the limited shellfish and clam tissue data and difficulties collecting additional data it may not be possible to reduce the COPC list at this time with these data.

4.3 FISH

Aqueous and sediment COPCs will be developed for fish in separate steps. To determine aqueous COPCs for fish in the ISA, maximum surface water analyte concentrations will be compared to corresponding chronic AWQC or other chronic toxicity values. A literature search will be conducted to locate appropriate toxicity reference values (TRV) (both no effects and effects concentrations) for measured analytes that do not have corresponding AWQC values. Analytes measured at concentrations greater than the corresponding AWQC or TRV value will be retained as COPCs for fish.

Maximum whole body fish tissue concentrations for each bioaccumulative analyte will be compared to corresponding fish tissue TRVs for non-metabolized COPCs. Dietary-based TRVs will be compared to a daily dose estimate for metabolized

COPCs. Analytes for which receptor tissue residue concentrations or dietary-dose estimates exceed their corresponding TRV values will be retained as COPCs for fish. Additional tissue data may be needed for the COPC elimination process for those species that were not collected in Round 1 (or if additional areas are selected for fish species that were collected).

The TRV selection process will be presented in details in a technical memorandum prior to the PRE.

4.4 AMPHIBIANS AND REPTILES

Amphibian and reptile COPCs will be determined by comparing relevant media maximum concentrations to appropriate TRVs or AWQCs. When available, data on the most sensitive life stage will be used in the evaluation. Analytes exceeding TRVs or AWQCs will be retained as COPCs.

4.5 WILDLIFE

Wildlife COPCs will be determined by comparing dietary dose TRVs to estimated daily doses for each of the specific wildlife receptors. All Round 1 data will be used in the calculations. If historical tissue data can be upgraded to Category 1 data, they will also be included in the calculations. The methods for calculating doses for wildlife receptors are presented in detail in Section 5.3. Conservative assumptions, such as 100 percent site use, will be used in estimating total exposure for the purposes of identifying COPCs. Analytes for which daily dose estimates exceed their corresponding TRV values will be retained as COPCs for that receptor. Maximum concentrations will be used to identify COPCs.

The TRV selection process will be presented in details in a technical memorandum prior to the PRE.

5.0 ANALYSIS AND RISK ESTIMATION PLAN

This analysis plan presents the general approach to exposure characterization, effects characterization, and risk estimation for each assessment endpoint and describes data needed to assess each endpoint using these methods. Prior to the PRE a comprehensive ERA approach memorandum will be presented describing the exposure and effect characterization, and risk estimation in details. In the exposure characterization, measures that will be used to estimate exposure of receptors to COPCs in the ISA from all the complete pathways identified in the problem formulation and their spatial and temporal extent are described. The effects characterization describes chemical-specific effects related to the assessment endpoints (e.g., through stressor-response profiles) and examines how the response changes with chemical concentration. Risk characterization is where information from the exposure and effects characterizations is integrated into an estimate of risk and the likelihood of adverse ecological effects is described. The methods for the risk estimation step vary by assessment endpoint and are included in this section. The approach for the latter step, risk description, is identical across assessment endpoints and is presented in the next section. Identification of data needs, which are based on the available information summarized in the problem formulation (Section 2) and the types of data required to complete the risk assessment, are summarized for each assessment endpoint. These data needs are summarized in the DQO process presented in Tables 5-1 through 5-4 (also found in the Programmatic Work Plan Section 7). The benthic invertebrate DQO table has been removed. The process for assessment of risk to benthic invertebrates will be presented in a technical memorandum.

In this section, the exposure point concentration (EPC) and hazard quotient calculations common to all assessment endpoints, except No. 1, are described. The approach of comparing EPCs to effect concentrations in a quotient is recommended by EPA guidance (EPA 1998). The exposure point concentration is a calculated value intended to represent exposure from a medium to the receptor and the hazard quotient approach is one of the common methods of risk estimation used in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and BERA. Following this, additional unique method details and a summary of the exposure and effects characterization approach are presented for each assessment endpoint. Note that the usefulness and feasibility of applying probabilistic risk assessment (PRA) techniques in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA to reduce uncertainties will be discussed with EPA and its partners. If a PRA approach is used to reduce uncertainties, a technical memorandum or work plan will be developed, based on EPA guidance, on the PRA approach and agreed to with EPA and EPA's partners prior to conducting this approach.

Assumptions regarding exposure conditions for each assessment endpoint will need to be defined before completion of the PRE. These specific assumptions will be developed through discussions with EPA and its partners and will be presented in a technical memorandum prior to the PRE. Similarly, refined exposure assumptions will be presented in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA.

5.1 EXPOSURE POINT CONCENTRATIONS

EPCs will be calculated to quantitatively estimate exposure for all receptors. The exposure point concentration represents the concentrations of COPCs in sediment, aqueous solutions, and prey items to which receptors may be exposed. A "high-end" exposure point concentration (EPA 1998), a conservative estimate of exposure, will be applied in the PRE by using the maximum concentration and by calculating the 95 percent upper confidence limit on the mean (95% UCL) of the relevant data. The data used will consist of those collected during Round 1 and historic data that have passed QA/QC criteria. For datasets where the 95% UCL exceeds the maximum detected concentration or sample sizes are less than ten, the maximum detected concentration will be used as the EPC (EPA 1992b). As noted above, one purpose of the PRE is to use conservative assumptions to help identify COPC/receptor pairs for which additional data and/or more detailed analysis is necessary in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA to make decisions regarding acceptable risk. In the Comprehensive Round 2 site characterization and data gaps analysis report and BERA, a measure of central tendency will be calculated in addition to the upper-bound estimates of exposure and risk. For aquatic plants and organisms that are immobile, the exposure point concentration will be the maximum concentration. Exposure for each receptor will be assessed for the ISA as a whole using EPCs based on receptor-specific foraging areas. Prior to the assessment the specific area of the ISA and the specific sediment samples selected to represent a receptor will be identified in a technical memorandum in cooperation with EPA. In addition, to determine key exposure pathways for identified sources and the contribution of individual sources to overall site exposure, another iteration of EPC calculations will be conducted based on a more localized spatial unit centered around identified sources. The spatial unit for this iteration will not be based on the foraging range of the receptor, but will focus on the spatial boundaries for each source. Prior to calculating the EPC for specific receptors the specific calculation method(s) will be selected in cooperation with EPA.

Using common goodness-of-fit tests and other statistical measures of testing data distributions, concentration datasets will be tested for normality. The 95% UCL will be calculated for normally distributed datasets as follows (EPA 1992b):

$$UCL = m + t\left(\frac{s}{\sqrt{n)}}\right)$$ **Equation 1**

Where:

UCL = Upper Confidence Limit
m = mean of the untransformed data
s = standard deviation of the untransformed data
t = student t-statistic (i.e., for alpha < 0.05)
n = number of samples

For lognormal datasets the following equation will be used (from EPA 1992):

$$UCL = e^{(m+0.5s^2+sH/\sqrt{n-1})}$$ **Equation 2**

Where:

UCL = Upper Confidence Limit
e = constant (base of the natural log, equal to 2.718)
m = mean of the natural log transformed data
s = standard deviation of the transformed data
H = H-statistic
N = number of samples

For nonparametric datasets, various methods such as bootstrapping techniques are available that do not require assumptions about distributions of the dataset.

5.2 THE HAZARD QUOTIENT APPROACH

The risk estimation is the process of integrating exposure and effects (EPA 1998). The hazard quotient method, comparing the exposure estimate to some kind of toxicity reference value (e.g., on a tissue residue, dietary dose, or media concentration–based value) will be used to estimate exposure through one or more pathways for all receptors except infaunal and epibenthic invertebrates, which are assessed using a sediment quality value approach. The following equation is used to estimate hazard quotients:

$$HQ = ED \text{ or } C/TRV$$ **Equation 3**

Where:

HQ = ecological hazard quotient (unitless)
ED = exposure dose (e.g., mg/kg bw-day dw, mg/kg sediment dw))
C = media concentration (mg/kg or mg/L)
TRV = toxicity reference value (same units as ED or C)

No-effect HQs that exceed 1.0 suggest that adverse effects are possible at the individual level. In these cases, the estimated exposure exceeds the highest dose at which no statistically significant effects were observed. Lowest-observed-adverse-effect HQs will also be calculated to examine potential population-level effects. HQs will be considered along with the associated uncertainty in the exposure and effects data to determine if a given COPC presents sufficient risk for a given measure of effect for each representative species.

Where possible, exposure-response functions will also be presented.

5.3 ANALYSIS PLAN BY ASSESSMENT ENDPOINT

The following section presents the analysis plan, organized by assessment endpoint. Within each assessment endpoint, the process for ***characterization of exposure*** is discussed first. Following this discussion, there is a discussion for how the ***characterization of effects*** will be completed. Following the characterization of exposure, the process for addressing variability and secondary stressors is outlined for the ***identification of ecosystem and receptor characteristics***. Four examples of secondary stressors that may influence receptor populations in the LWR are listed in Table 5-5.

Assessment Endpoint No. 1: Survival, growth, and reproduction of aquatic plant populations

Potential exposure of the aquatic plants in the ISA to COPCs will be evaluated qualitatively. Very few chemicals accumulate in plants; therefore, estimating exposure is probably more meaningful by examining water and sediment concentrations than plant tissue residues. However, there is very little information regarding the effects of COPCs in sediment or water on aquatic plants. A literature review of studies that examine toxicity and adverse effects of COPC exposure to aquatic plants will be conducted. The results of this review will be summarized in the effects characterization.

Sediment criteria for plants are not available, although there are some available for soil. However, application of soil criteria is inappropriate because plant toxicity varies significantly with physical conditions, such as pH and organic content of soil, and there is no information on relative toxicity of aquatic plants compared to terrestrial plants. The uncertainty associated with this evaluation is very large and would not offer a meaningful assessment of risk to aquatic plants. Therefore, the potential for adverse effects to aquatic plants from exposure to COPCs will be discussed qualitatively in the risk characterization of the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, and the BERA based on the site-specific and literature-derived information gathered to characterize exposure and effects. No data collection needs were identified for these risk assessment methods in the DQO process.

Other, non-chemical factors can influence the behavior and location of receptors of concern and may affect the exposure of a receptor to COPCs. These factors can include habitat alterations, changes in water quality, increased predation or competition for resources due to introduced species, and increased susceptibility to diseases or pathogens. Examples of habitat modification within the LWR include loss of riparian vegetation, physical habitat alteration, reduction in habitat diversity and complexity due to channelization and bank revetments, and increased habitat fragmentation and loss of connectivity to other aquatic and upland habitats (Adolfson et al. 2000). Loss of riparian vegetation also results in less shading which can lead to increased water temperatures and decreased dissolved oxygen concentrations. Changes in flow rate and increases in nutrient loading can further degrade water quality. Exotic fish, mammal, amphibian, and plant species in the LWR can impact receptor populations by altering habitat structure, increasing competition for food and habitat, and increasing predation (Altman et al. 1997). These factors, in combination with the health and predisposition of the receptor population, can increase or decrease the receptor's susceptibility to disease, and thus increase mortality (Arkoosh et al. 1998). The impacts of these factors on the receptor populations will be qualitatively reviewed to determine whether they will influence the exposure of receptor populations. This discussion will be included in the risk characterization.

Assessment Endpoint No. 2: Survival, growth, and reproduction of benthic invertebrate populations

The benthic invertebrates will be assessed using multiple lines of evidence that address different exposure pathways. These methods are described below.

Epibenthic and infaunal invertebrates will be assessed using two approaches. The first approach addresses direct exposure to chemicals adsorbed to sediment. This is a multi-step approach that begins by using existing sediment quality values and chemical data to rank sediment stations in the ISA over a concentration gradient. Bioassays will then be conducted at stations representing this gradient. Sediment chemistry and bioassay results will be used to develop a predictive model of chemistry-to-effects to assess risk from bulk sediment at other site locations. A benthic assessment interpretive approach will be presented in a technical memorandum prior to the Round 2 toxicity testing.

The second approach is the hazard quotient approach. To estimate exposure from bioaccumulative compounds, tissue residue concentrations will be compared to toxicity values in a hazard quotient approach (see Equation 3). Bivalve tissue will be used to identify bioaccumulating chemicals that potentially pose a risk to benthic organisms. Mollusk tissue TRVs are available to estimate effects for some COPCs (e.g., EVS Solutions 1999) and will be applied in a hazard quotient approach. Clam tissue will also be used to evaluate the feasibility of developing chemical specific biota-sediment accumulation factor (BSAF) for Portland Harbor, indicating whether or not a correlation exists between sediment and tissue concentrations. If a correlation between sediment and tissue does exist, invertebrate tissue concentrations may be estimated for a particular area using the site-specific BSAF. Attempts to collect invertebrate tissue samples in Round 1 met with mixed success. Grab samples from bulk sediments resulted in inadequate tissue mass for analysis. Clam tissue samples were obtained in sufficient mass, but from only three locations. If possible, additional clam tissue samples will be collected in subsequent sampling rounds.

Additional tissue samples may be collected for other invertebrates, based on discussion with EPA and the results of Round 1 and 2 sampling.

Similarly, risks to epibenthic macrofauna will be assessed by comparing crayfish tissue residue concentrations to TRVs in a hazard quotient approach. Crayfish are an important prey species and may potentially pass bioaccumulated contaminants on to higher trophic level organisms. Effects of COPC exposure to epibenthic macrofauna will be estimated using available tissue residue TRVs for decapods from the literature. Linear regression analysis will be conducted to examine the relationship of tissue concentrations in crayfish with co-located sediment concentrations. The objective is to examine the predictive power of sediment concentrations to estimate tissue concentrations. If a statistically strong relationship is observed, this regression relationship will be used to predict crayfish tissue concentrations in areas of the ISA where sediment data are available but tissue data are lacking. This approach, which will be developed in detail with EPA and its partners, will not be applied if the regression analyses results show a weak relationship between sediment and tissue concentrations If no correlation is seen between the tissue and sediment chemistry, various hypotheses will be evaluated and additional sampling may be conducted. For example, a surrogate organism with a higher correlation between tissue and sediment may be selected for additional sampling and analysis. To assess risks from the surface water pathways, surface water chemistry data will be compared to EPA chronic AWQC for aquatic life in a hazard quotient approach or other relevant toxicity value.

The results of the groundwater study conducted as part of the Round 1 analysis will be evaluated in order to determine if there is potential for exposure of infaunal invertebrates to groundwater chemicals as they enter the transition zone. A tiered approach for identifying significant contributions to risk to benthic infauna will be used. Decisions and data uses to be employed are:

- Determine what scale of investigation is important for assessing ecological risks in sediment and porewater (i.e. transition zone) from groundwater chemicals of interest (COIs).

- Identify locations where significant COI concentrations are present in upland groundwater and where known or probable pathways to the river exist.

- Identify locations where whole sediment chemistry data may not adequately reflect risks to benthos from potential groundwater sources. This identification would be based on areas where groundwater COIs identified during Step 1 could be present at concentrations that present an unacceptable risk.

- Identify locations where groundwater data are lacking and where additional sampling may be needed to support risk-based evaluations. The site will then be referred to DEQ for groundwater investigation and this analysis will later be performed on the results of the subsequent data collection activities. Alternatively, site-specific collection of data on COI concentrations in porewater (i.e. transition zone) or sediment, and/or bioassay testing may be conducted.

If contaminants in porewater (i.e. transition zone) are identified as potentially impacting benthic organisms, a benthic risk assessment for the groundwater/surface water interface pathway may be completed as part of the baseline risk assessment. Based on chemistry results, dose-response toxicity tests will be completed on benthic organisms to determine whether a predictive site-specific relationship can be developed between the chemistry and toxicity data.

As described under Assessment Endpoint No. 1, the potential effects of non-chemical factors on the receptor populations (i.e. habitat alterations, changes in physical characteristics of water quality, increased predation, and increased occurrences of diseases or pathogens) will be qualitatively reviewed to determine whether they influence the exposure of receptor populations. This discussion will be included in the risk characterization.

A preliminary ecotoxicological profile for benthic invertebrates has been constructed that summarizes the toxicity of the major COPC chemical groups (Attachment B.5).

Considering the risk assessment approach for this assessment endpoint and available historical data, the following data needs were identified. Data collection activities were conducted in 2002 or will be conducted in future sampling events to fulfill these needs.

- Multiplates were placed in the ISA during the spring and summer of 2002 to determine epibenthic community structure. Insufficient tissue volume was collected to enable chemical analysis. See Attachment B.1 for summary of taxa.
- Benthic infaunal grab samples were collected in Round 1 to better understand infaunal community structure. Insufficient tissue mass was obtained for chemical analysis. Analysis included taxonomic identification and enumeration. Data were being analyzed at the time of Work Plan preparation.
- Crayfish were collected in Round 1 with collocated surface sediment samples and chemically analyzed to assess risks to epibenthic macrofauna.
- A reconnaissance survey was conducted in Round 1 to determine locations of clam communities. A small number of samples (2) of adequate mass were collected with co-located surface sediment samples and chemically analyzed to assess risks to clams and the benthic community.

- Surface sediment grab samples co-located with tissue and benthic infaunal samples were collected at biota collection locations in Round 1 and chemically analyzed to assess risks to benthic organisms, and to assess relationships between sediment and tissue COPC levels. Additional sediment grab samples will be collected in Round 2 to support the benthic assessment.
- Surface water samples will be collected in Round 2 (and any subsequent sampling rounds) and chemically analyzed to identify potential adverse effects to aquatic invertebrates.
- Based on the results of the RI/FS Round 1 groundwater evaluation, potentially complete pathways from porewater (i.e. transition zone) to aquatic receptors will be identified.

Assessment Endpoint No. 3: Survival, growth, and reproduction of fish

Risks to fish receptors will be assessed using multiple lines of evidence. Total exposure from non-metabolized chemicals will be assessed by comparing whole-body-tissue residue data to TRVs using a hazard quotient approach (see calculation above). For chemicals that are metabolized or otherwise regulated by the fish (such as PAHs and certain metals), a tissue residue approach is not as appropriate (McCarty and MacKay 1993). Metabolized or regulated chemicals will be assessed by comparing estimated dietary concentrations to dietary TRVs. This dietary exposure approach requires an approximation of the COPC concentration in the prey of a representative receptor species. Analysis of whole-body composite samples of representative receptor species that may be potential prey will be used to determine exposure. If a metabolized chemical is also found in the fish tissue, a whole body TRV approach may also be used. The direct toxicity of surface water will be assessed by comparing surface water concentrations to chronic AWQC or other relevant toxicity values using the hazard quotient approach. If there is sufficient literature data available, TRVs will be developed for all pathways (e.g. uptake from water column, dietary exposure, direct exposure to sediment) and the resulting information will be used in a weight of evidence analysis. A more detailed description of these methods follows. The whole approach, including the time order of steps, is summarized in Figure 5-1.

Exposure of fish will be assessed using methods similar to those employed in the COPC screen for fish (Section 4.3). However, in the exposure assessment, where appropriate, more realistic assumptions of chemical exposure will be employed (e.g., use of 95th UCL on the mean[1]). Chemical concentrations in whole body tissues for

[1] The 95% UCL of the mean will be derived where sample size is ten or greater. Where sample size is less than 10, a 95% UCL is generally a poor estimate of the mean (EPA 1992b) and the maximum concentration will be used to represent chemical exposure.

each receptor of concern will be analyzed to determine exposure point concentrations for each fish species. Chemical concentrations in food will be calculated from concentrations in each component of the fish species' diet and each component's fraction of the diet. For example, the concentration in food for a representative species that might ingest fish, amphipods, and incidental sediment will be estimated as follows:

$$C_{food} = (C_f \times F_f) + (C_a \times F_a) + (C_s \times F_s) \qquad \textbf{Equation 4}$$

Where:

C_{food} = concentration in prey items plus sediment (mg COPC/kg food and sediment dw)
C_f = concentration in fish tissue (mg COPC/kg tissue dw)
C_a = concentration in benthic invertebrate tissue (mg COPC/kg tissue dw)
C_s = concentration in sediment (mg COPC/kg sediment dw)
F_f = fraction of the wildlife species diet that is fish (kg fish/kg food)
F_a = fraction of the wildlife species diet that is benthic invertebrates (kg benthic invertebrates/kg food)
F_s = fraction of the wildlife species diet that is sediment (kg sediment/kg food)

Whole body residue-based and dietary-based TRVs for fish receptors will be developed from the scientific literature. The details of TRV derivation and selection are presented in Attachment B.6 and will be further described in a technical memorandum to be presented prior to the PRE. The literature search for fish tissue residue and dietary TRVs will include searching for studies on early-life stages of fish.

Linear regression analysis will be conducted to examine the relationship of tissue concentrations in sculpin with co-located sediment concentrations. The objective is to examine the predictive power of sediment concentrations to estimate tissue concentrations. If a statistically strong relationship is observed, this regression relation will be used to predict sculpin tissue concentrations in areas of the ISA where tissue data is lacking. This approach, which will be developed in detail with EPA and its partners, will not be applied if the regression analyses results show a weak relationship between sediment and tissue concentrations. If this approach cannot be used for sculpin, application of a mass balance mechanistic food web model will be investigated, such as one of those reviewed in Attachment B.7, for estimating sculpin tissue concentrations in areas missing tissue data. Application of this approach would only be necessary for the sculpin because the other fish used as prey items in the risk assessment have larger foraging ranges and would be represented by the collected tissue samples.

A weight-of-evidence approach will be used to assess risk to all fish receptors. All life stages of fish receptors will be considered if they occur within the ISA. The lines of evidence will be 1) AWQC compared to surface water concentrations, 2) the adult TRV assessment and 3) available knowledge regarding the relative sensitivities of juveniles compared to adults. This approach will be developed in detail with EPA and its partners.

Lipophilic contaminants (e.g., PCBs, DDTs) are stored in lipid tissue if not immediately metabolized in the body. Therefore, whole body concentrations are often correlated with lipid content of the organism. For this reason, lipid normalization of whole-body concentrations in fish will be conducted for lipophilic COPCs that are assessed using a tissue residue approach (i.e., non-metabolized chemicals). Body residue TRVs are not typically lipid-normalized and require that an estimate of lipid content be generated in order to determine a hazard quotient. Lipid content analytical methods are not standardized, and therefore results can vary significantly between methods. Also, lipid content can vary between individuals of the same species. Therefore, the uncertainty associated with lipid-normalization of data from various sources can be high. To capture the impact of lipid normalization and its associated uncertainty, both lipid-normalized and non-lipid-normalized hazard quotients will be developed for lipophilic COPCs. Where lipid-normalized TRVs are not available, they will be estimated by examining the scientific literature to determine the natural variability of percent lipids in the fish species for which the TRV was developed. When variability in percent lipids is low (less than ±10% of mean), the mean percent lipid for that species will be used to normalize TRVs. Where variability is high (greater than ±10% of mean), the TRV normalization will be bracketed using a range of lipid content for that species. Both lipid-normalized and non-normalized tissue concentrations will be used to characterize exposure. The correlation between lipid content and contaminant concentrations will be performed and evaluated in conjunction with EPA and its partners.

Fish sampling during Round 1 provided an opportunity for the LWG to qualitatively examine a small number of stomachs from receptor species with the objective of characterizing the type of benthic invertebrates that are or are not consumed by these fishes. Stomachs for all receptor species except juvenile chinook salmon and Pacific lamprey were sampled. The notable observations from this stomach screening included: the high frequency of bryozoans in all fish stomachs, sediment only in fish stomachs containing filamentous algae, and the presence of crayfish in smallmouth bass stomachs. A summary of this qualitative examination is presented in Attachment B.8. The results of this stomach screening will not be used for any quantitative purpose in the PRE, Comprehensive Round 2 site characterization and data gaps analysis report, or BERA.

As described under Assessment Endpoint No. 1, the potential effects of non-chemical factors on the receptor populations will be qualitatively reviewed to determine whether they will influence the exposure of receptor populations. This discussion will be presented in the form of a stressor-response profile applicable to the appropriate level of biological organization and included in the risk characterization.

A preliminary ecotoxicological profile for fish has been constructed summarizing the toxicity of the major COPC chemical groups (Attachment B.5).

Based on these risk assessment methods and the site-specific historical data, data needs were established for the ERA. Data collection activities were conducted in 2002 or will be conducted in future sampling events to fulfill these needs.

- Fish tissue samples were collected from the ISA and analyzed. Fish tissue collected includes juvenile chinook salmon, largescale sucker, sculpin, smallmouth bass, peamouth, and northern pikeminnow. Carp tissue samples were collected for the human health risk assessment. The chemical data for dioxin like compounds and PCB coplanars will be used to assess risk to fish.
- Sediment samples were collected co-located with benthic invertebrate and sculpin tissue stations and analyzed to assess risks from the dietary pathway. More surface sediment samples will be collected during Round 2 (and any subsequent sampling rounds) to fill in any data gaps.
- Benthic invertebrate community samples were targeted for COPC analysis but insufficient volume was obtained. Crayfish and clam tissue samples were collected and analyzed to provide exposure estimates for higher trophic level species from ingestion of invertebrate prey
- Surface water samples will be collected and analyzed in Round 2 (and any subsequent sampling rounds) to identify potential adverse effects from surface water pathways.

Assessment Endpoint No. 4: Survival, growth, and reproduction of amphibians and reptiles

Exposure estimates for amphibians will be estimated as EPCs if an appropriate quantitative risk assessment method is applied (pending discussions with EPA and its partners). If toxicity values are required to assess risk to amphibians, toxicity studies for all life stages of amphibians available from the scientific literature will be reviewed. Because the toxicity data available for amphibians are primarily based on surface water exposure, surface water chemistry data will be needed. To determine potential risk to amphibian and reptilian populations, surface water will be collected in habitat areas where the presence of amphibians or reptiles would be expected.

As described under Assessment Endpoint No. 1, the potential effects of non-chemical factors on the receptor populations will be qualitatively reviewed to determine whether they are likely to influence the exposure of receptor populations. This discussion will be included in the risk characterization.

Assessment Endpoint No. 5 and 6: Survival, growth, and reproduction of birds and mammals

Risk to birds and mammals will be assessed by estimating daily exposure from food and sediment ingestions pathways and comparing this to a dietary-based TRV. This approach is summarized, including the sequence of steps, in Figure 5-2 and described in detail below.

Exposure of wildlife will be determined by calculating daily doses of each COPC to each representative species. Two exposure pathways will be evaluated: ingestion of prey and incidental ingestion of sediment. Other pathways considered in the CSM are considered minor and insignificant. Risks to wildlife from direct (or dermal) contact with sediment are considered minor relative to those from ingestion (EPA 2000). Likewise, direct contact with water is generally a minor contributor to the overall risk estimate for wildlife. Therefore, the exposure dose will be based on ingestion of prey items and sediment. For some chemicals, such as DDE, PCBs, dioxin and furans, the most sensitive life stage is the developing embryo or eggs. In these instances the exposure will be assessed by using NOAEL and LOAEL values for eggs and developing embryos where literature data are available.

The exposure dose estimates will be calculated using the following equation:

$$\text{Exposure Dose} = \frac{\left(\left[DFC \times C_{food}\right] + \left[DFC \times SIR \times C_{sedt}\right]\right) \times SUF}{BW} \qquad \textbf{Equation 5}$$

Where:

Exposure Dose	=	COPC mass ingested per day via food and sediment (mg COPC/kg body weight/day dw)
DFC	=	daily food consumption rate (kg food and sediment /day dw)
C_{food}	=	concentration in prey items and sediment (mg COPC/kg food and sediment dw)
SIR	=	sediment ingestion rate (% of DFC)
SUF	=	site use factor (unitless)
BW	=	wildlife species body weight (kg ww)

The site use factor (SUF) is the fraction of time that a receptor spends foraging at the site compared to other areas. SUFs of 100% will be used unless sufficient documentation and relevant literature studies are identified supporting the use of

SUFs less than 100%. Foraging ranges, daily food consumption rates, and body weights of representative species will be obtained from EPA's Wildlife Exposure Factors Handbook (EPA 1993), Atlas of Oregon Wildlife (Csuti et al 1997) and other local sources of information or published scientific literature. Regionally relevant sources will be preferred. Conservative assumptions, such as 100% site use, will be used in the PRE to fully bracket the risk estimate. These conservative assumptions will be replaced with more realistic, site-specific assumptions in the Comprehensive Round 2 site characterization and data gaps analysis report and BERA (EPA 1998).

Chemical concentrations in prey will be calculated from concentrations in each component of the wildlife species' diet and each component's fraction of the diet. For example, the concentration in food for a representative species that might ingest fish, amphipods, and incidental sediment will be estimated as follows:

$$C_{food} = (C_f \times F_f) + (C_a \times F_a) + (C_s \times F_s) \qquad \textbf{Equation 6}$$

Where:

C_{food}	=	concentration in prey items plus sediment (mg COPC/kg food and sediment dw)
C_f	=	concentration in fish tissue (mg COPC/kg tissue dw)
F_f	=	fraction of the wildlife species diet that is fish (kg fish/kg food)
C_a	=	concentration in benthic invertebrate tissue (mg COPC/kg tissue dw)
F_a	=	fraction of the wildlife species diet that is benthic invertebrates (kg benthic invertebrates/kg food)
C_s	=	concentration in sediment (mg COPC/kg sediment dw)
F_s	=	fraction of the wildlife species diet that is sediment (kg sediment/kg food)

Concentrations of chemicals in food items and sediment consumed by each representative species will be determined using data from biota and sediment collected from receptors' feeding habitats at the site. The feeding habitat for spotted sandpiper or shorebirds is defined as open sediment (e.g., beach) areas. Hooded merganser habitat is considered nearshore waters (i.e. outside of channel) anywhere in the ISA. Hooded merganser habitat is shown in Figure 2-8. Feeding habitat for osprey, bald eagle and mink is not limited and is defined as anywhere in the ISA. Data from sediment samples collected as part of the RI/FS from representative species feeding habitats will be used to estimate sediment exposure. Dietary components for each representative species will be obtained from EPA's Wildlife Exposure Factors Handbook (EPA 1993), Atlas of Oregon Wildlife (Csuti et al 1997) and other local sources of information or published scientific literature. Regionally relevant sources will be preferred.

TRVs for wildlife receptors will be developed from the scientific literature. The details of TRV derivation and selection are presented in Attachment B.9 and will be described further in a technical memorandum to be presented prior to the PRE. As described under Assessment Endpoint No. 1, the potential effects of non-chemical factors on the receptor populations will be qualitatively reviewed to determine whether they will influence the exposure of receptor populations. This discussion will be included in the risk characterization.

A preliminary ecotoxicological profile for birds and mammals has been constructed that summarizes the toxicity of the major COPC chemical groups (Attachment B.5).

Considering the risk assessment approach for these assessment endpoints and site-specific historical data, data needed to complete the ecological risk assessment are chemical concentrations in prey items and sediment in foraging areas. Fish and invertebrate tissue and surface sediment samples were collected during 2002 in bird and mammal foraging areas. Carp tissue samples were collected for the human health risk assessment. The chemical data for dioxin like compounds and PCB coplanars will be used to assess risk to birds and mammals through dietary exposure. Additional sediment samples will be collected as needed in Round 2 (and any subsequent sampling rounds) to complete representation of exposure areas in the ISA.

5.4 DATA GAP IDENTIFICATION AND COLLECTION OF ADDITIONAL DATA

Data needs identified in the previous sections will be satisfied over multiple rounds of sampling. The objectives for Round 1 data collection were to collect benthic community samples (diversity and chemistry), co-located sediment, crayfish, and clam tissue for chemistry, tissue samples for all the fish receptor species for chemistry, and conduct surveys for amphibians, reptiles and aquatic plants. Existing information regarding sources and known and new information about receptor habitat were used to design the sampling event. The details concerning sampling station locations, numbers of samples that were to be collected and other pertinent information about the collection and analysis of samples are presented in the Round 1 FSP.

The historical data (Category 1 and 2) combined with the Round 1 data will be used to scope the next sampling round. Round 2 sampling will target stations for bioassays (see Attachment B.4), additional *Corbicula* clam tissue samples, surface water chemistry, any additional sediment chemistry data gaps related to ecological risk assessment, and any other site data needed to parameterize the food web model (see Attachment B.7 for food web model approach). The data gaps that remain after Round 1 will be targeted in the Round 2 FSP. The PRE and Comprehensive Round 2 site characterization and data gaps analysis report will include data gap evaluations.

6.0 RISK DESCRIPTION

For chemicals where exposure and effects data are available in more than one medium or more than one assessment method is used, a lines of evidence approach will be used to estimate the likelihood of adverse effects from all potential and assessable pathways. Where more than one medium is relevant to the exposure estimation, exposure will first be calculated independently for each medium then summed for comparison to a TRV and calculation of a hazard quotient. Then, the contribution of each exposure pathway to the hazard quotient will be characterized. Where more than one assessment method is applied, the results of each risk estimation and the associated uncertainty will be examined as pieces of evidence that support or do not support the test hypotheses. Lines of evidence analysis will be based on considerations similar to those from Suter (1993), as summarized below:

Relevance—Evidence more directly related to the assessment endpoint will be given more weight. Considerations include mode of exposure, exposure media, duration of exposure, and relationship between test species and assessment endpoint.

Exposure-response—A line of evidence that demonstrates a relationship between the magnitude of exposure and the effect will be given more weight than one that does not.

Temporal scope—A line of evidence will be given more weight if the data encompass the relevant range of temporal variability in conditions.

Spatial scope—A line of evidence will be given more weight if the data adequately represent the area to be assessed, including directly contaminated areas, indirectly contaminated areas, and indirectly affected areas. For example, tissue residues of wide-ranging[2] organisms such as white sturgeon may be less reflective of exposure within the ISA than water or prey concentrations.

Quality—The quality of the data will be evaluated in terms of the protocols for sampling, analysis, and testing; the expertise of the individuals involved in the data collection; the adequacy of the quality control during sampling, sample processing, analysis, recording of results; and any other issues that are known to affect the quality of the data for purposes of risk assessment.

Quantity—The adequacy of the data will be evaluated in terms of the number of observations taken. Results based on small sample sizes are given less weight than those based on large sample sizes.

Uncertainty—A line of evidence that estimates the assessment endpoint with low uncertainty will be given more weight. Uncertainty in a risk estimate is in part a function of the data quality and quantity, discussed above. In most cases, however,

[2] Home ranges greater than the ISA.

the major source of uncertainty is the extrapolation from the measures of effect and the assessment endpoint. In addition, the extrapolation from the measures of exposure of the endpoint entities may be large due to considerations such as bioavailability and temporal dynamics.

The results, showing the lines of evidence, will be presented in the PRE and will be used to identify data gaps for the Comprehensive Round 2 site characterization and data gaps analysis report and BERA. The final results will be presented in the BERA. The ecological significance of the adverse effects will also be discussed. The testable hypotheses will be evaluated in terms of the risk characterization. The BERA will identify chemicals of concern that will be evaluated in the feasibility study.

7.0 UNCERTAINTY ANALYSIS

Uncertainty analysis is an important step of the ERA process. Uncertainty analysis increases the confidence of an ERA by explicitly describing the magnitude and direction of uncertainties (EPA 1998). There are inherent uncertainties throughout the ERA process that must be identified and evaluated for their impacts on risk estimation.

Uncertainties will be identified in three primary areas: knowledge of the site, the parameters used to evaluate risk, and the models used to represent and estimate risk. For example, information may be lacking about receptors at the site, and this knowledge gap would represent an uncertainty. Parameters such as sediment chemical concentrations are inherently variable, and this uncertainty will be considered in the determination of sample sizes and location. Models, which are simplified representations of physical and biological processes that may be too complicated to express in any other way, may be oversimplified or fail to capture important aspects of the processes under investigation. Such uncertainties, along with their implications for the final risk estimate for the study area, will be identified as they are encountered, discussed, and reviewed in context of the risk characterization.

There are multiple methods described in EPA guidance for analyzing uncertainties. The simplest method is to incorporate various exposure and effects scenarios in the risk estimation process that capture the range of uncertainties in assumptions. The risk estimates can be expressed as point estimates with statistical measures of uncertainty (e.g., confidence limits, percentiles). Another method to analyze uncertainty is sensitivity analysis, where parameter values are iteratively varied to examine the effect of the parameter on the risk estimate. Simulation software can be used to conduct Monte Carlo analysis for the purpose of examining uncertainty. This probabilistic approach is commonly applied and EPA supplies guidance regarding the application of probabilistic techniques to ERA. For the Portland Harbor ERA, one or more of these methods will be applied in the uncertainty analyses. LWG will discuss these options will EPA and its partners.

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Attachment B8: Fish Stomach Content Screening

1.0 INTRODUCTION

Understanding the diet of receptor species is critical in developing realistic risk assessments. It is not possible to characterize the potential exposure of an organism without making assumptions about what it ingests. These assumptions are usually based on descriptions of the organism's diet from the literature. Since community composition (both taxonomic diversity and relative abundance) differs across ecosystems, it is unknown how representative the literature descriptions are. Analysis of the stomach contents of individuals collected at the assessment site is useful for fine-tuning assumptions about diet composition and improving exposure characterizations.

The only known previous stomach content analysis performed on the Willamette River was by Buchanan et al. (1981) and focused solely on northern pikeminnow (*Ptychocheilus oregonensis*). Over 1,000 fish were collected in the spring of 1976 and 1977 from stations well upstream of the Initial Study Area (ISA) (two just south of Salem and one on the outskirts of Eugene). They found that the northern pikeminnow diet was variable, but the major components were fish (mostly sculpin), crayfish, and insects.

During the summer and fall of 2002, the Lower Willamette Group (LWG) collected target fish species from the ISA for the Round 1 preliminary human health and ecological risk evaluation. The primary purpose was to collect fish for tissue residue analysis. The field effort, however, provided LWG with an opportunity to retain some specimens for a reconnaissance-level analysis of stomach content of the target fish species. This study was not conducted to comprehensively examine and record the diets of the target fish species in the Lower Willamette River.

2.0 OBJECTIVES

The objective of this study was to develop a qualitative understanding of the potential diet of target fish species captured in the ISA.

3.0 METHODS

This section describes the field methods used to capture the target fish species and the laboratory methods used to remove and identify the stomach contents from each fish.

The fish used in this study were collected for the Round 1 preliminary risk evaluation, but were diverted for stomach content analysis once the tissue mass quotas for laboratory analyses were met for each species.

3.1 Field methods

The fish used in this study were caught between October 2 and November 8, 2002 using one of the six collection methods indicated in Table 1; see the Round 1 Field Sampling Plan for further details. Once caught, fish were placed in labeled Ziploc® bags and stored on ice until they were delivered to the fish-processing laboratory later the same day.

3.2 Laboratory methods

Upon arrival in the laboratory, fish were immediately transferred to a refrigerator until processing. All of the fish were processed within two days of capture, and most were processed within one day.

3.2.1 Stomach content removal

The fish were removed from the refrigerator and measured (total length) and weighed. The fish were dissected using a dissecting knife or fillet knife, depending on the size and species of fish. The stomach was located and removed from the fish. The stomach was then opened and the contents removed to a pre-labeled glass jar with 50% denatured ethanol as preservative. The jars were stored until they were returned to Seattle for identification.

3.2.2 Content identification

The contents of each jar were emptied onto a glass Petri dish under a dissecting scope and all contents were identified to the highest taxonomic level.

4.0 RESULTS

A total of 35 fish from seven species were collected for stomach content analysis (Table 1). Receptor species representing three of the four feeding guilds defined in the Ecological Risk Approach appendix to the Round 1 Work Plan (Windward 2003) were represented in the species collected. Peamouth (*Mylocheilus caurinus*) and sculpin (*Cottus* sp.) represent invertivorous fish, smallmouth bass (*Micropterus dolomieui*) and northern pikeminnow represent piscivorous fish, and largescale sucker (*Catostomus macrocheilus*) represents herbivorous/omnivorous fish. The only representative species absent from this analysis are juvenile chinook salmon and Pacific lamprey. Also among the fish collected were black crappie (*Pomoxis nigromaculatus*), which are piscivorous and are a target species in the human health risk assessment, and brown bullhead (*Ameiurus nebulosus*). Brown bullhead are in the same feeding guild as largescale sucker but are not a target species for either of the risk assessments. However, they are ecologically similar to yellow bullhead (*Ameiurus natalis*), a target species in the human health risk assessment.

Table 1. Stomach contents of target fish species caught in the ISA

Feeding Guild	Fish Species	Date Caught	Total Length (MM)	Weight (G)	Location	Collection Method	Stomach Content
Herbivore/ Omnivore	Largescale sucker	10/25/02	425	776.7	RM 8, Swan Isl. Lagoon	boat electrofishing	Bivalve (*Corbicula sp.*), chironomids, oligochaetes, bryozoans, gastropods, filamentous algae, sediment
		10/25/02	455	935.8	RM 8, Swan Isl. Lagoon	boat electrofishing	Bivalve (*Corbicula sp.*), chironomids, oligochaetes, bryozoans, gastropods, filamentous algae, sediment
		10/25/02	446	875.6	RM 8, Swan Isl. Lagoon	boat electrofishing	Bivalve (*Corbicula sp.*), chironomids, oligochaetes, bryozoans, gastropods, filamentous algae, sediment
		10/25/02	410	783.9	RM 6	trotline	Filamentous algae, detritus, sediment
	Brown bullhead	na	na	na	na	na	Chironomids, filamentous algae
		10/29/02	292	316.9	RM 4	trotline	Roundworm (parasite), unidentified invertebrate, filamentous algae, detritus, sediment
Invertivore	Sculpin (4)[a]	10/2/02	118, 112, 104, 107	19, 17, 13, 14	RM 8, Swan Isl. Lagoon	backpack electrofishing	Amphipods, gastropods (limpet, *Fisherola* sp.; snail, *Physa* sp.)
	Sculpin	10/15/02	166	62.4	RM 9	trotline	Amphipods, bryozoans
		10/15/02	109	13.7	RM 9	trotline	Roundworm (parasite)
		10/24/02	107	14.6	RM 3	backpack electrofishing	Dipteran (Family Sciomyzidae), gastropod (snail, *Physa* sp.)
		11/7/02	135	22.8	RM 7	crayfish trap	Bryozoan and statoblast (*Cristatalla mucedo*), unidentifiable
	Peamouth	10/29/02	190	62.6	RM 3	beach seine	Filamentous algae, terrestrial insect (wasp), sediment
		10/29/02	200	67.1	RM 4	trotline	Fish (unidentifiable), terrestrial insect (wasp)

Feeding Guild	Fish Species	Date Caught	Total Length (MM)	Weight (G)	Location	Collection Method	Stomach Content
		11/5/02	271	172.5	RM 8	trotline	Bryozoan and statoblast (*C. mucedo*)
		11/5/02	284	196.3	RM 3	na	Filamentous algae, sediment
		11/5/02	280	165.5	RM 3	na	Bryozoan and statoblast (*C. mucedo*), filamentous algae, terrestrial insect (wasp), sediment
Piscivore	Northern pikeminnow	10/24/02	224	97.5	RM 7	na	Roundworm (parasite), unidentifiable structures
		11/8/02	498	1087.1	RM 4	trotline	Fish (unidentifiable), amphipod
		NA	422	714.2	NA	na	Fish (3-spine stickleback), detritus
		11/6/02	398	582.4	RM 7	boat electrofishing	Fish (unidentifiable), crayfish
		11/7/02	460	421	RM 7	trotline	Fish (unidentifiable)
		11/7/02	255	115.1	RM 7	trotline	Crayfish
	Smallmouth bass	10/9/02	230	179.6	RM 5	boat electrofishing	Crayfish
		10/11/02	270	250	RM 6	boat electrofishing	Crayfish
		10/11/02	260	232.4	RM 6	boat electrofishing	Crayfish
		10/17/02	NA	NA	RM 8, Swan Isl. Lagoon	boat electrofishing	Water mite (Order Hydrachnida) bryozoan and statoblast (*C. mucedo*)
	Black crappie	10/15/02	249	224.8	RM 6-9	boat electrofishing	Fish (unidentifiable), isopod
		10/17/02	129	169.5	RM 6-9	boat electrofishing	Fish (shad), bryozoan and statoblast (*C. mucedo*)
		11/5/02	196	119	RM 6-9	hook and line	Amphipods

Feeding Guild	Fish Species	Date Caught	Total Length (MM)	Weight (G)	Location	Collection Method	Stomach Content
		11/5/02	196	127.2	RM 6-9	hook and line	Isopods
		11/6/02	227	156.1	RM 4	trotline	Crayfish
		11/6/02	224	215	RM 6-9	na	Unidentifiable

na – not applicable

[a] The stomach contents from four sculpin were preserved in the same jar

Of the 35 fish caught, 13 were invertivores (37%), 16 were piscivores (46%), and 6 were herbivore/omnivores (17%); 24 were collected from the upper half of the ISA (RM 6-9), and 10 of those were caught in Swan Island Lagoon (Table 1).

Overall, northern pikeminnow was the most reliably piscivorous species: four of six examined had fish in their stomachs. Two (of six) black crappie and none of the smallmouth bass examined had fish in their stomachs. Crayfish were the dominant prey of the four smallmouth bass examined, and a mix of aquatic invertebrates made up the rest of the black crappie stomach contents.

The sculpin examined were true invertivores with the exception of one infected with parasites which had only parasitic roundworms in its stomach. Stomach contents of all other sculpin were a mix of aquatic invertebrates including amphipods, gastropods, and bryozoans. Aquatic invertebrates did not, however, dominate the stomach contents of the five peamouth examined. Three of the five peamouth had ingested filamentous algae and terrestrial wasps.

Filamentous algae were found in the stomachs of all six herbivores examined. Largescale suckers were found to have ingested a variety of aquatic invertebrates usually associated with soft sediments (e.g., bivalves, chironomids, gastropods, oligochaetes). It is not surprising, therefore, that sediments were also found in the stomachs of all four sucker. The two brown bullhead examined were both found to have ingested filamentous algae and invertebrates. Sediments and detritus were also found in one bullhead.

Bryozoans were the most common item in the 35 fish stomachs examined (Table 2). They are sessile, colonial filter feeders that are superficially similar to marine corals. In the fall, bryozoans form dormant buds called statoblasts where they remain through the winter (Wood 2001). Mature bryozoans and/or their statoblasts were found in individuals from each of the three feeding guilds represented and five of the seven species examined. This is surprising given that Wood (2001) states that extensive fish predation on bryozoans has not been verified in the literature. These data alone are not adequate to determine whether fish are targeting bryozoans as a food resource or if their ingestion is more incidental. One study has suggested that fish may graze on bryozoans because they are sometimes inhabited by insect larvae (e.g. chironomids; cited in Wood [2001]).

5.0 CONCLUSIONS

It is difficult to draw many conclusions from such a small dataset. However, three findings are worth noting.

- Bryozoans were a common item ingested by fish from all feeding guilds.

- Sediments were found in the stomachs of only those individuals that also ingested filamentous algae. Only one individual that ingested algae did not have sediment in its stomach.
- The smallmouth bass appear to be ingesting crayfish.

Table 2. Distribution of stomach contents by species and number of individuals

Stomach Content	# of species (out of 7)	# of individuals (out of 35)
Filamentous algae	3	9
Bryozoan	5	9
Bivalve (*Corbicula*)	1	3
Gastropods	2	At least 5
Oligochaetes	1	3
Chironomids	2	4
Crayfish	3	6
Amphipods	3	At least 4
Isopods	1	2
Fish	3	7
Detritus	3	3
Sediment	3	8
Terrestrial insects	1	3
Water mites	1	1

6.0 REFERENCES

Buchanan DV, Hooton RM, Moring JR. 1981. Northern squawfish (*Ptychocheilus oregonensis*) predation on juvenile salmonids in sections of the Willamette River basin, Oregon. Can J Fish Aquat Sci 38:360-364.

Windward. 2003. Portland Harbor round 1 work plan, appendix C: Ecological risk approach. Windward Environmental LLC, Seattle, WA.

Wood T. 2001. Bryozoans. In: Thorp J, Covich A, eds, Ecology and classification of North American freshwater invertebrates. Academic Press, San Diego, CA. pp 505-525.

Attachment B9: Portland Harbor Round 1 Bird and Mammal TRV Selection

NOTE:

Details on the methods for wildlife TRV selection will be submitted to EPA along with selected TRVs as a technical memorandum prior to the risk assessment.

1.0 INTRODUCTION

Toxicity reference values (TRVs) are toxicity thresholds that are compared to total exposure estimates for a given receptor to characterize ecological risk. The ecological risk assessment for Portland Harbor will include assessment of risk to birds and mammals. Risk will be quantitatively characterized using the hazard quotient approach, comparing estimated total exposure to TRVs in terms of body-weight normalized daily doses. This paper describes the process by which these TRVs will be identified.

The TRV derivation process involves simultaneous consideration of various factors and can't be completely summarized in a concise list of rules. Ultimately, professional judgment plays a substantial role. However, defining the intent and method of searching for and evaluating TRVs before initiation of the TRV selection process assists in providing structure and maintaining consistency.

2.0 LITERATURE SEARCH PROCESS

Peer-reviewed publications will be targeted in a literature search including databases such as Ecotox and Toxnet and review articles such as the USFWS Biological Reports and ATSDR mammalian toxicity documents. The objective of the literature search is to find studies where growth, mortality, or reproductive endpoints of chemical exposure through the diet were measured. These general types of endpoints are commonly used in ecological risk assessment and are specifically identified as objectives for the RI in the AOC (EPA 2002). Where studies that examine growth, mortality or reproduction endpoints are not available, studies that examine alternative endpoints (e.g., behavior, immune system effects) will be collected for review. All life-stages of birds and mammals will be included in the search. Chemicals targeted will be those analyzed in fish tissue and sediment collected during Round 1. Studies suitable for TRV derivation must have negative controls. The literature search will have the goal of being comprehensive, to find all relevant publications.

3.0 LITERATURE REVIEW PROCESS

All studies identified in the literature search will be obtained if feasible. Each paper will be reviewed systematically by completing a TRV Study Review Form (attached). This form documents information on the study design (e.g., chemical form, dose concentrations, test species), exposure (e.g., exposure period, frequency, vehicle), and effects (e.g., endpoint of effect, significance). There is also space to include comments regarding the study to highlight unusual characteristics that may be important in final selection of TRV studies.

The TRV Study Review forms will be signed by the original reviewer and then transferred with the paper to a QA reviewer. The QA reviewer will read through the study and associated form and make comments/edits as needed. There will be a maximum of 2 QA reviewers for the bird and mammal TRV studies. QA reviewers will be experienced in the review of exposure studies and TRV derivation. The QA reviewer will also sign the TRV Study Review form after his/her review is completed. Only studies that have been reviewed in this manner will be considered as source studies for TRV derivation. No TRVs will be based on secondary references or existing TRV compilations.

4.0 STUDY SCREENING

Once the papers have been reviewed and summarized, they will be prioritized in two steps. The first step will examine the following preferences:

- Food is the preferred dose vehicle (IP injection and oral gavage may be considered if no dietary studies are available, but may not be necessarily accepted);
- Wild test species are generally preferred over domestic test species. For example, chickens can be extremely sensitive to chemicals and are bred to maximize reproductive production. Therefore, this species would be least appropriate to represent a wild species.
- For dietary TRVs, the test chemical is in same form to which receptor would be exposed in the ISA. If multiple forms are believed to be present in significant quantity at the site, toxicity data for the most toxic chemical form will be selected.
- Preferred exposure period is multigenerational>lifetime>chronic> subchronic. Multigenerational is defined as exposure through at least 2 generations; lifetime exposure is from birth to death; chronic exposure is through greater than 10 percent of the test species' average life expectancy (greater than 10 weeks for birds and greater than one year for mammals) or during a critical lifestage (i.e. reproduction, gestation, and development); subchronic exposure is 10 percent or less of the test species' average life expectancy.
- Test species that are most taxonomically similar to receptor and have similar physiology are preferred.
- Chemical exposure is to a single contaminant or to a mixture of contaminants for which clear effects of the chemical of interest can be identified and distinguished quantitatively from those of other chemicals;

- The effect level is proven to be statistically significant

When the number of studies remaining allows, the following preferences will be considered in step 2:

- Studies with larger sample sizes are preferred
- Bounded NOAELs and LOAELs, where the study observed an effect at one dose/concentration and no effect at another (in addition to control) for the endpoint of interest, are preferable to unbounded
- Multiple dose levels are preferred to single dose levels
- Studies where the dosed food was a prey item are preferred to those where lab chow is offered.
- Studies providing ingestion rates are preferred to studies which require assumptions about ingestion rates.

The result of these screening steps will be a list of prioritized studies.

5.0 SELECTION PROCESS

As part of the final review process, studies that examine all three categories of endpoint (i.e. reproduction, growth and mortality) will be reviewed and the most sensitive endpoint will be selected for use as a TRV. Both LOAELs and NOAELs will be used in the ecological risk assessment. One of the objectives of the ecological risk assessment is to test the risk hypotheses. These hypotheses are based on assessment endpoints that are selected to protect wildlife populations of various feeding guilds from reproductive, growth and mortality effects, with the exception of listed species which are assessed at the individual level. With this objective, the LOAEL will be applied as a population effect threshold and the NOAEL will be applied as an individual effect threshold.

Regarding adverse effects, LWG considers adverse effect those that have been shown to directly impact reproduction, growth, or survival. LWG may consider physiological effects, such as endocrine disruption, if evidence is strong enough to show a causal link to reproduction, growth, or survival at the appropriate level of protection (i.e. population or individual).

For many receptor species, no toxicity data is available. In these scenarios, surrogate species will be selected based primarily on taxonomic relationship to the receptor species of interest. Where it is appropriate, relative body size will also be taken into account as a basis for surrogate selection. Body weight can be used as a measure of metabolic rate, which is one measure of physiological similarity. EPA (1993) discusses the inverse relationship between body size and metabolism that generally occurs in birds and mammals. For example, in selection of a surrogate, if the test species available from toxicity studies are the rat and raccoon and the receptor is a shrew, the rat would be selected as the most appropriate surrogate, because it is closer to the target receptor in metabolic rate. The rat is in the order Rodentia and the raccoon is in the order Carnivora—neither is an insectivore. However, the rat is a much smaller mammal than a raccoon with a correspondingly faster metabolic rate than the raccoon, and more closely resembles the metabolic rate of the shrew, also a much smaller mammal than a raccoon.

There are situations where safety or uncertainty factors may be considered when determining NOAEL and LOAEL values. If LOAEL values have no associated NOAEL value, a safety factor will be applied to estimate the NOAEL. The other scenario where safety factors will be applied is where no chronic exposure studies are available. Safety factors will be used to estimate chronic exposure toxicity from subchronic exposure studies.

The calculations of NOAEL and LOAEL values will be performed using all the available relevant data from the study (i.e., ingestion rates, body weight). Where information is lacking from the study, values will be estimated using other literature sources for the test species. These will be selected by matching the characteristics of the test species (i.e., size, age, type of diet) as closely as possible. Ultimately, the highest NOAELs and lowest LOAELs derived from qualified source studies will be selected for use in the risk assessment. In cases where the highest NOAEL is higher than the lowest LOAEL, the studies will be reviewed in the context of the other available toxicity studies, preferably the most valid studies identified in the screening process. The other existing dose-response data will be considered as a “reality check” to determine if an alternative, more representative and qualified study should be selected for the NOAEL or LOAEL. A summary of the studies reviewed and the rationale for study rejection and final TRV selection will be presented in the Round 1 Preliminary Risk Evaluation.

6.0 REFERENCES

EPA. 1993. Wildlife exposure factors handbook. Volume I. EPA/600/R-93/187a. Office of Research and Development, US Environmental Protection Agency, Washington, DC.

EPA. 2001. Administrative order on consent for remedial investigation/feasibility study for Portland Harbor Superfund Site. US Environmental Protection Agency Region 10, Portland, OR.

TRV STUDY REVIEW FORM

Chemical: ________________

Bird Mammal Fish

LOAEL NOAEL LOEC NOEC

Reviewed by: ___________________ Date: ________

QA Review by: ____________________ Date: ________

Paper citation:____

****

Study design

Test chemical: _______________________ Chemical form: ____________________________

Test species: ____________________________ Age: __________ Body weight: _______ Length _________

Life stage or breeding status: _____________________

Number of males/females in test group: ___________ No. of replicates: ________

Number of individuals in control group: ___________

Test setting (circle): Lab Field

Exposure

Target dose concentrations (include control): ____________________________

Measured concentrations (if available): ________________________________

Background concentrations in control: _________________________________

Exposure period (include static or flow-through system): _______________________

Exposure mode: ____________________________

Exposure medium: __________________________

Dose frequency (circle): Daily Weekly Other: __________________

Food consumption rate: ____________________

Effects

Effects tested:____

Effects observed:____

Statistically significant effects (circle)? Yes No

Lowest exposure concentration at which significant effects were observed for each endpoint:

____

Highest exposure concentration at which no significant effects were observed for each endpoint:

____

Comments:____

____