Revised Study Plan

Boundary Hydroelectric Project (FERC No. 2144)

Study No. 4
Toxics Assessment:
Evaluation of Contaminant Pathways, Potential Project Nexus

Seattle City Light

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Study No. 4 – Toxics Assessment: Evaluation of Contaminant Pathways, Potential Project Nexus

1.0 INTRODUCTION

During preliminary planning for the relicensing effort in spring 2005, Seattle City Light (SCL) identified toxic substances (toxics) as an issue that needed to be addressed as part of the FERC relicensing and Washington State 401 certification processes. A Toxics Inventory and Screening was conducted by SCL in 2005 to identify toxics of potential concern in the Boundary Project (Project) area (R2 2006). The Toxics Inventory and Screening primarily focused on water quality data, but also reviewed sediment and fish tissue data and potential sources of contamination. After the release of the inventory and screening report, an additional evaluation of toxics was conducted by reviewing information contained in the Environmental Protection Agency's (EPA) Preliminary Assessments and Site Investigations Report for the Lower Pend Oreille River Mines and Mills (Ecology and Environment 2002). The review of the EPA data is summarized in Appendix 1 of this study plan. Based on the results of these initial reviews, further study has been recommended for six toxics: arsenic, cadmium, lead, mercury, zinc, and PCBs. This study plan describes the next steps in understanding the relationship between these toxics of concern and the Boundary Project. The study plan calls for a focused evaluation of existing information to determine how the bioavailability of toxics of concern is influenced by Boundary Project operations, i.e., establish specific Project nexus, and to develop and implement a Phase 2 Toxics Sampling and Analysis Plan (SAP) that will focus on field data collection and analysis. Phase 1 is scheduled to begin in early 2007, with Phase 2 to commence in summer of 2007 with carry over into 2008 as needed.

2.0 STUDY PLAN ELEMENTS

2.1. Nexus between Project Operations and Effects on Resources

Toxics of potential concern in the lower Pend Oreille River are five metals associated with historical and current mining activity and PCBs. As noted above, a Toxics Inventory and Screening, based on water column and biotic sampling results, was conducted by SCL in 2005 and an additional evaluation of potential contaminants was conducted in 2006, for which SCL reviewed existing sediment toxics data (Ecology and Environment 2002) to help identify additional toxics of concern for inclusion into Phase 1 of this study plan (see section 2.2). Based on the results of the screening and additional evaluation, six toxics of concern were identified for this assessment: arsenic, cadmium, lead, mercury, zinc, and PCBs.

Reservoirs can impact the presence and transport of toxics in several ways. The decrease in river velocity due to impoundment tends to increase the accumulation of fine sediment upstream of dams, and thereby increase the potential for the accumulation of toxics in those sediments (Ecology 2005). In addition, TDG supersaturation may result in the oxidation of dissolved metals into an insoluble particulate form, potentially affecting the bioavailability of toxics through metals precipitation. Further, fluctuating water levels within reservoirs may lead to erosion and re-suspension of fine particles containing toxics, thereby increasing the concentration of toxics in the water column, in surface sediments, and at the sediment-water interface. If such contaminated sediments occur in these locations, the biological availability of toxics would potentially increase.

To identify any connections between the toxics of concern and Project operations, and to help design an appropriate Phase 2 toxics sampling program, Phase 1 is intended to provide additional information on potential contaminant pathways in Boundary Reservoir. The toxics of concern can be found in a variety of forms or species (see Appendix 2, titled *Examples of Toxic Variants and Technical Sampling Considerations*). Determining what form(s) of toxic substances should be sampled in Phase 2 requires a better understanding of how Project operations interact with local water chemistry and the speciation, diagenesis, and toxicity of each of the toxics of concern under local conditions. In addition, there are multiple sampling methods and numerous sampling locations throughout the Project area that could be incorporated into a toxics sampling plan. A more detailed review of the toxics of concern and improved knowledge of potential sediment locations and transport mechanisms will facilitate the selection of the most appropriate methods and sampling locations within Boundary Reservoir, and thereby produce a Phase 2 sampling plan that will accurately assess the potential effect of the Project on toxics of concern in the Project area. These site-specific details will be clarified as part of Phase 1 of this study and will be used in development of the Phase 2 sampling program.

2.2. Agency Resource Management Goals

In addition to providing information needed to characterize Project effects, the assessment will provide information to help agencies with jurisdiction over aquatic and terrestrial animal populations and habitat (including water quality resources) and with responsibilities for health of users of such resources in the Project area identify appropriate conditions for the new Project license pursuant to their respective mandates. Boundary studies are specifically designed to meet relicensing requirements, but may also be relevant to recent or ongoing management activities by other agencies. A brief description of the related resource management goals, by entity, follows.

Washington Department of Ecology (Ecology)

Ecology's relevant toxic substance surface water quality standards, based on a hardness of 80 mg/L $CaCO_3$ and a pH of 8.0, are presented in Table 2.2-1.

Table 2.2-1. Washington Department of Ecology toxic substance surface water quality standards (WAC 1997).

Toxic Substance	Acute Criteria (µg/L)	Chronic Criteria (µg/L)
Toxic Substances (Aquatic Life/Public Health Category)	Must be below those which have the potential to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon that water, or adversely affect public health.	
Arsenic	360	190
Cadmium	3.7	1.03
Lead dd	51	2.0
Mercury s	2.1[2]	0.012[3]
Polychlorinated Biphenyls (PCBs)	2[1]	0.014[1]
Zinc	94.7[2]	86.5[3]

Notes:

Standards calculations assumes a hardness of 80 mg/L $CaCO_3$ and a pH of 8.0
1 A 24-hour average not to be exceeded
2 A 1-hr average concentration not to be exceeded more than once every three years on the average.
3 A 4-day average concentration not to be exceeded more than once every three years on the average

There are no specific Washington State standards for toxics in freshwater sediments. However, Ecology has established freshwater sediment quality values based on 33 studies and tested the efficiency and sensitivity that sediment quality values have in predicting biological effects. As a result of these studies, two levels of thresholds were developed, the Lowest Apparent Effects Threshold (LAET) and the Second Lowest Apparent Effects Threshold (2LAET). In evaluating the potential toxics for inclusion into Phase 1 of this study plan, SCL used the LAET and 2LAET, along with occurrence and biological toxicity information. The toxics that were found to have sediment concentrations that met or exceeded the assessment criteria described in Table A-1 in Appendix 1 in the Project area (Ecology and Environment 2002) (see Section 2.1) are listed in Table 2.2-2. The surface soil guidelines in Table 2.2-2 are based on the Model Toxics Control Act (MTCA) and Cleanup Regulation. (For greater details on these thresholds and guidelines, see Appendix 1). SCL used these thresholds in reviewing the existing data (Ecology and Environment 2002) to help identify the toxics of concern for inclusion in Phase 1 of this study plan.

Table 2.2-2. Surface soil and freshwater sediment cleanup levels, effects levels, and sediment quality values for significant toxics documented in the Lower Pend Oreille Preliminary Assessment and Site Investigation (Ecology and Environment 2002).

Constituent	Surface Soil[1]	Freshwater Sediment		
	MTCA Method A Cleanup Level for Unrestricted Land Use (mg/Kg)	Typical Background (mg/Kg)[2]	Lowest Apparent Effects Threshold (mg/Kg)[3]	Second Lowest Apparent Effects Threshold (mg/Kg)[3]
Arsenic	20.0	1.1	31.4	50.9
Cadmium	2.0	0.1-0.3	2.39	2.9
Lead	250	4-17	335	431
Zinc		7-38	683	1080

Notes:

1 Ecology Table 740-1
2 NOAA Screening Quick Reference Table for Inorganics in Solids
3 Ecology Sediment Quality Values (Michelsen 2003)

U.S. Environmental Protection Agency (EPA)

The Clark Fork – Pend Oreille Basin Water Quality Study: A Summary of Findings and a Management Plan was prepared in 1993 as a cooperative effort among the states of Montana, Idaho, and Washington with assistance from the EPA (EPA 1993). This report summarizes three years of water quality research in the Clark Fork-Pend Oreille River basin and provides a management plan for protection of the basin's water quality. This report identifies management objectives for the Clark-Fork River basin, Lake Pend Oreille, and the Pend Oreille River basin. Only one objective is applicable to toxics in the Pend Oreille River: Improve Pend Oreille River water quality through macrophyte management and tributary nonpoint source controls. Actions as related to this objective and toxics include:

1. Develop and maintain programs to educate the public on their role in protecting and maintaining water quality.
2. Establish and maintain a water quality monitoring network to monitor effectiveness and trends and to better identify sources of pollutants.

Water Resource Inventory Area (WRIA) 62

Numerous agencies and stakeholders in 1998 formed the Water Resource Inventory Area (WRIA) 62 planning unit, the goal of which is to "develop strategies that will balance competing demands for water, while at the same time addressing local concerns, preserving and enhancing the health of the watershed and considering the economic stability of the watershed." In January of 2005, a Watershed Management Plan for WRIA 62 was completed (Golder Associates 2005). This plan identified five goals and related objectives for water quality. The applicable goals and objectives as related to surface water quality and toxics in the Pend Oreille River are described below. This Toxics Assessment may help in understanding pathways by which toxics might influence water quality and the ability to meet standards.

- WQUAL-1: WRIA-wide coordination of water quality monitoring.
- WQUAL-3a: Watershed Planning Implementing Body to participate in (interact and provide input to) the TMDL process for tributary streams that originate within WRIA 62.

  Objective: Remove tributary streams in WRIA 62 from the 303(d) list of impaired waters by meeting State and tribal (where appropriate) water quality standards in impaired tributary streams
- WQUAL-3b: Watershed Planning Implementing Body to participate in (interact and provide input to) the TMDL process for the mainstem of the Pend Oreille River.

  Objective: Meet State and tribal (where appropriate) water quality standards in the mainstem Pend Oreille River
- WQUAL-5: Protect water bodies of high water quality and improve water quality of impaired water bodies.

  Objective: Maintain compliance with state water quality standards and prevent degradation of waters that meet or exceed state water quality standards in WRIA 62.

USDA Forest Service (USFS)

Portions of the Boundary Project are located within the Colville National Forest. As such, the USFS is a participating stakeholder in the relicensing of the Boundary Project. The information collected as part of the Boundary Toxics Assessment will support management goals and objectives identified by the USFS for the Pend Oreille Basin. The Land and Resource Management Plan, completed in 1988, is applicable to water quality and management within the basin (USFS 1988). This plan identifies five management activities in the soil and water division including:

1. Coordinate with other resources to provide support and advice that helps protect the soil and water resource.
2. Monitor the effect of the Forest Plan activities on the soil and water resources.
3. Restore damaged soil and water resources.
4. Work with Washington State Department of Ecology or others as needed to secure water rights.
5. Coordinate with other agencies or interested parties.

US Fish and Wildlife Service (USFWS)

The U.S. Fish and Wildlife Service is responsible for some federally listed species, including threatened bull trout (*Salvelinus confluentus*), migratory birds, and the habitats that support them. A short reach of Sullivan Creek, commencing at its confluence with the Pend Oreille River, has been designated as critical habitat for bull trout. The draft Bull Trout Recovery Plan identifies as a recovery objective, “restore and maintain suitable habitat conditions for all bull trout life history stages and strategies," and identifies investigation and improvement of water quality as a specific action to address this objective.

2.3. Study Goals and Objectives

The goals of Phase 1 of the Toxics Assessment are to identify any pathways of contamination or mechanisms for changing the bioavailability in Boundary Reservoir of toxics of concern and to evaluate any effect of Boundary Project operations on these pathways and mechanisms. Developing a more complete assessment of the effect of Project operations on the availability or conveyance of one or more of the toxics of concern will allow for the development of an appropriate toxics sampling plan (e.g., biota, water column, or sediments) for Phase 2 of this assessment. The goals of Phase 2 are to assess Project impacts on toxics of concern that were identified as having a potential Project nexus in Phase 1 and to generate information that will be useful to the relicensing participants in developing appropriate measures for the State 401 water quality certification and the new FERC license.

In developing the Phase 2 sampling plan, SCL intends to work in collaboration with the mandatory conditioning agencies, the Tribes and the other relicensing participants to design an appropriate and rigorous sampling design to document Project effects. SCL intends to schedule a formal study plan meeting with relicensing participants in mid-2007 to collaborate on the development of the Phase 2 study plan. Thereafter, SCL will complete the Phase 2 sampling plan and submit it to FERC for its review and concurrence, and upon FERC approval proceed with implementation of Phase 2 in the second half of 2007 and, if appropriate, into 2008.

The specific objectives of the Phase 1 and Phase 2 components of this study plan are listed below.

Phase 1

Objective 1. Update data/information for toxics of concern summarized in the Toxics Inventory and Screening and the EPA data review with any new studies or reports.

Objective 2. Characterize existing conditions in Boundary Reservoir that are relevant to toxics contamination and bioaccumulation.

i) Use existing information to describe reservoir surface elevation changes, flows, velocities, sediment dynamics, temperature, TDG, and DO.
ii) Identify data gaps for information necessary to understand a potential Project nexus.

Objective 3. Determine the potential pathways of contamination and mechanisms affecting bioavailability for arsenic, cadmium, lead, mercury, zinc, and PCBs that could occur in Boundary Reservoir.

i) Document what conditions are conducive to, alter, or prevent leaching of arsenic, cadmium, lead, and/or zinc in nearby waters including the influence of dissolved oxygen and pH.

ii) Document what conditions are conducive to, alter, or disrupt the precipitation of arsenic, cadmium, lead, and/or zinc in aquatic environments including the influence of dissolved oxygen and pH.

iii) Document factors that influence the rate of methylation of mercury.

iv) Document current sources and probable pathways for PCBs into Project waters and biota present within Project waters.

v) Document what conditions are conducive to the transformation of lead into inert or bioavailable forms.

vi) Document the levels of cadmium that begin to disrupt primary production and that cause adverse impacts to bull trout.

vi) Document the effects of changing water hardness on the toxicity of arsenic, cadmium, lead, and zinc to aquatic organisms.

Objective 4. Determine areas within Boundary Reservoir where sediments with grain size characteristics similar to mine waste rock and/or tailings are likely to have been deposited.

i) Document historical location, volume, and particle size of mine waste rock and/or tailings supplied to the Pend Oreille River, including potential input from Box Canyon Dam.

ii) Utilize a one-dimensional model to determine the capacity of the Pend Oreille River to transport sediment with similar grain-size characteristics as the mine waste rock and/or tailings over a wide range of flow conditions.

iii) Based on daily flow records for the Pend Oreille River prior to September 1967, determine the capacity of the Pend Oreille River to transport mine waste rock and/or tailings on an annual basis prior to closure of Boundary Dam and the initiation of Boundary Project operations.

iv) Determine if there was potential for the Pend Oreille River in the Project area to have received large deposits of mine waste rock and/or tailings just prior to closure of Boundary Dam and the initiation of Boundary Project operations.

v) Identify zones of sediment deposition within Boundary Reservoir; these zones of deposition will contain sediment from all sources, of which mine waste rock and/or tailings are expected to be a small portion of the total accumulation of sediment.

vi) Determine where sediments with grain-size characteristics similar to mine waste rock and/or tailings are likely to have accumulated in Boundary Reservoir between 1967 and 2006.

Objective 5. Identify any relationship between Boundary Reservoir operations and pathways of contamination and/or mechanisms of bioavailability for the six toxics of concern (Ar, Cd, Pb, Hg, Zn, & PCBs).

i) Describe the conditions identified in Objective 3 that are currently occurring in Boundary Reservoir.

ii) Document the data or factual evidence that indicates a Project-related influence on a pathway of contamination or mechanism of bioavailability (i.e., a Project nexus) or the lack thereof.

To address the objectives of Phase 1, SCL will complete the following tasks: [1]

1. Review and analyze literature and existing data
2. Develop a conceptual model of potential contaminant pathways in the Boundary Project area. The conceptual model will be a pictorial "roadmap," characterizing potential contamination pathways and Project influences on those pathways. This approach, commonly and effectively used in ecological risk assessments, will help identify appropriate sampling times and locations as well as appropriate sampling media. The approach will be iterative, with refinements to the model taking place as additional information becomes available.
3. Develop a one-dimensional, steady-state hydraulic model for initial evaluation of sediment transport (sediment with grain-size characteristics of waste rock and/or tailings) in the mainstem Pend Oreille River within the Project area
4. Develop hypotheses regarding potential impacts of Project operations on the availability or conveyance of the toxics of concern

Phase 2

Objective 1. Develop an appropriate sampling plan for the toxics of concern that have been identified in Phase 1 as being potentially affected by Boundary Project operations. The sampling plan will identify the specific sites, sampling methodologies and techniques, and other relevant procedures and protocols as appropriate. Multiple sampling options are reviewed in Appendix 2 (*Examples of Toxic Variants and Technical Sampling Considerations*). The sampling plan design and methods will be consistent with generally accepted scientific practice.

Objective 2. Conduct field sampling and sample analysis. Sampling sites will likely be located below active or inactive mining areas that are adjacent to the reservoir or that contain surface water drainage that connects to the Pend Oreille River. Sampling sites also will likely include locations within and below the drawdown zone of the Project reservoir where Project operations have the potential to affect the deposition or transport of contaminated sediments. Results of the one-dimensional hydraulic model completed in Phase 1 also will be used to focus sampling efforts. Sampling will include sediments, water column, and aquatic biota as appropriate based on the results of Phase 1. Sampling would begin in 2007 after the completion of Phase 1, and may carry over into 2008.

Objective 3. Conduct additional sampling as necessary. SCL will consult with Ecology to establish appropriate triggers that indicate if additional field sampling is required. If

[1] Phase 1 tasks were discussed with relicensing participants and FERC during a conference call on January 12, 2007.

the results of sampling indicate that triggers are activated for any of the toxics of concern, additional sampling, such as tissue sampling, could be conducted in late 2007 or 2008. The sampling design and methods would be consistent with generally accepted scientific practice.

Objective 4. Review new information from related studies. SCL will conduct three studies in 2007 that may be relevant to this Toxics Assessment: the Sediment Transport and Boundary Reservoir Tributary Delta Habitats Study [Attachment 2, Study No. 8 of this RSP], the Mainstem Aquatic Habitat Modeling Study, hydraulic routing model component [Study No. 7], and the Erosion Study [Study No. 1]. SCL will review the results from these studies to determine if additional Phase 2 sampling may be necessary or useful to evaluate Project impacts. Any additional sampling required would be incorporated into the Phase 2 sampling plan for 2008.

2.4. Need for Study

Summary of Existing Information

Toxics can potentially enter the Boundary Project area through river and stream point and nonpoint sources, fallout from the atmosphere, and recycling from sediments. Nonpoint source pollution is caused by rainfall or snow melt moving over and through the ground and picking up natural and human-made pollutants in the process. The main contaminant sources of concern are those associated with historical and current mining activities. A detailed summary of available information on location and historical mining activities of the mines in the Project area (the Metaline Mining District) was included in Appendix 4-1 of the Boundary Project relicensing Pre-Application Document (PAD, SCL 2006a).

Mining in the Pend Oreille River area dates back to 1855 (Ecology and Environment 2002); however, permanent settlement of the area did not occur until 1884. The Lehigh Cement Co. Plant and quarries were developed in 1904 followed by the opening of several lead-zinc mines. The Lehigh Cement Company operated a cement plant in Metaline Falls from 1914 to 1989. Cement kiln dust from the cement-making process was landfilled on site and capped in 1996. Groundwater contamination below the landfill and downgradient now requires cleanup; contaminants include arsenic, chromium, lead and manganese. Contaminated groundwater flows into Sullivan Creek and Sullivan Creek flows into the Pend Oreille River. Extensive mining did not occur in the area until after dynamiting of the Box Canyon channel in 1906, which allowed for navigation downstream to Metaline Falls. The Pend Oreille River area was home to two of the largest mines in Washington, the Pend Oreille Mine and Grandview Mine. The Pend Oreille Mine is a lead and zinc mine, which by 1964 had produced 63 percent of the total lead and zinc mined (Baltien 1996) in Pend Oreille County. Between 1952 through 1967, mine tailings were discharged directly to the Pend Oreille River, while after 1967 tailings were deposited on land at the mine site (Ecology 2004). The Pend Oreille Mine closed in 1977, but was reopened in early 2004 by Teck Cominco. Claims for the Grandview Mine were patented before 1900 and between 1940 to 1951 production was l.2 million tons of zinc, lead, and traces of silver (Baltien 1996). However, by 1964 the Grandview Mine was reported to be exhausted and the operation was closed.

Historically, metal extraction and processing were relatively inefficient, yielding large volumes of metal-rich tailings that were deposited to nearby streams (Maret and Skinner 2000). Mine tailings in the Boundary Project vicinity typically contain elevated levels of arsenic, cadmium, copper, lead, mercury, and zinc (Ecology and Environment 2002). As described in Appendix 4-1 of the PAD (SCL 2006a), the Pend Oreille Mine is currently the only active mine in the Project vicinity.

Point sources are authorized discharges to the Pend Oreille River, regulated by the Washington Department of Ecology through the National Pollutant Discharge Elimination System (NPDES) permitting process. Any authorized discharge through the NPDES permitting program requires routine monitoring and reporting of all discharges to the river. The Pend Oreille Mine, the wastewater treatment plants associated with the small municipalities along the river and the Ponderay Newsprint Company all manage outfalls to the Pend Oreille River.

A nonpoint toxic of concern is PCBs. PCBs were banned in the United States in the 1970s, but continue to be a problem in the environment. PCBs have been found in the tissue of fish captured in Boundary Reservoir at concentrations above the Ecology/EPA recommended health standard for human consumption of fish (see section 4.4.5.5.3 of the PAD, Toxic Compounds [SCL 2006a] for a thorough description of existing information on toxics in the Project area). The source of PCB contamination is unknown.

Other pathways of toxics into the Project area are from atmospheric fallout and recycling from the sediments. No information is available regarding atmospheric fallout. Recycling from sediments has been shown in some cases to be an important pathway. The transport of dissolved chemical species between the water column and the underlying sediment is termed benthic flux (USGS 2000). Benthic flux is considered to be positive when the transport of metals is from the sediment into the water column, but can also be negative when the transport of metals is from the water column into the sediment. Several factors affect the transport of metals between the sediment and water column including advection, diffusion, oxidation-reduction reactions, and several biological processes. At the sediment-water interface, advection is the transport of metals by the movement of the overlying water. Diffusion refers to the transport of metals between the sediment and water column as a result of a concentration gradient. Metals temporarily stored in sediments may dissolve in pore waters and diffuse to overlying waters due to gradient concentrations (Zago et al. 1999). If the concentration of a metals species is greater in the sediment pore water than in the water column, there is a tendency for the metals to transfer from the sediment into the water, and vice versa.

The geochemistry of the sediment and overlying water is also an important factor in the magnitude of benthic flux by metal species. Metal speciation is a function of pH, redox potential, and the presence of complexing ligands such as carbonate, dissolved organic carbon, and sulfide (IWRRI 2002). One example is the reduction of iron from ferric to ferrous forms under anoxic conditions. In this example, the presence or absence of oxygen influences the benthic flux of iron. Anoxic conditions favor the dissolution of certain metal oxides and can thereby enhance metal desorption and mobilization (IWRRI 2002). In this case, the concentration gradient of one species is interrelated with that of another and the release of one solute only occurs when another solute is depleted. Ligands, molecules that may donate an electron to a metal by a covalent bond, can also be a factor. Both dissolved sulfides and organic molecules are ligands. Sulfides, for example, can inhibit the release of trace elements by the formation of insoluble sulfidic minerals.

Other biological factors may also influence the rate of benthic flux. For example, bioturbation, the mixing of sediment by burrowing, ingestion, and defecation by benthic communities, can increase the sediment-water interface affecting the chemical fluxes between the sediment and water column. Similarly, bioirrigation, the flushing of burrows with overlying waters by benthic organisms, can also enhance the exchange of dissolved solutes.

In order to determine which toxics may be present within Boundary Reservoir, two reviews of toxics have been conducted, as noted above. The first, the Toxics Inventory and Screening was conducted by SCL in 2005 to identify toxics of potential concern in the Project area, i.e., those for which recent exceedances of water quality standards have been documented in the existing literature and for which there is thought to be a potential Project nexus (R2 2006). Based on results of this review of existing information, toxics were grouped into one of two categories: low concern or medium concern (refer to the Toxics Inventory and Screening for more detail). No toxics of high concern were identified. Toxics of low concern will receive no additional evaluation as part of the FERC relicensing and 401 certification processes. The four toxics (cadmium, lead, mercury, and PCBs) determined during the Toxics Inventory and Screening to be of medium concern and with a potential for a Project nexus will be further evaluated in this Toxics Assessment study. Below is a summary of the initial assessment of these four toxics completed during the Toxics Inventory and Screening (R2 2006).

Cadmium — Cadmium is a natural element found in soils and rocks and is often extracted during the production of other metals such as zinc, lead, and copper. Boundary Reservoir operations could affect cadmium concentrations through toxics accumulation, metals precipitation, or erosion and leaching. There were five dissolved concentrations and three total concentrations exceeding the cadmium criteria in the 1970s and in 1985 at the Metaline Falls and International Border water quality monitoring stations. Dissolved cadmium data collected in the early 1990s at the Newport station were below detection limits. EPA found elevated levels of cadmium in soils at the Josephine, Grandview, and Oriole abandoned mines and at the Pend Oreille Mine site (Ecology and Environment 2002). Cadmium is considered of medium concern given the lack of recent measurements in the Project area and the potential contamination sources from active and abandoned mines (R2 2006).

Lead — Operations of Boundary Reservoir could influence lead contamination through toxics accumulation and erosion and leaching. Historical measurements collected between 1975 and 1991 at the Newport and International Border stations show exceedances of dissolved lead concentrations beyond the chronic water quality standard. Measurements exceeding the chronic criterion of approximately 2 µg/L were 10 µg/L (7/11/1977), 10 µg/L (10/16/1979), and 7 µg/L (11/6/1985). The measurement exceeding the acute criterion of approximately 51 µg/L was 500 µg/L (12/8/1975). The mean value of recent total lead concentrations collected by the Kalispel Tribe in Box Canyon reservoir is below water quality standards, but the standard deviation of the data suggests a recent exceedance of the chronic standard. However, this measurement is of the total concentration and the standard is based on the dissolved fraction, which may be much lower. Two recent readings of lead collected in Boundary Reservoir did not show water quality exceedances. The current source of lead is assumed to be runoff from abandoned mine sites. Lead may also be discharged in effluent from the Pend Oreille Mine, but these discharges must meet water quality guidelines outlined by Ecology in the mine's NPDES permit. Given the exceedances and the current sources of contamination from abandoned mine sites, lead is considered of medium concern (R2 2006).

Mercury — Mercury is a naturally occurring metal that can take several forms in the environment. In soil and water, bacteria can form methylmercury, a form that can accumulate in fish tissue. The methylation of mercury is found to be more pronounced in wetland areas and to be enhanced by low DO, increased nutrients, and increased temperature. Current sources of mercury contamination include abandoned mine sites and effluent from the Pend Oreille Mine. Boundary Project operations could affect contamination of mercury through increased methylation rates and erosion. Absence of recent data and uncertainty associated with previous data due to historically high method detection limits make qualitative assessment of mercury contamination difficult. Given the lack of recent data, the current sources in the Project area, and the ability of mercury to bioaccumulate, mercury is considered of medium concern (R2 2006). Additional assessment of the potential for mercury contamination in Boundary Reservoir is needed.

Polychlorinated Biphyenyls — PCBs are man-made mixtures of chlorinated compounds used as coolants and lubricants in electrical equipment. Manufacture of PCBs was banned in 1977. PCBs bind strongly to soil and adhere to organic compounds and sediments. They are also taken up by small organisms and can accumulate in fish. The operation of Boundary Reservoir can potentially influence the contamination of PCBs through erosion caused by the daily fluctuation of reservoir levels. An Ecology fish tissue verification study completed in 2004 found PCBs above the recommended health standard for the consumption of fish. In Boundary Reservoir, total PCB fish tissue concentrations were measured at 16.8 µg/Kg ww and 14.5 µg/Kg ww in largescale suckers, 7.4 µg/Kg ww in northern pike minnows, and less than detection in yellow perch. The NTR criterion for total PCBs is 5.3 µg/Kg wet weight. To address PCB contamination from a regional perspective, this study also compared total PCB concentrations in the Pend Oreille River to other fish tissue samples collected in Washington state. This comparison found total PCBs collected in the Pend Oreille River to fall below the 30th percentile. PCB concentrations of fish tissue samples of largescale suckers collected in the Pend Oreille River are low relative to other samples. As a result, the Ecology report suggested that a TMDL specific to the Pend Oreille River is not necessarily warranted, but that perhaps a statewide approach is better. Despite the documented bioaccumulation of PCBs in fish tissue located in the Project area, PCBs are considered to be of medium concern because levels are low compared to other statewide samples and given the conclusions of the Ecology fish tissue verification study (R2 2006). More information is needed to assess PCBs in Boundary Reservoir.

The Toxics Inventory and Screening reviewed all types of toxics data (water, sediment, and fish tissue), but mainly focused on available water quality data. As described above, SCL conducted an additional screening effort that reviewed the mine and mills sampling data reported in the

Preliminary Assessment and Site Investigation Report prepared by EPA (Ecology and Environment 2002). Unlike the Toxics Inventory and Screening, the EPA review focuses on the toxicity of sediment samples taken from mine sites rather than water samples in the Pend Oreille River. The recent review of EPA toxicity data is described in Appendix 1.

In the EPA study, 21 active mines (including Pend Oreille Mine, 2 miles downstream, or north of, Metaline Falls) and abandoned mine sites along the Pend Oreille River from Metaline to the international border were assessed. Of the 21 sites visited, 5 were found to have potential contamination sources. At these five sites, sediment, surface soil, and some water quality samples were collected and their concentrations were evaluated by EPA for determination of those that were "elevated" or "significant" compared to background levels. SCL reviewed the data for elevated/significant toxics identified in the EPA report and compared it to regional toxicity guidelines and contaminant toxicity information in order to determine what contaminants should be considered in more detail as part of SCL's Boundary relicensing studies. Fourteen elevated or significant toxics were found and subsequently evaluated.

A two-tiered system was used to compare elevated/significant toxics with scientific criteria (refer to Table A-1 in Appendix 1 of this study plan). The first tier compared concentrations of toxics to Ecology's freshwater sediment and surface soil guidelines (refer to Appendix 1 for details and references). If the concentration of a toxic substance within EPA samples was below these guidelines, then the toxic was not considered for further analysis. If the concentration of a toxic within EPA samples exceeded guidelines, then the second tier criteria were evaluated. The second tier consists of three separate criteria: 1) was the constituent detected in a waterway or from a target sample (as defined in Appendix 1), 2) was the constituent of medium or high toxicity (as described in Appendix 1), and 3) was there documented reoccurrence of elevated/significant levels of the toxic within the basin. If the toxic met the first tier criteria and two or more of the second tier criteria, then it was recommended for further study.

Of the 14 constituents evaluated, 4 (arsenic, cadmium, lead, and zinc) were recommended for further study (Table A-5 in Appendix 1). The other 10 (barium, chromium, copper, DDT, manganese, mercury, nickel, selenium, silver, and vanadium) were recommended for omission. Eight of the nine toxics were omitted because their concentrations did not exceed state guidelines. Only one toxic, silver, exceeded state guidelines but was omitted because it did not meet the second tier criteria. A summary of the four toxics recommended for further analysis based on review of data in the EPA report is provided below.

Arsenic — Arsenic is a naturally occurring element that is used to preserve wood and used in some pesticides (US Dept of Health and Human Service 2006). Arsenic can be toxic in the environment. Inorganic forms are more toxic to organisms in the environment than organic forms, and, among inorganic forms, arsenite is more toxic than arsenate (Greenfacts 2006). Arsenite is thought to be toxic because it binds to sulfhydryl groups, which are found on proteins. Arsenate affects the key energy producing process that takes place in all cells. Arsenic compounds can cause short-term and long-term effects in plants and animals including death, inhibition of growth, photosynthesis and reproduction, and behavioral effects (Greenfacts 2006). Arsenic-contaminated environments are characterized by limited species abundance and diversity. Based on the above information, arsenic was classified as having high biological toxicity. Arsenic concentrations were found to have values exceeding surface soil guidelines. Although there was low reoccurrence within the watershed, given the elevated levels of arsenic found in target samples and its high toxicity, it is recommended that arsenic be included in the toxic assessment study.

Cadmium — Cadmium is a natural element found in soils and rocks and is often extracted during the production of other metals such as zinc, lead, and copper. Cadmium is highly toxic and bioaccumulates at all trophic levels, accumulating in the livers and kidneys of fish (Sindayigaya et al. 1994). Cadmium can be toxic to plants at lower soil concentrations than other heavy metals and is more readily taken up than other metals. Based on the information above, cadmium is considered to be of high biological toxicity. Based on the tier 1 and tier 2 assessment criteria, it is recommended that cadmium be included in the toxic assessment. Note that cadmium was already recommended for inclusion in further relicensing studies based on the water quality assessment described in the Toxics Inventory and Screening.

Lead — Lead adversely affects algae, invertebrates, and fish. Fish exposed to high levels of lead exhibit a wide range of effects including muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis (Eisler 1988). Lead can cause reduced growth, photosynthesis, mitosis, and water absorption at elevated levels in plants (Eisler 1988). Lead can be bioconcentrated from water, but does not bioaccumulate and tends to decrease with increasing trophic levels in freshwater habitats (Eisler 1988). Lead partitions primarily to sediments, but becomes more bioavailable under low pH, hardness and organic matter content. Lead bioaccumulates in algae, macrophytes and benthic organisms, but the inorganic forms of lead do not biomagnify. Based on the information above, lead is considered to be of medium biological toxicity. It is recommended that lead be included in the toxic assessment study because it met the tier 1 criteria and three of the tier 2 criteria. Note that lead was already recommended for inclusion in further relicensing studies based on the water quality assessment described in the Toxics Inventory and Screening.

Zinc — Zinc is a common element found in air, soil, and water. Zinc is currently, and was historically, found adjacent to the Project area. It is also used in industry to make paint, dyes, wood preservatives, and ointments. Elevated levels of zinc can adversely affect the growth, survival, and reproduction of aquatic plants and animals (Eisler 1993). Based on the information above, zinc is considered to be of medium biological toxicity. Zinc meets the tier 1 criteria as well as three of the tier 2 criteria and should therefore be included in the toxic assessment study.

Two of the four toxics of concern recommended for further analysis after review of the EPA data were among the four recommended for further analysis in the Toxics Inventory and Screening (R2 2006). Thus there are six total toxics of concern that are recommended for the Phase 1 Toxic Assessment: arsenic, cadmium, lead, mercury, PCBs, and zinc.

Need for Additional Information

The Toxics Inventory and Screening evaluated toxics in the Project area based on water column information, and also reviewed sediment and fish tissue information and potential sources of contamination. Toxics with little or no information, recent exceedances of water quality standards, or potential sources of contamination in the Project area were considered to be of medium concern. The EPA (2002) report evaluated toxics in the Project area based on sediment data and the presence of contaminants in waterways. These two assessments identified toxics of concern in the Project area, but neither the screening nor the review of the EPA report identified a nexus between any toxics and specific Project operations. More information is required to assess the potential influence of Project operations on the bioavailability and transport of the six toxics identified for further evaluation.

Phase 1 of this Toxics Assessment will develop the information needed to design the Phase 2 SAP, which will include collection of field samples for toxic analysis within Boundary Reservoir. Given the length of the reservoir (17.5 miles long), and a desire for an accurate assessment of Project conditions, a mechanism to focus future sampling effort is warranted. In addition to the results of the Phase 1 analysis, three of the studies proposed for implementation in 2007 (the Sediment Transport and Boundary Reservoir Tributary Delta Habitats Study [Attachment 2, Study No. 8 of this RSP], Mainstem Aquatic Habitat Modeling Study, hydraulic routing model component [Study No. 7], and Erosion Study [Study No. 1]) may provide information useful to help determine potential sites for collection of sediment samples during Phase 2. However, results from these three studies will only be available to guide potential sampling in 2008; i.e., the results of these studies will not be available until the end of the 2007 study season. To inform potential sediment sampling in the interim period prior to completion of the three aforementioned studies, Objective 4 has been included in the Phase 1 Assessment to identify areas within Boundary Reservoir where accumulation of sediments similar in size to mine waste rock and/or tailings may have been deposited.

Completing Phase 1 and Phase 2 of this Assessment will provide the missing information to allow SCL and relicensing participants to assess the Project's potential influence on the bioavailability of the six toxics of concern. It is SCL's intent that the decision regarding the nature and extent of the Phase 2 sampling will be made in collaboration with the relicensing participants and submitted to FERC for its review and approval, and that Phase 2 sampling will be initiated in the summer of 2007. Phase 2 sampling may carry over into 2008, following evaluation of the results from the Mainstem Sediment Transport, Hydraulic Routing Model, and Shoreline Erosion studies.

2.5. Detailed Description of Study

Study Area

The study area encompasses Boundary Reservoir and adjacent potential source areas for toxics. (Refer to section 1.3 of the Proposed Study Plan [PSP; SCL 2006b] for a description of the Boundary Project location, facilities, and reservoir.) Potential toxics sources include the five mines identified in the Preliminary Assessments and Site Investigations Report as having potential sources of contamination and historical users of PCBs. PCBs have been banned since 1977, but because they bind tightly to soil and can accumulate in fish, they are still present in the Project vicinity. The five mines identified as having potential sources of contamination include the Pend Oreille, Josephine, Blue Bucket, Oriole, and Grandview mines. The Blue Bucket mine is located less than half a mile from the west side of the Pend Oreille River between river miles 29 and 30. The Oriole mine is located approximately 1.5 miles from the west side of the Pend Oreille River between river miles 27 and 28. The Josephine mine is located less than 0.25 miles from the west side of the Pend Oreille River between river miles 25 and 26 downstream of Flume Creek. The Grandview mine is located less than 0.25 miles from the east side of the Pend Oreille River near river mile 26. The Pend Oreille mine is located less than 0.5 miles from the east side of the Pend Oreille River between river miles 25 and 26. The Lehigh Cement Company landfill is located in Metaline Falls at approximately milepost 14.7 along Highway 31. These potential sources of contamination within the Project vicinity, including tributaries and mines, are shown in Figure 2.5-1.

Proposed Methodology

A detailed literature-based assessment of the toxics of concern identified in the Toxics Inventory and Screening and additional toxics assessment, i.e., arsenic, cadmium, lead, mercury, zinc, and PCBs, will be conducted. The purpose of this assessment is to develop an understanding of the nexus between Project operations and the availability and transport of these toxics. The assessment will focus on researching and answering Objectives 1 through 5 described above. The next step will be to develop an appropriate SAP as part of Phase 2 described above.

To determine whether the relationship between operations of Boundary Reservoir and the potential mobilization of contaminants, several sampling strategies are available. As part of this study, all of the potential sampling strategies will be reviewed and the most appropriate selected. Some of the potential sampling schemes are described below.

Analysis of concentrations of toxics currently occurring in Boundary Reservoir would require sampling of the possible media where toxics are concentrated. This could include sampling and analyzing the water column, surface sediments, and deep sediments. Sampling and analyzing tissue from aquatic biota (macroinvertebrates and fish) may also occur, depending upon the results of the water and sediment analysis. Collection of water, sediment, and biotic tissue samples would involve analysis of toxic concentrations by a certified laboratory. Sampling these media would provide information on current concentrations of target toxics in the sampling location. Biota sampling can be conducted for either pelagic and/or benthic organisms to evaluate the transportation and accumulation of toxics in the food web and can provide some information on concentration in the water column and/or surface sediments.

To understand the transport of toxics from the sediment into and out of the water column, benthic flux studies can be conducted. Sampling programs to document the occurrence of benthic flux include water column and pore water sampling. Water column sampling at different depths will measure water column gradients and generally would indicate a potential benthic source. However, toxic concentration gradients may also be a result of settling of detrital material from the euphotic zone or a density-driven horizontal source (USGS 2000). Pore water samples also can be tested for toxic concentrations. For this method, devices are inserted into the sediment to collect the pore water and allowed to equilibrate for several weeks. After equilibration, pore water is extracted and measured for metals concentrations.

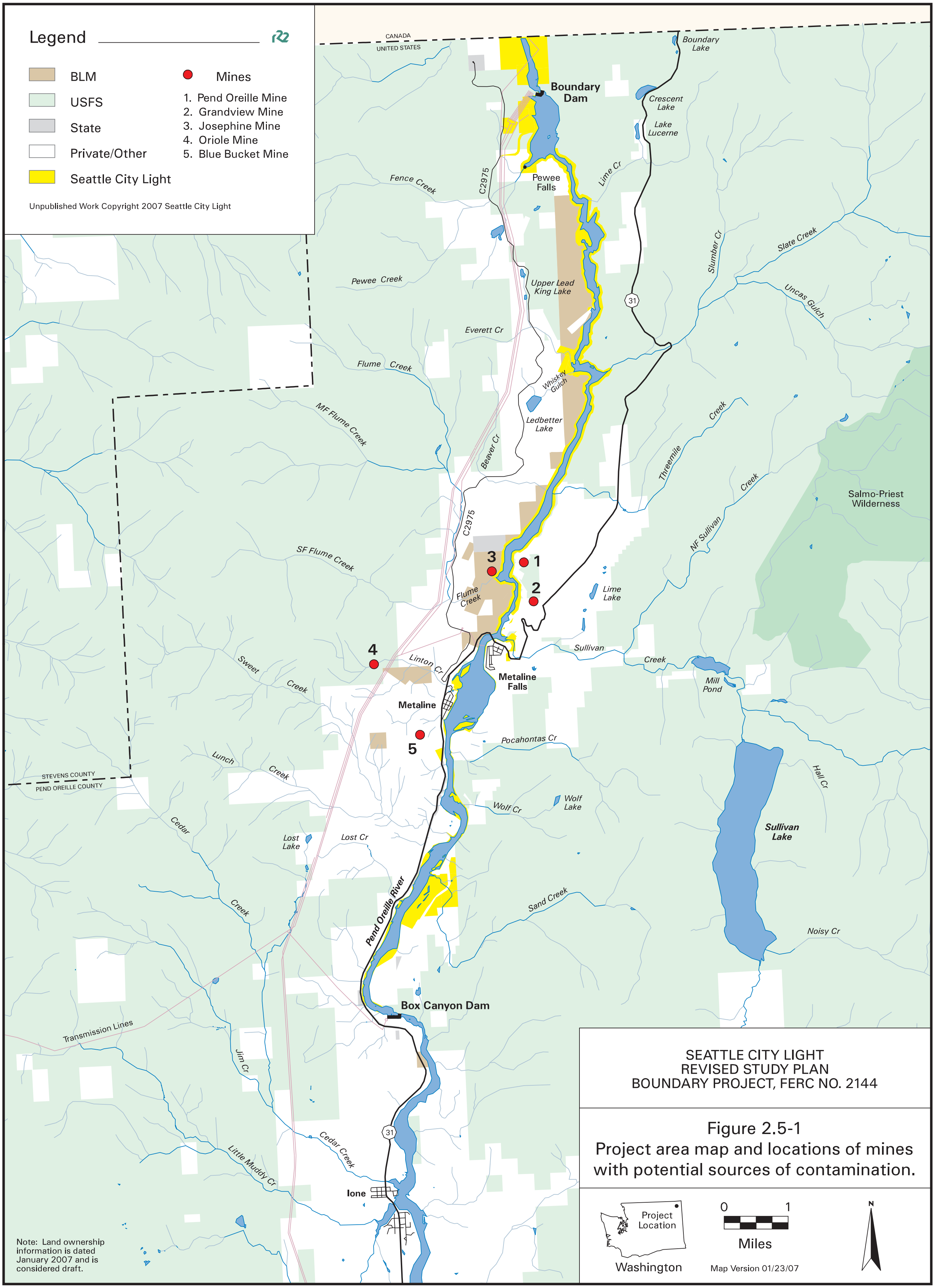

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Figure 2.5-1
Project area map and locations of mines with potential sources of contamination.

During Phase 1 of the Toxic Assessment, the advantages and disadvantages of different sampling options will be considered to identify an appropriate sampling strategy in Phase 2. The sampling strategies selected will be dependent on the target toxics to be analyzed as well as the existing environmental conditions in the reservoir and potential Project effect. Regardless of the sampling strategy, sampling sites should be strategically located in areas with the maximum potential for contamination, such as downstream of historic mining sites, near target sources identified in the EPA PA/SI report, or in areas of specific geochemical conditions that might influence the transport of toxics. To facilitate success of possible future sediment sampling efforts SCL proposes to determine what areas in Boundary Reservoir are likely to have sediments characteristic of mine tailings. The proposed approach incorporates two basic methods: 1) comparison of historic and current bathymetric maps to determine where sediment has been deposited within the reservoir between 1967 and 2006; and 2) development of a one-dimensional hydraulic model to determine where sediment with grain size characteristics similar to mine tailings were likely to have accumulated within the reservoir. Specific tasks associated with this approach include the following:

i) Review available literature to document historical location, volume, and particle size of mine waste rock and/or tailings supplied to the Pend Oreille River (including potential input from Box Canyon Dam).

ii) Develop a one-dimensional, steady-state hydraulic model of the Pend Oreille River from Box Canyon Dam to the international border using bathymetry of the river prior to construction of the dam.

iii) Use the hydraulic model to determine the capacity of the Pend Oreille River to transport sediment with similar grain size characteristics as the mine waste rock and/or tailings for a wide range of flow conditions.

iv) Use daily flow records of the Pend Oreille River prior to September 1967 to determine the capacity of the Pend Oreille River to transport mine waste rock and/or tailings on an annual basis prior to closure of Boundary Dam and initiation of Project operations.

v) Compare the annual quantities of mine waste rock and/or tailings transport capacity with quantities of mine tailings supplied to the river to determine if there was potential for the Pend Oreille River in the Project area to have large deposits of mine waste rock and/or tailings just prior to closure of Boundary Dam and initiation of Project operations.

vi) Compare bathymetry of the river prior to construction of the dam (USGS 1938 and Seattle City Light 1957) with available current bathymetry (2006) to identify zones of sediment deposition within the reservoir. These zones of deposition will consist of sediment from all sources.

vii) Use the hydraulic model to help determine where sediments with grain size characteristics similar to mine waste rock and/or tailings were likely to accumulate within the reservoir between 1967 and 2006.

The Phase 2 SAP will address the types (i.e., water, sediment, fish tissue, etc., and dissolved versus total concentration), frequency, time of year to collect, and location of samples needed to best evaluate the effects of the operation of Boundary Reservoir on the toxics of concern. As part of a SAP, SCL will develop a Quality Assurance Project Plan (QAPP). The QAPP will describe the project team and responsibilities, the sampling locations, sampling frequency, data collection methods, laboratory analysis, including measurement methods and method detection limits, QA/QC measures including quality control sample types and frequency and measurement quality objectives, and data management. The QAPP will be consistent with Ecology and EPA protocols.

2.6. Work Products

Draft and final reports will summarize the findings of the Phase 1 Toxics Assessment. Following issuance of the draft Phase 1 report, SCL will meet with relicensing participants to review the findings from Phase 1 and to develop the details of the Phase 2 SAP. SCL intends to schedule a formal study plan meeting with relicensing participants in order to collaborate on the design of Phase 2. Following the meeting, SCL will produce the final Phase 1 report, which will contain the proposed draft SAP and QAPP. The final Phase 1 report will be completed and the Phase 2 SAP will be submitted to FERC for its review and concurrence.

The SAP will address the following issues: the goals of the study, steps needed to meet those goals, the type of sampling necessary (i.e., water column, sediment, fish tissue, etc), the specific analyses required, the number of samples, the frequency of sampling, and a schedule of sampling. The QAPP will address elements specified by Ecology guidelines including the following items.

- Title Page with Approvals
- Table of Contents with Distribution List
- Background
- Project Description
- Organization and schedule
- Quality Objectives
- Sampling Process Design
- Sampling Procedures
- Measurement Procedures
- Quality Control
- Data Management Procedures
- Audits and Reports
- Data Verification and Validation
- Data Quality Assessment

The SAP and QAPP are similar in content except the SAP will focus on what questions need to be answered and how they will be answered through additional field sampling. The QAPP, on the other hand, will focus on the methodology to collect the field data and the QA/QC procedures required to ensure a robust sampling program. These two work products will be combined into a single document.

Additional work products for this study include interim and final study reports that will be distributed in January 2008 and December 2009, respectively. These reports will be integrated into the Initial Study Report (ISR) and Updated Study Report (USR) to be filed with FERC in March of 2008 and 2009, respectively.

2.7. Consistency with Generally Accepted Scientific Practice

The approach to this Toxics Assessment has been developed in consultation with relicensing participants. The SAP and QAPP referred to herein would follow Ecology guidelines.

2.8. Consultation with Agencies, Tribes, and Other Stakeholders

As indicated above, SCL met with Ecology in 2005 to identify issues to be addressed as part of the 401 certification process. The following relicensing participants reviewed the scope of the Toxics Inventory and Screening in 2005: Ecology, USFS, WDFW, Pend Oreille Mine, and Teck Cominco American, Inc. The screen was requested by and provided to the following relicensing participants: Jean Parodi (Ecology), Jon Jones (Ecology), David Knight (Ecology), Tom Shuhda (USFS), Doug Robison (WDFW), Kevin Kinsella (Pend Oreille Mine), and Bill Duncan (Teck Cominco American, Inc.).

Input regarding the literature-based assessment study plan was provided by relicensing participants during Workshops and Workgroup meetings. Workshops were held in Spokane, Washington, on November 30, 2005, and February 16, 2006. Workgroup meetings were held in Spokane on May 22, 2006, and August 16, 2006, and in Metaline Falls on June 29, 2006.

During the May 22 workgroup meeting, an outline for the Assessing Toxics of Concern: Evaluation of Contaminant Pathways and Potential Project Nexus study plan was presented. During the June 29 workgroup meeting, the draft Assessing Toxics of Concern: Evaluation of Contaminant Pathways and Potential Project Nexus study plan was presented. The four toxics of concern included in this plan, which were identified during the Toxics Inventory and Screen (SCL 2005), were cadmium, lead, mercury, and PCBs. During the August 16 workgroup meeting, SCL presented the next iteration (with revised title) of the draft Phase 1 Toxics Assessment: Evaluation of Contaminant Pathways, Potential Project Nexus study plan, which was revised based on relicensing participant comments provided at the June 29 workgroup meeting. In preparation of this revised study plan, SCL reviewed the EPA's 2002 Preliminary Assessments and Site Investigations Report for the Lower Pend Oreille River Mines and Mills (PASI) to ascertain whether additional toxics should be included in the Phase 1 toxics assessment. Based on evaluation of the PASI document, arsenic and zinc were added to the list of four toxics of concern, i.e., cadmium, lead, mercury, and PCBs, identified by the toxics inventory and screening (for greater detail on study plan development, see section 2.4 of this study plan, under Summary of Existing Information).

Relicensing participants providing comments on the study approach at these meetings included Ecology, the USFS, U.S. Fish and Wildlife Service, Confederated Tribes of the Colville Reservation, Kalispel Tribe of Indians, Canadian Columbia River Intertribal Fisheries Commission, BC Hydro, Pend Oreille County Public Utility District, Columbia Power Corporation, Environment Canada, Ponderay Newsprint, and Teck Cominco. Comments provided by relicensing participants are summarized in the PSP Attachment 3-5 (SCL 2006b) and can also be found in workgroup meeting summaries (available on SCL's relicensing website [http://www.seattle.gov/light/news/issues/bndryRelic/]).

Relicensing participants' comments on the PAD, FERC's Scoping Document 1, and SCL's proposed study program were submitted to FERC on or before September 1, 2006. Following review of these comments, SCL revised the Phase 1 Toxics Assessment: Evaluation of Contaminant Pathways, Potential Project Nexus study plan to clarify the intent and goals of the overall approach to toxics assessment in Boundary Reservoir. The Project Nexus section of the study plan was revised to reflect that Phase 1 is being conducted to develop an understanding of the connections between the toxics of concern and Project operations, and to design an appropriate Phase-2 toxics sampling program for the reservoir. Similar revisions were made to the Study Goals and Objectives, Need for Additional Information, Proposed Methodology, and Work Products sections of the study plan. The modified Phase 1 Toxics Assessment: Evaluation of Contaminant Pathways, Potential Project Nexus study plan was included in the PSP that was filed with FERC on October 16, 2006.

In its PAD/Scoping comments, Ecology asked whether SCL planned to conduct field verifications of the results of its Phase 1 sediment deposition analysis (Ecology 2006). SCL does not intend to conduct field studies to "ground-truth" the results of the Phase 1 sediment deposition analysis. Rather, if sediment sampling is identified as the appropriate medium through which to evaluate toxics in the reservoir, on-site verification of the results of the Phase 1 sediment deposition analysis may be required as part of the Phase 2 study.

Since filing the PSP, SCL has continued to work with relicensing participants on its proposed study plans. In response to comments made during the November 15 study plan meeting, comments filed with FERC by the USFS (2007), USFWS (2007), and FERC (2007) , and comments provided by the USFS, USFWS, FERC, Ecology, Confederated Tribes of the Colville Reservation, and Teck Cominco during telephone calls (September 22, 2006; December 1, 2006; December 20, 2006; January 12, 2007), SCL has further modified the plan (with revised title) for the Toxics Assessment: Evaluation of Contaminant Pathways, Potential Project Nexus. (SCL's responses to comments are summarized in Attachment 3 and consultation documentation is included in Attachment 4 of this RSP.) Modifications included adding clarification, additional supporting rationale, and additional detail to address USFS, USFWS, FERC, and the Colville Tribes' comments. Where differences remain between study requests and study elements, SCL has so noted in Attachment 3 of this RSP.

After the RSP is filed, FERC will issue its final study plan determination; however, involvement of relicensing participants in the design and execution of the Phase 1 and Phase 2 Toxics Assessment will continue throughout the study program.

2.9. Schedule

The schedule for completing the Toxics Assessment: Evaluation of Contaminant Pathways, Potential Project Nexus study is provided in Table 2.9-1. The final Phase 1 study report and draft Phase 2 SAP will be completed by June 29, 2007. The final Phase 2 SAP will be submitted to FERC by July 31, 2007. Phase 2 field sampling, the extent of which will be determined based on the outcome of Phase 1, will be initiated in summer of 2007 and continue through 2008, as necessary.

Table 2.9-1. Project schedule, Toxics Assessment: Evaluation of Contaminant Pathways, Potential Project Nexus.

Phase	Target Date
Study mobilization/startup	January 2007
Secure FERC final determination on the RSP	March 2007
Initiate Phase 1 of the Assessment	March 2007
Task 1 Complete literature and existing data review and analysis	March 30, 2007
Task 2 Develop conceptual pathways of contaminant dynamics	March 30, 2007
Task 3 Develop one-dimensional steady state hydraulic model	May 1, 2007
Task 4 Identify operational impact-Draft	May 18, 2007
Draft Phase 1 Study Report	May 31, 2007
Conduct formal study plan meeting on the draft Phase 1 report	Week of June 11, 2007
Issue the Final Phase 1 Study Report and Draft Phase 2 Sampling and Analysis Plan (SAP)	June 29, 2007
Conduct formal study plan meeting on the draft Phase 2 SAP	Week of July 9, 2007
Complete the Phase 2 SAP and submit it to FERC	July 31, 2007
Commence Phase 2 Sampling and Analysis	Summer 2007
Prepare interim study report (first-year results)	November-December 2007
Distribute interim study report	January 2008
Meet with relicensing participants to review first year efforts and results and discuss plans for second year efforts	February 2008
Include interim report in Initial Study Report (ISR) filed with FERC	March 2008
Hold ISR meeting and file meeting summary with FERC	March 2008
Continue Phase 2, Year 2 Sampling and Analysis (if necessary)	2008
Prepare "draft" final study report	October-November 2008
Distribute "draft" final study report for relicensing participant review	December 2008
Meet with relicensing participants to review study efforts and results of "cross-over" study results	January 2009
Include final study report in Updated Study Report (USR) filed with FERC	March 2009
Hold USR meeting and file meeting summary with FERC	March 2009

2.10. Progress Reports, Information Sharing, and Technical Review

SCL will distribute the draft Phase 1 study report by May 31, 2007 and initiate communication with relicensing participants to discuss the study results. A formal study plan meeting to discuss the draft Phase 1 report with relicensing participants will be held no later than June 15, 2007. Comments from relicensing participants will be addressed in the final Phase 1 report and the draft Phase 2 SAP. A formal meeting to discuss the draft Phase 2 SAP with relicensing participants will be held during the week of July 9, 2007. The Phase 1 final report will contain an appendix of water quality data reviewed during the study; these data will also be available in digital format.

In accordance with the results of the Phase 1 evaluation, a detailed Phase 2 SAP will be developed and submitted to FERC for approval. Sampling will begin in summer 2007. Formal reporting requirements related to Phase 2 will include the Initial Study Report (March 2008), the Updated Study Report (March 2009), and corresponding meetings to discuss these reports. Prior to release of these reports, SCL will meet with agencies, tribes, and other relicensing participants to discuss the study results. In addition, SCL plans to provide updates, generally on a quarterly basis, to keep relicensing participants apprised of study progress and to communicate significant developments. Following each official Study Report meeting, the FERC ILP regulations provide the opportunity for SCL and the relicensing participants to request modifications to the study plan in light of the progress of the study program and results to date.

2.11. Anticipated Level of Effort and Cost

Based on a cursory review of study needs, the anticipated cost for Phase 1 is $95,000, which is required in 2007 for the Phase 1 Toxic Assessment and report preparation. A Phase 2 sampling cost estimate cannot be generated until a SAP is developed at the onset of Phase 2.

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Appendix 1: Review of EPA DATA for the Lower Pend Oreille Mines and Mills

Review of EPA Data for the Lower Pend Oreille Mines and Mills

Introduction

The Preliminary Assessments and Site Investigations Report for the Lower Pend Oreille River Mines and Mills, prepared by EPA (EPA 2002) was reviewed to determine any potential sources of toxics contamination in the Boundary Project area from historical mining activities. The EPA report investigated potential contaminant sources to the lower reach of the Pend Oreille River from 21 mines and mills in the area. Toxic contaminants were measured in sediment, surface soil, and surface water samples at the five mines that were found to have mechanisms that could potentially transport contaminants to the river. The report summarizes the analytical monitoring results, with emphasis on the constituents found in significant concentrations in source samples and elevated concentrations in target samples. Source samples are those collected at the source of contamination (e.g., mine tailings), whereas target samples are those collected in areas potentially impacted through contaminant migration. Significant/elevated samples were those that were either equal to or greater than the detection limit when a non-Contract Laboratory Program (CLP) was used, equal to or greater than the background level when the background level was below detection limits, or at least three times greater than the background concentration when the background concentration exceeded detection limits.

Methods

The information available in the EPA report, along with regional toxicity criteria or guidelines and contaminant toxicity information, were reviewed to assess what contaminants evident from the EPA report might be important to consider in more detail as part of SCL's Boundary relicensing studies. To assess each constituent, a two-tiered evaluation process was followed. The first tier was comparison with Ecology's freshwater sediment and surface soil guidelines. If none of the source or target samples exceeded these guidelines, then the toxic was not considered for further analysis and it was recommended for omission from further study. If measurements did exceed guidelines, then the second tier criteria were evaluated. The second tier consists of three separate criteria: 1) whether the constituent was detected in the waterways or target samples at elevated concentrations, 2) whether the constituent was of medium or high toxicity, and 3) whether there was documented reoccurrence of the toxic within the basin. If two of these three criteria were met, the toxic was recommended for inclusion in the *Assessing Toxics of Toxics: Phase 1*study plan (toxic assessment study).

The two-tier assessment criteria approach is conservative given that source and target concentrations were used in the rating process, both of which may be located in areas remote from the river floodplain. In addition, the higher-than-threshold concentrations found in soil or sediment would most likely dilute to below levels-of-concern by the flow and sediment load in the river mainstem and do not necessarily represent toxic concentrations within the wetted area influenced by the Boundary Project. This assessment provides information in addition to a previous report prepared for SCL, the *Toxics Inventory and Screening* (R2 2006). The *Toxics Inventory and Screening* focused on water quality data, while the current investigation focuses primarily on sediment and soil contamination resulting from historical or active mines in the Project area.

Results and Conclusions

A summary of each constituent and supporting information is provided in the text and tables below. Table A-1 summarizes the assessment criteria, and Table A-2 summarizes the surface soil and freshwater sediment guidelines and thresholds. The surface soil guidelines provided in Table A-2 are based on the Model Toxics Control Act (MTCA) and Cleanup Regulation. This act sets specific standards for soil cleanup while also providing flexibility for cleanups to be addressed on a site-specific basis. Cleanup standards are selected based on three methods (A through C). Method A, which provides cleanup levels that are protective of human health for 25-30 of the most common hazardous substances found in soil and groundwater at sites, is presented in Table A-2. There are no specific Washington State standards for toxics in freshwater sediments. Instead, criteria are established on a site-by-site basis. However, Ecology established freshwater sediment quality values based on studies conducted in 1997, 2002, and 2003 that reviewed data from 33 studies and tested the efficiency and sensitivity that sediment quality values have in predicting biological effects. As a result of these studies, two levels of thresholds were developed, the Lowest Apparent Effects Threshold (LAET) and the Second Lowest Apparent Effects Threshold (2LAET), both of which are presented in Table A-2. The 2LAET's are used as indications of violations of the Clean Water Act, while the LAET's are used as clean-up screening level (CSL) (Adolphson, 2006).

These guidelines and thresholds were compared to data from the EPA report as summarized in Tables A-3 and A-4. Table A-3 summarizes the constituents found in mine source samples as having significant concentrations, while Table A-4 summarizes the constituents found in mine target samples as having elevated concentrations. A summary of the supporting information is provided in the text below.

Table A-1: Summary of assessment criteria.

Criteria	Requirement
Tier 1	
Criterion 1	Measured Values above Thresholds or Guidelines
Tier 2	
Criterion 2	Elevated levels in target samples or detection within waterways
Criterion 3	Toxicity (medium or high)
Criterion 4	Reoccurrence within the watershed (medium or high)

Barium – Barium is a silvery–white metal which exists in nature in ores containing mixtures of elements. It combines with other chemicals to form barium compounds which are used by the oil and gas industries to make drilling muds. Drilling muds make it easier to drill through rock by keeping the drill bit lubricated. The persistence of barium in the environment depends on the form. Some compounds (i.e., barium sulfate and barium carbonate) do not dissolve well in water and are longer lasting. Others (i.e., barium chloride, barium nitrate, or barium hydroxide) dissolve easily in water. The dissolvable forms usually combine with naturally occurring sulfate or carbonate and become the longer lasting forms. Elevated levels of barium can induce a wide range of effects in mammals including gastrointestinal distress, muscular paralysis, and cardiovascular effects (Moore 1991). No toxic effects have been reported in aquatic plants due to barium at the usual concentrations found in water (WHO 1991). Barium and its compounds have a moderate acute and chronic toxicity to aquatic life. Reproduction and growth in *Daphnia* spp. were impaired by barium concentrations of 5.8 mg/L (WHO 1991). Barium does not bioaccumulate. Based on the information above, barium is considered to be of medium biological toxicity. Barium did not meet the tier 1 criterion with no measurements exceeding guidelines or threshold values. Based on this criteria, it is recommended that barium be omitted from further investigation (Table A-5).

Chromium – Chromium is a naturally occurring element found in soil, rocks, animals, and plants. Chromium is used in industry to make steel, for chrome plating, dyes and pigments, leather tanning, and wood preserving. Chromium attaches strongly to soil and does not accumulate in fish tissue. Based on the information above, chromium is considered to be of medium biological toxicity. Chromium did not meet the tier 1 criteria and therefore it is recommended that it be omitted from further studies (Table A-5).

Copper – Copper is naturally occurring in soils, water, rock, and air and is an essential element in plants and animals. Copper is used in the production of many products and is commonly used in agriculture to treat plant diseases and as a preservative for wood, leather, and fabrics. Copper is highly toxic in aquatic environments and has effects in fish, invertebrates, and amphibians. There is a low potential for bioconcentration in fish and a moderate potential for bioaccumulation in plants. Based on the information provided above, copper is considered to be of high biological toxicity. Since copper did not meet the tier 1 criteria because no values exceeded guidelines or thresholds, it is recommended that it be omitted from further relicensing studies (Table A-5).

DDE/DDT/DDD – DDE, DDT, and DDD are pesticides used to kill insects in agriculture. They are rapidly broken down by sunlight, but adhere strongly to soil and once in soil break down slowly. They will also accumulate in plants and in the fatty tissue of fish and animals. Boundary Reservoir operations can potentially influence DDE/DDT/DDD concentrations through toxicant accumulation, erosion and leaching, and bioaccumulation. Based on the information above, DDE/DDT/DDD were considered to be of high biological toxicity. DDT did not meet the tier 1 criteria and should therefore be omitted from further studies (Table A-5).

Manganese – Manganese is a naturally occurring essential trace element found in many types of rocks. It can combine with other substances such as oxygen, sulfur, or chlorine. Manganese can enter the air from iron, steel, power plants, coke ovens, and from dust from mining operations. Manganese is an essential trace element for microorganisms, plants, and animals and can reduce the hazard posed by other metals. It is only slightly to moderately toxic to aquatic organisms in excessive amounts. Plants in the water can take up some of the manganese from water and concentrate it. Based on the information above, manganese is considered to be of low biological toxicity. Manganese does not have sediment guidelines or thresholds, but based on the low toxicity, the non-detection within target samples or waterways, and the low reoccurrence within the watershed, it is recommended that magnesium be omitted from further studies (Table A-5).

Mercury – Mercury is a naturally occurring metal that can take several forms in the environment. Inorganic mercury compounds include mercuric sulphide, mercuric oxide, and mercuric chloride, while organic mercury is formed when mercury combines with carbon and other elements. The most commonly found form is methylmercury, which is a cation and is the most toxic (Greenfacts 2006). Inorganic mercury can be methylated by bacteria in both anaerobic and aerobic environments. This form can accumulate in living organisms and reach high levels in fish and marine mammals via biomagnification. The methylation of mercury is found to be more pronounced in anoxic areas, such as wetlands, and can be enhanced by increased nutrients, and increased temperature. Current sources of mercury contamination include abandoned mine sites and effluent from the Pend Oreille Mine (Ecology and Environment 2002, Ecology 2001a). Based on the information above, mercury is considered to be of high biological toxicity. Mercury did not meet the tier 1 criterion (Table A-5). However, mercury was recommended for further study in the *Toxics Inventory and Screening* (R2 2006). The combination of a lack of recent water quality data, current sources of mercury in the Project area, the ability of mercury to bioaccumulate, and the potential for reservoir fluctuation to affect mercury methylation has prompted SCL to take a more detailed look at mercury to understand the potential risk of this toxicant in the Project area.

Nickel – Nickel is an abundant natural element used in many industrial processes and products. It attaches to particles with iron or manganese, but does not accumulate in fish, plants, or animals. Observed effects of nickel in aquatic environments include tissue damage, genotoxicity, and growth reduction (Environment Canada 1994a). Based on the information above, nickel is considered to be of medium biological toxicity. Nickel does not meet the tier 1 criterion and is recommended to be omitted from further studies (Table A-5).

Selenium – Selenium is a naturally occurring mineral element distributed widely in nature. It is widely used in industry in electronics, the preparation of pharmaceuticals, pesticides, and fungicides. Some selenium compounds will dissolve in water while others will settle as particles. Selenium can accumulate up the food chain and undergoes bioconcentration, bioaccumulation, and biomagnification as trophic levels increase (Taylor et al 1992). Based on the information above, selenium is considered to be of high biological toxicity. It is recommended that selenium be omitted from further studies given that it is detected below MTCA surface soil guidelines and there are no freshwater sediment thresholds (Table A-5).

Silver – Silver is a naturally occurring element that does not concentrate to significant amounts in aquatic organisms. However, silver is highly toxic to aquatic organisms (EPA 1992). Elevated levels can cause larval mortality, developmental abnormalities, and reduced larval growth in fish. Based on the information above, silver is considered to be of medium biological toxicity. Silver concentrations exceed the tier 1 criterion, but since it was not detected within a waterway or target sample and has low reoccurrence within the watershed, it is recommended that it be omitted from further studies (Table A-5).

Vanadium – Vanadium is a compound that occurs in nature as a white to gray metal. It usually combines with other elements such as oxygen, sodium, sulfur, or chloride. It can be found in the earth's crust, in rocks, some iron ores, and crude petroleum deposits. Vanadium stays in the air, water, and soil for a long time and does not dissolve well in water and does stick to soil sediments. Low levels have been found in plants, but it is not likely to build up in the tissues of animals. The growth of some aquatic plants is stimulated by trace quantities of vanadium (1–10 µg/L), but concentrations above 100 µg/L are toxic (WHO 1990). Based on the information above, vanadium is considered to be of low biological toxicity. There are no thresholds for vanadium, but since the values are below typical background conditions, there is low reoccurrence within the watershed, and it is of low biological toxicity, it is therefore not recommended for further study (Table A-5).

Arsenic – Arsenic is a naturally occurring element that is used to preserve wood and in some pesticides (U.S. Dept of Health and Human Service 2006). Arsenic can be toxic in the environment. Inorganic forms are more toxic to organisms in the environment than organic forms, and, among inorganic forms, arsenite is more toxic than arsenate (Greenfacts 2006). Arsenite is thought to be toxic because it binds to sulfhydryl groups, which are found on proteins. Arsenate affects the key energy producing process that takes place in all cells. Arsenic compounds can cause short-term and long-term effects in plants and animals including death, inhibition of growth, photosynthesis and reproduction, and behavioral effects (Greenfacts 2006). Arsenic-contaminated environments are characterized by limited species abundance and diversity. Based on the above information, arsenic was classified as having high biological toxicity. Arsenic concentrations were found to have values exceeding surface soil guidelines (Table A-5). Although there was low reoccurrence within the watershed, given the elevated levels of arsenic found in target samples and high toxicity, it is recommended that arsenic be included in the toxic assessment study (Table A-5).

Cadmium – Cadmium is a natural element found in soils and rocks and is often extracted during the production of other metals such as zinc, lead, and copper. Cadmium is highly toxic and bioaccumulates at all trophic levels, accumulating in the livers and kidneys of fish (Sindayigaya et al 1994). Cadmium can be toxic to plants at lower soil concentrations than other heavy metals and is more readily taken up than other metals. Based on the information above, cadmium is considered to be of high biological toxicity. Based on the tier 1 and tier 2 assessment criteria, it is recommended that cadmium be included in further studies (Table A-5). Note that cadmium was already recommended for inclusion in further studies based on the water quality assessment described in the *Toxics Inventory and Screening*.

Lead – Lead adversely affects algae, invertebrates, and fish. Fish exposed to high levels of lead exhibit a wide-range of effects including muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis (Eisler 1988). Lead can cause reduced growth, photosynthesis, mitosis, and water absorption at elevated levels in plants (Eisler 1988). Lead can be bioconcentrated from water, but does not bioaccumulate and tends to decrease with increasing trophic levels in freshwater habitats (Eisler 1988). Lead partitions primarily to sediments, but becomes more bioavailable under low pH, hardness and organic matter content. Lead bioaccumulates in algae, macrophytes and benthic organisms, but the inorganic forms of lead do not biomagnify. Based on the information above, lead is considered to be of medium biological toxicity. It is recommended that lead be included in further studies because it met the tier 1 criterion and three of the tier 2 criteria (Table A-5). Note that lead was already recommended for inclusion in further studies based on the water quality assessment described in the *Toxics Inventory and Screening*.

Zinc – Zinc is a common element found in air, soil, and water. Zinc is currently, and was historically, mined within the Lower Pend Oreille area. It is also used in industry to make paint, dyes, wood preservatives, and ointments. Elevated levels of zinc can adversely affect the growth, survival, and reproduction of aquatic plants and animals (Eisler 1993). Based on the information above, zinc is considered to be of medium biological toxicity. Zinc meets the tier 1 criterion as well as three of the tier 2 criteria and should therefore be included in further studies (Table A-5).

The information used in the assessment of EPA toxics data and the recommendations for inclusion or omission from future studies are summarized in Table A-5. Fourteen toxics found in the source and target samples were evaluated. Of these, ten (barium, chromium, copper, DDT, manganese, mercury, nickel, selenium, silver, and vanadium) were recommended for omission from further study, and four (arsenic, cadmium, lead, and zinc) were recommended for further study based on the criteria specified. Although not recommended based on sediment data, mercury was recommended for inclusion based on water quality data reviewed in the *Toxics Inventory and Screening*. PCBs were not included in the EPA report and were therefore not reviewed in the current assessment, but are also recommended for further study based on the findings in the *Toxics Inventory and Screening*. In total, six toxics (arsenic, cadmium, lead, mercury, zinc, and PCBs) are recommended for inclusion in further studies.

Table A-2: Surface soil and freshwater sediment cleanup levels, effects levels, and sediment quality values.

	Surface Soil[1]	**Freshwater Sediment**		
Constituent	**MTCA Method A Cleanup Level for Unrestricted Land Use (mg/Kg)**	**Typical Background (mg/Kg)** [2]	**Lowest Apparent Effects Threshold (mg/Kg)** [3]	**Second Lowest Apparent Effects Threshold (mg/Kg)** [3]
Arsenic	20.0	1.1	31.4	50.9
Barium		0.700		
Cadmium	2.0	0.1-0.3	2.39	2.9
Chromium	100	7-13	95	133
Copper		10-25	619	829
Lead	250	4-17	335	431
Manganese		400		
Mercury	2	0.004-0.051	0.8	3.04
Nickel		9.9	53.1	113
Selenium		0.29		
Silver		<0.5	0.545	3.5
Vanadium		50		
Zinc		7-38	683	1080
“4,4’-DDT	3		19	-

[1]Ecology Table 740-1
[2]NOAA Screening Quick Reference Table for Inorganics in Solids
[3]Ecology Sediment Quality Values (Michelsen 2003)

Table A-3: Mine source samples identified in the lower Pend Oreille area as having significant concentrations.

Sample ID	Mine	Sample Type	Location	Constituent	Concentration	Units	Comparison to Guidelines/ Thresholds[1]
01264273	Oriole	Sediment	ORSP02SD	Arsenic	13.8	mg/kg	Below LAET
01264252	Pend Oreille	Surface Soil	POTP01SS	Arsenic	20.6	mg/kg	Above MTCA
01264255	Pend Oreille	Surface Soil	POTP04SS	Arsenic	8.5	mg/kg	Below MTCA
01264256	Pend Oreille	Surface Soil	POTP05SS	Arsenic	40.0	mg/kg	Above MTCA
01264257	Pend Oreille	Surface Soil	POTP06SS	Arsenic	20.8	mg/kg	Above MTCA
01264258	Pend Oreille	Surface Soil	POTP07SS	Arsenic	26.4	mg/kg	Above MTCA
01264259	Pend Oreille	Surface Soil	POTP08SS	Arsenic	22.4	mg/kg	Above MTCA
01264260	Pend Oreille	Surface Soil	POTP09SS	Arsenic	21.1	mg/kg	Above MTCA
01264354	Pend Oreille	Surface Soil	POWP02SS	Arsenic	21.8	mg/kg	Above MTCA
01264355	Pend Oreille	Surface Soil	POWP03SS	Arsenic	35.1	mg/kg	Above MTCA
01264272	Oriole	Sediment	ORSP01SD	Barium	234	mg/kg	NA
01264267	Blue Bucket	Sediment	BBPP01SD	Cadmium	1.7	mg/kg	Below LAET
01264269	Blue Bucket	Sediment	BBPP02SD	Cadmium	2.8	mg/kg	Above LAET
01264272	Oriole	Sediment	ORSP01SD	Cadmium	8.5	mg/kg	Above 2LAET
01264273	Oriole	Sediment	ORSP02SD	Cadmium	27	mg/kg	Above 2LAET
01264423	Josephine	Sediment	JOPP01SD	Cadmium	9.6	mg/kg	Above 2LAET
01264418	Grandview	Sediment	GMPP05SD	Cadmium	1.6	mg/kg	Below LAET
01264411	Pend Oreille	Sediment	POPP02SD	Cadmium	6.1	mg/kg	Above 2LAET
01264252	Pend Oreille	Surface Soil	POTP01SS	Cadmium	15.0	mg/kg	Above MTCA
01264254	Pend Oreille	Surface Soil	POTP03SS	Cadmium	9.2	mg/kg	Above MTCA
01264258	Pend Oreille	Surface Soil	POTP07SS	Cadmium	30.4	mg/kg	Above MTCA
01264259	Pend Oreille	Surface Soil	POTP08SS	Cadmium	20.1	mg/kg	Above MTCA
01264260	Pend Oreille	Surface Soil	POTP09SS	Cadmium	10.4	mg/kg	Above MTCA
01264353	Pend Oreille	Surface Soil	POWP01SS	Cadmium	4.0	mg/kg	Above MTCA
01264354	Pend Oreille	Surface Soil	POWP02SS	Cadmium	34.2	mg/kg	Above MTCA
01264355	Pend Oreille	Surface Soil	POWP03SS	Cadmium	44.1	mg/kg	Above MTCA
01264256	Pend Oreille	Surface Soil	POTP05SS	Cadmium	8.2	mg/kg	Above MTCA
01264257	Pend Oreille	Surface Soil	POTP06SS	Cadmium	11.9	mg/kg	Above MTCA

Table A-3: Mine source samples identified in the lower Pend Oreille area as having significant concentrations.

Sample ID	Mine	Sample Type	Location	Constituent	Concentration	Units	Comparison to Guidelines/ Thresholds[1]
01264273	Oriole	Sediment	ORSP02SD	Copper	71.7	mg/kg	Below LAET
01264252	Pend Oreille	Surface Soil	POTP01SS	Copper	176	mg/kg	Below LAET
01264255	Pend Oreille	Surface Soil	POTP04SS	Copper	90.0	mg/kg	Below LAET
01264257	Pend Oreille	Surface Soil	POTP06SS	Copper	178	mg/kg	Below LAET
01264258	Pend Oreille	Surface Soil	POTP07SS	Copper	242	mg/kg	Below LAET
01264259	Pend Oreille	Surface Soil	POTP08SS	Copper	113	mg/kg	Below LAET
01264260	Pend Oreille	Surface Soil	POTP09SS	Copper	88.0	mg/kg	Below LAET
01264269	Blue Bucket	Sediment	BBPP02SD	Lead	72.5	mg/kg	Below LAET
01264267	Blue Bucket	Sediment	BBPP01SD	Lead	59.9	mg/kg	Below LAET
01264272	Oriole	Sediment	ORSP01SD	Lead	301	mg/kg	Below LAET
01264273	Oriole	Sediment	ORSP02SD	Lead	714	mg/kg	Above 2LAET
01264356	Josephine	Surface Water	JOSP01SW	Lead	21.5	µg/L	Above Chronic
01264423	Josephine	Sediment	JOPP01SD	Lead	17400	mg/kg	Above 2LAET
01264417	Grandview	Surface Water	GMPP05SW	Lead	4.1	µg/L	Above Chronic
01264418	Grandview	Sediment	GMPP05SD	Lead	449	mg/kg	Above 2LAET
01264252	Pend Oreille	Surface Soil	POTP01SS	Lead	680	mg/kg	Above MTCA
01264254	Pend Oreille	Surface Soil	POTP03SS	Lead	467	mg/kg	Above MTCA
01264255	Pend Oreille	Surface Soil	POTP04SS	Lead	666	mg/kg	Above MTCA
01264256	Pend Oreille	Surface Soil	POTP05SS	Lead	1650	mg/kg	Above MTCA
01264257	Pend Oreille	Surface Soil	POTP06SS	Lead	818	mg/kg	Above MTCA
01264258	Pend Oreille	Surface Soil	POTP07SS	Lead	1760	mg/kg	Above MTCA
01264259	Pend Oreille	Surface Soil	POTP08SS	Lead	1000	mg/kg	Above MTCA
01264260	Pend Oreille	Surface Soil	POTP09SS	Lead	919	mg/kg	Above MTCA
01264353	Pend Oreille	Surface Soil	POWP01SS	Lead	3010	mg/kg	Above MTCA
01264354	Pend Oreille	Surface Soil	POWP02SS	Lead	8100	mg/kg	Above MTCA
01264355	Pend Oreille	Surface Soil	POWP03SS	Lead	6030	mg/kg	Above MTCA
01264401	Pend Oreille	Surface Water	POPP01SW	Lead	8.7	µg/L	Above Chronic
01264410	Pend Oreille	Surface Water	POPP02SW	Lead	9.3	µg/L	Above Chronic

Table A-3: Mine source samples identified in the lower Pend Oreille area as having significant concentrations.

Sample ID	Mine	Sample Type	Location	Constituent	Concentration	Units	Comparison to Guidelines/ Thresholds[1]
01264411	Pend Oreille	Sediment	POPP02SD	Lead	346	mg/kg	Above LAET
01264272	Oriole	Sediment	ORSP01SD	Manganese	4210	mg/kg	NA
01264273	Oriole	Sediment	ORSP02SD	Manganese	2230	mg/kg	NA
01264417	Grandview	Surface Water	GMPP05SW	Manganese	25.5	µg/L	NA
01264410	Pend Oreille	Surface Water	POPP02SW	Manganese	33.0	µg/L	NA
01264423	Josephine	Sediment	JOPP01SD	Mercury	0.16	mg/kg	Below LAET
01264252	Pend Oreille	Surface Soil	POTP01SS	Mercury	0.25	mg/kg	Below MTCA
01264254	Pend Oreille	Surface Soil	POTP03SS	Mercury	0.16	mg/kg	Below MTCA
01264255	Pend Oreille	Surface Soil	POTP04SS	Mercury	0.15	mg/kg	Below MTCA
01264256	Pend Oreille	Surface Soil	POTP05SS	Mercury	0.10	mg/kg	Below MTCA
01264257	Pend Oreille	Surface Soil	POTP06SS	Mercury	0.18	mg/kg	Below MTCA
01264258	Pend Oreille	Surface Soil	POTP07SS	Mercury	0.58	mg/kg	Below MTCA
01264259	Pend Oreille	Surface Soil	POTP08SS	Mercury	0.25	mg/kg	Below MTCA
01264260	Pend Oreille	Surface Soil	POTP09SS	Mercury	0.16	mg/kg	Below MTCA
01264354	Pend Oreille	Surface Soil	POWP02SS	Mercury	0.16	mg/kg	Below MTCA
01264355	Pend Oreille	Surface Soil	POWP03SS	Mercury	0.19	mg/kg	Below MTCA
01264353	Pend Oreille	Surface Soil	POWP01SS	Selenium	3.1	mg/kg	Below MTCA
01264355	Pend Oreille	Surface Soil	POWP03SS	Selenium	1.7	mg/kg	Below MTCA
01264423	Josephine	Sediment	JOPP01SD	Silver	2.3	mg/kg	Above LAET
01264272	Oriole	Sediment	ORSP01SD	Silver	2.8	mg/kg	Above LAET
01264273	Oriole	Sediment	ORSP02SD	Silver	5.6	mg/kg	Above 2LAET
01264256	Pend Oreille	Surface Soil	POTP05SS	Silver	2.3	mg/kg	Above LAET
01264269	Blue Bucket	Sediment	BBPP02SD	Zinc	560	mg/kg	Below LAET
01264267	Blue Bucket	Sediment	BBPP01SD	Zinc	329	mg/kg	Below LAET
01264273	Oriole	Sediment	ORSP02SD	Zinc	5740	mg/kg	Above 2LAET
	Oriole	Surface Water	ORSP01SW	Zinc	102	µg/L	Above Acute
01264272	Oriole	Sediment	ORSP01SD	Zinc	784	mg/kg	Above LAET
01264423	Josephine	Sediment	JOPP01SD	Zinc	2040	mg/kg	Above 2LAET

Table A-3: Mine source samples identified in the lower Pend Oreille area as having significant concentrations.

Sample ID	Mine	Sample Type	Location	Constituent	Concentration	Units	Comparison to Guidelines/ Thresholds[1]
01264356	Josephine	Surface Water	JOSP01SW	Zinc	117	µg/L	Below LAET
01264418	Grandview	Sediment	GMPP05SD	Zinc	864	mg/kg	Above LAET
01264417	Grandview	Surface Water	GMPP05SW	Zinc	20.6	µg/L	Below Chronic
01264410	Pend Oreille	Surface Water	POPP02SW	Zinc	62.5	µg/L	Below Chronic
01264401	Pend Oreille	Surface Water	POPP01SW	Zinc	212	µg/L	Above Acute
01264355	Pend Oreille	Surface Soil	POWP03SS	Zinc	9300	mg/kg	NA
01264354	Pend Oreille	Surface Soil	POWP02SS	Zinc	7420	mg/kg	NA
01264260	Pend Oreille	Surface Soil	POTP09SS	Zinc	2270	mg/kg	NA
01264353	Pend Oreille	Surface Soil	POWP01SS	Zinc	890	mg/kg	NA
01264259	Pend Oreille	Surface Soil	POTP08SS	Zinc	4540	mg/kg	NA
01264258	Pend Oreille	Surface Soil	POTP07SS	Zinc	6450	mg/kg	NA
01264257	Pend Oreille	Surface Soil	POTP06SS	Zinc	2520	mg/kg	NA
01264256	Pend Oreille	Surface Soil	POTP05SS	Zinc	2500	mg/kg	NA
01264255	Pend Oreille	Surface Soil	POTP04SS	Zinc	1590	mg/kg	NA
01264254	Pend Oreille	Surface Soil	POTP03SS	Zinc	2190	mg/kg	NA
01264252	Pend Oreille	Surface Soil	POTP01SS	Zinc	4130	mg/kg	NA
01264411	Pend Oreille	Sediment	POPP02SD	Zinc	2370	mg/kg	Above LAET

[1] LAET = Lowest Apparent Effects Threshold, MTCA= Model Toxic Control Act,
[2] LAET = Second Lowest Apparent Effects Threshold;
NA= no applicable guideline/threshold was available.

Table A-4: Mine target samples identified in the lower Pend Oreille area as having elevated concentrations.

Sample ID	River/Tributary	Sample Type	Location	Constituent	Concentration (µg/L, mg/Kg)	Comparison to Guidelines[1]
01264351	Pend Oreille Mine	Sediment	POSP01SD	Arsenic	17.2	Below LAET
01264352	Pend Oreille Mine	Sediment	POSP02SD	Arsenic	11.8	Below LAET
01264263	Creek 1	Sediment	POCK01SD	Cadmium	3.5	Above 2LAET
01264352	Pend Oreille Mine	Sediment	POSP02SD	Cadmium	14.6	Above 2LAET
01264405	Everett Creek	Sediment	PRTB02SD	Cadmium	6.1	Above 2LAET
01264403	Lime Creek	Sediment	PRTB01SD	Chromium	57.7	Below LAET
01264405	Everett Creek	Sediment	PRTB02SD	Chromium	86.2	Below LAET
01264352	Pend Oreille Mine	Sediment	POSP02SD	Copper	165	Below LAET
01264263	Creek 1	Sediment	POCK01SD	Lead	180	Below LAET
01264351	Pend Oreille Mine	Sediment	POSP01SD	Lead	351	Above LAET
01264352	Pend Oreille Mine	Sediment	POSP02SD	Lead	1960	Above 2LAET
01264352	Pend Oreille Mine	Sediment	POSP02SD	Mercury	0.39	Below LAET
01264263	Creek 1	Sediment	POCK01SD	Nickel	44.8	Below LAET
01264403	Lime Creek	Sediment	PRTB01SD	Selenium	4.9	NA
01264263	Creek 1	Sediment	POCK01SD	Vanadium	26.8	Below normal background
01264352	Pend Oreille Mine	Sediment	POSP02SD	Vanadium	20.8	Below normal background
01264266	Creek 1	Surface Water	POCK01SW	Zinc	63.2	Above Acute
01264263	Creek 1	Sediment	POCK01SD	Zinc	326	Below LAET
01264351	Pend Oreille Mine	Sediment	POSP01SD	Zinc	3320	Above 2LAET
01264352	Pend Oreille Mine	Sediment	POSP02SD	Zinc	2610	Above 2LAET
01264406	Ledbetter Creek	Sediment	PRTB03SD	“4,4’-DDT”	10	Below LAET

[1] LAET = Lowest Apparent Effects Threshold, MTCA = Model Toxic Control Act,
[2] LAET = Second Lowest Apparent Effects Threshold;
NA= no applicable guideline/threshold was available.

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Barium	Medium	Blue Bucket Oriole	 Potential overland flow from waste rock pile to muddy area and eventually Linton Creek	Not detected in significant concentrations Detected below covered waste rock pile			Omit ▪ First Tier o Thresholds/ guidelines not available ▪ Second Tier o Not detected in target samples o **Medium toxicity** o low reoccurrence
		Josephine		Not detected in significant concentrations			
		Grandview		Not detected in significant concentrations			
		Pend Oreille		Not detected in significant concentrations	Not detected in significant concentrations	Not detected in significant concentrations	
		Pend Oreille River		Not detected in significant concentrations			
		Tributaries		Not detected in significant concentrations			

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Chrom-ium	Medium	Blue Bucket		Not detected			Omit ▪ First Tier Below guidelines/ thresholds
		Oriole		Not detected			
		Josephine		Not detected			
		Grandview		Not detected			
		Pend Oreille		Not detected	Not detected		
		Tributaries		Detected at mouth of Everett Creek, detected at mouth of Lime Creek			

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Copper	High	Blue Bucket		Not detected at significant concentrations			Omit ▪ First Tier o Below guidelines/ threshold
		Oriole	Potential overland flow from the spring to a muddy area and eventually Linton Creek	Detected near covered waste rock pile			
		Josephine		Not detected at significant concentrations			
		Grandview		Not detected at significant concentrations			
		Pend Oreille	Seep areas located by TDF-1, TDF-2 & TDF-3 into Creek 2 and surface water runoff from TDF-1 & TDF-2 into the Pend Oreille River	Not detected at significant concentrations	Detected in all tailing disposal facilities		
		Tributaries		Not detected at significant concentrations			
		Pend Oreille River		Not detected at significant concentrations			
DDT	High	Tributaries		Detected at mouth of Ledbetter Creek			Omit ▪ First Tier o Below guidelines/ thresholds

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Manganese	Low	Blue Bucket		Not detected at significant concentrations			Omit ▪ First Tier o No guidelines/ thresholds ▪ Second Tier o not detected in waterways/target samples o Low toxicity o Low reoccurrence within the watershed
		Oriole	Potential overland flow from the spring to a muddy area and eventually Linton Creek	Detected downstream of spring and near covered waste rock pile			
		Josephine		Not detected at significant concentrations			
		Grandview				GMP05SW	
		Pend Oreille	Seep areas located by TDF-1, TDF-2 & TDF-3 into Creek 2	Not detected at significant concentrations		Detected at mouth of Creek 2	
		Pend Oreille River		Not detected at significant concentrations			
		Tributaries		Not detected at significant concentrations			
Mercury	High	Josephine	Flow from a spring through a waste rock pile to the Pend Oreille River	Detected at mouth of spring			Omit ▪ First Tier o Below guidelines/thresholds **NOTE: include based on findings in *Toxics Inventory and Screening***
		Pend Oreille	Flow from the ventilation shaft, seep areas located by TDF-1, TDF-2 & TDF-3 into Creek 2, surface water runoff from TDF-2 & TDF-3, and surface water runoff from waste rock	Detected at elevated concentrations	Detected in all tailing disposal facilities and in the waste rock pile		

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Nickel	Medium	Blue Bucket Oriole		Not detected Not detected			Omit ▪ First Tier o Below guidelines/ thresholds
		Josephine		Not detected			
		Grandview		Not detected			
		Pend Oreille	Drainage near Creek 1	Detected at mouth of Creek 1	Not detected		
		Pend Oreille River		Not detected			
		Tributaries		Not detected			
Selenium	High	Pend Oreille	Flow from the ventilation shaft, seep areas located by TDF-1, TDF-2 & TDF-3 into Creek 2		Detected at TDF-1		Omit ▪ First Tier o Below MTCA guidelines, no sediment thresholds
		Pend Oreille River		Not detected			
		Tributaries		Detected at mouth of Lime Creek			

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Silver	Medium	Oriole	Potential overland flow from the spring to a muddy area and eventually Linton Creek	Detected downstream of spring and near large waste rock pile			Omit ▪ First Tier o **Above guidelines/ thresholds** ▪ Second Tier o Not detected in waterways or target samples o **Medium toxicity** o Low reoccurrence within the watershed
		Josephine	Flow from a spring through a waste rock pile to the Pend Oreille River	Detected at mouth of spring			
		Pend Oreille	seep areas located by TDF-1, TDF-2 & TDF-3 into Creek 2, surface water runoff from TDF-2 & TDF-3		Detected at TDF-3		
Vanadium	Low	Grandview		Not detected			Omit ▪ First Tier o Below normal background
		Pend Oreille	seep areas located by TDF-1, TDF-2 & TDF-3 into Creek 2 and drainage near Creek 1.	Detected at Creek 1, TDF-1,	Not detected		
		Pend Oreille River		Not detected			
		Tributaries		Not detected			

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Arsenic	High	Blue Bucket		Not detected			Include ▪ First Tier o **Soil samples above MTCA guidelines** ▪ Second Tier o **Elevated levels detected in target samples** o **High toxicity** o Medium reoccurrence within the watershed
		Oriole	Potential overland flow from waste rock pile to muddy area and eventually Linton Creek	Detected below covered waste rock pile, not detected at base of spring			
		Josephine		Not detected in significant concentrations			
		Grandview		Not detected in significant concentrations			
		Pend Oreille	Flow from the ventilation shaft, seep areas located by TDF-1, TDF-2, & TDF-3 into Creek 2, surface water runoff from TDF-2 & TDF-3, surface water runoff from waste rock.	Not detected in significant concentrations	Detected in all tailing disposal facilities and in the waste rock pile		
		Pend Oreille River		Not detected in significant concentrations			
		Tributaries		Not detected in significant concentrations			

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Cadmium	High	Blue Bucket	Potential flow from shaft to unnamed creek, potential overland flow from waste rock pile to unnamed creek	Detected upstream and downstream of waste rock pile			Include ▪ First Tier o **Measured values above thresholds/ guidelines** ▪ Second Tier o **Elevated levels in target samples and migration samples** o **High toxicity** o **High reoccurrence within the watershed**
		Oriole	Potential overland flow from the spring to a muddy area and eventually Linton Creek	Detected downstream of spring and below the covered waste rock pile			
		Josephine	Flow from a spring through a waste rock pile to the Pend Oreille River	Detected at mouth of spring			
		Grandview	Potential surface water pathway from suspected tailings pile to Pend Oreille River	Detected downstream of suspected tailings pile			
		Pend Oreille	Flow from the ventilation shaft, seep areas located by TDF-1, TDF-2 & TDF-3 into Creek 2, surface water runoff from TDF-2 & TDF-3, surface water runoff from waste rock, and drainage near Creek 1.	Detected at mouth of Creek 2 and in Creek 1	Detected in all tailing disposal facilities and in the waste rock pile		
		Pend Oreille River		Not detected			
		Tributaries		Detected at mouth of Everett Creek			

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Lead	Medium	Blue Bucket	Potential flow from shaft to unnamed creek, potential overland flow from waste rock pile to unnamed creek	Detected upstream and downstream of waste rock pile			Include ▪ First Tier o **Above guidelines/ thresholds** ▪ Second Tier o **Detected in target samples** o **Medium toxicity** o **High reoccurrence within the watershed**
		Oriole	Potential overland flow from the spring to a muddy area and eventually Linton Creek	Detected downstream of spring and near covered waste rock pile			
		Josephine	Flow from a spring through a waste rock pile to the Pend Oreille River	Detected at mouth of spring		Detected at mouth of spring (exceeds chronic criteria)	
		Grandview	Potential surface water pathway from suspected tailings pile to Pend Oreille River	Detected downstream of suspected tailings pile		GMP05SW (exceeds acute and chronic criteria)	
		Pend Oreille	Flow from the ventilation shaft, seep areas located by TDF-1, TDF-2 & TDF-3 into Creek 2, surface water runoff from TDF-2 & TDF-3, surface water runoff from waste rock, and drainage near Creek 1.	Detected at the mouth of Creek 2 at the Pend Oreille River	Detected at TDF 2 & 3 and in the waste rock pile	Detected at the mouth of Creek 2 and the Pend Oreille River (exceeds chronic criteria)	
		Pend Oreille River		Not detected at significant concentrations			
		Tributaries		Not detected at significant concentrations			

Table A-5: Summary the biological toxicity, transport mechanisms, and significant/elevated concentrations of toxics at the five mine sites identified by the EPA report.

Toxic	Biological Toxicity	Mine	Transport Mechanism	Sediment Results	Surface Soil Results	Surface Water Results	Recommendation/ Comments[1]
Zinc	Medium	Blue Bucket	Potential flow from shaft to unnamed creek, potential overland flow from waste rock pile to unnamed creek	Detected upstream and downstream of waste rock pile			Include ▪ First Tier o **Above guidelines/ thresholds** ▪ Second Tier o **Elevated levels in target samples** o **Medium toxicity** o **High reoccurrence within the watershed**
		Oriole	Potential overland flow from the spring to a muddy area and eventually Linton Creek	Detected downstream of spring and near large waste rock pile		Detected near spring (exceeds acute and chronic criteria)	
		Josephine	Flow from a spring through a waste rock pile to the Pend Oreille River	Detected at mouth of spring		Detected at mouth of spring (exceeds acute and chronic criteria)	
		Grandview	Potential surface water pathway from suspected tailings pile to Pend Oreille River	Detected downstream of suspected tailings pile		GMPP05SW (does not exceed standards)	
		Pend Oreille	Flow from the ventilation shaft, seep areas located by TDF-1, TDF-2, & TDF-3 into Creek 2, surface water runoff from TDF-2 & TDF-3, surface water runoff from waste rock.	Detected at mouth of Creek 2	Detected in all mine tailings piles and in the waste rock pile	Detected in the Pend Oreille River downstream of the ventilation shaft (exceeds standards), at the mouth of Creek 2 (does not exceed standards), and in Creek 1 (does not exceed standards)	
		Pend Oreille River		Not detected			
		Tributaries		Not detected			

\1Bold indicates criteria of concern; TDF – Tailings Disposal Facility ;Tributaries include Lime Creek, Everett Creek, Ledbetter Creek, Unnamed Tributary, Slate Creek, Peewee Creek, Beaver Creek, Sullivan Creek, Flume Creek, Linton Creek

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Appendix 2: Examples of Toxic Variants and Technical Sampling Considerations

Table A-1. Examples of Toxic Variants and Technical Sampling Considerations

Toxic Substance	*Species/Forms Possible*	*Toxicity Influenced By*	**Comments**
Arsenic (As)	Arsenite (As(III)) Aresenate (As(V)) Monomethylarsonic Acid (MMA) Dimethylarsenic Acid (DMA) Arsenobetaine (AsB) Arsenocholine (AsC)	• water temperature • pH • organic carbon content • dissolved oxygen • redox potential • bacterial density	• As(III) is considered more toxic and appears to bioaccumulate more readily than As(V), which is considered more stable and common in aquatic systems. • As(III) compounds are 4-10 times more soluble than As(V) compounds. • As(III) has been shown to oxidize to As(V), and As(V) reduce to As(III).
Cadmium (Cd)	Divalent ionic cadmium (Cd^{2+}) Monovalent hydroxylated cadmium ($CdOH^+$) Cadmium oxide (CdO) Cadmium chloride ($CdCl_2$) Cadmium sulfate ($CdSO_4$) Cadmium sulfide (CdS)	• water temperature • pH • hardness • dissolved oxygen • other metals (zinc and selenium)	• Cadmium is most often present in nature as complex oxides, sulfides, and carbonates in zinc, lead, and copper ores. • The chlorides and sulfates are the forms that most easily dissolve in water. • Cadmium concentrations in bed sediments are generally at least an order of magnitude higher than in the overlying water.
Mercury (Hg)	Metallic mercury (Hg^0) Inorganic mercury (Hg^{2+}) - Mercuric (II) chloride ($HgCl_2$) - Mercurous(I) chloride (Hg_2Cl_2) - Mercuric (II) sulfide (HgS) Organic mercury (Hg + C) - Methylmercury chloride (CH_3HgCl) - Phenylmercuric acetate ($C_8H_8HgO_2$) - Dimethyl mercury (C_2H_6Hg)	• pH • organic carbon content • other metals (zinc and selenium)	• Most common natural forms of mercury found in the environment are metallic mercury, mercuric sulfide (cinnabar ore), mercuric chloride, and methylmercury. • In sediments, mercury is usually found in its inorganic forms, but aquatic environments are a major source of methylmercury. • Methylmercury is the most toxic and the most readily bioaccumulated form of mercury, and is taken up primarily through the diet, accounting for more than 90% of the total amount of methylmercury accumulated.

Table A-1. Examples of Toxic Variants and Technical Sampling Considerations

Toxic Substance	*Species/Forms Possible*	*Toxicity Influenced By*	**Comments**
Lead (Pb)	Metallic lead (Pb^0) Inorganic lead (Pb^{2+}) Organic lead (Pb^{4+}) - Tetramethyl lead - Tetraethyl lead - Methyl-ethyl lead compounds	• water temperature • hardness • pH • organic carbon content • redox potential • metal salt content	• Organic lead compounds are generally more toxic than inorganic. • Aquatic organisms are influenced more by dissolved than by total lead, because lead characteristically precipitates out in aqueous environments to bed sediments. • Water hardness is an importance influence on inorganic lead toxicity because lead precipitates out of solution as hardness increases.
Zinc (Zn)	Two oxidation states: Zn^0 Zn^{2+} - Zinc oxide (ZnO) - Zinc chloride ($ZnCl$) - Zinc sulfide (ZnS) - Zinc sulfate ($ZnSO_4$)	• water temperature • hardness • pH • alkalinity • dissolved oxygen • other metals (cadmium, copper, iron, molybdenum)	• There are approximately 55 mineralized forms of zinc. • In humans and animals, zinc is an essential nutrient that plays a role in membrane stability, in over 300 enzymes, and in the metabolism of proteins and nucleic acids. • Release of zinc from sediment is enhanced by the combination of high dissolved oxygen, low salinity, and low pH.
PCBs	209 potential congeners: - Aroclor 1254 – most common - Non-ortho substituted congeners - Mono-ortho substituted congeners	• Number of chlorine atoms in congeners • Planar compounds	• The most toxic PCBs are the non-ortho and mono-ortho substituted congeners, which tend to be planar compounds. • PCBs are typically found at low water concentrations because of their high affinity for sediment and biological tissues. • It is possible for high sediment concentrations, and water concentrations that are below the chronic criterion or are undetectable, to co-occur in streams.

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