Boundary Hydroelectric Project (FERC No. 2144)

Study No. 4

Toxics Assessment: Evaluation of Contaminant Pathways

Final Report

Prepared for
Seattle City Light

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Study No. 4: Toxics Assessment: Evaluation of Contaminant Pathways
Final Report
Boundary Hydroelectric Project (FERC No. 2144)

1 INTRODUCTION

Study No. 4, Toxics Assessment: Evaluation of Contaminant Pathways, was conducted in support of the relicensing of the Boundary Hydroelectric Project (Project), Federal Energy Regulatory Commission (FERC) No. 2144, as identified in the Revised Study Plan (RSP) (SCL 2007a) submitted by Seattle City Light (SCL) on January 29, 2007, and approved by FERC in its Study Plan Determination letter dated March 15, 2007. Further details on the rationale, methods, and schedule for this study are provided in the Final Phase 2 Sampling and Analysis Plan submitted by SCL in July 2007, as modified in SCL's September 28, 2007 response to comments, and approved by FERC in its October 25, 2007 determination (Sampling and Analysis Plan [SAP]) (SCL 2007b). The RSP calls for a two-phase study: Phase 1—development of the testable hypotheses, i.e., key pathways for six toxics of concern (SCL completed Phase 1 of the study in 2007 and submitted the final Phase 1 report in July 2007 as Appendix 1 to the Phase 2 SAP [SCL 2007b]); and Phase 2—development and implementation of the SAP.

On August 15, 2008, SCL filed the Toxics Assessment: Evaluation of Contaminant Pathways Interim Report ("Interim Report") (SCL 2008a), as required by FERC's October 25, 2007, study plan determination. The Interim Report analyzed results from the 2007 and early 2008 study efforts for Phase 2 of the Toxics Assessment and included SCL's conclusion that there was no evidence of any nexus between toxics bioavailability and Project operations. As a result, no additional toxics sampling was warranted. However, SCL agreed in the Interim Report to conduct limited additional sampling at select locations in the reservoir to validate the findings presented in the Interim Report. In its September 24, 2008, Study Plan Determination for the Boundary Hydroelectric Project Toxics Analysis, FERC concurred with SCL's conclusions in the Interim Report and SCL's associated September 15, 2008, response to agency comments. FERC determined that the data in the Interim Report, along with the additional sampling results proposed by SCL, would adequately address all toxics study needs for the relicensing. This is the final study report for Phase 2 of the Toxics Assessment. Results of fall 2008 validation sampling are included as an addendum (Appendix 1) to the main body of this report and are referenced throughout the report where appropriate.

The RSP (SCL 2007a), Phase 2 SAP (SCL 2007b), and Interim Report (SCL 2008a) document the progress of SCL and relicensing participants in evaluating and addressing toxics of concern in the Boundary Reservoir and potential Project effects on toxics. During the study phase for the relicensing effort, SCL proceeded with the study of the six toxics of concern to be addressed as part of the FERC relicensing and Washington State Section 401 certification processes: arsenic, cadmium, lead, mercury, zinc, and polychlorinated biphenyls (PCBs). One purpose of this phase

was, in part, to determine if there was a need for additional sampling, including sampling of biota, by applying the decision making process set out in Section 2.4 of the FERC-approved Phase 2 SAP (2007b). The decision making is presented in the Interim Report, and resulted in the limited additional sampling that SCL conducted in October 2008 to validate the analysis of earlier sampling as presented in the Interim Report.

Field and laboratory water quality and media sampling results for water, sediment pore water, and sediment contained in this report have been used to characterize the chemical and physical conditions in the water fluctuation zone as well as the entire water storage volume and reservoir sediments of the Boundary Reservoir. In addition, these studies have informed an analysis as to any relationship between the chemical and physical conditions, and Project operations.

As indicated above, Phase 2 sampling took place in fall of 2007 and spring of 2008 with additional validation sampling in the fall of 2008. Based on the results of the entire 2007/2008 toxics dataset, SCL's conclusion is that there is no evidence of any nexus between Project operations and increased bioavailability of toxics in the Project area. The concentrations of toxics from water fluctuation zone sampling were either below detection limits or just at detectable concentrations. Sampling of the water fluctuation zone found no active recruitment of toxics from any portion of the reservoir. Toxics concentrations identified in isolated media (e.g., pore water, sediment or water column samples) indicated that localized sources outside of the reservoir were most likely responsible for the presence. In addition, ambient water chemistry inhibits the transfer of toxics.

2 STUDY OBJECTIVES

The following objectives were established in the FERC-approved Phase 2 SAP (SCL 2007b) and are based on the RSP.

Objective 1. Develop a SAP for toxics of concern that have been identified in the Phase 1 Toxics Assessment Report (Appendix 1 of the Phase 2 SAP [SCL 2007b]) as being potentially affected by Project operations.

Objective 2. Conduct field sampling and sample analyses.

Objective 3. Review new information from related studies such as one-dimensional hydraulic routing model results, and submerged mines analysis for potential contribution of toxics to surface water. In addition, also review information from three other studies conducted in 2007 that may be relevant to this Toxics Assessment: Study 8, Sediment Transport and Boundary Reservoir Tributary Delta Habitats Study (SCL 2009a); Study 7, the Mainstem Aquatic Habitat Modeling Study, hydraulic routing model component (SCL 2009b); and Study 1, the Erosion Study (SCL 2009c), to determine if additional Phase 2 sampling may be necessary or useful for evaluating Project operation impacts.

Objective 4. Conduct additional sampling as necessary, based on the results of the 2007 and early 2008 toxics sampling (Objective 2) and results of other ongoing studies (Objective 3).

Objective 1 was completed with FERC's approval of the Phase 2 SAP. Objectives 2 and 3 were completed with FERC's approval of the Interim Report and its plan for limited additional validation sampling. Objective 4 was completed through the October 2008 sampling effort pursuant to the Interim Report. This final report includes the data from the October 2008 sampling (Appendix 1), and provides a comprehensive analysis of the sampling effort conducted for the toxics assessment. It also validated conclusions regarding potential Project effects on the bioavailability of toxics.

2.1. Sampling Rationale

The following sections present the rationale and perspective for addressing the four study objectives through sampling of media in the Boundary Reservoir. The following sampling strategies were developed to test the relationships (hypotheses) between steps in toxicological and pathway models described in the Phase 1 Toxics Assessment Final Report (Appendix 1 to the Phase 2 SAP [SCL 2007b]). These steps represented the potential for toxics to move between sediment, pore water, and surface water (pathway models) in the Reservoir and the physical/chemical factors that promote this movement (toxicological models e.g., pH, hardness, dissolved organic carbon, and others). The broad survey of water, sediment, and pore water throughout Boundary Reservoir examines potential transfer mechanisms of toxics between media. During late fall 2007, water fluctuation zone sampling was conducted. In spring 2008, further characterizations included sediment, pore water, and water column profile sampling. Additional samples were collected in October 2008 at select sites throughout the Boundary Reservoir (sites 1, 5, 8, and 14 were revisited for more extensive sampling of sediments, pore water, and the water column). Sampling was conducted at the original sampling locations visited in March 2008, with additional collection both upstream and downstream of these locations wherever sampleable sediments were found (see results in Appendix 1). The sampling rationale and specific sampling plan described below, including sample locations, timing, and methods, are all detailed in the FERC-approved Phase 2 SAP and the FERC-approved Interim Report.

2.1.1. Water Fluctuation Zone Sampling Rationale

The water fluctuation zone surface water sampling was conducted to determine whether toxics entered the water column and resided in the surface or at depth (0.5 foot and 10 feet, respectively). Toxics entering the water column and residing in the water fluctuation zone could be related to water level fluctuations associated with Project operations. Sampling at the surface and at depth was expected to identify the potential for transfer of toxics from sediment in Boundary Reservoir to the surface water associated either with very fine particulates or with heavier sand-sized particles that may settle in deeper portions of the moving water mass.

The sampling was conducted on November 13–15, 2007, during low-water conditions to isolate the potential presence of toxics relative to the effects of Project operations as provided in the Phase 2 SAP. The fall was chosen for sampling instead of the spring to eliminate potential confounding effects on toxics transport from spring runoff. In summary, the water fluctuation zone characterizations determine the potential for toxics transfer from hydrosoils during pool elevation fluctuation.

2.1.2. Sediment Sampling Rationale

Sediment sampling was conducted on March 17–19, 2008, to characterize the longitudinal gradient of potential toxics concentrations. Sampling sediment at the 14 locations identified in the Phase 2 SAP (SCL 2007b) provided the following information: potential toxics sources based on proximity of mine and industrial sites, potential for migration of sediments from source to downstream locations, and the potential relationship to Project operations based on use of the hydraulic routing model and by use of the water fluctuation zone results. In summary, the sediment characterizations determine the presence of toxics as sources that can potentially migrate into pore water or be ingested as food by burrowing organisms. As provided in the Interim Report, additional sediment sampling was conducted at select sites in October 2008 to validate the analysis of earlier sampling results.

2.1.3. Pore Water Sampling Rationale

Pore water samples were collected on March 17–19, 2008, along with sediment samples. Pore water was collected at the seven sites identified in the Phase 2 SAP (2007b) that represented the greatest likelihood for the potential transfer of toxics (e.g., from sediment to pore water and from pore water to surface water, depending on the toxic). These seven locations were identified through careful examination of mine and industrial site factors and Project operation-related factors. These factors were identified as having the potential to enhance conveyance of toxics from sources or allow migration in the aquatic environment due to Project operation-related factors (e.g., physicochemical conditions identified in toxicological models; see the Phase 2 SAP, Appendix 7 [SCL 2007b]). In summary, the pore water sample sites were selected to determine the potential for transfer of toxics between sediments and surface water. As provided in the Interim Report, additional sediment pore water sampling was conducted at select sites in October 2008 to validate the analysis of earlier sampling results.

2.1.4. Water Column Profile Rationale

Sampling for characterization of the water column profile also occurred on March 17–19, 2008. The water column characterization represents a longitudinal profile of the Boundary Reservoir study reach. In conjunction with the water fluctuation zone sampling, the water column sampling provides a three-dimensional view of the water quality characteristics (e.g., horizontal channel location, longitudinal location in the study reach, and depth characterization) at select locations throughout the reservoir. As identified in the Phase 2 SAP (SCL 2007b), the influence of channel morphology and description of physicochemical conditions were tested by comparing differences between successive downstream stations. The differences included geologic setting, potential for influence of groundwater and unique water chemistry, hydrologic setting, and biological influences. These physicochemical and biological influences are key factors reported in the toxicological models that determine the movement of toxics between media, for example, from sediment to the water column or from the water to biota. In summary, the water column characterizations determine the potential for toxics transfer from sediments or from nearby sources including mine and industrial sites. As provided in the Interim Report, additional water column sampling was conducted at select sites in October 2008 to validate the analysis of earlier sampling results.

3 STUDY AREA

The study area encompassed Boundary Reservoir and adjacent potential source areas for toxics. The Boundary Reservoir study area is shown in Figure 3.0-1. For purposes of the Toxics Assessment Study, four zones have been identified:

- Upper Reservoir Zone—Box Canyon Dam to Sand Creek
- Metaline Falls Zone—Sand Creek to below Pend Oreille Mine
- Canyon Zone—below Pend Oreille Mine to above Pewee Creek
- Forebay Zone—above Pewee Creek to Boundary Dam

A detailed description of the zones is provided in the Phase 2 SAP (2007b) and in Table 3.0-1. General characterization of channel shape and topographic setting are used in addition to geographical landmarks that specifically identify dividing lines between zones. The reservoir zones are illustrated in Figure 3.0-2.

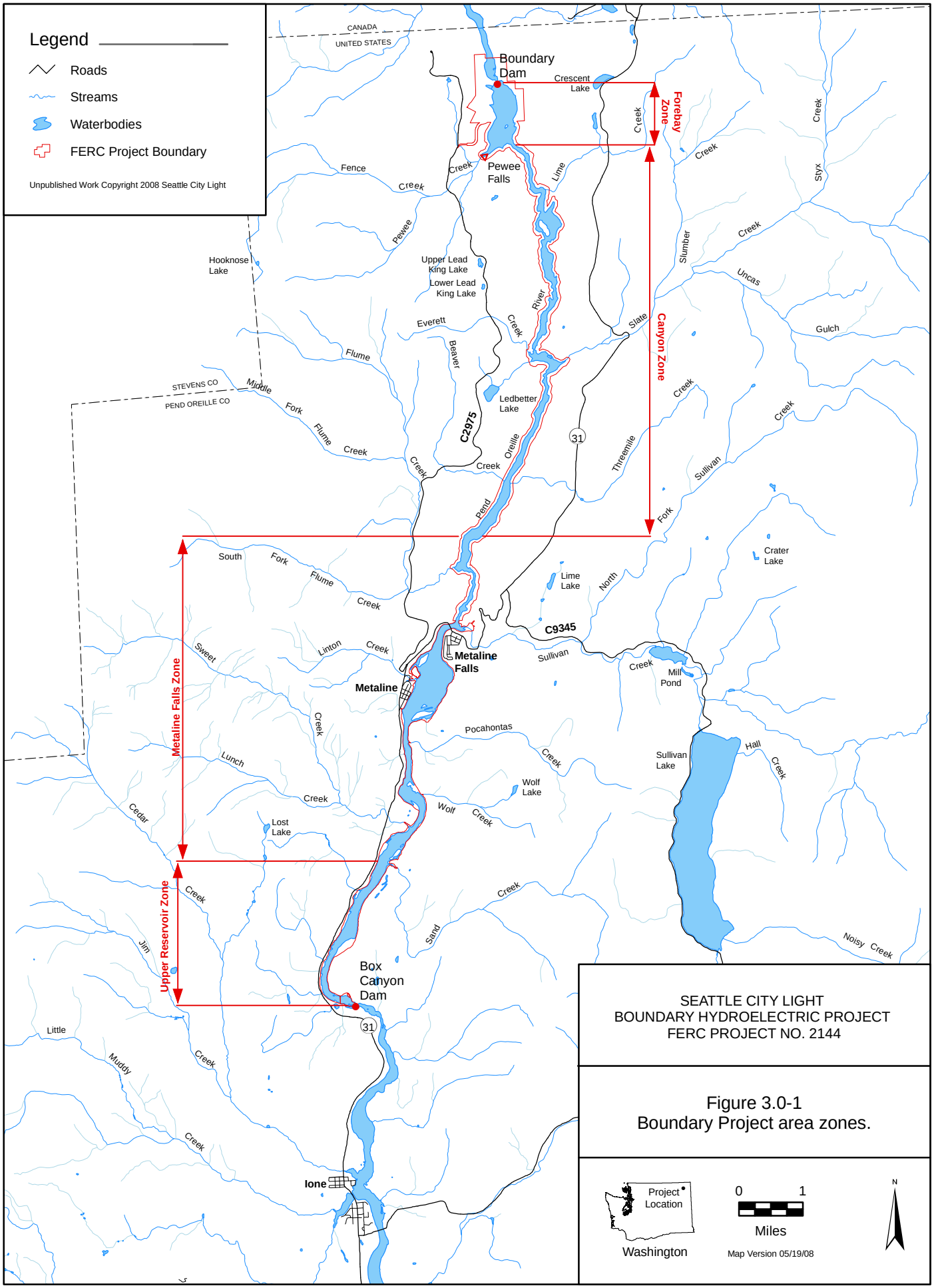


Figure 3.0-1
Boundary Project area zones.

Table 3.0-1. Project area zones for the toxics study.

General Characteristics of Zones
• ***Upper Reservoir Zone***: relatively shallow, gently sloping banks and landscape topography, some shoreline wetlands (extends from Box Canyon Dam downstream to below the confluence with Sand Creek)
• ***Metaline Falls Zone***: somewhat deeper, presence of aquatic vegetation, several potential mine influences; potential effects from the town of Metaline Falls; several relatively larger tributaries (below the confluence with Sand Creek to below the Pend Oreille Mine Site)
• ***Canyon Zone***: very steep sideslopes, narrow channel, some deep areas, select locations with higher current velocity (below the Pend Oreille Mine Site to above Pewee Creek)
• ***Forebay Zone***: lake-like, steep sideslopes, deep areas (above Pewee Creek to Boundary Dam)

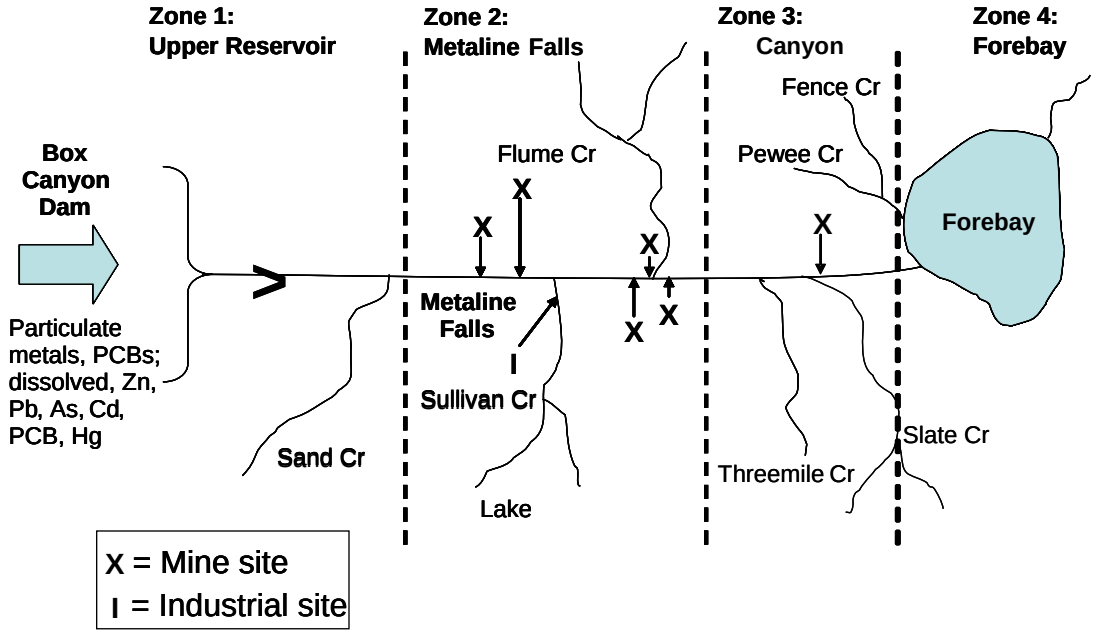


Figure 3.0-2. Spatial zonation of the Project area for toxics study.

4 METHODS

4.1. Sample Site Locations

Initial sampling effort occurred on November 13–15, 2007, and included surface water sampling in the water fluctuation zone of Boundary Reservoir. As provided in the Phase 2 SAP (2007b), sampling occurred at transects established at 7 of 14 sites for water fluctuation zone physicochemical characterization. Sampling was continued in late winter-early spring 2008 (March 17–19) to characterize the potential for toxics contamination in sediments, pore water, and in the water column throughout Boundary Reservoir. Following examination of March 2008 sampling data, it was determined in the Interim Report that additional sampling was warranted to verify select results and to investigate spatial extent of toxics presence at these sites. There were four sites re-visited (e.g., sites 1, 5, 8, and 14) during the October 2008 sampling effort and samples were analyzed for the same parameters and media (e.g., water column profile, sediment, and pore water) as in previous sampling events. Table 4.2-1 indicates the sampling strategy employed at each site, and the site locations for each of the sampling strategies established in the Phase 2 SAP are depicted on the aerial photographs that comprise Figure 4.1-1. Sampling locations for the October 2008 sampling effort are shown in Appendix 1, Figure 1.0-1.

4.1.1. Water Fluctuation Zone Locations

Sample sites were chosen based on proximity to known mine and industrial sites that have a potential to contribute contaminants to the water column (e.g., via repeated inundation and dewatering related to power generation at Boundary Dam). The sites for water fluctuation sampling are identified in Section 4.2.1 and shown in Figure 4.1-1.

Sites shown in Figure 4.1-1 represent pre-sampling approximations of locations and were definitively established with Global Positioning System (GPS) coordinates before actual field sampling began. The endpoints of transects were also established with GPS coordinates (all GPS coordinates are permanently stored with Tetra Tech).

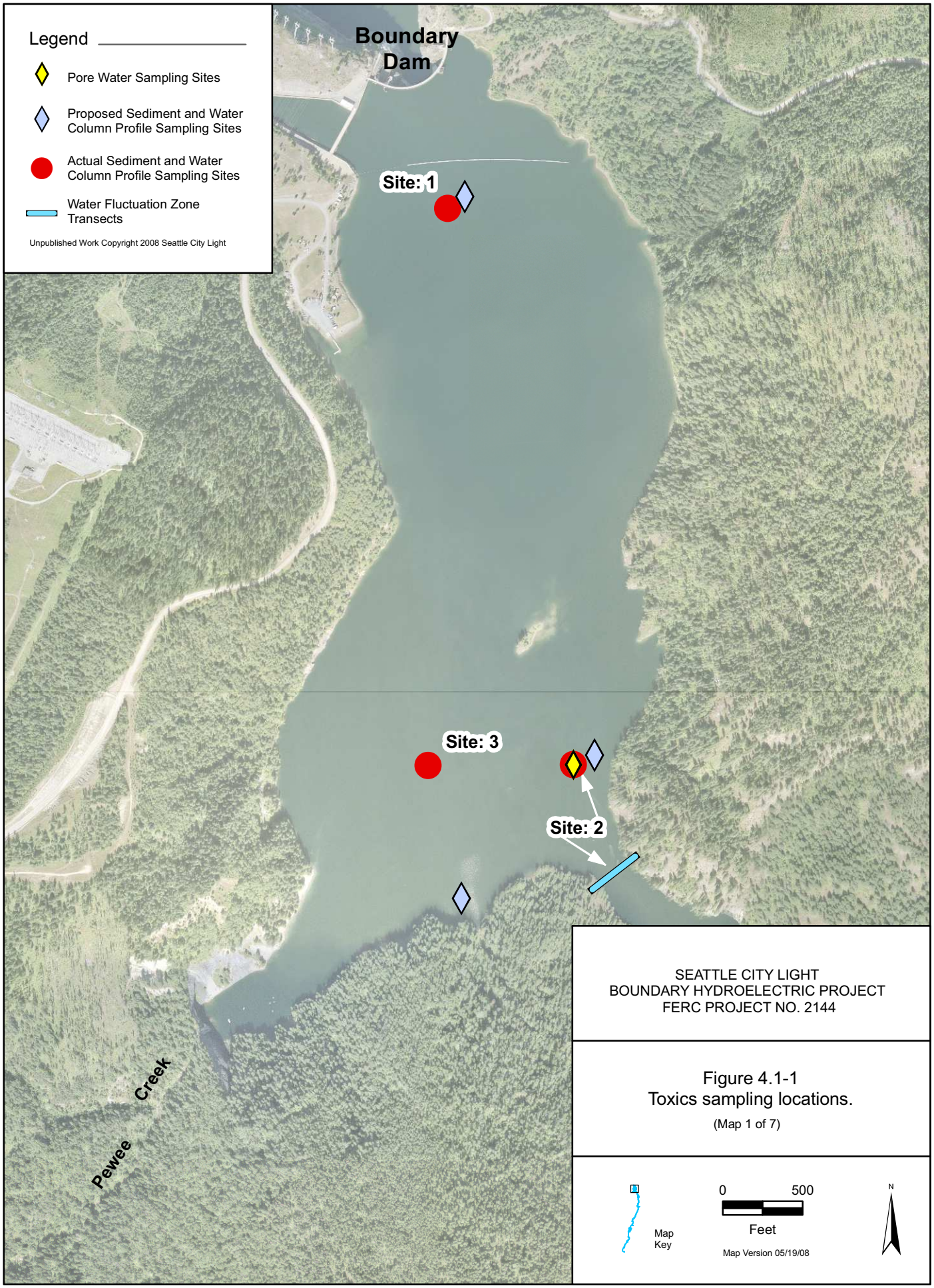
4.1.2. Sediment Sampling Locations

Sediment sampling was conducted at all 14 sites in March, 2008 to characterize the longitudinal gradient of potential concentrations (Figure 4.1-1). Sampling sediment at all 14 locations enabled identification of what the potential toxics sources are (e.g., based on proximity of mine and industrial sites), how sediments might migrate downstream, and how Project operations might relate to this migration, based on use of the hydraulic routing model and water fluctuation zone results.

Sediment samples in the Forebay Zone (Sites 1, 2, and 3) were collected from below the water fluctuation zone in the permanently wetted (deep water) area of Boundary Reservoir. Sampleable sediments in the Forebay Zone occurred in the permanently wetted areas. In addition, at sites 4 through 14, successful sediment collection efforts were accomplished within the water fluctuation zone. The search for sampleable sediments began at the locations identified in the Phase 2 SAP (SCL 2007b) and proceeded to likely locations for sediment deposition in the immediate vicinity. This procedure was facilitated by use of a detailed bathymetric map

prepared for use in the field at each sampling site. In some cases, several sediment collection attempts were made before samples meeting the criteria for retention were met (Appendix 2, Figure A.2b-1). The final location of sampleable sediments at each site was identified using a GPS unit.

Based on the Interim Report, additional sediment samples were collected in October 2008 at select sites throughout the Boundary Reservoir; these included sites 1, 5, 8, and 14 which were revisited for more extensive sampling of sediments. Sampling was conducted at the original sites visited in March 2008 with additional collection at locations both immediately upstream and downstream of these sites wherever sampleable sediments were found. Three replicate samples were collected from each of the downstream, original, and upstream locations (total of nine samples) at each site. Sediment sampling locations for the October 2008 sampling effort are shown in Appendix 1, Figures 1.0-1 through 1.0-4.


Legend
Pore Water Sampling Sites
Proposed Sediment and Water Column Profile Sampling Sites
Actual Sediment and Water Column Profile Sampling Sites
Water Fluctuation Zone Transects
Unpublished Work Copyright 2008 Seattle City Light
Boundary Dam
Site: 1
Site: 3
Site: 2
Pewee Creek
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 4.1-1
Toxics sampling locations.
(Map 1 of 7)
Map Key
0
500
Feet
Map Version 05/19/08
N

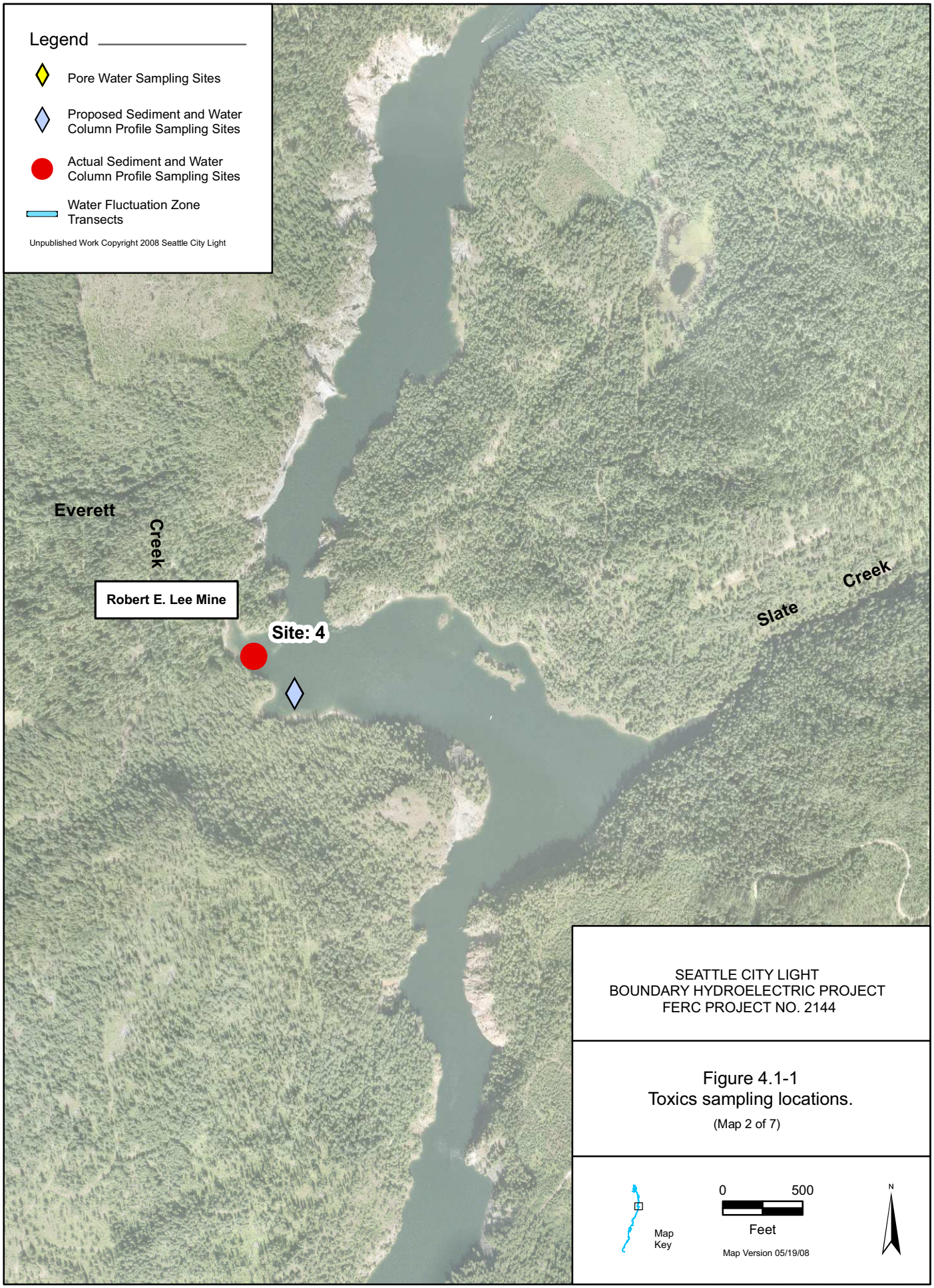

Legend
Pore Water Sampling Sites
Proposed Sediment and Water Column Profile Sampling Sites
Actual Sediment and Water Column Profile Sampling Sites
Water Fluctuation Zone Transects
Unpublished Work Copyright 2008 Seattle City Light
Everett
Creek
Robert E. Lee Mine
Site: 4
Slate
Creek
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
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Figure 4.1-1
Toxics sampling locations.
(Map 2 of 7)
Map Key
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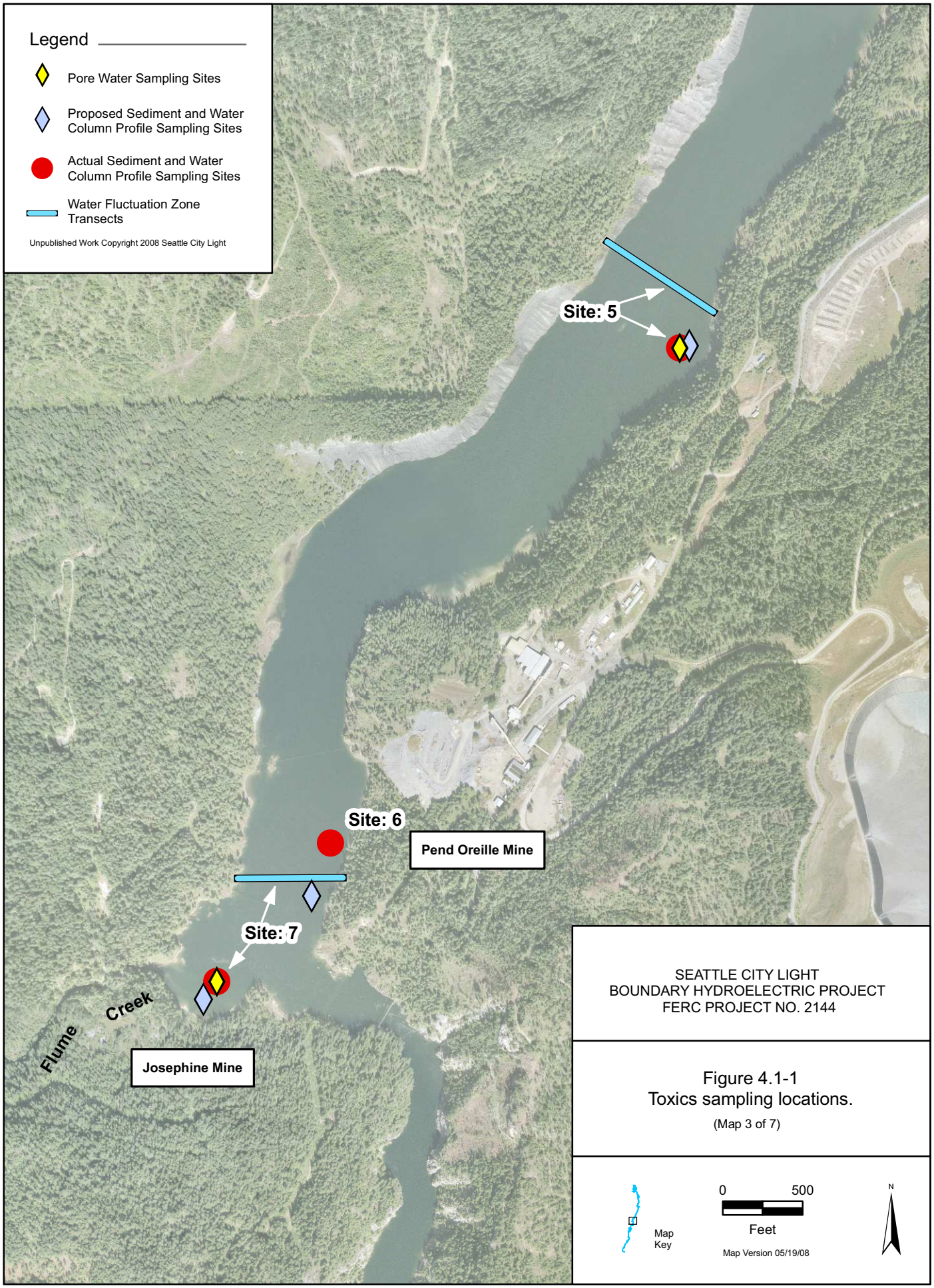
Legend
Pore Water Sampling Sites
Proposed Sediment and Water Column Profile Sampling Sites
Actual Sediment and Water Column Profile Sampling Sites
Water Fluctuation Zone Transects
Unpublished Work Copyright 2008 Seattle City Light
Site: 5
Site: 6
Pend Oreille Mine
Site: 7
Flume Creek
Josephine Mine
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 4.1-1
Toxics sampling locations.
(Map 3 of 7)
Map Key
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Feet
Map Version 05/19/08
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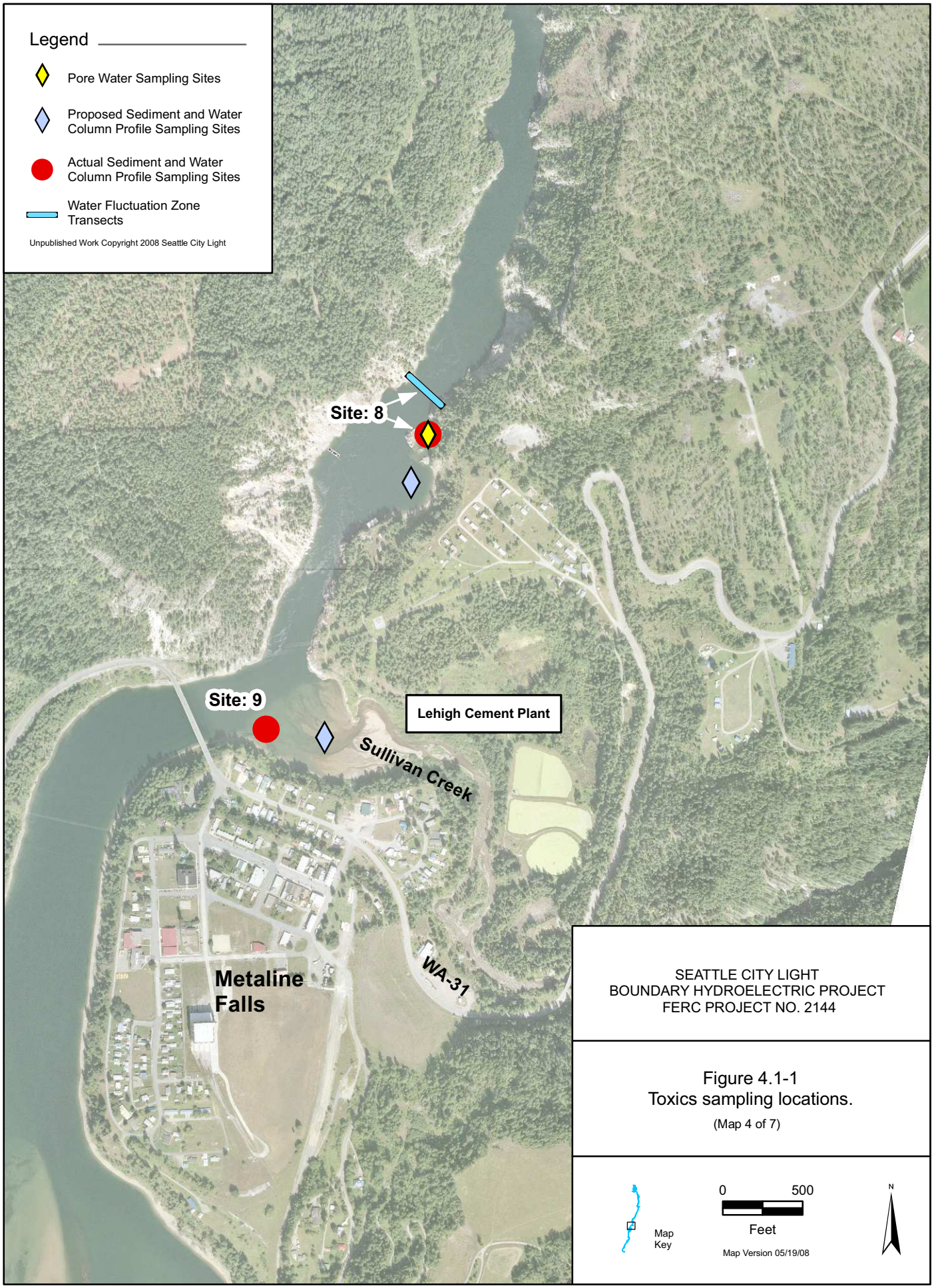

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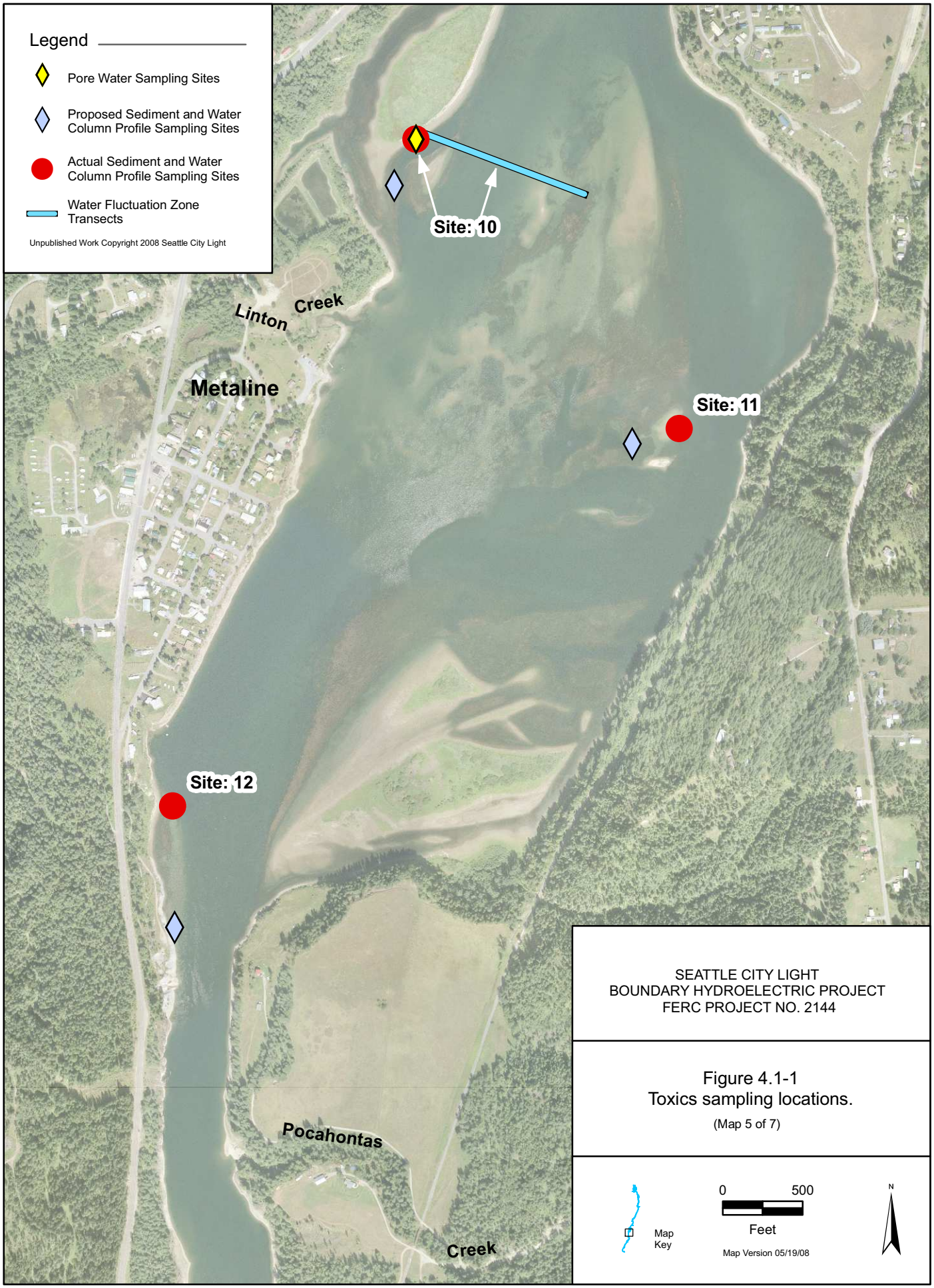
Figure 4.1-1
Toxics sampling locations.
(Map 4 of 7)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Pore Water Sampling Sites
Proposed Sediment and Water Column Profile Sampling Sites
Actual Sediment and Water Column Profile Sampling Sites
Water Fluctuation Zone Transects
Unpublished Work Copyright 2008 Seattle City Light
Site: 10
Linton Creek
Metaline
Site: 11
Site: 12
Pocahontas Creek
SEATTLE CITY LIGHT
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Figure 4.1-1
Toxics sampling locations.
(Map 5 of 7)
Map Key
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500
Feet
Map Version 05/19/08
N

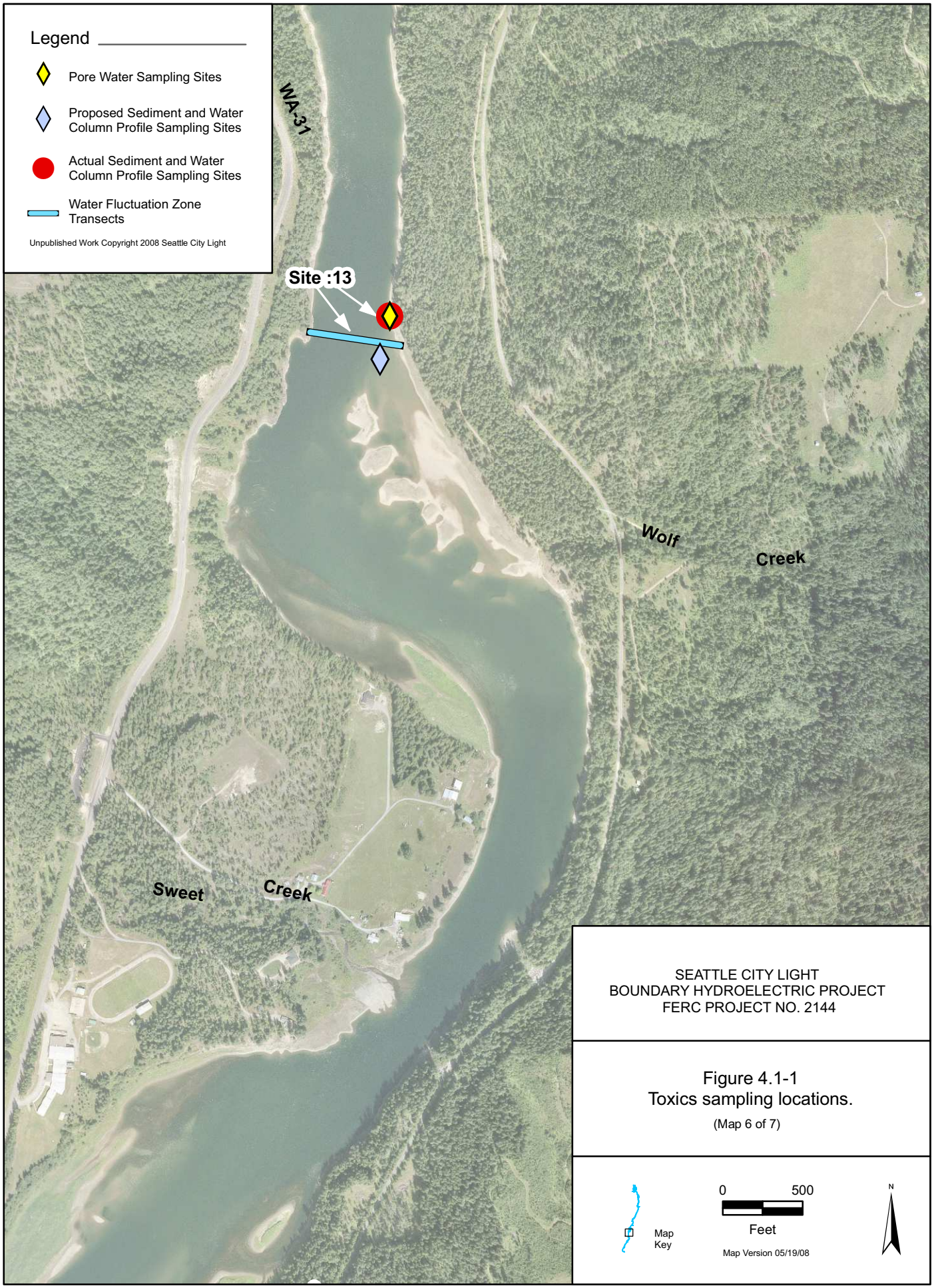

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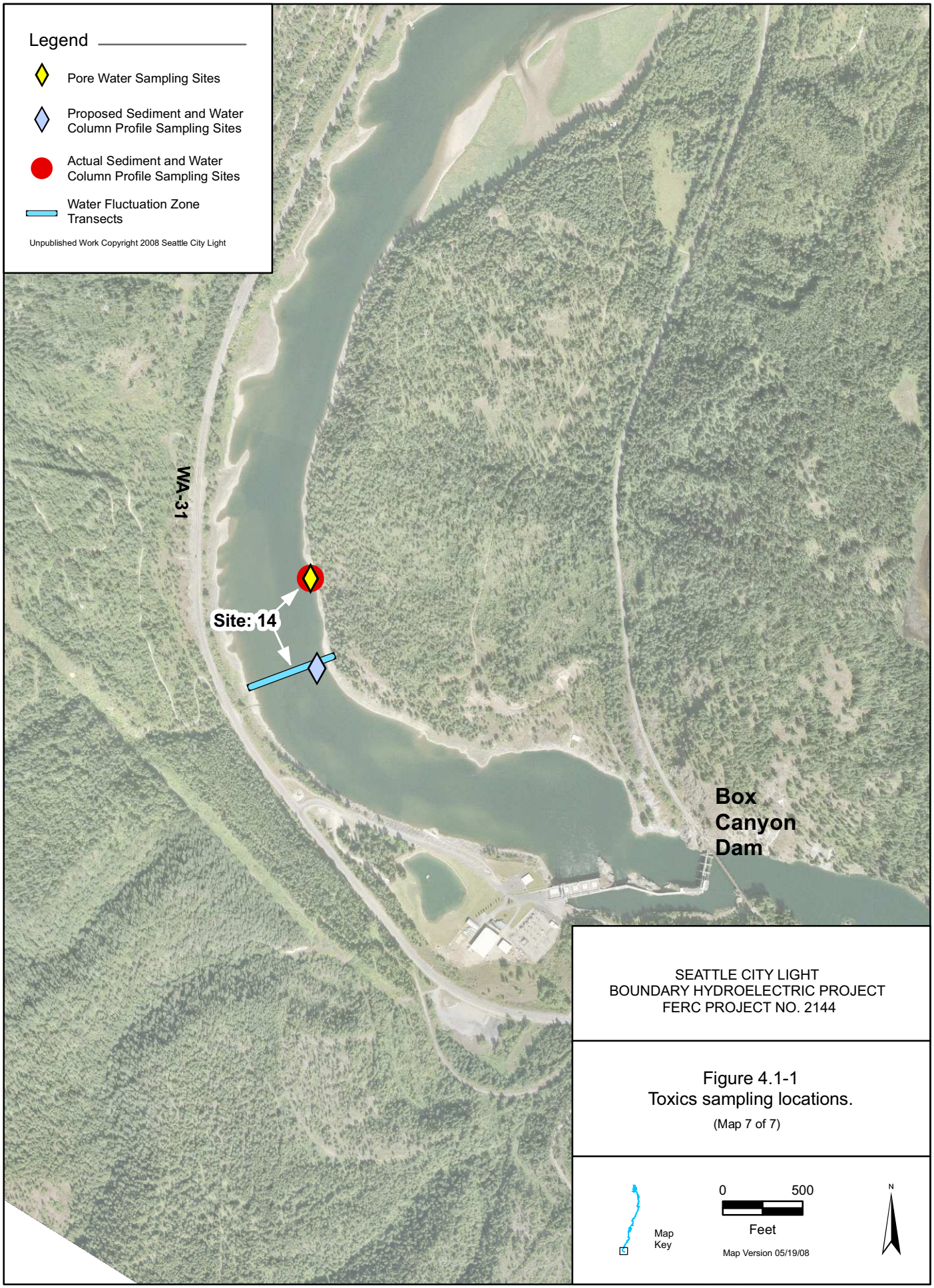
Figure 4.1-1
Toxics sampling locations.
(Map 6 of 7)



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FERC PROJECT NO. 2144

Figure 4.1-1
Toxics sampling locations.
(Map 7 of 7)

4.1.3. Pore Water Sampling Locations

Pore water samples were collected along with sediment samples in March, 2008 at the seven sites identified in the Phase 2 SAP (2007b) that represented the greatest likelihood for the potential transfer of toxics (Figure 4.1-1 and Table 4.2-1). This likelihood was identified through careful examination of mine and industrial site factors that would enhance conveyance of toxics from sources or allow migration in the aquatic environment due to Project operation-related factors (e.g., physicochemical conditions identified in toxicological models; see Phase 2 SAP, Appendix 1 [SCL 2007b]).

Based on the Interim Report, additional pore water samples were collected in October 2008 at select sites throughout the Boundary Reservoir; these included sites 1, 5, 8, and 14 that were revisited for more extensive sampling (Appendix 1). Sampling was conducted at the original sites visited in March 2008 with additional collection at locations both upstream and downstream of these sites wherever sampleable sediments were found. Three replicate samples were collected from each of the downstream, original, and upstream locations (total of nine samples) at each site. Pore water samples were taken at the same locations as the sediment samples discussed in Section 4.1.2.

4.1.4. Water Column Profile Sampling Locations

The water column profile characterization represents a longitudinal profile of the Boundary study area. Measuring surface water conditions longitudinally and at depth (i.e., surface, mid-depth, and near the bottom) accounted for general physicochemical conditions in shallow and deep water. A description of the continuum of surface water conditions at sites from the Box Canyon Tailrace to the Forebay Reach just upstream of Boundary Dam characterizes the factors that influence the bioavailability of toxics (Figure 4.1-1). Water quality conditions in each segment between two successive (adjacent) site locations (e.g., site 5 and site 6) along the Boundary Reservoir were further examined for natural and human influences that may cause changes in surface water characteristics. These physical and chemical influences are key factors reported in the toxicological models (see Phase 2 SAP, Appendix 1 [SCL 2007b]) that determine the movement of toxics between media (e.g., sediment-pore water exchange or sediment-surface water exchange).

Based on the Interim Report, additional water column samples were collected in October 2008 at select sites throughout the Boundary Reservoir; these included sites 1, 5, 8, and 14 that were revisited for more extensive sampling of the water column profile (Appendix 1). Water column sampling was conducted at the original sites visited in March 2008 with additional collection at locations both upstream and downstream of these sites in the same locations as sediment sampling. Three samples (surface, mid-column, and bottom) were collected from each of the downstream, original, and upstream locations (total of nine samples) at each site.

4.2. Sampling Methods

4.2.1. Water Fluctuation Zone Sampling

Surface water sampling in the water fluctuation zone (i.e., the normal fluctuation range for Project operations of 10 feet in the Reservoir) occurred on November 13–15, 2007. The

sampling strategy included establishing transects in the Water Fluctuation Zone column at the seven sites indicated in Table 4.2-1. Three locations along each transect were sampled for water quality characterization at the surface (i.e., within 0.5 foot) and at depth (i.e., at 10 feet). The sampling locations along each transect were located at distances of 25 percent, 50 percent, and 75 percent of river channel width. The sampling occurred when pool elevation was declining (verified using lake elevation trend records at the powerhouse control room and provided by the Dam Operator) in the reservoir, beginning downstream and proceeding upstream.

Surface water samples were collected within 0.5 foot of the surface and at a 10-foot depth, both depths reflecting the potential for toxics transport dynamics within a water fluctuation range associated with Project operations. Discrete samples were collected from specific depths using either: 1) a surface grab sample collected by hand, or 2) Tygon® tubing lowered to the 10-foot depth with an attached weight to keep the collection end vertical in the water column. Latex® gloves were used by field staff handling water samples to minimize contamination. Samples collected at depth used an automatic pump system and an anchor weight, clear surgical Tygon® tubing for the intake hose, a water pump, electrical connections, and a cable winch. Samples were collected in high density polyethylene (HDPE) sample bottles approved for use in collecting metals samples to minimize contamination for metals analysis. Upon each setup, the pump was run for a calculated period of time to flush the length of the hose system with the ambient water from the sample location. Each sample bottle was rinsed three times with water from the sample location before the sample was collected.

Table 4.2-1. Sample collection schedule at sites throughout the Boundary study area.

Sample Site Location	Depth Profile (Surface Water)	Sediment[1]	Pore Water[2]	Water Fluctuation Zone[3]
1[4]	✓	✓	✓[5]	
2	✓	✓	✓	✓
3	✓	✓		
4	✓	✓		
5[4]	✓	✓	✓	✓
6	✓	✓		
7	✓	✓	✓	✓
8[4]	✓	✓	✓	✓
9	✓	✓		
10	✓	✓	✓	✓
11	✓	✓		
12	✓	✓		
13	✓	✓	✓	✓
14[4]	✓	✓	✓	✓

Notes:
1 Three sediment samples collected from each site.
2 Three pore water samples were collected at selected sites and extracted from the sediment samples.
3 Samples collected during decreasing pool elevation; samples collected along a transect at 25%, 50%, and 75% of the width of the channel with two samples at each location, one at surface and one at 10 feet depth.
4 Site resampled in October 2008 for sediment, pore water, and water column characterizations.
5 Pore water analysis was conducted at site 1 during the October 2008 sampling event even though not previously analyzed during the November 2007 and March 2008 sampling events.

Water samples submitted to the laboratory for dissolved metals analyses were batched and filtered with a 0.45 micrometer (µm) membrane filter at the end of each field collection day. All collection vessels that came into contact with the water samples were HDPE bottles to minimize contamination. Samples were individually labeled and analyzed as described in the Phase 2 SAP (SCL 2007b).

In addition to surface water sample collection, temperature, conductivity, dissolved oxygen (DO), and pH were measured at four depth intervals in a vertical profile beginning with a surface measurement using a calibrated HydroLab®. The increased frequency of field measurements from those of the water quality samples provided a source for more detailed information to analyze the potential for bioavailability at either the surface or at depth.

4.2.2. Sediment Sampling

Surficial sediment sampling was conducted with a Van Veen sampler lowered from a boat by a power winch. This sampling device collected high quality sediment samples from the top 4 to 6 inches of sediment (EPA 2001). For most sediment types, the Van Veen sampler is better than other sampling devices for reducing sample loss from debris blockage. The Van Veen sampler also minimizes surrounding water disturbance as the device is lowered through the water column, and collects high quality samples (EPA 2001). The support frame enhances the versatility of the Van Veen sampler, with features allowing the addition of weights (to increase penetration in compact sediments) or pads (to provide added bearing support in extremely soft sediments) (EPA 2001). It is commonly used in national and regional sediment monitoring programs including the National Oceanic and Atmospheric Administration's National Status and Trends Program, the U.S. Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program, and the EPA National Estuary Program.

Three sediment samples were collected per visit at each of the sites sampled. These three samples were collected and analyzed separately to characterize the presence of metals and generate statistical summaries for site characterization. A photographic record of each sediment sample was assembled from images of newly collected material. At least one image for each sediment sample collected at a site was retained and permanently stored with Tetra Tech, Inc.

Sediment sample collection incorporated specific field methods that define high quality samples (from EPA 2001):

- Sampler is not overfilled with sediment.
- Overlying water is present when the sampler is retrieved.
- Overlying water is clear, not turbid.
- At least 2 inches of sediment depth is collected.
- There is no evidence of incomplete closure of the sampling device.

If a sediment sample did not meet all of the above criteria, it was discarded and another sample was collected. Acceptable sediment samples were processed in the following manner: the outside of the sampler was rinsed with surface water from the site and the overlying water present in the sampler was removed by siphoning using a clean plastic tube placed on one side of the sampling container. Remaining sediment was released carefully into a large bowl and slowly

homogenized using a Teflon® or plastic spoon. The sample was transferred to appropriate containers for shipping and laboratory chemical analysis.

Sediment samples were collected in March 2008 in shallow water areas of the Reservoir at sites 4 through 14. Some of the shallow water areas of the Reservoir can be dry during normal Project operations, but in all instances during this effort, sediment samples were collected from below water areas. At sites 1 through 3, sampling was conducted in deep water of the Forebay Zone in the Reservoir. The deep water sampling locations are permanently wetted during normal Project operations. October 2008 included sediment sampling at site 1 and site 5 at depths that were permanently wetted (e.g., deep water zones). Sediment samples collected at site 8 and site 14 during October 2008 were taken in areas that were inundated during the time of sampling, but site 8 is periodically above the pool surface elevation.

4.2.3. Pore Water Sampling

Sediment interstitial water, or pore water, is defined as the water occupying the space between sediment particles. Interstitial waters were collected from sites as indicated in Table 4.2-1 and separated from sediments in the field house laboratory using a pump apparatus to draw pore water from each of the replicate[1] samples. Filtering of samples used a 0.45 µm pore size filter in both the lab and field apparatus. In some cases, pore water was drawn from sediment samples in the field by using 100 milliliter (mL) syringes immersed in the dredge sample once a sediment sample was collected in a sample jar. These were cases where sediment samples had slightly coarser particle sizes and pore water extraction in the field was possible. In other instances, sediment samples had finer particle sizes requiring more time to draw samples for laboratory analysis; these samples were transferred to the field laboratory for pore water extraction.

4.2.4. Water Column Profile Sampling

Surface water was collected at all sampled sites near the surface, mid-depth, and within 3 feet of the sediment/water interface. A portion of each water sample was filtered on-site (0.45 µm membrane filter) for dissolved metal analysis. All collection vessels that came in contact with the water sample were constructed of HDPE to minimize metal contamination not associated with the sampled medium. Samples were individually labeled and analyzed as described in Section 7 of the Phase 2 SAP (SCL 2007b).

4.3. Water Quality Parameters

Water quality parameters were analyzed from samples collected during the water fluctuation zone sampling, sediment and pore water sampling, and water column profile characterization. The water samples were analyzed for total recoverable and dissolved metals fractions in surface water as well as parameters that either enhance or abate the potential toxicity. The water quality parameters sampled in surface water, sediment, and pore water are listed in Table 4.3-1.

[1] In accordance with standard practice, "replicate" is used in this report to refer to a repeated measure at the same location. Furthermore, the term refers to situations where multiple sediment and pore water samples were taken at the same sampling location. In regard to water column sampling, water samples were collected at individual levels in the water column (bottom, middle and surface); these are considered separate samples, and thus, are called "samples" for distinction.

Table 4.3-1. Summary of parameters measured at each sampling site.

Sampling Site	Surficial Sediment Metals, AVS, TOC, Particle Size	Surficial Sediment PCBs	Water Column Profile and Fluctuation Zone[1] total and dissolved metals, hardness, alkalinity, pH, DOC, turbidity, D.O., temp, conductivity, Redox	Interstitial (Pore) water dissolved metals, calcium, magnesium, hardness, pH, DOC, turbidity, SRP
1[2]	X		X	X
2	X	X	X[1]	X
3	X		X	
4	X	X	X	
5[2]	X		X[1]	X
6	X		X	
7	X	X	X[1]	X
8[2]	X		X[1]	X
9	X		X	
10	X		X[1]	X
11	X		X	
12	X		X	
13	X	X	X[1]	X
14[2]	X		X[1]	X

Notes:
1 Samples collected from Water Fluctuation Zone transects at these sites.
2 Site resampled in October 2008 for sediment, pore water, and water column characterizations.
AVS – acid volatile sulfide
DO – dissolved oxygen
DOC – dissolved organic carbon
PCB – polychlorinated biphenyl
TOC – total organic carbon

A HydroLab Datasonde 5 was used to measure temperature, pH, dissolved oxygen, conductivity, and redox potential. These parameters were instantaneous measurements collected at depth intervals at the water column profile locations and at four depth intervals at each of three transect locations per transect site (a maximum of four measurements beginning at the surface with equally spaced intervals to a depth of 10 feet). Additional analytes were measured as summarized in Tables 4.3-2 and 4.3-3. Details for quality assurance information can be found in the Final Phase 2 SAP (SCL 2007b).

Table 4.3-2. Preservation and holding times for the analysis of samples.

Analyte	Matrix	Container	Necessary Volume	Preservation and Filtration	Holding Time
Arsenic	Sediment	HDPE	200 g	<4° C	6 months
Cadmium	Sediment	HDPE	200 g	<4° C	6 months
Lead	Sediment	HDPE	200 g	<4° C	6 months
Mercury	Sediment	HDPE	200 g	<4° C	28 days
Zinc	Sediment	HDPE	200 g	<4° C	6 months
PCBs	Sediment	Glass Jar	200 g	<4° C	14 days
AVS	Sediment	Glass Jar	250 mL	2N $Zn(O_2CCH_3)_2$ 6N NaOH	7 days
Particle Size	Sediment	HDPE	100 g	NA	NA
TOC	Sediment	HDPE	1 L	<4° C	28 days
Arsenic	Water/Pore water	HDPE	600 mL	HNO_3 to pH < 2	6 months
Cadmium	Water/Pore water	HDPE	600 mL	HNO_3 to pH < 2	6 months
Lead	Water/Pore water	HDPE	600 mL	HNO_3 to pH < 2	6 months
Mercury	Water/Pore water	HDPE	600 mL	HNO_3 to pH < 2	28 days
Zinc	Water/Pore water	HDPE	600 mL	HNO_3 to pH < 2	6 months
Turbidity	Water	HDPE	2 L	<4° C	7 days
Alkalinity	Water/Pore Water	HDPE	250 mL	<4° C	7 days
Hardness	Water/Pore Water	HDPE	250 mL	<4° C	7 days
DOC	Water/Pore Water	HDPE	1 L	<4° C	28 days
SRP	Pore Water	HDPE	250 mL	Filter within 12 hours, cool to <4° C	48 hours

Notes:
AVS – acid volatile sulfide
DOC – dissolved organic carbon
g – gram
HDPE – high density polyethylene
L – liter
mL – milliliter
NA – not applicable

Once samples were collected and stored in containers they were sent via courier to the accredited contract laboratory (Aquatic Research Incorporated, Seattle, Washington) for analysis. Table 4.3-3 provides details regarding sample analysis and describes the dissolved and total recoverable fractions of reporting for each of the toxics. Quality assurance results from each of the sampling strategies are found in Appendix 3.

Table 4.3-3. Measurement methods for laboratory analysis of surface water, pore water, and sediment samples.

Analyte	Sample Matrix	Number of Samples	Expected Range of Results	Method Detection Limit (MDL)	Reporting Limit (RL)	Sample Prep Method	Analytical (Instrumental) Method
WATER/PORE WATER							
Arsenic	Water	100	RL to 10 µg/L	0.4 µg/L	1.0 µg/L (direct analysis)[1] 1.0 µg/L (total recoverable analysis)[1]	**Dissolved:** filtration. **Total Recoverable**: acid digestion/ extraction	EPA 200.8
Cadmium	Water	100	RL to 10 µg/L	0.1 µg/L	0.2 µg/L (direct analysis)[1] 0.2 µg/L (total recoverable analysis)[1]	**Dissolved:** filtration. **Total Recoverable**: acid digestion/ extraction	SM3113B
Lead	Water	100	RL to 100 µg/L	0.2 µg/L	0.2 µg/L (direct analysis)[1] 0.2 µg/L (total recoverable analysis)[1]	**Dissolved:** filtration. **Total Recoverable**: acid digestion/ extraction	EPA 200.8
Mercury	Water	100	RL to 6 µg/L	0.00002 µg/L	0.0002 µg/L[2]	For soluble mercury – filter for dissolved mercury	EPA 1631
Zinc	Water	100	RL to 212 µg/L	3.0 µg/L	5.0 µg/L (direct analysis) 5.0 µg/L (total recoverable analysis)[1]	**Dissolved:** filtration. **Total Recoverable**: acid digestion/ extraction	EPA 200.7
Dissolved Organic Carbon	Water	100	RL to 10 mg/L	0.100 mg/L	0.250 mg/L[3]	Filtration in field or by 48 hrs; removal of inorganic carbon	EPA 415.1
Alkalinity	Water	100	RL to 100 mg/L	1.00 mg/L	1.00 mg/L	None	EPA 310.1
Hardness	Water	100	RL to 100 mg/L	1.00 mg/L	2.00 mg/L	None	Standard Methods 2340C[3]

Table 4.3-3, continued…

Analyte	Sample Matrix	Number of Samples	Expected Range of Results	Method Detection Limit (MDL)	Reporting Limit (RL)	Sample Prep Method	Analytical (Instrumental) Method
Soluble Reactive Phosphorus (SRP)	Water	100		1.0 µg/L	1.0 µg/L	0.45µm filtration	EPA 365.1
Dissolved Oxygen (DO)[4]	Water	100	RL to 12 mg/L		<0.1 mg DO/L	None	Standard Methods 4500-O G[3]
pH [4]	Water	100	pH 3-9		pH<1	None	Standard Methods 4500-H^{+}[3]
Temperature[4]	Water	100	0-30 ^{0}C		32°C	None	Standard Methods 2550B[3]
Conductivity[4]	Water	100	RL to 200 µ siemens/ cm		1 Microsiemens /cm[5]	None	USGS NFM 6.3.3A-SW
Redox Potential	Water	100	-400 to +400 mV		25-50 mV	None	
Turbidity	Water	100	RL to 40 NTU	0.1 NTU	0.1 NTU	None	EPA Method 180.1
SEDIMENT							
Arsenic	Sediment	30	Not known	Varies based on volume of sample analyzed.	3.0 mg/kg (total recoverable analysis)[1]	**Total Recoverable:** acid digestion/ extraction	EPA 200.7
Cadmium	Sediment	30	Not known	Varies based on volume of sample analyzed.	1.0 mg/kg (total recoverable analysis)[1]	**Total Recoverable:** acid digestion/ extraction	EPA 200.7
Lead	Sediment	30	Not known	Varies based on volume of sample analyzed.	1.5 mg/kg (total recoverable analysis)[1]	**Total Recoverable:** acid digestion/ extraction	EPA 200.7
Mercury	Sediment	30	Not known	Varies based on volume of sample analyzed.	0.1 mg/Kg (CRDL)[7]	Digestion with aqua regia, followed by addition of potassium permanganate and further digestion	EPA 245.2
Zinc	Sediment	30	Not known	Varies based on volume of sample analyzed.	3.5 mg/kg (total recoverable analysis)[1]	**Total Recoverable**: acid digestion/ extraction	EPA 200.7

Table 4.3-3, continued…

Analyte	Sample Matrix	Number of Samples	Expected Range of Results	Method Detection Limit (MDL)	Reporting Limit (RL)	Sample Prep Method	Analytical (Instrumental) Method
PCBs (Aroclors: 1016, 1221, 1232, 1242, 1248, 1254, 1260)	Sediment	30	Not known	Varies based on volume of sample analyzed.	50-70 µg/kg	Solid samples extracted with hexane-acetone or methylene chloride-acetone	SW-846 Method 8082
AVS	Sediment	30	Not known	Varies based on volume of sample analyzed.	0.2 mg/kg	Acid-soluble samples – sulfuric acid, heat; Acid-insoluble samples – hydrochloric acid and agitation, w/tin (II) present	EPA 9030B [6]
Particle Size	Sediment	30	Not known				Standard Method 2540G[3]
Total Organic Carbon (TOC)	Sediment	30	Not known		200 mg/kg (CRDL)[7]	Homogenization of sample, followed by acidification and drying	EPA SW-846 Method 9060

Notes:

1 For EPA Method 200.8 analytes in water and in solids, the reporting limits (RLs) are 5 times the method detection limits specified in the method. The RLs for analytes in water were determined by selection ion monitoring, whereas the analytes in solids were determined in a scanning mode – see table 7 in the method.

2 EPA Method 1631 has a reporting limit of 0.5 ng/L. This extremely low level is not deemed necessary for this investigation.

3 All Standard Methods are from Eaton et al. (2005).

4 This is a field measurement.

5 Cell chosen, based on anticipated conductance will determine reporting limit.

6 Method provides semi-quantitative determination of sulfide comments considered "acid insoluble" in Solid sample (e.g., CuS and SnS_2).

7 Expressed in method as Contract Required Detection Limit (CRDL).

AVS – acid volatile sulfide
µg/L – microgram per liter
mg/kg – milligram per kilogram
NTU – nephelometric turbidity unit
µg/kg – microgram per kilogram
mg/L – milligram per liter
mV – millivolt
PCB – polychlorinated biphenyl

5 SUMMARY AND ASSESSMENT OF RESULTS

Water quality, sediment, and pore water samples were collected to generate a three-dimensional characterization of sampling sites throughout the Boundary Reservoir study reach. The initial step in water quality sampling of the reservoir determined whether toxics were directly entering the water column, where the potential for toxics entry occurs, and whether the toxics are entrained into the water column and carried to other locations. In addition, results from surface water sampling were used to determine if any direct toxic effects are available to Boundary

Reservoir biota in the surface water portion of identified pathways (see Phase 1 Toxics Assessment in SCL [2007b]). Sampling sediment at all fourteen locations enabled identification of potential sources of toxics (e.g., based on proximity of mine and industrial sites), potential for migration of sediments from source to downstream locations, and potential relationship to Project operations. Pore water was collected along with sediment samples at seven sites that represented the greatest likelihood for the potential transfer of toxics. Pore water can convey toxics from sediments to surface water, where toxics have the potential to be bioavailable in dissolved form.

The overall goal of Phase 2 of the Toxics Assessment (2007b), and the resulting three-dimensional characterization, was to determine if additional sampling, including biota sampling, was warranted and to assess potential Project effects on toxics bioavailability. The Interim Report addressed the question of additional sampling and provided initial conclusions regarding potential Project effects, subject to validation through the October 2008 sampling effort. SCL completed the October 2008 sampling as provided in the Interim Report, and the following sections reflect that effort and provide the final validated conclusions regarding potential Project effects on toxics bioavailability.

5.1. Water Fluctuation Zone

Conditions in the water fluctuation zone (i.e., top 10 feet of the reservoir) were examined for the presence of toxics. In addition, general water quality conditions were evaluated for the potential to make toxics bioavailable to resident aquatic life. This sampling strategy determined whether toxics were drawn from the Boundary Reservoir banks in part as the result of water fluctuation, were entrained in the upper water column of the Boundary Reservoir, and moved downstream.

Data were analyzed by characterizing a three-dimensional view of the upper water column of the Reservoir (0.5-foot to 10-foot depth from surface). Surface water toxics data were compared between successive downstream transects; an increase between two points would indicate a toxics source. Toxics data were also examined at locations across each transect to identify the shape of any plumes, if present. Finally, toxics data were examined at depth along each transect to identify where contaminants, if any, may be settling in the water column. This enabled further examination of potential toxics settling zones from information predicted by the one-dimensional hydraulic model. Results for water fluctuation zone sampling are found in Appendix 4.

5.1.1. Verification and Validation of Data Quality Elements

Data were evaluated for quality and usability by verification and validation procedures outlined in the Phase 2 SAP (SCL 2007b). Specific procedures for this evaluation are described in Section 11 of the Phase 2 SAP and include decision-making elements established in Section 4 of the Data Quality Objectives and Decisions Criteria (SCL 2007b). Laboratory performance results were compared against measurement quality objectives for the water fluctuation zone samples (reported in Appendix 3 and are summarized in Table 5.1-1). Data quality objectives that pass expectations originally described in the Phase 2 SAP are indicated by a check mark. Any qualifiers for data quality objectives are noted in the table.

Table 5.1-1. Summary of data quality objectives that meet field and laboratory performance expectations.

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Samples RPD	Matrix Spikes % Recovery Limits	Required Reporting Limit
Arsenic	Water	♦	✓	✓	✓
Cadmium	Water	♦	✓	✓	✓
Lead	Water	✓	✓	✓	✓
Mercury	Water	✓	✓	✓	✓
Zinc	Water	✓	✓	✓	✓
Dissolved Organic Carbon	Water	✓	✓	✓	✓
Alkalinity	Water	✓	NA	✓	✓
Hardness	Water	✓	NA	✓	✓
Dissolved Oxygen	Water	✓	NA	✓	✓
pH	Water	✓	NA	✓	✓
Temperature	Water	✓	NA	✓	✓
Conductivity	Water	✓	NA	✓	✓
Turbidity	Water	✓	✓	✓	✓

Notes:
LCS – laboratory control sample
NA – not applicable
RPD – relative percent difference
♦ – <3% lower recovery than minimum expected for this analyte (blank samples are clean so does not affect concentration estimates); laboratory performance may have slightly underestimated concentrations for these elements in surface water samples.

5.1.2. Analytical Results from Water Fluctuation Zone Sites

Concentrations for dissolved toxics from the water fluctuation zone sites are summarized in Table 5.1-2. The data summaries include all observations made from each of the site transects (e.g., three locations on each transect and two depths—surface and 10 feet—for metals samples). When a range for concentrations is included at a transect site, the second expression indicates the presence of a detectable dissolved metal concentration. Chronic and acute criteria are included at the bottom of the table for each of the metals (Ecology 2006). Complete results for dissolved toxics sampling are provided in Appendix 4, Table A.4-3.

Approximately 84 percent of the water fluctuation zone transects resulted in non-detectable concentrations for dissolved toxics (indicated by a "<" symbol in Table 5.1-2). In all cases where there were detectable concentrations, the observed concentrations were well below relevant criteria, meaning that there would be neither chronic nor acute effects from trace concentrations of metals.

This indicates that Project operations do not mobilize toxics or make them bioavailable. Further, the detectable concentrations were much lower than chronic or acute criteria for each of the

metals (see bottom of Table 5.1-2) and Project operations do not influence metals concentrations in the water fluctuation zone.

Table 5.1-2. Range of results for dissolved concentrations of toxics from water fluctuation zone sites in Boundary Reservoir.

Site No.	Arsenic (µg/L)	Cadmium (µg/L)	Mercury (µg/L)	Zinc (µg/L)	Lead (µg/L)
2	< 1.0 – 1.2	< 0.20	< 0.002	< 5.0	< 0.20
5	< 1.0 – 1.0	< 0.20	< 0.002	< 5.0 – 6.0	< 0.20
7	< 1.0 – 1.2	< 0.20	< 0.002	< 5.0	< 0.20
8	< 1.0 – 1.0	< 0.20	< 0.002	< 5.0	< 0.20
10	< 1.0 – 1.0	< 0.20	< 0.002	< 5.0	< 0.20
13	< 1.0 – 1.1	< 0.20	< 0.002	< 5.0	< 0.20
14	1.1 – 1.2	< 0.20	< 0.002	< 5.0 – 5.0	< 0.20
Chronic Criteria (µg/L)	190	1.03	N/A	86.5	2
Acute Criteria (µg/L)	360	3.7	2.1	94.7	51

Notes:
µg/L – microgram per liter
N/A – criteria not available

Again, a large proportion—approximately 72 percent—of the water quality observations for total recoverable toxics from each transect resulted in non-detectable concentrations. There are no criteria for determining potential effects from total recoverable metals because this form is not bioavailable, and therefore, is not toxic to aquatic biota. Detectable concentrations of total recoverable metals were so low in water fluctuation zone sampling that they were equal to the concentrations measured for the dissolved fraction.

The very low concentrations of total recoverable metals at sampling locations suggest that there is little to no reserve of metals that exists and becomes bioavailable from the water fluctuation zone. Bioavailability depends on specific factors (e.g., pH, hardness, dissolved organic carbon, and others) that promote transition of a total recoverable metal to the dissolved form; as the current characterization of the water fluctuation zone indicates, these factors do not promote this transition.

Concentrations for total recoverable toxics from the water fluctuation zone sites are summarized in Table 5.1-3. The data summaries include all observations made from each of the site transects (e.g., three locations on each transect and two depths—surface and 10 feet). When a range for concentrations is included at a transect site the second expression indicates the presence of a detectable dissolved metal concentration. Complete results for dissolved toxics sampling are provided in Appendix 4, Table A.4-4.

Table 5.1-3. Range of results for total recoverable concentrations of toxics from water fluctuation zone sites in Boundary Reservoir.

Site No.	Arsenic (µg/L)	Cadmium (µg/L)	Mercury (µg/L)	Zinc (µg/L)	Lead (µg/L)
2	<1.0 – 1.2	< 0.20	< 0.002	< 5.0	< 0.20 – 0.23
5	1.1 – 1.3	< 0.20	< 0.002	< 5.0 – 6.0	< 0.20
7	1.1 – 1.2	< 0.20	< 0.002	< 5.0	< 0.20 – 0.54
8	1.0 – 1.2	< 0.20	< 0.002	< 5.0 – 6.0	< 0.20
10	< 1.0 – 1.2	< 0.20	< 0.002	< 5.0 – 5.0	< 0.20
13	1.1 – 1.3	< 0.20	< 0.002	< 5.0 – 5.0	< 0.20
14	1.0 – 1.1	< 0.20	< 0.002	< 5.0 – 6.0	< 0.20

Note:
µg/L – microgram per liter
Note: There are no chronic or acute criteria for total recoverable metals.

Field parameters were recorded at each of the three transect locations with a HydroLab instrument and measurements were made at four equidistant depths, beginning at the surface and extending to a 10-foot depth. Field parameters (Table 5.1-4) showed uniformity at depth (from surface to 10 feet) and among all sampling locations throughout the Reservoir. In some cases, the difference among measurements at depth intervals at a single site showed a difference as small as the margin for error of the instrument (e.g., pH <1 or dissolved oxygen <0.1) as reported in Table 5.1-4 at sampling locations 2 and 14.

The data summaries include all observations made from each of the site transects (e.g., three locations on each transect and four depths—surface, 3.3 feet, 6.6 feet, and 10 feet) (Table 5.1-4). Range of observations measured at each transect and for each parameter showed low variability from surface to 10-foot depths. The well-oxygenated surface water and high pH measurements were consistent from both lower and upper reservoir transects. Complete results for dissolved toxics sampling are provided in Appendix 4, Table A.4-1.

Table 5.1-4. Range of results for field parameters collected from water fluctuation zone sites in Boundary Reservoir.

Site No.	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (µmhos/cm)	Redox (mV)
2	7.8 – 7.9	10.8 – 10.9	8.08 – 8.18	162 – 163	379 – 411
5	7.5 – 7.6	10.8 – 11.2	7.99 – 8.07	161 – 162	395 – 400
7	7.5	10.7 – 11.2	7.98 – 8.07	162 – 163	392 – 401
8	7.5 – 7.6	10.7 – 11.2	8.00 – 8.09	162 – 163	392 – 420
10	7.3	11.0 – 11.5	7.95 – 8.08	165	459 – 467
13	7.3	11.0 – 11.2	7.97 – 8.04	165	453 – 466
14	7.3	11.0 – 11.1	7.97 – 8.05	165	465 – 474

Notes:
µmhos/cm – micromhos centimeter
mg/L – milligram per liter
mV – millivolt

Concentrations for general chemistry parameters from the water fluctuation zone sites are summarized in Table 5.1-5. The data summaries include all observations made from each of the site transects (e.g., three locations on each transect and two depths—surface and 10 feet). Range of observations measured at each transect and for each parameter showed low variability from surface and 10-foot depths. Turbidity and dissolved organic carbon (DOC) measurements were low at all sites. Concentrations of DOC were uniform throughout the Reservoir from below Box Canyon Tailrace to the sampling location at Boundary Dam. Water quality characteristics that tend to diminish toxicity of metals through binding with dissolved ions in freshwater (e.g., hardness and alkalinity) were found in moderate concentrations. Moderate to high levels of one or more of these parameters indicate the potential to bind and remove dissolved metals from the water column and reduce the potential for biological effects. Complete results for dissolved toxics sampling are provided in Appendix 4, Table A.4-2.

Table 5.1-5. Range of results for general chemistry concentrations and measurements collected from water fluctuation zone sites in Boundary Reservoir.

Site No.	Turbidity (NTU)	Alkalinity (mg $CaCO_3$/L)	DOC (mg/L)	Hardness (mg $CaCO_3$/L)
2	0.30 – 0.34	79.9 – 80.3	1.11 – 1.27	75.8 – 77.8
5	0.27 – 0.34	78.5 – 80.2	1.14 – 1.63	75.8 – 77.8
7	0.31 – 0.38	79.4 – 79.8	1.15 – 1.55	75.8 – 78.0
8	0.26 – 0.36	79.8 – 81.0	1.23 – 1.37	75.2 – 77.0
10	0.31 – 0.41	80.2 – 81.4	1.20 – 1.32	75.4 – 77.2
13	0.28 – 0.31	79.8 – 81.5	1.17 – 1.67	75.8 – 78.0
14	0.23 – 0.31	79.7 – 81.0	1.18 – 1.68	76.4 – 78.8

Notes:
$CaCO_3$ – calcium carbonate
mg/L – milligram per liter
NTU – nephelometric turbidity unit

5.1.3. Hypothesis Testing: Water Fluctuation Zone and the Toxicological Models

Factors affecting mobilization of toxics between media were originally outlined in toxicological models developed for the Phase 1 Toxics Assessment Report in Appendix 1 to the Phase 2 SAP (SCL 2007b). Field parameters and general chemistry results were selected to evaluate those factors that would promote the potential for bioavailability of the toxics. The following toxicological models presented the basis for hypothesis development and are tested here by comparing results from the water fluctuation zone sampling from March 2008 with variables highlighted in each of the presented figures. Based on examination of toxicological models and routes of exposure to biota, predictions were made in Table 5.1-6 that state which media (e.g., sediment, water, or food) may be likely to present a risk of bioaccumulation.

Table 5.1-6. Potential sources, bioaccumulation potential, major factors affecting bioavailability, and routes of exposure for each toxic of concern.

Contaminant of Concern	Potential Sources	Bioaccumulation Potential	Critical Factors Affecting Bioaccumulation/Toxicity Potential	Route of Exposure		
				Sediment	Water	Food
Zinc	Mining, Upstream	Low	**Sediment Redox Potential (AVS/SEM)**, **Organic matter concentration/DOC**, **Water hardness**; **Water DOC; Sediment particle size; Suspended solids**; pH; Temperature	Low	**High**	Low
Cadmium	Mining, Upstream	Low-Med	**Sediment Redox Potential (AVS/SEM)**; **Water hardness**; **Water DOC; Sediment particle size; Suspended Solids;** pH; Chloride; Temperature	**High**	Med	Med
Lead	Mining, Upstream	Low-Med	**Sediment redox potential (AVS/SEM)**; **Organic matter concentration/DOC**; **Water hardness**; **Suspended solids**; **Sediment particle size**; pH; Temperature	**High**	Med	Med
Mercury	Mining, Atmospheric, Upstream	High	**Aquatic vegetation**; **Sediment redox potential (AVS/SEM)**; **Organic matter concentration/ DOC;** Nutrients; Temperature; Microbial respiration; pH; Selenium concentration	**High**	Low	**High**
Arsenic	Mining, Upstream	Med	**Sediment redox potential (AVS/SEM)**; **pH**; **Suspended solids; Sediment particle size;** Microbial respiration; Nitrification	Med	Med	Med
PCBs	Upstream, Atmospheric	High	**Sediment redox potential**; **Organic matter concentration/DOC**; **Suspended solids**, **PCB chlorination/weight; Sediment particle size**	**High**	Low	**High**

Notes:
Critical factors in **bold** are often the most important factors affecting bioavailability for that toxicant.
AVS – acid volatile sulfide
DOC – dissolved organic carbon
PCB – polychlorinated biphenyl
SEM – simultaneously extracted metals

5.1.4. Potential for Bioavailability of Zinc in the Water Fluctuation Zone

The study indicates that while zinc was observed in the water fluctuation zone at low levels, all observations were below water quality criteria. Further, observed water chemistry limits bioavailability of the zinc that is present. The exposure risk of aquatic biota to zinc and the

likelihood of bioaccumulation are greatest in surface water (as opposed to sediment or pore water). Important factors with the potential to promote zinc bioavailability in surface water are low hardness, low DOC, and low suspended material (see the water column portion of Figure 5.1-1). One or more of these factors can limit bioavailability and control effects to biota. Of these three factors, hardness in all samples was consistently high at all transects, while zinc concentrations were consistently low (more than 10 times below criteria) at surface and 10-foot depths along each transect; therefore, zinc was not bioavailable. Low total recoverable zinc concentrations and low or no dissolved concentrations were observed, indicating that bioavailability of zinc in the water fluctuation zone was not influenced by Project operations or transfer from other media (e.g., pore water or sediment).

Note: Figures 5.1-1 through 5.1-5 represent the hypotheses that required validation through the monitoring program. The blue arrows indicate likely pathways of toxics movement in Boundary Reservoir given existing data. The up and down arrows at left indicate high and low concentrations, respectively, of the parameters listed that may promote bioavailability of the toxics if present. The bold portions of this list are the focus of analysis.

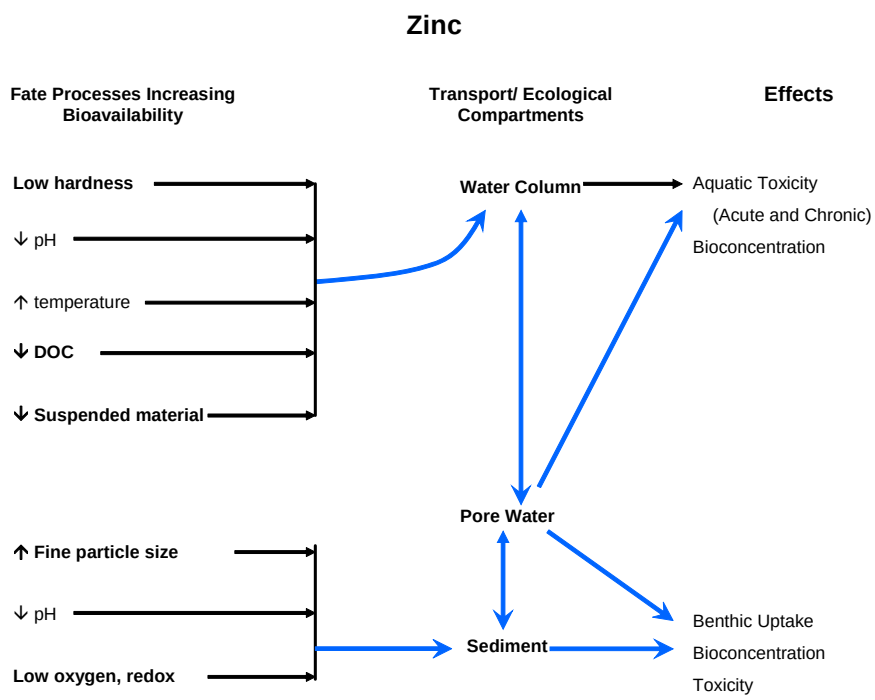


Figure 5.1-1. Generalized toxicological model for zinc in an aquatic system.

5.1.5. Potential for Bioavailability of Cadmium in the Water Fluctuation Zone

Cadmium was not detected in the water fluctuation zone, indicating that it is not bioavailable. Further, even if present, observed water chemistry would limit its bioavailability. The exposure risk of aquatic biota to cadmium and the likelihood of bioaccumulation are predicted to be

greatest in sediment (the risk of bioaccumulation is moderate in surface water and pore water). Important factors with the potential to promote cadmium bioavailability in surface water are low hardness and low suspended material (Figure 5.1-2). One or more of these factors can limit bioavailability and control effects to biota. Of these two factors, hardness in all samples was consistently high at all transects and at depth, limiting bioavailability. Cadmium concentrations were not found at any of the transect samples in detectable concentrations and, therefore, cadmium was not bioavailable. Total recoverable cadmium concentrations and dissolved concentrations were all below detection limits, indicating that bioavailability of cadmium in the water fluctuation zone was not influenced by Project operations or transfer from other media (e.g., pore water or sediment).

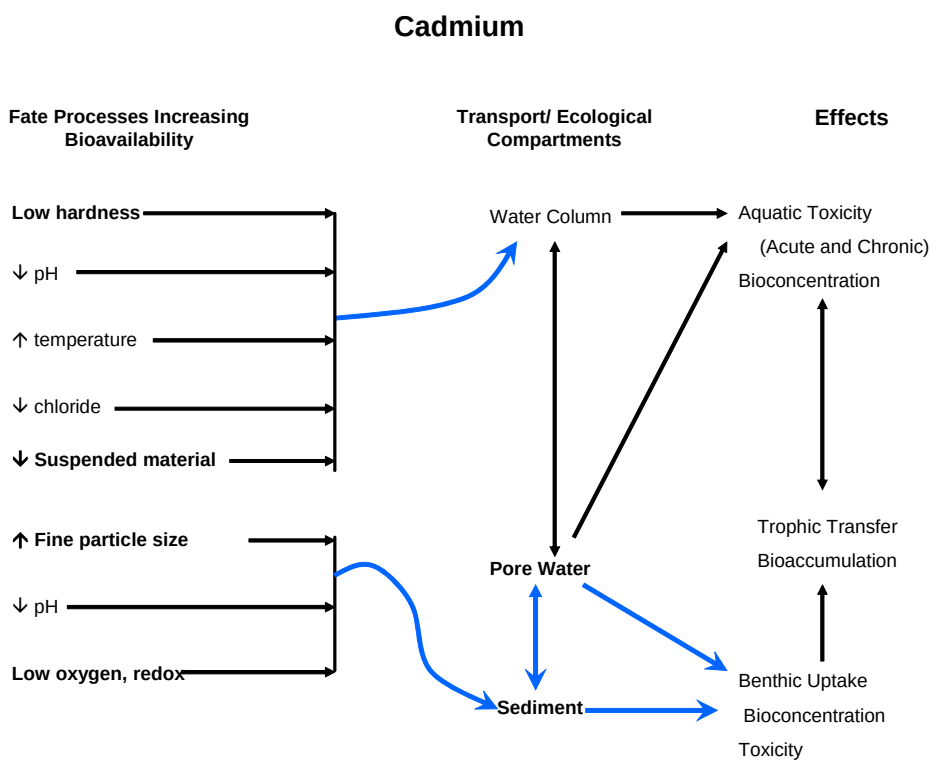


Figure 5.1-2. Generalized toxicological model for cadmium in an aquatic system.

5.1.6. Potential for Bioavailability of Lead in the Water Fluctuation Zone

Dissolved lead was not detected in the water fluctuation zone, indicating that it is not bioavailable. While total recoverable lead was present at low levels, observed water chemistry limits its bioavailability. The exposure risk of aquatic biota to lead and the likelihood of bioaccumulation are greatest in sediment (the risk of bioaccumulation is moderate in surface water and pore water). Important factors with the potential to promote lead bioavailability in surface water are low hardness, low DOC, and low suspended material (Figure 5.1-3). One or

more of these factors can limit bioavailability and control effects to biota. Of these three factors, hardness in all samples was consistently high at all transects, limiting bioavailability. Lead is normally tightly bound to sediments and is less soluble in surface water than either zinc or cadmium under oxygenated conditions, such as those found in Boundary Reservoir. Low total recoverable lead concentrations and no dissolved concentration were observed indicating that bioavailability of lead in the water fluctuation zone was not influenced by Project operations or transfer from other media (e.g., pore water or sediment).

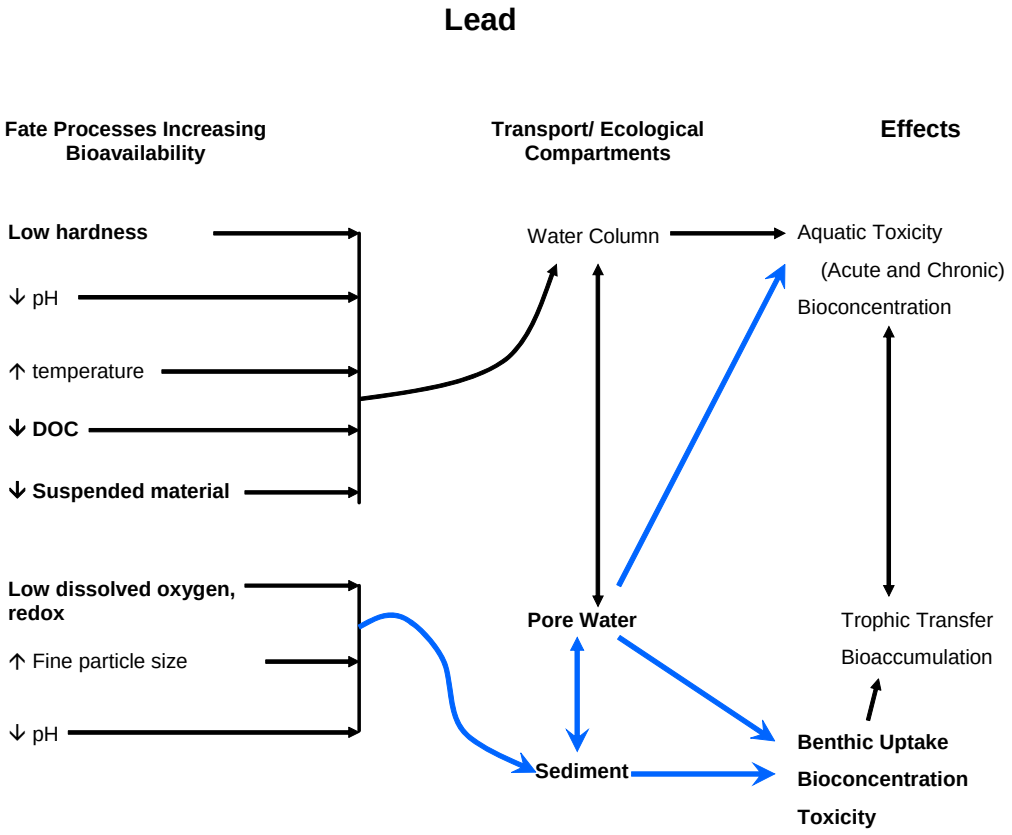


Figure 5.1-3. Generalized toxicological model for lead in an aquatic system.

5.1.7. Potential for Bioavailability of Arsenic in the Water Fluctuation Zone

The study indicates that while arsenic was observed in the water fluctuation zone at low levels, all observations were below water quality criteria. Further, observed water chemistry limits bioavailability of the arsenic that is present. The exposure risk of aquatic biota to arsenic and the likelihood of bioaccumulation were predicted to be moderate in all media of the Boundary Reservoir (e.g., sediment, pore water, and surface water). An important factor that could promote arsenic bioavailability in surface water is a reducing condition (low dissolved oxygen or anoxic conditions) (Figure 5.1-4). Dissolved oxygen concentrations were high at all transects and from all samples collected from surface and at depth, therefore limiting arsenic bioavailability. Project operations did not influence water chemical conditions that would

promote anoxia in the water fluctuation zone as all samples were well-oxygenated at surface and at a 10-foot depth.

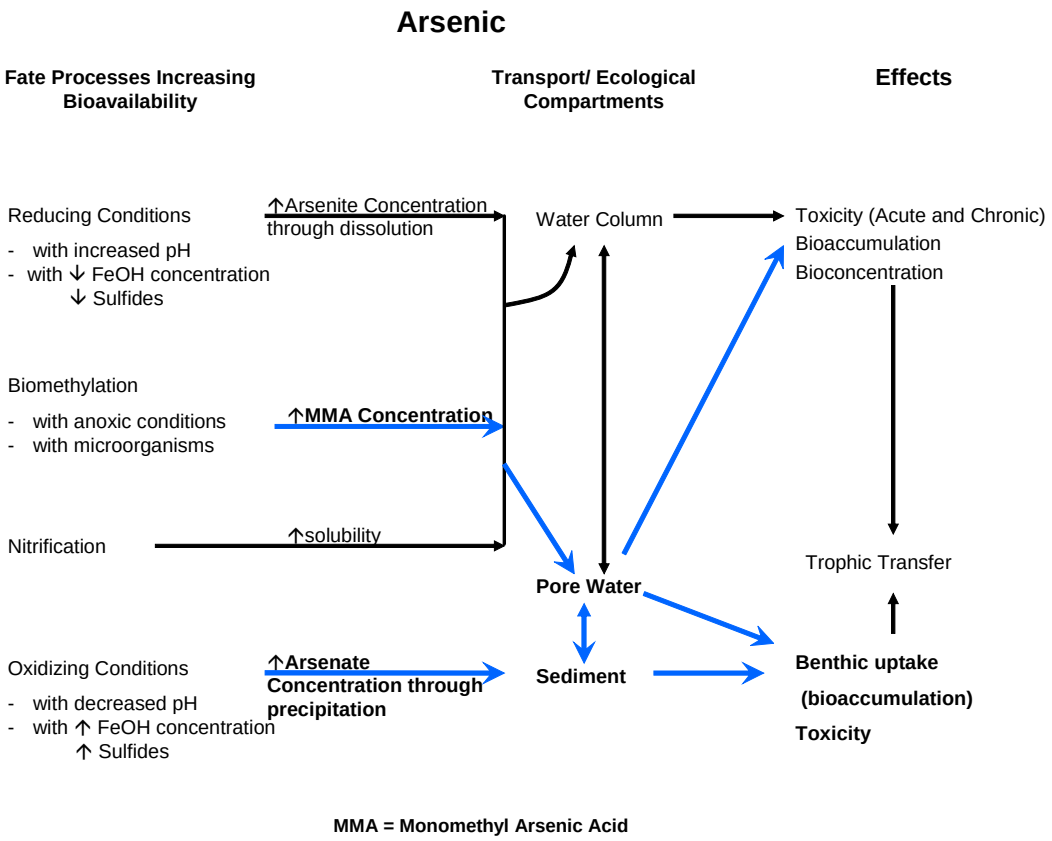


Figure 5.1-4. Generalized toxicological model for arsenic in an aquatic system.

5.1.8. Potential for Bioavailability of Mercury in the Water Fluctuation Zone

Mercury was not detected in the water fluctuation zone, indicating that it is not bioavailable. Further, even if it were present, observed water chemistry would limit its bioavailability.

The exposure risk of aquatic biota to mercury and the likelihood of bioaccumulation are greatest in sediment and food sources (risk of bioaccumulation is low in surface water). Important factors with the potential to promote mercury bioavailability in surface water are neutral to low pH, increased DOC, and increased temperature (Figure 5.1-5). One or more of these factors can limit bioavailability and control effects to biota. Of these factors, pH and dissolved oxygen concentrations were consistently high in all samples collected from transects and limit mercury bioavailability. Samples collected from the surface and at the 10-foot depth showed no detectable concentration for dissolved or total recoverable mercury. Project operations did not influence any of the factors that would promote mercury bioavailability by transfer from the total recoverable form to dissolved concentrations.

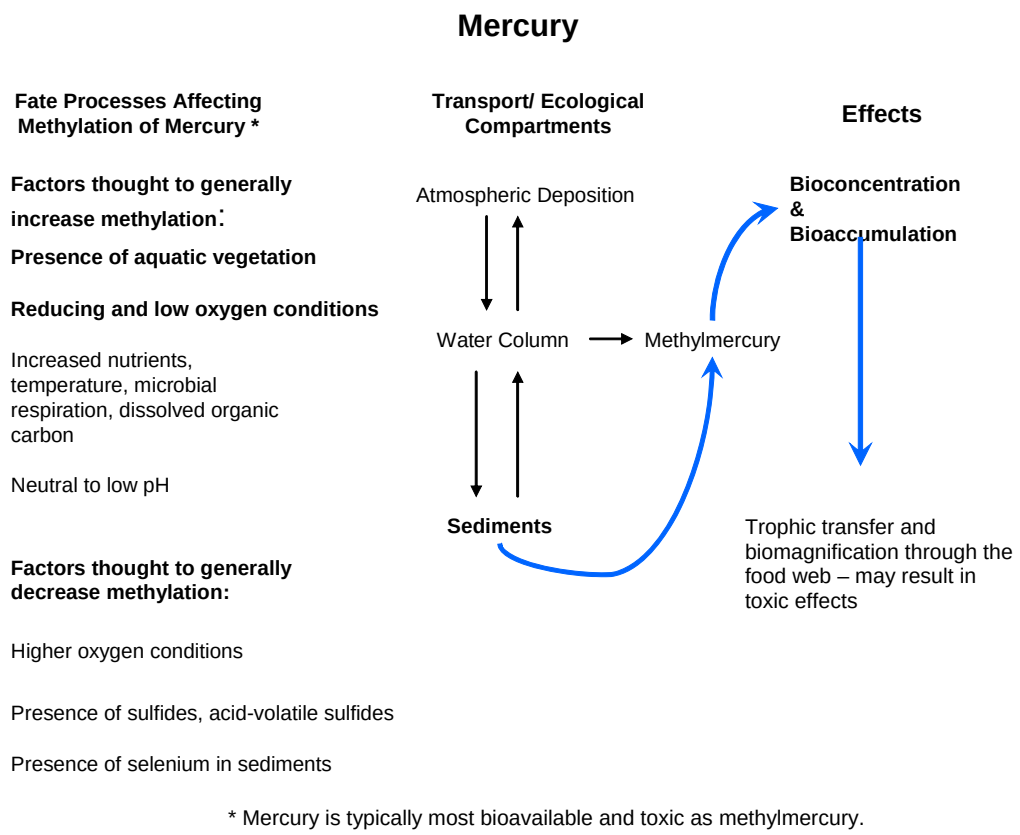


Figure 5.1-5. Generalized toxicological model for mercury in an aquatic system.

5.2. Sediment Sampling

Sediment sampling was conducted in March 2008 at all 14 sites to characterize the longitudinal gradient of potential metals concentrations. Sampling sediment at all fourteen locations enabled potential sources of toxics to be identified (e.g., based on proximity to mine and industrial sites), potential for migration of sediments from source to downstream locations, and potential relationship to Project operations. The Interim Report addressed the question of additional sampling and provided initial conclusions regarding potential Project effects, subject to validation through the October 2008 sampling effort. SCL completed the October 2008 sampling as provided in the Interim Report, and the following sections reflect that effort and provide the final validated conclusions regarding potential Project effects on toxics bioavailability.

Data were analyzed by comparing sediment results to sediment quality guidelines expressed as lowest apparent effects threshold (LAET) and second LAET (Michelsen 2003; SCL 2007a). These thresholds suggest the potential for adverse effects on aquatic organisms exposed to toxics. In addition, presence of toxics in sediments was evaluated for transferability to other media such as pore water and surface water, and potential bioavailability. Most sediment

sampling sites were located within the zone of fluctuation and showed no exceedence of LAETs or second LAET thresholds. The purpose for sampling sediment within the zone of fluctuation was to determine if the vertical movement of water from Project operations may be linked to detectable metals concentrations from a nearby source.

5.2.1. Verification and Validation of Data Quality Elements

Data were evaluated for quality and usability by verification and validation procedures outlined in the Phase 2 SAP (SCL 2007b). Specific procedures for this evaluation are described in Section 11 of the Phase 2 SAP and include decision-making elements established in Section 4 of the Data Quality Objectives and Decisions Criteria (SCL 2007b). Results for quality assurance of data from sediment sample analysis are reported in Appendix 3. Data quality objectives were met for all of the analyses performed by the contact laboratory on sediment samples collected from the Boundary Reservoir. Quality assurance for October 2008 sediment sampling is discussed in Appendix 1.

5.2.2. Analytical Results from Sediment Sampling Sites

Concentrations for toxics from the March, 2008 sediment sampling in Boundary Reservoir are summarized in Table 5.2-1. The data summaries include all observations made from each site (e.g., three samples at each location). Sediment observations from each transect that resulted in non-detectable concentrations are indicated by a "<" symbol. When a range for concentrations is included at a site, the second expression indicates the presence of a detectable sediment concentration. Primary and secondary LAET are included at the bottom of the table for each of the metals and PCBs. Complete results for March 2008 sediment sampling are provided in Appendix 2, Table A.2a-1. Results of the October 2008 sediment sampling are provided in Appendix 1.

All of the observed concentrations in March, 2008 were below the relevant LAETs and, except in a few instances, were generally many times lower than those limits. This means that the presence of detectable toxics in sediments at sites from Boundary Reservoir does not influence development or abundance of biotic groups. In addition, the transfer of toxics from sediment to other media (e.g., pore water and surface water) is less likely to occur with low sediment concentrations. As discussed in Appendix 1, one of three replicate samples from October 2008 at the original site 8 exceeded the primary LAET for lead. All other October 2008 samples were below LAETs.

Table 5.2-1. Range of results for sediment concentrations of toxics in Boundary Reservoir (dry weight) for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	Arsenic (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	Lead (mg/kg)	PCBs (mg/kg)
1	13.2 – 14.3	0.45 – 0.63	0.052 – 0.062	117.5 – 145.3	29.6 – 33.7	
2	9.41 – 11.7	0.48 – 0.61	0.045 – 0.046	125.7 – 146.4	24.9 – 33.5	<0.05
3	11.8 – 15.6	0.51 – 0.67	0.057 – 0.064	127.4 – 151.5	27.2 – 33.2	
4	9.46 – 10.8	0.56 – 0.68	0.042 – 0.059	136.9 – 151.1	26.5 – 32.7	<0.05
5	5.01 – 7.17	0.34 – 0.70	0.015 – 0.020	110.1 – 196.2	17.5 – 30.1	
6	3.75 – 5.78	0.16 – 0.19	<0.01	52.4 – 71.3	14.5 – 17.8	
7	3.85 – 5.85	0.97 – 1.12	0.015 – 0.036	299.2 – 385.7	59.9 – 147.3	<0.05
8	3.80 – 4.18	0.79 – 0.92	<0.01 – 0.019	461.4 – 518.2	115.4 – 291.2	
9	2.06 – 5.52	0.11 – 0.26	<0.01 – 0.12	34.1 – 35.4	10.0 – 26.6	
10	5.05 – 9.11	0.24 – 0.30	0.024 – 0.030	77.4 – 101.4	14.6 – 19.2	
11	6.11 – 8.90	0.32 – 0.45	0.015 – 0.025	102.0 – 150.5	9.85 – 15.8	
12	3.74 – 6.03	0.18 – 0.29	<0.01 – 0.016	68.6 – 96.7	18.0 – 19.4	
13	2.02 – 4.44	0.24 – 0.54	<0.01	25.1 – 40.2	4.26 – 7.44	<0.05
14	2.89 – 3.68	0.10 – 0.13	<0.01	39.2 – 45.2	4.76 – 7.15	
LAET	31.4	2.39	0.8	683	335	62
Second LAET	50.9	2.9	3.04	1,080	431	354

Notes:
LAET – lowest apparent effects threshold
mg/kg – milligram per kilogram
PCBs – polychlorinated biphenyls

Concentrations and composition of sediment samples for parameters are summarized in Table 5.2-2. The data summaries include all observations made from each of the site samples (e.g., three samples at each location). Range of observations measured at each site and for each parameter showed low variability. Uniform measurements observed from replicates at a sampling site indicate that any accrual or movement of toxics from these locations is minimal. Higher variability can indicate site-specific environmental variation that can include influx of groundwater or biological activity. Total organic carbon content in samples was low overall, but with highest measurements made in the Forebay Zone sampling locations (e.g., sites 1, 2, and 3). Similarly, sulfide content in sediments was relatively low throughout the Reservoir with the exception of higher concentrations in the Forebay Zone. These two parameters are important factors (i.e., Toxicological Models) that bind metals and PCBs and reduce or eliminate toxicity to benthic-dwelling biota. Complete results for March, 2008 toxics sediment samples are provided in Table A.2a-1. Results of the October 2008 sediment concentration and composition sampling are provided in Appendix 1.

Table 5.2-2. Range of results for general chemistry concentrations and measurements collected from sediment sites in Boundary Reservoir for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	Total Solids (%)	Water (%)	Total Organic Carbon (%)	Sulfides (mg/kg)
1	31.3 – 34.4	65.6 – 68.6	2.58 – 2.78	1.22 – 2.37
2	34.3 – 46.8	53.2 – 65.7	2.67 – 3.35	0.87 – 11.6
3	31.9 – 32.5	67.5 – 68.1	2.93 – 3.00	11.2 – 15.1
4	39.4 – 47.8	53.2 – 60.6	2.45 – 2.77	1.18 – 9.11
5	65.5 – 72.2	27.8 – 34.5	1.12 – 1.73	0.59 – 5.58
6	79.3 – 81.2	18.8 – 20.7	0.75 – 1.29	0.48 – 0.51
7	30.6 – 83.4	16.6 – 69.4	0.53 – 11.6	0.49 – 1.36
8	72.3 – 74.3	25.7 – 27.7	1.74 – 2.98	0.58 – 2.59
9	52.6 – 75.1	24.9 – 47.4	1.22 – 2.04	0.58 – 0.82
10	67.7 – 72.4	27.6 – 32.4	0.40 – 0.63	0.45 – 0.62
11	58.8 – 72.6	27.4 – 41.2	0.52 – 1.60	0.42 – 0.62
12	69.9 – 75.7	24.3 – 30.1	0.49 – 0.69	0.37 – 0.47
13	72.6 – 82.2	17.8 – 27.4	0.57 – 0.67	0.30 – 0.39
14	67.2 – 78.4	21.6 – 32.9	0.94 – 1.49	0.31 – 0.44

Note:
mg/kg – milligram per kilogram

5.2.3. Hypothesis Testing: Sediment Sampling and the Toxicological Models

Factors affecting mobilization of toxics between media were originally outlined in toxicological models developed for the Phase 1 Toxics Assessment Report in Appendix 1 to the Phase 2 SAP (SCL 2007b). Field and general chemistry parameters were selected to evaluate those factors that would promote the potential bioavailability of toxics of concern. The toxicological models presented in Figures 5.1-1 though 5.1-5 formed the basis of hypothesis development and were tested by comparison to results from the water chemistry sampling of variables known to affect bioavailability of contaminants of concern in the sediments of Boundary Reservoir.

5.2.4. Potential for Zinc Bioavailability in Sediment

Zinc has a higher affinity to exist in a dissolved form in surface water of the Boundary Reservoir than in other media, such as sediments or pore water. However, zinc can be found in sediments and become bioavailable when low pH, low dissolved oxygen, and reducing conditions occur (redox potential). All of these factors favoring zinc concentration in sediments often co-occur so one or more of these factors can limit bioavailability and control effects to biota (see sediment portion of Figure 5.1-1).

Zinc concentrations measured in all sampling locations in Boundary Reservoir in March and October 2008 were below both LAETs examined (Michelsen 2003) indicating that there would be no apparent effects to sediment-dwelling organisms (October 2008 results can be found in

Appendix 1). Redox potential is primarily a function of oxides or sulfides present which is, in turn, a function of the oxygen concentration in the overlying water (Chapman et al. 2003). Sulfides measured in the sediments of Boundary Dam were low for all sites with the exception of sampling locations downstream of Project river mile (PRM) 25 (i.e., sampling locations 1, 2, 3, 4, and 5). Sampling locations in the Forebay Zone and the downstream end of the Canyon Zone showed increased sulfide concentrations. The low sulfide concentration is consistent with aerobic (oxygenated) conditions, which tend to limit the bioavailability of zinc and other metals. Sediment and overlying surface water pH were high and so did not promote bioavailability of toxics.

Therefore, factors that would promote bioavailability of zinc did not exist at any of the sites sampled in the Reservoir. Project operations that would influence sediment sampling locations in and above the Forebay Zone did not show any effects on water chemistry from water fluctuation, and therefore, on bioavailability. Conditions of overlying surface water quality did not promote release of zinc in sediments based on factors such as high oxygen concentrations and the low concentrations of zinc in sediments.

5.2.5. Potential for Cadmium Bioavailability in Sediment

Much of the cadmium entering freshwaters from industrial sources is rapidly adsorbed to particulate matter, where it may settle out or remain suspended, depending on local conditions. In freshwaters, particulate matter and dissolved organic material may bind a substantial portion of cadmium, and under these conditions, cadmium may not be bioavailable due to this binding (Callahan et al. 1979; Kramer et al. 1997). In sediments, cadmium bioavailability is promoted by low dissolved oxygen concentrations, low redox potential (reducing environment), and low pH. In addition, the concentrations of reducing ligands and sulfides have a similar effect to decreasing zinc bioavailability through sediments (Figure 5.1-2.).

Cadmium concentrations measured in all sampling locations in Boundary Reservoir in March and October 2008 were well below both LAETs (October 2008 results can be found in Appendix 1). The concentrations for cadmium in sediments did not show any pattern throughout the Reservoir as related to mine or industrial sites and were within the same range of concentrations at each site. Like zinc, anaerobic conditions (low dissolved oxygen) will increase cadmium solubility in sediments and the potential bioavailability. Dissolved oxygen concentration measured at the bottom of the water column was used as an indicator for identifying anaerobic conditions at the sediment-water interface and was greater than 12.0 mg/L at all sites (an anaerobic condition or high dissolved oxygen) with lowest concentrations occurring during July 2007. Dissolved oxygen concentrations during the warmer months of the season did not drop below 7.0 mg/L at the bottom of the water column as reported in the Study 5 Final Report (SCL 2009d). The similar cadmium concentrations in sediment throughout the reservoir suggest that Project operations do not influence the presence of this metal and that the potential for bioavailability does not exist.

5.2.6. Potential for Lead Bioavailability in Sediment

When deposited in water, whether from air or through run-off from soil, lead partitions rapidly between the sediment and aqueous phase, depending on the ionic content of the water as well as

the presence of organic-complexing agents. Lead is rapidly removed from water when it passes through bottom sediments. This is due to the high capacity of organic matter to tightly bind lead. Lead concentrations in natural waters are generally low resulting from the strong affinity to bind with complexing agents and reside in sediments. Lead bioavailability in sediments is governed by the same processes described for zinc and cadmium: metal concentrations, redox potential, pH, and DOC will all affect the degree to which lead is bound to sediments and not present in pore water or released to the water column (Figure 5.1-3). One or more of these factors can affect binding of dissolved forms of lead and retention in sediments. Pore water pH was greater than 7.7 at all sites (except one replicate from site 5) and redox potential high at all sediment sampling locations. These factors promoted reduction of bioavailability and retention in sediment, where detected.

Sediment concentration of lead in all Boundary Reservoir sampling locations in March, 2008 was below both LAETs. The highest concentrations of lead were observed in the sediments at sampling locations 7 and 8, with a mean concentration of 91 milligrams per kilogram (mg/kg) and 228 mg/kg, respectively. These concentrations were higher than other sites examined for lead. However, sediment lead concentrations were still below the more conservative LAET of 335 mg/kg at these locations. High lead concentrations in pore water was not detected in high concentrations among all replicates from either of these sites and lead concentration in overlying surface water did not exceed water quality criteria. This suggested concentration in sediment was localized (there is a nearby source for this toxic) and contained in this portion of the reservoir. Surface water was well-oxygenated at all portions of the reservoir and as indicated for zinc and cadmium this close contact to sediments favors insolubility of metals and does not promote bioavailability.

Additional sampling for sediment in October 2008 confirmed high lead concentrations in one of three replicates (8-Sed-3; 344 mg/kg) collected from the same location as in March 2008. This observation was slightly above the LAET (335 mg/kg) concentration for protection of sediment-burrowing aquatic life; effects to aquatic life are likely to occur, but are not likely to result in mortality (i.e., chronic effects). The other two replicate samples collected from this location resulted in much lower sediment concentrations for lead (e.g., 25.5 mg/kg in 8-Sed-1 and 29.4 mg/kg in 8-Sed-2). The average for these three replicates was only 133 mg/kg and therefore well below the LAET guideline concentration of 335 mg/kg. All replicates at the upstream and downstream locations at site 8 were below the LAETs for lead, as were all results from sites 1, 5, and 14. Complete results of the October 2008 sampling are provided in Appendix 1.

5.2.7. Potential for Arsenic Bioavailability in Sediment

Arsenic can be present in surface waters and sediments, as well as the interstitial pore water between sediment particles. Fluxes in arsenic concentration are dependent on physical, chemical, and biological characteristics of the aquatic environment. The distribution and transport of arsenic in sediment is a complex process that depends on arsenic concentration, water quality, native biota, and sediment type. There is a potential for arsenic release when there is fluctuation in redox potential, pH, and sediment organic content (Abdelghani et al. 1981) (Figure 5.1-4). One or more of these factors can affect binding of dissolved forms of arsenic and retention in sediments.

Arsenic concentration in sediments of Boundary Reservoir in March and October 2008 were less than the LAETs (October 2008 results can be found in Appendix 1). Concentrations averaged one-third less than the more conservative LAET. Highest levels were found in sediments of the Forebay Zone with concentrations ranging from 10.9–14 mg/kg. However, sediment arsenic concentration was consistent throughout the remainder of sampling locations in Boundary Reservoir ranging from 3.4–10.1 mg/kg at remaining sites. Important factors mediating bioavailability of arsenic include pH, which was consistently higher than 7.7 during the time of sediment sampling. Similarly, pH conditions at depth during other parts of the year (SCL 2009d) remained above 8.0 and anaerobic conditions were non-existent, indicating that arsenic bioavailability from sediments was not promoted.

Low dissolved oxygen and pH are other contributing factors to increased bioavailability of arsenic from the sediment. As indicated in the previous sections, dissolved oxygen levels measured in close proximity to the sediment indicated highly oxygenated overlying waters and that the pH of pore waters was neutral (>7). Therefore, the conditions necessary for arsenic bioavailability (anaerobic conditions or low pH) were not present in the sediments near Boundary Dam.

5.2.8. Potential for Mercury Bioavailability in Sediment

Mercury occurs in several forms in aquatic systems. Although it makes up a relatively small fraction of the total mercury in most systems, methylmercury (mono-methylmercury) is of greatest concern given its propensity to bioaccumulate and biomagnify its toxic properties affecting both human health and ecological receptors (e.g., damage to kidney and nervous system functions). The bioavailability of mercury is primarily related to the availability of methyl-mercury and the ability of chemical conditions that promote the biological ability to methylate available inorganic mercury. Although the rate of mercury methylation is influenced by a variety of site-specific factors such as concentration of inorganic mercury, low pH, low dissolved oxygen, and increased DOC (Figure 5.1-5.), conditions in Boundary Reservoir do not promote the methylation process. One or more of these factors can affect methylation of inorganic forms of mercury and potential for bioavailability. The pH in pore water was generally greater than 7.0, and dissolved oxygen concentrations were greater than 12.0 mg/L in overlying surface water at all sites.

Concentrations of inorganic mercury were measured in all sample grabs from 14 sampling locations in Boundary Reservoir. The measured concentration of mercury was below both LAETs (Michelson 2003) at all sites samples in March and October 2008 (October 2008 results can be found in Appendix 1). Sediment concentrations at all sites were approximately 10 times lower than the LAET and in some cases were not detected.

Anaerobic conditions characterized by low pH and low dissolved oxygen will increase the methylation rate of mercury by enhancing microbial respiration. In freshwater systems, inorganic mercury is typically converted to methylmercury as a byproduct of microbial respiration. Therefore, an increase in microbial respiration will lead to an increase in the methylation of inorganic mercury. Anaerobic conditions were not observed in surface waters in contact with the sediment, and pore water had a neutral pH (≈ 7). Anaerobic or acidic conditions

were not observed in Boundary Reservoir sampling locations and, therefore, mercury bioavailability is low.

5.2.9. Potential for Polychlorinated Biphenyl Bioavailability in Sediment

PCBs are synthetic organic chemicals that were widely used as industrial lubricants and electrical insulators prior to their ban in the United States in 1977. PCBs are typically closely associated with sediments and colloidal particles. Similar to atmospheric transport, those PCBs with fewer chlorine atoms tend to occur more frequently as dissolved particles in the water column, while those with more chlorine atoms are more closely associated with sediments and are less likely to be soluble (ATSDR 2000). PCBs are removed from the water column by way of volatilization to the atmosphere, becoming adsorbed to sediments and suspended particulate matter, or taken up by biota (Figure 5.2-1). Likewise, PCBs can be released from sediments by diffusion or resuspension. The rate of diffusion from the sediments to water column increases with temperature and is typically greatest in the summer (Sanders et al. 1996).

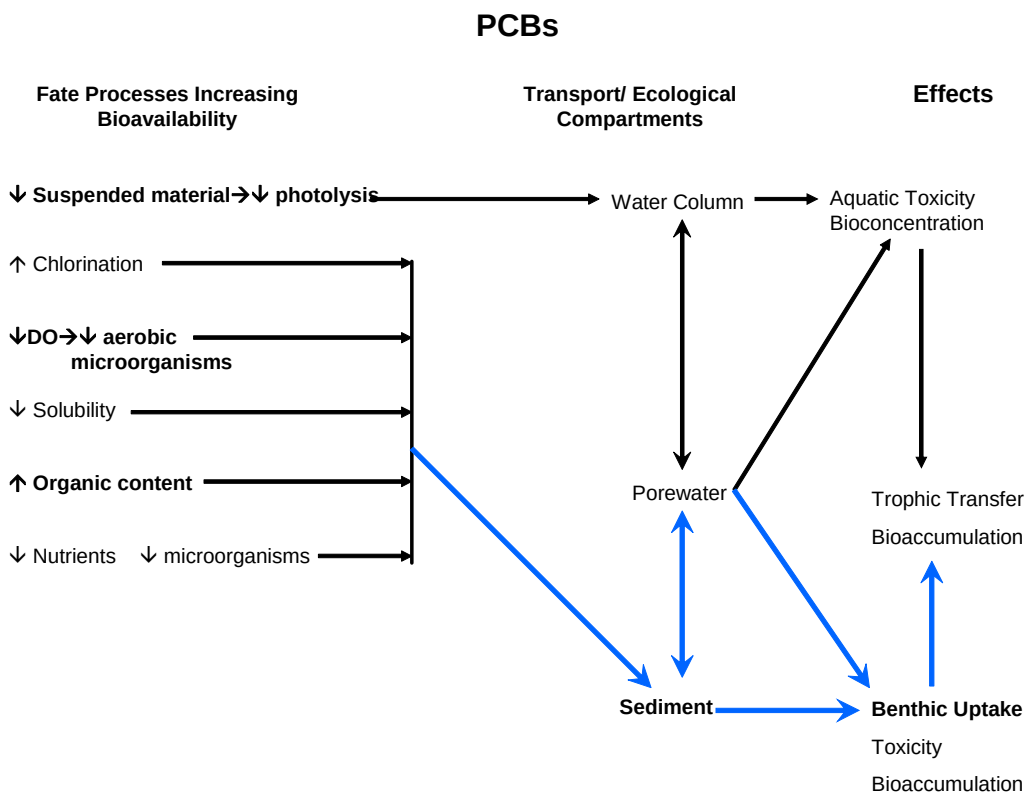


Figure 5.2-1. Generalized toxicological model for PCBs in an aquatic system.

PCBs were sampled at 4 of the 14 water profile sampling locations (i.e., locations 2, 4, 7, and 13) during March 2008. PCB concentrations were below detection limits at all sampling locations within Boundary Reservoir and well below both LAETs (Michelson 2003). Furthermore,

bioavailability of PCBs would be very limited even if they were present. PCB bioavailability is affected by decreased dissolved oxygen and increased organic content. As indicated for mercury, arsenic, and the divalent metals (e.g., lead, cadmium, and zinc) dissolved oxygen concentrations near the sediments were high, thereby reducing bioavailability (PCBs were not sampled during October 2008).

5.3. Pore Water

Pore water was collected along with sediment samples at seven sites in March 2008 that represented the greatest likelihood for the potential transfer of toxics (e.g., sites 2, 5, 7, 8, 10, 13, and 14) (Appendix 5). The greater likelihood for transfer of toxics at these seven locations was identified through careful examination of mine and industrial site factors that would enhance conveyance of toxics from sources or allow migration in the aquatic environment due to Project operation-related factors (e.g., physicochemical conditions identified in toxicological models). The Interim Report addressed the question of additional sampling and provided initial conclusions regarding potential Project effects, subject to validation through the October 2008 sampling effort. SCL completed the October 2008 sampling as provided in the Interim Report at select sites throughout the reservoir (e.g., sites 1, 5, 8, and 14). Results for October sampling can be found in Appendix 1.

Data were analyzed for presence of toxics in pore water and compared to acute and chronic criteria available for surface water (Ecology 2006). Pore water can convey toxics to surface water where toxics can be bioavailable in a dissolved form. Therefore, factors in surface water that enhance solubility of toxics and that can potentially be influenced by Project operations are the focus for these evaluations.

5.3.1. Verification and Validation of Data Quality Elements

Data were evaluated for quality and usability by verification and validation procedures outlined in the Phase 2 SAP (SCL 2007b). Specific procedures for this evaluation are described in Section 11 of the Phase 2 SAP and include decision-making elements established in Section 4 of the Data Quality Objectives and Decisions Criteria (SCL 2007b). Results for quality assurance analysis of data from pore water samples are reported in Appendix 3. Data quality objectives were met for most quality assurance tests except for hardness. The result from duplicate sample analysis was slightly higher than required for this parameter. However, the difference between original and duplicate samples was well within the range of variability from individual pore water replicates from a sampling location. Blank samples were below detection limit and duplicates were similar to the range of results collected from Boundary Reservoir and determined to be within the natural variability for samples collected from each location. Quality assurance for October 2008 pore water sampling is discussed in Appendix 1.

5.3.2. Analytical Results from Pore Water Sampling Sites

Concentrations for dissolved toxics from the pore water sites are summarized in Table 5.3-1. Complete results for dissolved toxics sampling are provided in Table A.4-3. The data summaries include all observations made from each of the grabs at each sampling location (e.g., three grabs at each location). When a range for concentrations is included at a transect site, the second

expression indicates the presence of a detectable dissolved metal concentration. Chronic and acute criteria are included at the bottom of the table for each of the metals. Exceedances for dissolved metals in pore water occurred at site 5 downstream of the Pend Oreille Mine in one of three replicates (replicate #2) and at site 8 in one of three replicates (replicate #1) downstream of the Grandview Mine. Dissolved lead exceeded chronic criteria at site 5 while dissolved zinc exceeded acute criteria at both sites 5 and 8 (per Ecology [2006] Water Quality Standards). Results of the October 2008 pore water sampling are provided in Appendix 1.

Approximately 92 percent of the water quality observations from the March, 2008 pore water sampling resulted in non-detectable concentrations (indicated by a "<" symbol) for dissolved arsenic and cadmium, meaning that neither of these metals were found in toxic concentrations. Approximately 30 percent of pore water sampling observations did not detect dissolved lead and zinc concentrations at sampling locations. To the extent that concentrations were detectable, the results for the most part fell well below the chronic and acute surface water criteria, (e.g., average zinc concentration in pore water in the Forebay Zone was 10.6 µg/L whereas the chronic and acute criteria are 86.5 and 94.7 µg/L, respectively). In limited instances where there were exceedences of the chronic or acute criteria, analysis of overlying surface water and sediment data suggest a source or influence on these results. In particular, the results of replicate samples at the sites indicate that Project operations are not responsible for the exceedences. A large-scale influence such as Project operations would result in a broader and detectable condition when toxics exceed criteria, whereas in this case, exceedences from only individual samples in a batch of replicates indicates a local source or a biotic disturbance.

Toxics in pore water may migrate back and forth between sediment-bound and dissolved forms depending on factors present that promote movement. In addition to evaluating the potential for bioavailability through direct contact (comparison to surface water criteria), sediment toxics from the same sample are compared to the LAETs so that both routes of bioaccumulation are considered in evaluation for potential bioavailability. The presence of toxics in sediments may be ingested as food and is evaluated based on comparison to LAETs (Table 5.3-1). Below Table 5.3-1, Table 5.2-1 is repeated (for convenience) as Table 5.3-2: it references metals concentrations in sediments that were directly beneath the pore water samples collected. Note that the surface water criteria and the LAET and second LAET thresholds are measured using different units of measurement.

As discussed in Appendix 1, all three replicate pore water samples from October 2008 at the original site 8, and one of three replicates at the location downstream of site 8, exceeded the chronic water quality criteria for lead. All other October 2008 pore water samples were below water quality criteria.

Table 5.3-1. Range of results for dissolved concentrations of toxics from pore water in water fluctuation zone sites in Boundary Reservoir for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	Arsenic (µg/L)	Cadmium (µg/L)	Zinc (µg/L)	Lead (µg/L)	Mercury (µg/L)
2	1.5, 1.8	<0.2	10.0, 11.0	<0.2	0.00088, 0.00331
5	<1.0 – 1.9	<0.2 – 0.27	26.0 – 279	0.29 – 3.98	0.00138 – 0.00162
7	<1.0	<0.2	14.0 – 17.0	<0.2 – 0.58	0.00535 – 0.00976
8	<1.0	<0.2 – 0.22	56.0 – 566	1.06 – 1.57	0.00587 – 0.0104
10	<1.0 – 1.0	<0.2 – 0.27	8.0 – 80	0.39 – 0.79	0.00376 – 0.00556
13	<1.0 – 1.0	<0.2	12.0 – 21.0	<0.2 – 0.31	0.00156 – 0.00537
14	<1.0	<0.2	14.0 – 22.0	<0.2 – 0.22	0.00073 – 0.0416
Chronic Criteria (µg/L)	190	1.03	86.5	2	N/A
Acute Criteria (µg/L)	360	3.7	94.7	51	2.1

Notes:
µg/L – microgram per liter
N/A – criteria not available
(Source for criteria: Ecology 2006)

Table 5.3-2. Range of results for sediment concentrations of toxics in Boundary Reservoir (dry weight) for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	Arsenic (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	Lead (mg/kg)	PCBs (mg/kg)
1	13.2 – 14.3	0.45 – 0.63	0.052 – 0.062	117.5 – 145.3	29.6 – 33.7	
2	9.41 – 11.7	0.48 – 0.61	0.045 – 0.046	125.7 – 146.4	24.9 – 33.5	<0.05
3	11.8 – 15.6	0.51 – 0.67	0.057 – 0.064	127.4 – 151.5	27.2 – 33.2	
4	9.46 – 10.8	0.56 – 0.68	0.042 – 0.059	136.9 – 151.1	26.5 – 32.7	<0.05
5	5.01 – 7.17	0.34 – 0.70	0.015 – 0.020	110.1 – 196.2	17.5 – 30.1	
6	3.75 – 5.78	0.16 – 0.19	<0.01	52.4 – 71.3	14.5 – 17.8	
7	3.85 – 5.85	0.97 – 1.12	0.015 – 0.036	299.2 – 385.7	59.9 – 147.3	<0.05
8	3.80 – 4.18	0.79 – 0.92	<0.01 – 0.019	461.4 – 518.2	115.4 – 291.2	
9	2.06 – 5.52	0.11 – 0.26	<0.01 – 0.12	34.1 – 35.4	10.0 – 26.6	
10	5.05 – 9.11	0.24 – 0.30	0.024 – 0.030	77.4 – 101.4	14.6 – 19.2	
11	6.11 – 8.90	0.32 – 0.45	0.015 – 0.025	102.0 – 150.5	9.85 – 15.8	
12	3.74 – 6.03	0.18 – 0.29	<0.01 – 0.016	68.6 – 96.7	18.0 – 19.4	
13	2.02 – 4.44	0.24 – 0.54	<0.01	25.1 – 40.2	4.26 – 7.44	<0.05
14	2.89 – 3.68	0.10 – 0.13	<0.01	39.2 – 45.2	4.76 – 7.15	
LAET	31.4	2.39	0.8	683	335	62
Second LAET	50.9	2.9	3.04	1,080	431	354

Notes:
LAET – lowest apparent effects threshold
mg/kg – milligram per kilogram
PCBs – polychlorinated biphenyls

Concentrations for general chemistry parameters from the pore water in water fluctuation zone sites are summarized in Table 5.3-3. Complete results for dissolved toxics sampling are provided in Table A.5-1. The data summaries include all observations made from each of the sample grabs (e.g., three grabs at each location). Range of observations measured at each location showed low variability with the exception of hardness, which had higher variability at all locations except sites 7 and 14. Observations for water hardness are highly influenced by surrounding geology in a watershed and can have a large amount of spatial variability when compared among multiple locations. Groundwater influence on observed hardness concentrations at a sampling location provides one explanation for variability among replicate samples within a site. Another reason might be the chemical composition of sediments at a site and spatial variability in the sediment matrix. Results of the October 2008 sampling of general chemistry parameters in pore water are provided in Appendix 1.

Table 5.3-3. Range of results for general chemistry concentrations and measurements collected from pore water in the water fluctuation zone sites in Boundary Reservoir for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	pH (su)	DOC (mg/L)	SRP (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg $CaCO_3$/L)
2	7.50 - 7.82	3.91, 9.40	0.002, 0.030	23.3, 33.1	5.53, 6.96	81.0, 111.3
5	6.38 – 7.78	1.49 – 5.60	0.012 – 32.9	22.8 – 29.5	6.61 – 7.17	84.1 – 103.3
7	7.80 – 7.92	1.31 – 1.60	0.003 – 0.017	21.9 – 24.5	6.17 – 6.59	81.9 – 86.5
8	7.34 – 7.86	1.70 – 5.64	0.004 – 2.82	21.8 – 32.4	6.50 – 11.6	81.2 – 128.8
10	7.61 – 7.95	3.14 – 4.21	0.017 – 17.1	21.7 – 34.5	7.26 – 8.61	87.3 – 120.3
13	7.57 – 7.96	2.32 – 16.0	0.001 – 0.528	25.1 – 31.5	6.55 – 8.48	89.7 – 113.6
14	7.64 – 7.94	1.39 – 1.73	0.001 – 0.006	21.2 – 24.1	6.25 – 6.79	78.6 – 88.2

Notes:
$CaCO_3$ – calcium carbonate
DOC – dissolved organic carbon
mg/L – milligram per liter
SRP – soluble reactive phosphorous
su – standard units

5.3.3. Hypothesis Testing: Pore Water Sampling and the Toxicological Models

Factors affecting mobilization of toxics between media were originally outlined in toxicological models developed for the Phase 1 Toxics Assessment Report in Appendix 1 to the Phase 2 SAP (SCL 2007b). Field parameters and general chemistry results were selected to evaluate those factors that would promote the potential for bioavailability of the toxics. The toxicological models presented in Section 5.1 formed the basis for hypothesis development and are tested here by comparing results from pore water sampling with factors known to promote bioavailability of contaminants of concern in the pore water of Boundary Reservoir. Because bulk sediment metal concentrations are often poorly related to biological effects, many researchers prefer to use pore water metal concentration as a more accurate indicator of metal bioavailability in sediments. In this approach, metals in pore water have been compared with EPA water quality criteria or state aquatic life metal standards for water (Sibley et al. 1996). Comparisons between observed dissolved metals concentrations from pore water have been compared with the Ecology (2006) Water Quality Standards (WAC 173-201A-240).

5.3.4. Potential for Zinc Bioavailability in Pore Water

The exposure risk of aquatic biota to zinc and the likelihood of bioaccumulation are greatest in surface water (as opposed to sediment or pore water). Factors predicted to promote zinc bioavailability in pore water at Boundary Reservoir are affected by both the surface water and the sediment due to the interaction of the pore water with both media. The major factors predicted to promote zinc bioavailability in pore water are low hardness, low DOC, and low pH (Figure 5.1-1). Of these three factors, hardness in all samples was consistently high at all

locations (> 70 mg/L as $CaCO_3$), indicating that zinc is a complex including calcium, magnesium, and other cations and therefore, not bioavailable. The pH of the pore water samples was relatively neutral (≈ 7) and the DOC of surface waters was fairly high (2 to 4 mg/L) indicating that zinc is not likely to be in an ionic form. There were isolated zinc exceedences in March, 2008 and they appear to be related to local sources. There were exceedences at site 5 downstream of the Pend Oreille Mine and site 8 downstream of the Grandview Mine, but not in other locations (one replicate, sample 8-PW-2, exceeded chronic and acute criteria of WDOE Water Quality Standards [Table 5.3-1]). No exceedences were observed in the October 2008 sampling, including sampling at original sites 5 and 8 at and locations upstream and downstream of the original sites. In any event, given the physiochemical conditions, the bioavailability of zinc in the pore water of Boundary Reservoir confirms that the concentration for zinc in pore water does not exceed water surface criteria and is not bioavailable. Zinc concentrations in pore water at site 5 and 8 were below chronic and acute surface water criteria during October 2008 sampling and indicate that exceedences are transient over time and do not occur over large areas at a site. Complete results of the October 2008 pore water sampling for zinc are presented in Appendix 1.

5.3.5. Potential for Cadmium Bioavailability in Pore Water

The exposure risk of aquatic biota to cadmium and the likelihood of bioaccumulation are not as great in pore water as they are in sediment. For the March 2008 samples, dissolved cadmium was detected in three locations, and at these locations was detected in only one of three replicates. Therefore, the low detection frequency of cadmium is indicative that conditions are not favorable for bioavailability of cadmium from pore water. The most important factors that would promote cadmium bioavailability in pore water are low hardness, low dissolved oxygen, and low pH (Figure 5.1-2). Of these three factors, hardness in all samples was consistently high at all locations, thereby resulting in low toxicity of cadmium in pore water. Dissolved oxygen concentrations near the sediment-surface water interface were high indicating aerobic conditions, and pH was approximately neutral (>7.5) at all pore water sampling locations. These three conditions indicate that cadmium will bind to the sediment and not be in the pore water, thereby resulting in low bioavailability.

Complete results of the October 2008 pore water sampling for cadmium are provided in Appendix 1.

5.3.6. Potential for Lead Bioavailability in Pore Water

The exposure risk of aquatic biota to lead and the likelihood of bioaccumulation are not as great in pore water as it is in the sediment. Of the 14 sites sampled in March, 2008, dissolved lead was detected in only 1 of 3 replicate samples (5-PW-2) and exceeded the chronic water quality criteria of 2 µg/L (Table 5.3-1). Overall, the low concentrations of lead observed in pore water indicate that conditions are not favorable for lead to be present in this component of the sampling. The most important factors that would promote lead bioavailability in pore water are low hardness, low dissolved oxygen, and low pH (Figure 5.1-3); one of these factors is necessary to limit transferability of this metal between media (e.g., sediment or surface water) and reduce bioavailability. Of these three factors, hardness in all samples was consistently high at all

locations thereby limiting bioavailability of lead in pore water. Dissolved oxygen concentrations near the sediment-surface water interface were high indicating aerobic conditions, and pH was approximately neutral (>7.5) at all pore water sampling locations. These three conditions indicate that lead will bind to the sediment and not be in the pore water, thereby resulting in low bioavailability.

Additional sampling for pore water in October 2008 found no elevated lead concentrations at Site 5, where it had been observed in March 2008. October 2008 sampling found elevated lead concentrations in four of nine replicates from site 8 (e.g., 8-PW-1, 3.87 µg/L; 8-PW-2, 2.41 µg/L ; 8-PW-3, 5.31 µg/L) collected from the same, original location as in March 2008 (where no lead exceedences were found in March) and at the downstream site 8 location (DN-PW-2, 4.05 µg/L). These observations exceeded chronic water quality criteria of 2 µg/L for lead in surface water. The bioavailability of dissolved lead in aquatic organisms would be through absorption by respiratory tissues and not through food. Organic content in these samples was very low (e.g., 0.21–0.34 percent organic content by weight) and would not serve as a contaminated food base that results in bioaccumulation of toxics. Complete results of the October 2008 pore water sampling for lead are provided in Appendix 1.

5.3.7. Potential for Arsenic Bioavailability in Pore Water

The exposure risk of aquatic biota to arsenic and the likelihood of bioaccumulation were predicted to be moderate in all media of the Boundary Reservoir (e.g., sediment, pore water, and surface water). For the March 2008 and October 2008 samples, direct measurements of dissolved arsenic concentrations were at the detection limit or below criteria. The few detected arsenic concentrations measured were all below acute and chronic water quality criteria. The most important factors or conditions identified that promote arsenic bioavailability in pore water are reducing conditions (low dissolved oxygen or anoxic conditions) (Figure 5.1-4). Dissolved oxygen concentrations measured at the interface of sediment and surface water were high at all sampling locations. The lack of reducing conditions indicates that arsenic will be bound to sediment and will not be in pore water, and therefore, not bioavailable.

Complete results of the October 2008 pore water sampling for arsenic are provided in Appendix 1.

5.3.8. Potential for Mercury Bioavailability in Pore Water

The exposure risk of aquatic biota to mercury and the likelihood of bioaccumulation are not as great in pore water as they are in the sediment and food sources. Direct measurements of mercury in pore water in March 2008 indicated measurable concentrations at all 14 sampling locations from each replicate. The range of dissolved mercury concentrations from sampling locations were 0.00073 µg/L to 0.0416 µg/L (Table 5.3-1). All observations were well below the acute water quality criteria (2.1 µg/L). Sampling in October 2008 generated similar results, which are provided in Appendix 1. There are no chronic criteria based on the dissolved mercury fraction in surface water. The most important factors predicted to promote mercury bioavailability in pore water are neutral to low pH, low dissolved oxygen, low DOC, and increased temperature (Figure 5.1-5): one of these factors is necessary to limit transferability of this metal between media (e.g., sediment or surface water) and reduce bioavailability. Of these

factors, dissolved oxygen concentrations were consistently high in all samples collected from sampling locations, indicating limited conditions for mercury methylation and lack of mercury bioavailability.

Complete results of the October 2008 pore water sampling for mercury are provided in Appendix 1.

5.4. Water Column Profile

The water column characterization represents a longitudinal profile of the Boundary study reach. This is a 3-dimensional view (e.g., horizontal channel location, longitudinal location in the study reach, and depth characterization at each location) of the water quality characteristics at select locations throughout the reservoir. By measuring the water quality variables listed in Table 4.6-3, the influence of channel morphology and resulting physicochemical conditions will be identifiable by comparisons between successive downstream stations. These physicochemical influences are key factors reported in the toxicological models that determine the movement of toxics between media. Therefore, examination of surface water at each of the sites will isolate sources of toxics or will identify if Project operations have an influence on physicochemical conditions that can make toxics bioavailable from other media (e.g., pore water and sediments). Results for water column profile sampling are found in Appendix 6.

The Interim Report addressed the question of additional sampling and provided initial conclusions regarding potential Project effects, subject to validation through the October 2008 sampling effort. SCL completed the October 2008 sampling as provided in the Interim Report, and Appendix 1 provides the final validated conclusions regarding potential Project effects on toxics bioavailability.

5.4.1. Verification and Validation of Data Quality Elements

Data were evaluated for quality and usability by verification and validation procedures outlined in the Phase 2 SAP (SCL 2007b). Specific procedures for this evaluation are described in Section 11 of the Phase 2 SAP and include decision-making elements established in Section 4 of the Data Quality Objectives and Decisions Criteria (SCL 2007b). Results for quality assurance analysis of data from pore water samples are reported in Appendix 3. Data quality objectives were met for most quality assurance tests, except for the cadmium matrix spike recovery. Analytical results from the laboratory reported cadmium recovery from dissolved metals samples were +1.0 percent higher than expected. This means that cadmium concentration estimates may be greater than the actual quantities in collected samples (i.e., approximately 1 percent greater than actual concentration). Blank samples were below the detection limit which indicated that contamination from handling in the field or laboratory was not a potential source. Quality assurance for October 2008 water column sampling is discussed in Appendix 1.

5.4.2. Analytical Results from Water Column Profile Sampling Sites

Concentrations for dissolved toxics from the water column profile sites are summarized in Table 5.4-1. The data summaries include all observations made from each of the sampling sites transects (e.g., three depths at each location: bottom, mid, and surface). Methyl-Hg samples

were collected from the bottom of the water column at each sampling location. In addition, a surface sample was collected for methyl-Hg at sampling location 2 along with a bottom sample in order to compare the potential bioavailability of mercury in the water column and whether potential bioavailability was present near the sediments or in the water column. Most of the water quality observations from remaining locations resulted in non-detectable concentrations (indicated by a "<" symbol). When a range for concentrations was included at a sampling site, the second expression indicated the presence of a detectable dissolved metal concentration. Chronic and acute criteria are included at the bottom of the table for each of the metals. Complete results for the March, 2008 dissolved toxics sampling are provided in Table A.4-3. Results of the October 2008 water column sampling for dissolved metals are provided in Appendix 1.

Approximately 83 percent of the water quality observations from water column sampling in March, 2008 resulted in non-detectable concentrations (indicated by a "<" symbol) for all metals. Most of the total recoverable metals concentrations were below detection limits except for lead where approximately 17 percent of observations were below detection limits. No exceedence of surface water criteria was noted at water column sampling sites except at sites 10 and 11. Concentrations for dissolved lead exceeded chronic criteria from the bottom of the water column at site 10 below Linton Creek and at the middle and bottom of the water column at site 11 (Ecology 2006). These were shallow water sites in the upper Reservoir adjacent to the town of Metaline.

Dissolved lead concentrations in the water column at sites 10 and 11 were distinct exceedences of chronic criteria at a single portion of the river and were not detected at either upstream site 12 or downstream site 9. In addition, there were no toxics exceeding criteria at site 9 or site 12. The occurrence of lead concentrations above chronic criteria in the mainstem surface water of the Pend Oreille River suggests a source for this toxic such as a tributary (e.g., Linton Creek) or from a more localized source such as runoff from suburban residential, light commercial, or highway accumulations adjacent to this portion of the river (from Metaline).

Table 5.4-1. Range of results for dissolved concentrations of toxics from water column profile sites in Boundary Reservoir for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	Arsenic (µg/L)	Cadmium (µg/L)	Mercury (µg/L)	Zinc (µg/L)	Lead (µg/L)	Methyl-Hg (µg/L)
1	<1.0	<0.2	<0.0002	<5.0	<0.2	0.00008
2	<1.0	<0.2	<0.0002	<5.0	<0.2	0.00004*, 0.00008
3	<1.0 – 1.1	<0.2	<0.0002	<5.0	<0.2	0.00019
4	<1.0	<0.2	<0.0002 – 0.002	<5.0	<0.2 – 0.56	0.00007
5	<1.0	<0.2	<0.0002 – 0.00038	<5.0	<0.2	0.00007, 0.00009
6	<1.0	<0.2	<0.0002 – 0.00023	<5.0	<0.2	0.00044
7	<1.0	<0.2	0.00027 – 0.00033	<5.0	<0.2	0.00046
8	<1.0	<0.2	<0.0002 – 0.00167	<5.0	<0.2	0.00009
9	<1.0	<0.2	<0.0002 – 0.00034	<5.0	<0.2	<0.00002
10	<1.0	<0.2	<0.0002 – 0.00028	<5.0	<0.2 – 3.46	0.00009
11	<1.0	<0.2	<0.0002 – 0.00028	<5.0 – 6.0	<0.2 – 5.46	0.00063
12	<1.0	<0.2	<0.0002 – 0.00043	<5.0	<0.2 – 0.28	0.00007, 0.00008
13	<1.0	<0.2	<0.0002 – 0.0002	<5.0	<0.2 – 0.66	0.00005
14	<1.0 – 1.0	<0.2	<0.0002 – 0.00065	<5.0	<0.2 – 0.7	0.00004
Chronic Criteria (µg/L)	190	1.03	N/A	86.5	2	N/A
Acute Criteria (µg/L)	360	3.7	2.1 (µg/L)	94.7	51	N/A

Notes:
*Surface methyl-Hg sample
µg/L – microgram per liter
N/A – criteria not available
(Source for criteria: Ecology 2006)

Concentrations for total recoverable toxics from the water column profile sites are summarized in Table 5.4-2. . The data summaries include all observations made from each of the sampling sites (e.g., three depths at each location: bottom, mid, and surface). Most of the water quality observations from each location resulted in non-detectable concentrations (indicated by a "<"

symbol). When a range for concentrations is included at a sampling location, the second expression indicates the presence of a detectable dissolved metal concentration. Complete results for the March 2008 dissolved toxics sampling are provided in Appendix 6, Table A.6-4. Results of the October 2008 water column sampling for total recoverable metals are provided in Appendix 1.

Table 5.4-2. Range of results for total recoverable concentrations of toxics from water column profile sites in Boundary Reservoir for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	Arsenic (µg/L)	Cadmium (µg/L)	Zinc (µg/L)	Lead (µg/L)
1	<1.0 – 1.1	<0.20	<5.0 – 7.0	<0.20
2	<1.0	<0.20	<5.0 – 6.0	<0.20
3	<1.0	<0.20	5.0	<0.20
4	<1.0	<0.20	5.0 – 6.0	<0.20
5	<1.0	<0.20	5.0 – 6.0	<0.20 – 0.26
6	<1.0	<0.20	<5.0 – 6.0	<0.20
7	<1.0	<0.20	7.0 – 9.0	<0.20 – 0.26
8	<1.0	<0.20	6.0 – 7.0	<0.20
9	<1.0 – 1.0	<0.20	<5.0 – 6.0	<0.20
10	<1.0 – 1.0	<0.20	6.0 – 14.0	<0.20 –12.5
11	<1.0	<0.20	<5.0 – 17.0	<0.20 – 17.3
12	<1.0 – 1.0	<0.20	6.0 – 7.0	<0.20 – 0.64
13	<1.0	<0.20	<5.0 – 7.0	<0.20 – 1.42
14	<1.0 – 1.0	<0.20	<5.0 – 16.0	<0.20 – 1.4

Note:
µg/L – microgram per liter

Field parameters were recorded at each of the three depths and are summarized in Table 5.4-3. . The data summaries include all observations made from each of the site transects (e.g., three depths at each location: bottom, mid, and surface). Range of observations measured at each location and for each parameter showed low variability. The uniformity of surface water quality field parameters at depth and throughout the length of the reservoir suggest no Project operation effect on factors that are known to promote bioavailability of toxics (e.g., pH or Redox). Complete results for the March, 2008 dissolved toxics sampling are provided in Appendix 6, Table A.6-1. Results of the October 2008 sampling of field parameters in water column samples are provided in Appendix 1.

Table 5.4-3. Range of results for field parameters collected from water column profile sites in Boundary Reservoir for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	Temperature (ºC)	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (µmhos/cm)	Redox (mV)
1	4.7 – 4.8	10.66 – 12.82	7.58 – 7.99	162.9 – 164.1	169 – 439
2	4.69 – 4.74	12.41 – 12.71	7.75 – 7.87	160.9 – 161.3	390 – 403
3	4.74 – 4.77	12.42 – 12.66	7.70 – 7.84	161.2 – 161.6	424 – 433
4	4.85 – 4.88	12.76 – 12.77	7.68 – 7.70	160.0 – 161.1	419 – 427
5	4.76 – 4.77	12.56 – 12.68	7.83 – 7.84	160.1 – 160.6	431 – 432
6	4.74 – 4.75	12.62 – 12.66	7.81 – 7.89	159.6 – 159.8	440 – 443
7	4.69	12.63 – 12.69	7.82 – 7.88	158.5 – 158.9	447 – 450
8	4.77	12.64 – 12.67	7.89 – 7.90	159.5 – 159.8	164 – 465
9	4.77 – 4.78	12.63 – 12.70	7.77 – 7.82	159.5 – 15938	467 – 468
10	4.85 – 4.86	12.70 – 12.74	7.86 – 7.90	159.5 – 160.0	465 – 467
11	4.82	12.72 – 12.75	7.81 – 7.84	159.7 – 159.9	468 – 470
12	4.92	12.59 – 12.74	7.83 – 7.87	160.1 – 160.5	465 – 467
13	4.91	12.03 – 12.79	7.83 – 7.86	159.2 – 159.3	464 – 466
14	4.88 – 4.89	12.82 – 12.83	7.82 – 7.95	159.2 – 159.6	468

Notes:
µmhos/cm – micromhos per centimeter
mg/L – milligram per liter
mV – millivolt

Concentrations for general chemistry parameters from the water column profile sites are summarized in Table 5.4-4. The data summaries include all observations made from each of the site transects (e.g., three depths at each locations: bottom, middle, and surface). Range of observations measured at each location and for each parameter showed low variability from surface to bottom depths. Water quality parameters such as hardness were uniformly high at all depths and sampling locations and serve as and important factor in reducing the toxicity of dissolved metals in the water column and at the sediment/surface water interface (e.g., boundary layer). Complete results for the March 2008 dissolved toxics sampling are provided in Appendix 6, Table A.6-2. Results of the October 2008 sampling of general chemistry parameters in water column samples are provided in Appendix 1.

Table 5.4-4. Range of results for general chemistry concentrations and measurements collected from water column profile sites in Boundary Reservoir for March 2008 samples (results from October 2008 can be found in Appendix 1).

Site No.	Turbidity (NTU)	Alkalinity (mg $CaCO_3$/L)	DOC (mg/L)	Hardness (mg $CaCO_3$/L)
1	0.70 – 0.76	80.3 – 82.0	1.18 – 1.37	78.0 – 81.1
2	0.73 – 0.78	80.4 – 81.0	1.24 – 1.50	77.6 – 77.8
3	0.67 – 0.74	80.3 – 80.9	1.21 – 1.28	77.8 – 80.3
4	0.81 – 0.84	79.4 – 79.9	1.18 – 1.38	77.0 – 77.6
5	0.78 – 0.83	79.2 – 79.8	1.24 – 1.46	77.2 – 77.8
6	0.74 – 0.83	78.4 – 80.4	1.21 – 1.34	77.0 – 77.4
7	0.76 – 0.81	78.7 – 79.4	1.25 – 1.34	76.8 – 77.4
8	0.77 – 0.80	78.1 – 80.3	1.34 – 1.59	77.4 – 78.6
9	0.78 – 0.79	78.2 – 79.3	1.45 – 1.91	77.0 – 78.0
10	0.78 – 2.0	79.5 – 80.3	1.27 – 1.51	76.2 – 77.8
11	0.84 – 4.9	78.7 – 79.5	1.25 – 1.463	77.8 – 78.8
12	0.94 – 1.7	78.2 – 79.4	1.27 – 1.85	76.2 – 78.2
13	0.73 – 1.8	78.3 – 79.9	1.25 – 1.45	77.8 – 78.8
14	0.73 – 0.85	78.4 – 80.0	1.27 – 1.31	76.8 – 77.8

Notes:
$CaCO_3$ – calcium carbonate
mg/L – milligram per liter
NTU – nephelometric turbidity unit

5.4.3. Hypothesis Testing: Water Column Sampling and the Toxicological Models

Factors affecting mobilization of toxics between media were originally outlined in toxicological models developed for the Phase 1 Toxics Assessment Report in Appendix 1 to the Phase 2 SAP (SCL 2007b). Field parameters and general chemistry results were selected to evaluate those factors that would promote the potential for bioavailability of the toxics. The toxicological models presented in Section 5.1 form the basis for hypothesis development and are tested here by comparing results from the water column sampling with variables shown to affect bioavailability of contaminants of concern in the waters of Boundary Reservoir.

5.4.4. Potential for Bioavailability of Zinc in the Water Column

The most important factors that will directly promote the bioavailability of zinc in the surface waters of Boundary Reservoir include zinc concentration, low hardness, and low pH. Direct measurements of total and dissolved zinc in the surface waters of Boundary Reservoir indicate that zinc is associated with bound material due to the lack of dissolved zinc being detected in the surface waters. Both total (maximum detected = 17 µg/L) and dissolved (only detection = 6 µg/L) zinc concentrations observed in March and October 2008 were below the acute (94.7

µg/L) and the chronic (86.5 µg/L) water quality criteria, thereby limiting bioavailability. The most important physicochemical factors affecting bioavailability of zinc in water are hardness and pH (EPA 1987; Florence and Batley 1980). High hardness and pH limit zinc bioavailability in surface waters of Boundary Reservoir and are consistently high throughout the water column at other times of the year as reported in Study 5 (SCL 2009d).

5.4.5. Potential for Bioavailability of Cadmium in the Water Column

The exposure risk of aquatic biota to cadmium and the likelihood of bioaccumulation are not as great in surface water as they are in sediment due to the rapid sorption of cadmium to particulate matter. The most important factors influencing cadmium bioavailability in surface water are increased cadmium concentration, low hardness, and low suspended material (Figure 5.1-2). Total and dissolved cadmium were not detected in any of the water column sampling locations in either March or October 2008 and so were not bioavailable.

5.4.6. Potential for Bioavailability of Lead in the Water Column

The exposure risk of aquatic biota to lead and the likelihood of bioaccumulation are low in the surface waters of Boundary Reservoir. Lead is normally tightly bound to sediments and is less soluble in surface water than either zinc or cadmium under oxygenated conditions. The most important factors promoting lead bioavailability in surface water are increased concentration, low hardness, low DOC, and low suspended material (Figure 5.1-3). Concentrations of total and dissolved lead were detected in 28 percent of the samples in Boundary Reservoir from March, 2008. Site 11 middle and bottom water column samples and site 10 bottom water column sample yielded detectable concentrations of dissolved lead in excess of the chronic water quality criteria of 2 µg/L, but there were no concentrations measured above the acute water quality criteria of 51 µg/L (Table 5.4-1). Most of the samples from October 2008 had no detectable lead concentrations, and none of them exceeded the chronic criteria. One of several factors is necessary to limit transferability of this metal between media (e.g., sediment or surface water) and reduce bioavailability. Of these factors, hardness was high in all samples and served as a continuous buffer limiting bioavailability.

5.4.7. Potential for Bioavailability of Arsenic in the Water Column

The exposure risk of aquatic biota to arsenic and the likelihood of bioaccumulation were predicted to be moderate in all media of the Boundary Reservoir (e.g., sediment, pore water, and surface water). The most important factors or condition promoting arsenic bioavailability in surface water are increased concentration and reducing conditions (low dissolved oxygen or anoxic conditions) (Figure 5.1-4). Concentrations of dissolved arsenic were detected in fewer than 5 percent of the samples (2 of 43) from March, 2008, while total arsenic was detected in 17 percent of samples (7 of 43). The detectable concentrations of both total and dissolved arsenic were two orders of magnitude less than the chronic water quality criteria. Results from October 2008 sampling was similar. The potential for bioavailability of arsenic is diminished by the lack of arsenic in the Reservoir and also by the high dissolved oxygen concentrations measured in the water column. Dissolved oxygen concentrations were high at all sampling locations and from all samples collected from surface and at depth. Therefore, due to the low arsenic concentration and

the highly oxygenated waters, the potential for arsenic bioavailability is negligible in Boundary Reservoir.

5.4.8. Potential for Bioavailability of Mercury in the Water Column

The exposure risk of aquatic biota to mercury and the likelihood of bioaccumulation are greatest in sediment and food sources (risk of bioaccumulation is low in surface water). Concentrations of dissolved inorganic mercury in the surface waters of Boundary Reservoir during March and October 2008 were well below the acute (2.1 µg/L) criteria (chronic criteria do not exist for dissolved Hg or methyl-Hg). The most important factors promoting mercury bioavailability in surface water at Boundary Reservoir are neutral to low pH, low dissolved oxygen, low DOC, and increased temperature (Figure 5.1-5). One of several factors is necessary to limit transferability of this metal between media (e.g., sediment or surface water) and reduce bioavailability. Physicochemical factors that limit bioavailability of methyl mercury in Boundary Reservoir are high pH, high dissolved oxygen, and low DOC throughout the water column at all sites. The high pH and dissolved oxygen concentrations limit the bioavailability of mercury in Boundary Reservoir.

Anaerobic conditions characterized by low pH and dissolved oxygen can increase the methylation of mercury by enhancing microbial respiration. In freshwater systems, inorganic mercury is typically converted to methyl-mercury as a byproduct of microbial respiration. Therefore, an increase in microbial respiration will lead to an increase in the methylation of inorganic mercury. Dissolved oxygen concentrations were high in surface waters in contact with the sediment, and pore water pH was neutral (>7); thus, anaerobic conditions were not observed at Boundary Reservoir sampling locations, resulting in low bioavailability of mercury in the water column. DOC was low, which would also limit bioavailability of mercury in the Reservoir.

5.5. Nexus Between Project Operations and Bioavailability

Project operations at Boundary Reservoir do not affect the concentration and distribution of divalent metals, organometals, and PCBs as demonstrated by sampling surface water, sediment, and pore water in the water fluctuation zone as well as deep water areas. Many physical and physicochemical parameters that influence potential toxicity and bioavailability of the toxics of concern were evaluated. Pool elevation fluctuation could theoretically influence processes such as direct entrainment of sediment that may be contaminated with toxics, hydration and dissolution of toxics from soils within the water fluctuation zone, and resuspension/mobilization of sediments. However, this study shows that pool elevation fluctuation at Boundary Reservoir is not contributing to toxics loading. At Boundary Reservoir, the physicochemical aspects that could lead to toxics availability, including dissolved oxygen concentrations, pH, DOC, suspended solids, and hardness are such that they limit the movement of toxics from one medium to another. In addition, this study shows that Project operations do not have an effect on any of these factors because water quality characteristics are consistent throughout the Reservoir and water column despite water level fluctuations.

The fluctuation of pool levels was evaluated for influence of entrainment and transport of fine sediments from the shoreline of Boundary Reservoir. The influence of pool level fluctuation on

areas related to past and current mining activities was described in the Erosion Study (SCL 2009c). Mine sites from which materials could potentially reach the reservoir were on upland areas and above the high water mark. Sources of elevated lead concentrations found in the water column at sites 10 and 11 during March 2008 sampling appear to have been affected by nearby tributaries or surface runoff from adjacent land use activities that were above the influence of the water surface elevation fluctuation in the reservoir.

Isolated exceedences of water quality criteria such as those found at sites 10 and 11 in March 2008 did not occur at adjacent sites, either upstream or downstream or in other media at sites 10 and 11. The lack of larger scale identification (i.e., at a greater number of locations) of higher toxics concentrations together with low sediment concentrations indicates that localized effects were most likely responsible for these exceedences.

Additional sampling in October 2008 focused on sites 5 and 8, where March 2008 pore water sampling had detected dissolved zinc and lead concentrations at site 5 and zinc concentrations at site 8 (at site 5, one out of three pore water replicates for zinc and lead exceeded criteria for surface water - at site 8, one out of three pore water replicates for zinc exceeded criteria for surface water). At sites 5 and 8, the contribution of upland materials from mine or industrial sites located outside of the water fluctuation zone or shallow interflow seeps are likely the sources of elevated lead and zinc concentrations. Site 1 (Forebay) and site 14 (Box Canyon Tailrace) were sampled to establish a frame of reference so that comparisons could be made against toxics concentrations at the upstream and downstream ends of the reservoir.

Use of surface water criteria to evaluate pore water sample toxicity is not well-defined in the current Washington state regulation. The absence of freshwater sediment criteria means that evaluation of media associated with sediments (e.g., pore water and sediment) needs to be evaluated using multiple sources of information. Toxics associated with hard sediment are not consumed as food and, therefore, are not bioavailable, whereas toxics in pore water may be adsorbed by sediment-dwelling organisms through respiratory tissue (e.g., gills). Sediment-dwelling organisms are more tolerant of low dissolved oxygen concentrations and pH, and are short-lived (e.g., 2 weeks to 1-year), so that bioaccumulation is not a factor that determines rate of mortality as much as predation or physical disturbance of the environment. Long-term exposure to toxics in sediment and pore water will determine effects on sediment-dwelling biota, but if the concentrations in the media are transient, then biota will either be unaffected due to the short duration of exposure or may move to an adjacent location where environmental conditions are more suitable. The measurement of toxics in pore water may also overestimate concentrations from ambient conditions, as sample handling and extraction techniques disturb in-river conditions. Disturbance of sediment as it is being collected and stored following sampling may change the oxygen demand from organic content in the sediment matrix. Chemical characteristics can change (e.g., pH) in the sediment sample environment and release toxics adsorbed to fine sediment particles.

Results from October 2008 sampling at site 5 showed that no lead or zinc (or other analyzed toxics) concentrations exceeded surface water criteria or LAET thresholds from sediment, pore water, or surface water. The zinc and lead concentrations in pore water that exceeded surface water criteria in 1 of 3 samples in March 2008 were a transient condition that did not persist, as

confirmed by the absence of exceedences at site 5 during October 2008 sampling. Zinc and lead pore water exceedences were also not found in October 2008 at immediately upstream or downstream locations of the original site 5 sampling location, meaning that toxic effects are neither long-lived nor widespread. Zinc and lead are not bioavailable under current Project operations at site 5, as physicochemical factors such as pH, DO, and hardness are at levels that inhibit transfer between media. Moreover, these physicochemical factors were shown to be constant during both sampling events, indicating that inhibition of toxics transfer is characteristic of the reservoir.

October 2008 sampling detected lead concentrations in pore water that exceeded chronic surface water criteria in all three replicates at the original site 8 (although no such exceedences were observed there in March 2008) and in one of three replicates at the downstream location. Average pore water concentrations at the upstream and downstream locations at site 8 did not exceed chronic criteria. Average sediment concentrations at Site 8 and the upstream and downstream locations were all below the LAETs. The discovery of sediments at the upstream and downstream locations during the October 2008 sampling differed from the March 2008 conditions, when sediments were absent at these locations, demonstrating that sediments are transient at site 8.

Sampling at site 8 isolated pore water exceedences for lead to the original location sampled in March 2008. Water quality factors associated with transfer of the lead (e.g., low pH and low hardness) from pore water to surface water within the reservoir were not present, as was confirmed by the water column sampling, where no lead was detected at Site 8 or the upstream or downstream locations. The original site 8 sampling location has adjacent bank materials originating from above the Project operation zone, located between the upstream sampling location and the original sampling location, both of which were sampled in October 2008 (Appendix 1). Toxics introduced by Project operations would have been detected in similar concentrations at the upstream site 8 location if originating from within the reservoir. Study 1 Erosion (SCL 2009c) indicated that the shoreline adjacent site 8 and the Grandview Mine is dominated by gravel and has a moderate susceptibility to erosion from Project operations. Toxics are not associated with coarse gravel material and so sources of finer material (silt and sand) from outside the fluctuation zone appear to be the source of toxics being introduced into the reservoir. Given the slope of the banks surrounding the site 8 sampling location and its makeup (gravel), the upland lead sources appear to be originating from outside the Project high water mark and will enter the reservoir regardless of water level fluctuations (see Figure 4.2-9 in Appendix 1). The upland source of toxics is being addressed through the CERCLA process.

5.5.1. Divalent Metals

Water quality conditions that promote divalent metal bioavailability in either the water column or the sediment, due to Project operation, are absent. These factors include hardness, dissolved oxygen, and pH that control toxicity and bioavailability of divalent metals (zinc, lead, and cadmium). Project operations do not affect these factors, as evidenced by consistent water quality characteristics throughout the Reservoir and water column. This is an important observation that reveals there is little to no effect from Project operations on water quality.

Boundary Reservoir water hardness (average 77.7 mg $CaCO_3$/L ± 0.92 mg $CaCO_3$/L) indicates low variability from one site to the next and was not stratified within any particular site in the March 2008 survey. Dissolved oxygen levels measured throughout the water column indicated aerobic conditions (>12.0 mg/L) and near saturation throughout the study period. In Boundary Reservoir, pH measurements historically have been between 7.2 and 8.0; therefore, Project operations do not influence pH. Based on available data, Project operations do not affect the concentration or bioavailability of divalent metals in the water column.

5.5.2. Organometals

The fluctuation of water level due to Project operations at Boundary Dam has no effect on the concentration and distribution of organometals (arsenic and mercury) in Boundary Reservoir. Potential pathways involving Project operations that could affect organometal contamination are the same as those noted for divalent metals.

Similar to divalent metals, organometals are also affected by water column and sediment dissolved oxygen and pH. Both dissolved oxygen and pH were measured to be consistently high throughout the Reservoir. Therefore, ongoing Project operations have little to no impact on factors that could affect organometal toxicity and bioavailability.

If high concentrations of organics exist in the sediment, sediment concentrations of organometals are the most likely exposure pathway for bioavailability through ingestion. Boundary Reservoir sediment organic concentration is low and limits uptake. Also, concentrations of organometals are low in the sediment. Water quality conditions that serve as primary drivers for promoting bioavailability of these toxics (pH and dissolved oxygen concentrations) show a consistent pattern throughout the year as reported in this field sampling effort and results reported in Study 5 (SCL 2009d). This means that bioavailability of toxics is not seasonally or spatially dependent and will not present a risk to biota in the reservoir.

5.5.3. Polychlorinated Biphenyls

Similar to mercury and other metals discussed above, bioaccumulation potential of PCBs is associated with anoxic conditions, fine sediment particle size, and higher DOC content. Sediment concentrations of PCBs were not detected at any site sampled in the March 2008 survey and, based on this, bioavailability is low.

5.6. Conceptual Decision Matrix for Determining Bioavailability

A decision matrix was developed and presented to the FERC as a revision to Section 2.4 – Additional Sampling Decisions of the SAP (filed by SCL on September 28, 2007, and approved per the FERC letter dated October 25, 2007). Figure 2.4-1b, Conceptual Decision Matrix for Evaluating Potential Biological Effects, is a one-page decision matrix that graphically portrays the process by which the presence of toxics in each of the media (e.g., surface water sampling-transects, sediment sampling, water column profile, and pore water sampling) were to be evaluated. Each of the decisions in the matrix used data collected from field sampling, and determinations were then made on the potential for bioavailability of toxics. This decision

process merges the identification of observations that exceeded applicable criteria or thresholds and determinations from toxicological and pathway models.

For illustration and clarity purposes, six conceptual matrix diagrams have been developed for each of the six toxics of concern and are included in this section.

5.6.1. Zinc

Zinc was found in March 2008 at sites 5 and 8 in pore water at levels that exceeded acute criteria, but in both cases, only from one of three replicates collected (5-PW-2 and 8-PW-1, respectively). In October 2008 all samples results, including from re-sampling at sites 5 and 8, were below the chronic criteria. Using the conceptual decision matrix (Figure 5.6-1) and beginning with "Pore Water Sampling" under Sampling Strategy, toxics were present when evaluated for status. The LAET and second LAET were not exceeded under Decision Criteria, indicating that a sediment source for zinc does not account for these exceedences based on factors absent from the water column that promote toxics movement from sediment to pore water; therefore, the final decision was that potential bioavailability of zinc was not possible.

5.6.2. Lead

Lead was found at site 10 near the bottom of the water column and at site 11 near the bottom and middle of the water column. Concentrations of lead at both sampling locations exceeded acute criteria based on WDOE Water Quality Standards. The source for lead does not originate from sediments, as samples indicate no exceedence of the LAET and second LAET, and factors that promote toxics movement from sediment to pore water were absent. Further examination of the potential for bioavailability using the conceptual decision matrix in Figure 5.6-2, determined that bioavailability of lead was not possible.

Lead was also found in pore water at site 5 that exceeded chronic water quality standards in one of the three replicates collected (5-PW-2) during March 2008. The LAET and second LAET were not exceeded under Decision Criteria, indicating that a sediment source for lead does not account for these exceedences based on factors absent from the water column that promote toxics movement from sediment to pore water. Further examination of the potential for bioavailability using the conceptual decision matrix in Figure 5.6-2, determined that bioavailability of lead was not possible. October 2008 sampling indicated that no toxics in pore water exceeded chronic surface water criteria at site 5. The absence of lead at site 5 in a subsequent sampling event (i.e., subsequent to March 2008 sampling) indicates the transient nature of lead concentrations and that elevated concentrations are limited to a very limited area at any time.

Lead concentrations found in pore water at site 8 (October 2008 sampling) that exceeded chronic water quality criteria occurred in all three samples at the original location (e.g., site 8-PW-1, 8-PW-2, and 8-PW-3) and at one of the locations downstream (e.g., 8 DWN-PW-2). In addition, one of three sediment samples at the original site 8 location exceeded the LAET threshold. Transfer of lead from between media based on Project operations did not occur, as factors preventing bioavailability (e.g., high hardness and neutral pH) were present in overlying surface water and in pore water. Since factors were unchanged in surface and pore waters during current

Project operations, lead bioavailability is not possible for lack of identifiable pathways that would promote transfer from physical media to biological organisms.

5.6.3. Cadmium

Cadmium was either not found in detectable quantities in some media (e.g., surface water) or in concentrations substantially lower than applicable Washington State Department of Ecology (Ecology) Water Quality Standards or thresholds (Figure 5.6-3). Cadmium was not bioavailable in the Reservoir.

5.6.4. Arsenic

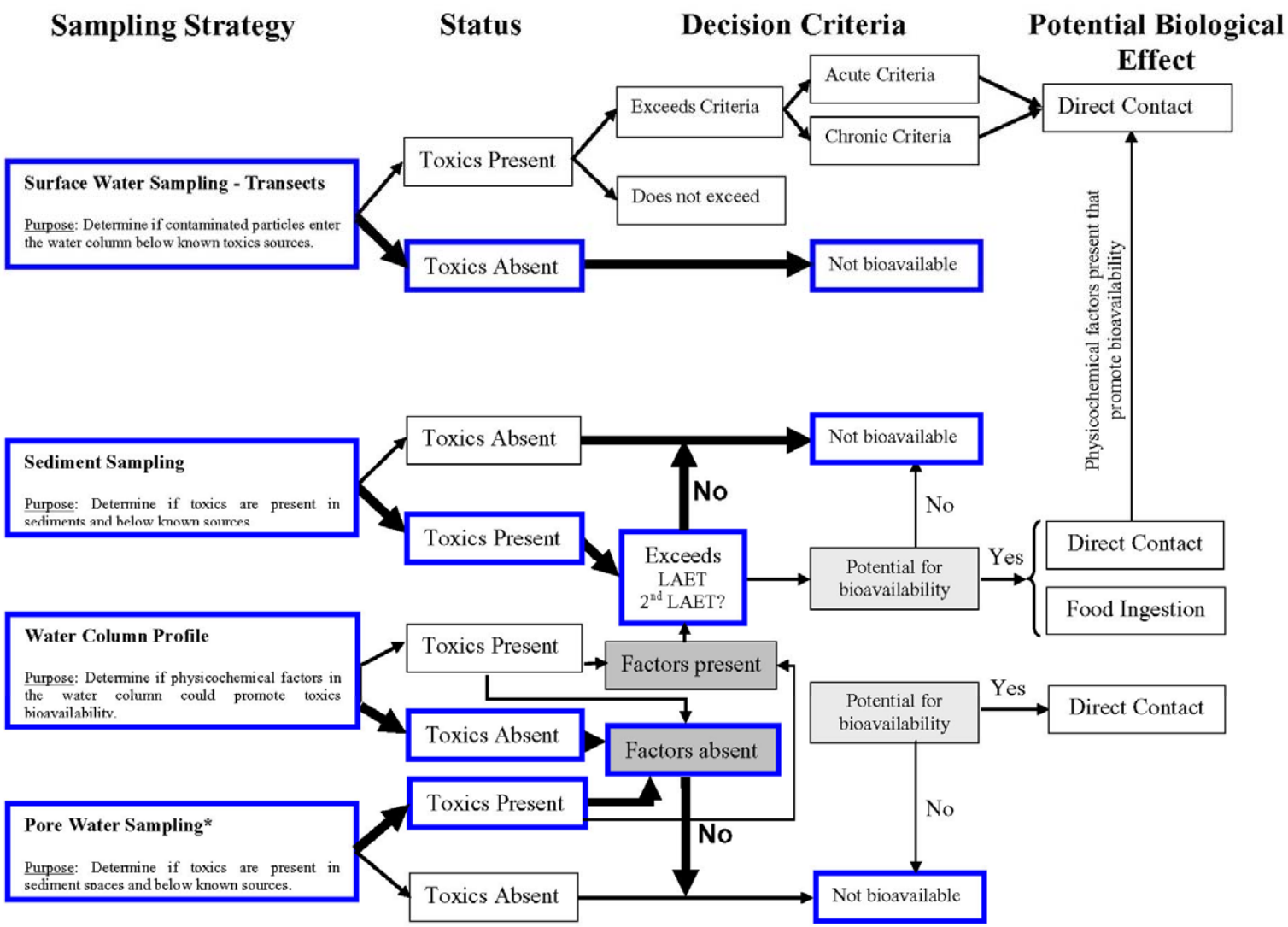
Arsenic was either not found in detectable quantities in some media (e.g., surface water) or in concentrations substantially lower than applicable Ecology Water Quality Standards or thresholds (Figure 5.6-4). Arsenic did not exceed LAETs in any of the sediment samples collected from locations in the Boundary Reservoir and was not bioavailable.

5.6.5. Mercury

Mercury was found in very low concentrations in media (e.g., surface water, pore water, and sediment) throughout the Reservoir. All detectable concentrations were substantially lower than applicable Ecology Water Quality Standards or thresholds (Figure 5.6-5). Mercury did not exceed LAETs in any of the sediment samples collected from locations in the Boundary Reservoir and was not bioavailable.

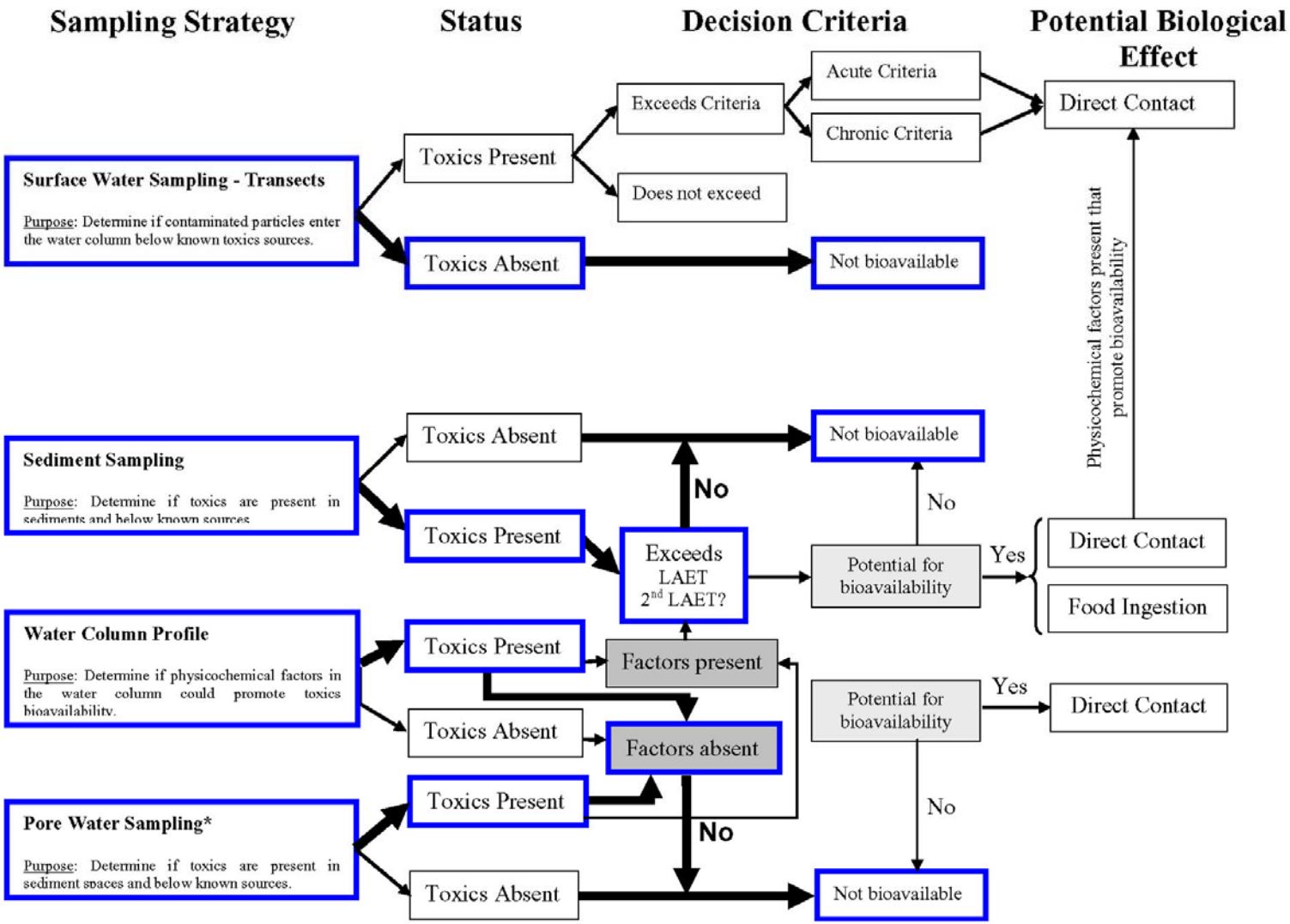
5.6.6. PCBs

PCBs were not found in detectable quantities in sediments from sites in Boundary Reservoir. PCB aroclors are not bioavailable from sediments in Boundary Reservoir and water quality conditions do not promote bioavailability (Figure 5.6-6).



note: a) Dark shaded boxes indicate information originates from Toxicological Models for each toxic (Final Phase 1 Report).
b) Light shaded boxes indicate information considered from other Relicensing studies (Figure 2.4-1a, Box 2c.) to support determination for potential bioavailability.
c) *Site 5-PW-2 and Site 8-PW-1 (one of three replicates at each site) exceeded the acute water quality standard (did not exceed sediment LAETs) (March 2008 sampling results).

Figure 5.6-1. Conceptual decision matrix for evaluating potential biological effects from zinc (for March and October 2008 sampling results).



note: a) Dark shaded boxes indicate information originates from Toxicological Models for each toxic (Final Phase 1 Report).
b) Light shaded boxes indicate information considered from other Relicensing studies (Figure 2.4-1a, Box 2c.) to support determination for potential bioavailability.
c) § Exceeds chronic criteria in the water column at Site 10 and Site 11(March 2008 sampling); source not from sediments because factors absent for transfer between media.
d) * Site 5-PW-2 (one of three replicates) exceeded the chronic water quality standard (did not exceed sediment LAETs) (March 2008 sampling results); site 8-PW-1 through 8-PW-3 (all three replicates) and 8 DWN-PW-2 exceeded the chronic water quality standard (exceeded sediment LAET at 8-SED-2) (October 2008).

Figure 5.6-2. Conceptual decision matrix for evaluating potential biological effects from lead (for March and October 2008 sampling results).

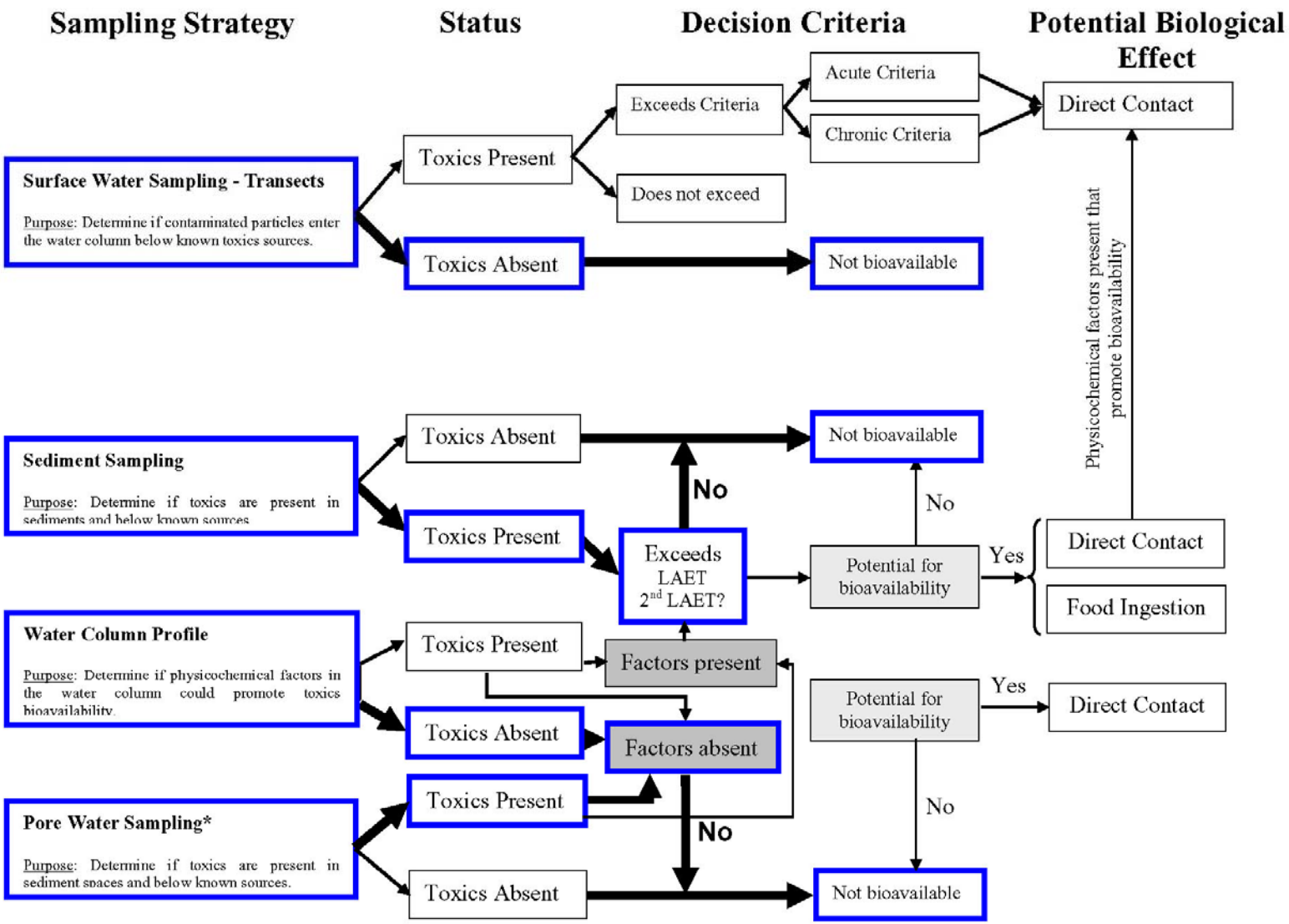
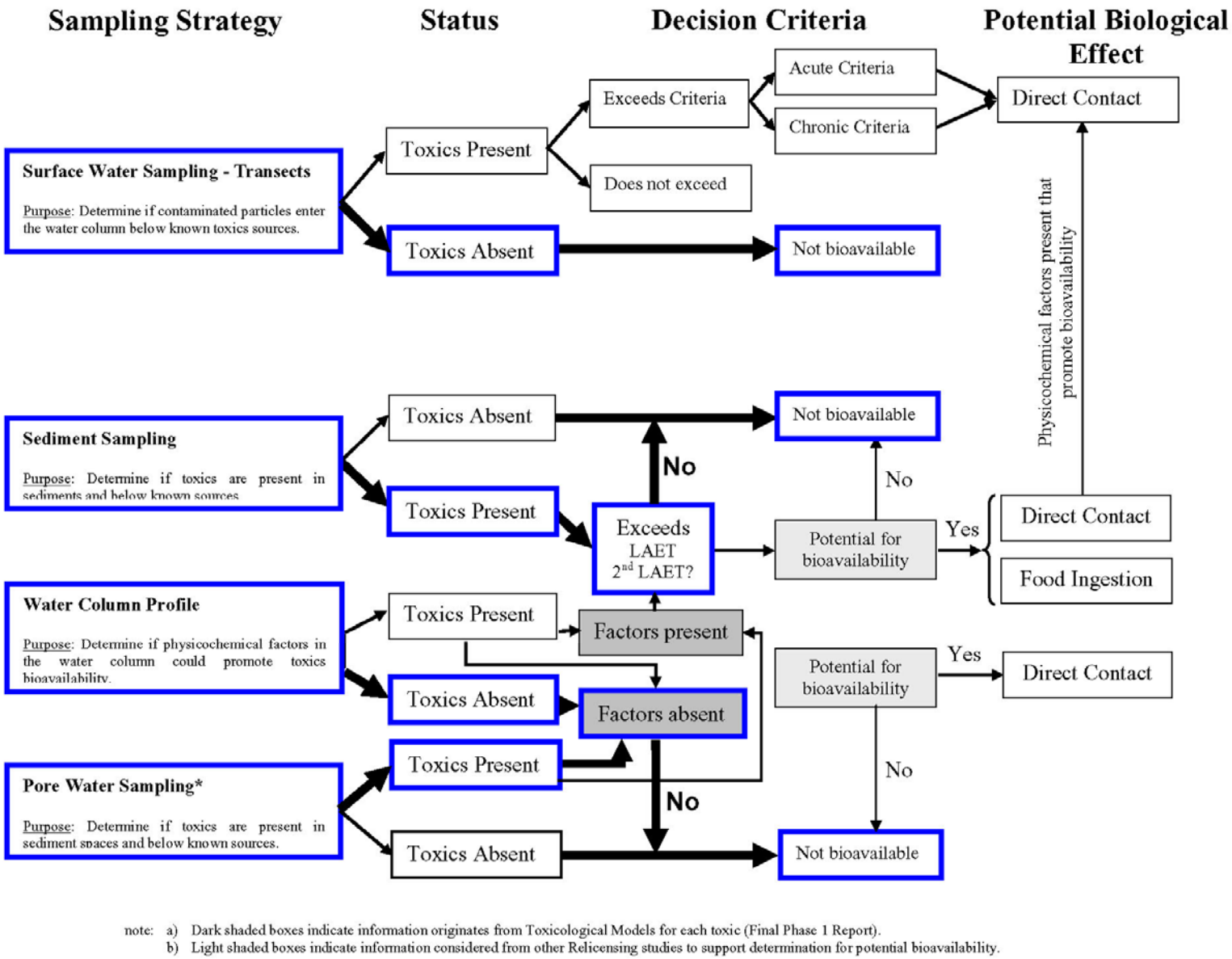
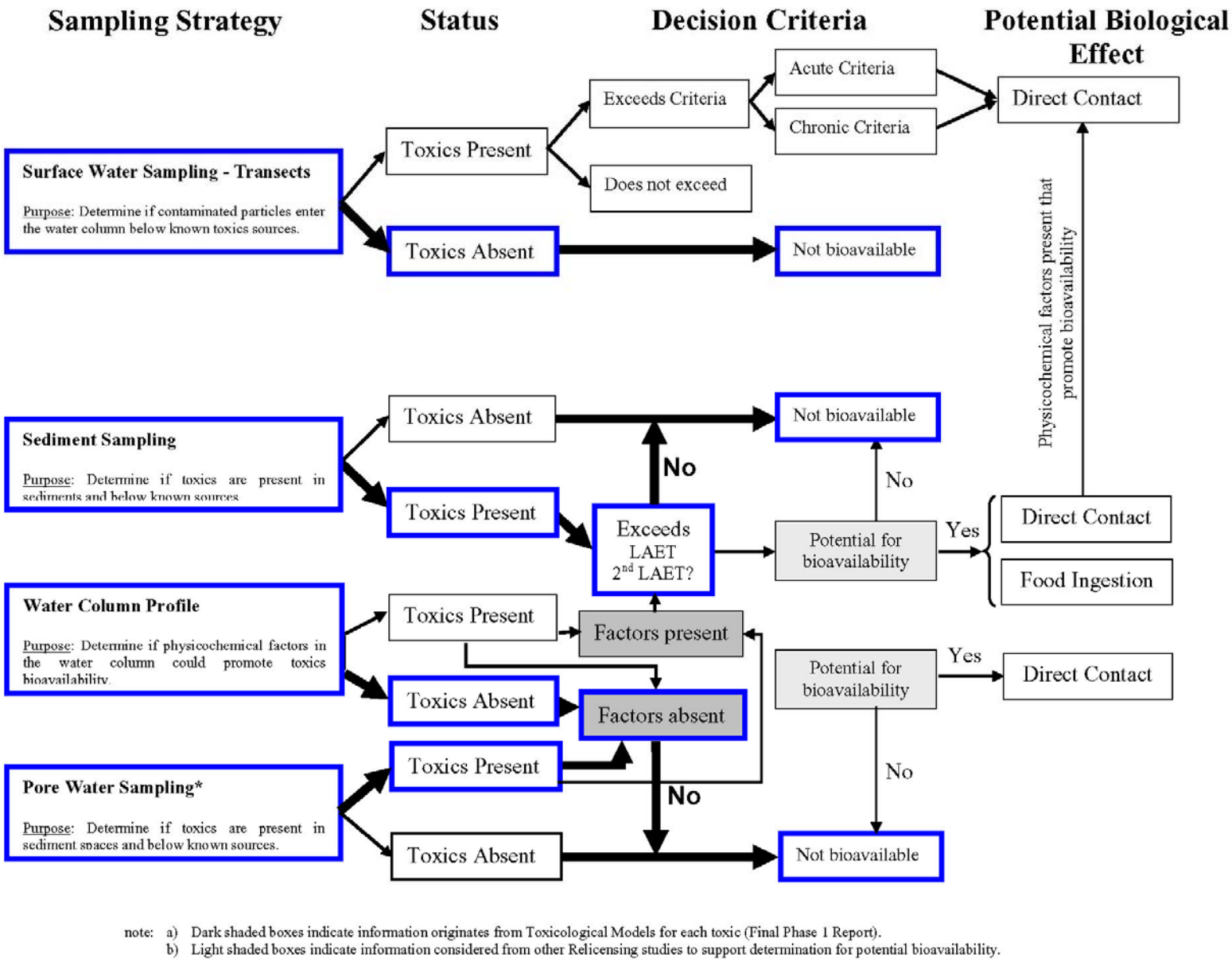


Figure 5.6-3. Conceptual decision matrix for evaluating potential biological effects from cadmium (for March 2008 sampling results).



note: a) Dark shaded boxes indicate information originates from Toxicological Models for each toxic (Final Phase 1 Report).
b) Light shaded boxes indicate information considered from other Relicensing studies to support determination for potential bioavailability.

Figure 5.6-4. Conceptual decision matrix for evaluating potential biological effects from arsenic (for March 2008 sampling results).



note: a) Dark shaded boxes indicate information originates from Toxicological Models for each toxic (Final Phase 1 Report).
b) Light shaded boxes indicate information considered from other Relicensing studies to support determination for potential bioavailability.

Figure 5.6-5. Conceptual decision matrix for evaluating potential biological effects from mercury (for March 2008 sampling results).

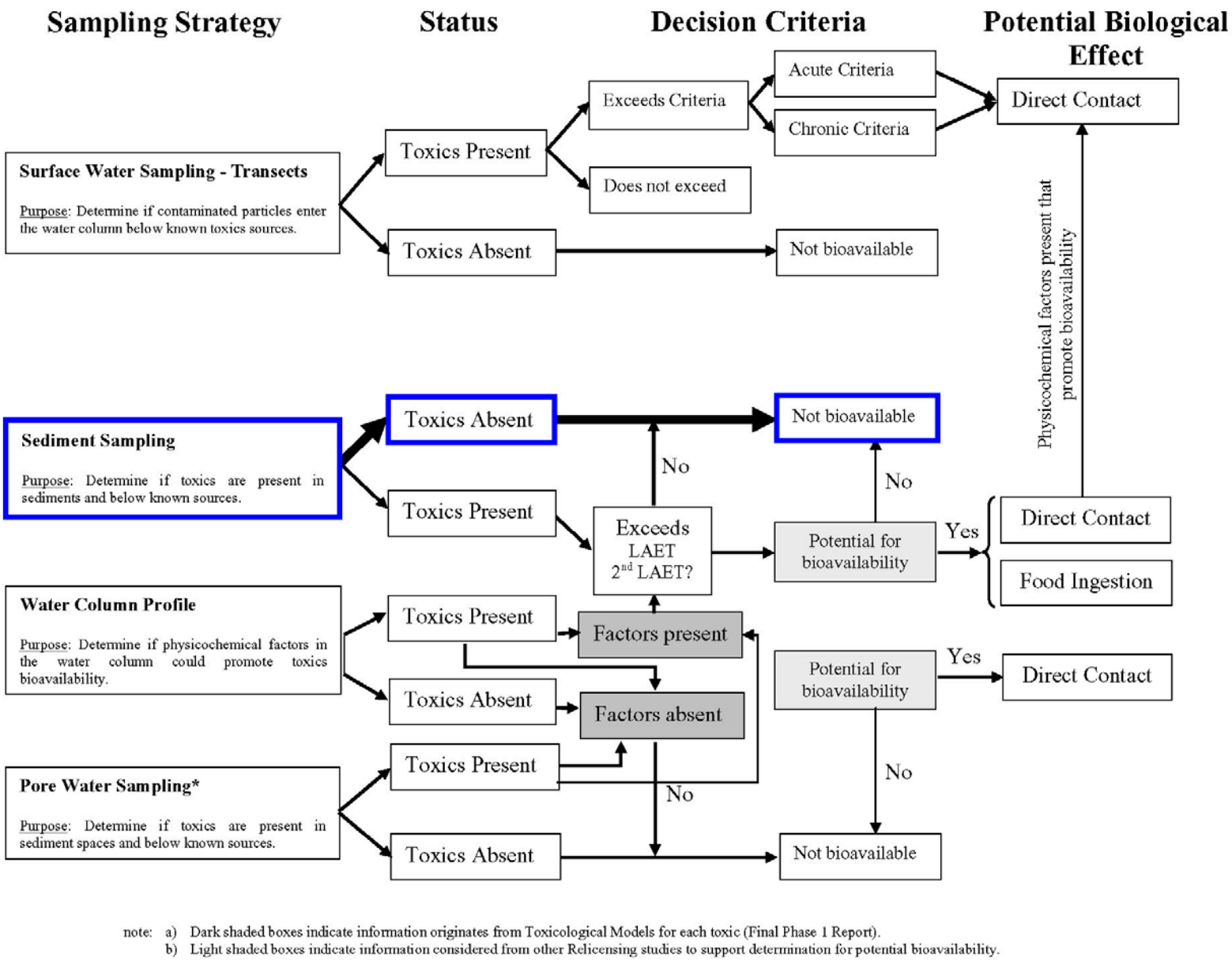


Figure 5.6-6. Conceptual decision matrix for evaluating potential biological effects from PCBs (for March 2008 sampling results).

6 CONCLUSIONS

Several tools were used to evaluate the presence and potential for bioavailability of toxics throughout Boundary Reservoir. These tools included direct sampling of media (water, sediment, and sediment pore water), toxicological models (identified factors that could promote bioavailability of toxics), pathway models (how toxics move between media such as sediments, pore water, and surface water), and the conceptual decision matrix. In addition, the effect from Project operations was evaluated based on results from the analysis. The combined conclusions from those tools and interpretations are presented here.

During sampling conducted in March 2008, overall concentrations of toxics were either low or absent in media sampled from throughout the reservoir. Isolated exceedences were detected from two surface water sites (i.e., bottom at site 10 and mid- and bottom at site 11 for lead) and from two pore water sites (i.e., sites 5 and 8 for zinc and site 5 for lead), but these did not suggest sources originating from within the reservoir. Re-sampling at site 5 in October 2008 showed that no concentrations of lead or zinc in pore water exceeded chronic surface water quality criteria based on a broader sampling effort (e.g., downstream, original location, and upstream). October sampling at site 8 showed exceedence of average pore water concentrations of lead in pore water at the original location, but no zinc exceedences. Linkages that would indicate within-reservoir sources for these toxics did not exist (e.g., sediment-pore water-surface water associations), and water chemistry factors that would promote transfer of these toxics into bioavailable forms were absent. The appearance of elevated lead concentrations at site 8 in October 2008, but not March 2008, indicate the transient nature of low-level concentrations that occur.

Multiple lines of evidence were examined to assess any transfer of toxics that might indicate bioavailability attributable to Project operations. This information was used to evaluate potential origins such as mobilization of toxics from reservoir banks, or movement of toxics from the permanently wetted area and in a downgradient direction. There were no detectable concentrations of toxics in the upper portion of the water column. This indicates that Project operations are not attracting additional toxics-laden material into the reservoir because they were not found either in the active water fluctuation zone (surface to 10-foot depth) or laterally across the reservoir.

Results from Study 5 (SCL 2009d) for all seasons confirm the presence of high pH, hardness, and relatively high DO, all of which inhibit transfer of toxics to biota. Moreover, hardness, pH, and DO are dominant factors over temperature in terms of influencing toxics bioavailability.

Similarly, toxics were not detected in significant concentrations at sampling locations adjacent to where exceedences were measured (i.e., upstream, downstream, or both), suggesting transfer within the channel and in a down-gradient direction does not occur. Lead detected in the water column in isolated replicate samples (at sites 10 and 11; March 2008 sampling results) was not transferred between media because ambient water chemistry suppressed mobilization (e.g., high hardness serving as a continuous buffer limiting bioavailability and well-oxygenated surface water), and because sediment concentrations at these sites were lower than in overlying surface water, as were pore water concentrations. Lead concentrations in sediments were well below the

LAETs at these sites and were similar to other sampling locations in the Upper Reservoir, Metaline Falls, Canyon, and Forebay zones.

The reservoir showed characteristic signs of a riverine system based on sediment particle size analysis. Results from size fractionation of sediments generally showed coarser sediment sizes in the upper reservoir and finer sediment in the Boundary Forebay Zone. An earlier hypothesis for the potential transfer of toxics was that movement from the Box Canyon tailrace toward Boundary Dam was occurring (meaning that upriver contaminant sources outside of the reservoir as far as the Clark Fork system were hypothesized to be moving downstream through the basin). Regardless of source for toxics (above the Boundary Reservoir or from mining and industrial sites within), empirical evidence indicates that no significant downstream migration of toxics is occurring, because elevated concentrations of select toxics such as zinc did not exceed established thresholds for freshwater sediments, even in the presence of regular pool fluctuations.

The goal of the Toxics Assessment was to determine whether the toxics of concern (arsenic, cadmium, lead, mercury, zinc, and PCBs) were present in the reservoir, and if so, whether Project operations increased their bioavailability. Based on the combined results of sampling conducted in November 2007 and in March and October 2008, multiple lines of evidence, including a variety of analytical techniques, indicate that Project operations do not increase or influence the bioavailability or mobility of toxics.

Toxics are generally found in very low concentrations and exceedences are spatially and temporally infrequent, reflecting input from localized terrestrial sources rather than large-scale effects due to Project operations. Moreover, overlying surface water conditions are such (i.e., high hardness, pH, and DO levels) that they inhibit movement of toxics from the sediment to other media (e.g., pore water and diffusion into surface water), thereby preventing toxics of becoming available to biota.

The following are the objectives and accomplishments for each in this study:

Objective 1. Develop a SAP for toxics of concern that were identified in the Phase 1 Toxics Assessment Report (Appendix 1 of the Phase 2 SAP [SCL 2007b]) as being potentially affected by Boundary Project operations.

- FERC approved the Phase 2 SAP in a letter dated October 25, 2007.

Objective 2. Conduct field sampling and sample analyses.

- Field work and sample analysis included water fluctuation zone Sampling (November 2007), water column, pore water, and sediment sampling (March 2008; all sites visited), water column, pore water, and sediment sampling (October 2008 at sites 1, 5, 8, and 14).

Objective 3. Review new information from related studies such as one-dimensional hydraulic routing model results, and submerged mines analysis for potential contribution of toxics to surface water. In addition, also review information from three other studies conducted in 2007

that may be relevant to this Toxics Assessment: Study 8, Sediment Transport and Boundary Reservoir Tributary Delta Habitats Study (SCL 2008b); Study 7, the Mainstem Aquatic Habitat Modeling Study, hydraulic routing model component (SCL 2008c); and Study No. 1, the Erosion Study (SCL 2008d) to determine if additional Phase 2 sampling may be necessary or useful for evaluating Project operation impacts.

- SCL filed the Study 4 Interim Report with FERC on August 15, 2008, and FERC concurred with report findings and conclusions regarding additional sampling in a letter dated September 24, 2008.

- Study 1 Erosion (SCL 2009c) indicated that the shoreline adjacent site 8 and the Grandview Mine is dominated by gravel and has a moderate susceptibility to erosion from Project operations. Toxics are not associated with coarse gravel material and so sources of finer material (silt and sand) from outside the fluctuation zone appear to be the source of toxics being introduced into the reservoir.

Objective 4. Conduct additional sampling as necessary, based on the results of the 2007 and early 2008 toxics sampling (Objective 2) and results of other ongoing studies (Objective 3).

- SCL conducted additional sampling at sites 1, 5, 8, and 14 in October 2008.

- Results from additional sampling showed no zinc exceedences where previously detected (e.g., sites 5 and 8).

- Results from additional sampling showed lead exceedences for chronic criteria in pore water where not previously found (e.g., site 8).

- Low concentrations of lead and zinc are spatially transient (not in widespread concentrations at a given location) and temporally transient and are influenced by local sources outside of the reservoir.

7 VARIANCES FROM FERC-APPROVED STUDY PLAN

There were no variances from the FERC-approved Study Plan.

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Appendix 1: Assessment of Additional Sampling Final Report

Boundary Hydroelectric Project (FERC No. 2144)

Study No. 4

Toxics Assessment: Evaluation of Contaminant Pathways

Appendix 1

Assessment of Additional Sampling
Final Report

Prepared for
Seattle City Light

Prepared by
Robert Plotnikoff, Harry Gibbons, Shannon Brattebo,
Adam Baines, Marcus Bowersox, and Jerry Diamond
Tetra Tech

March 2009

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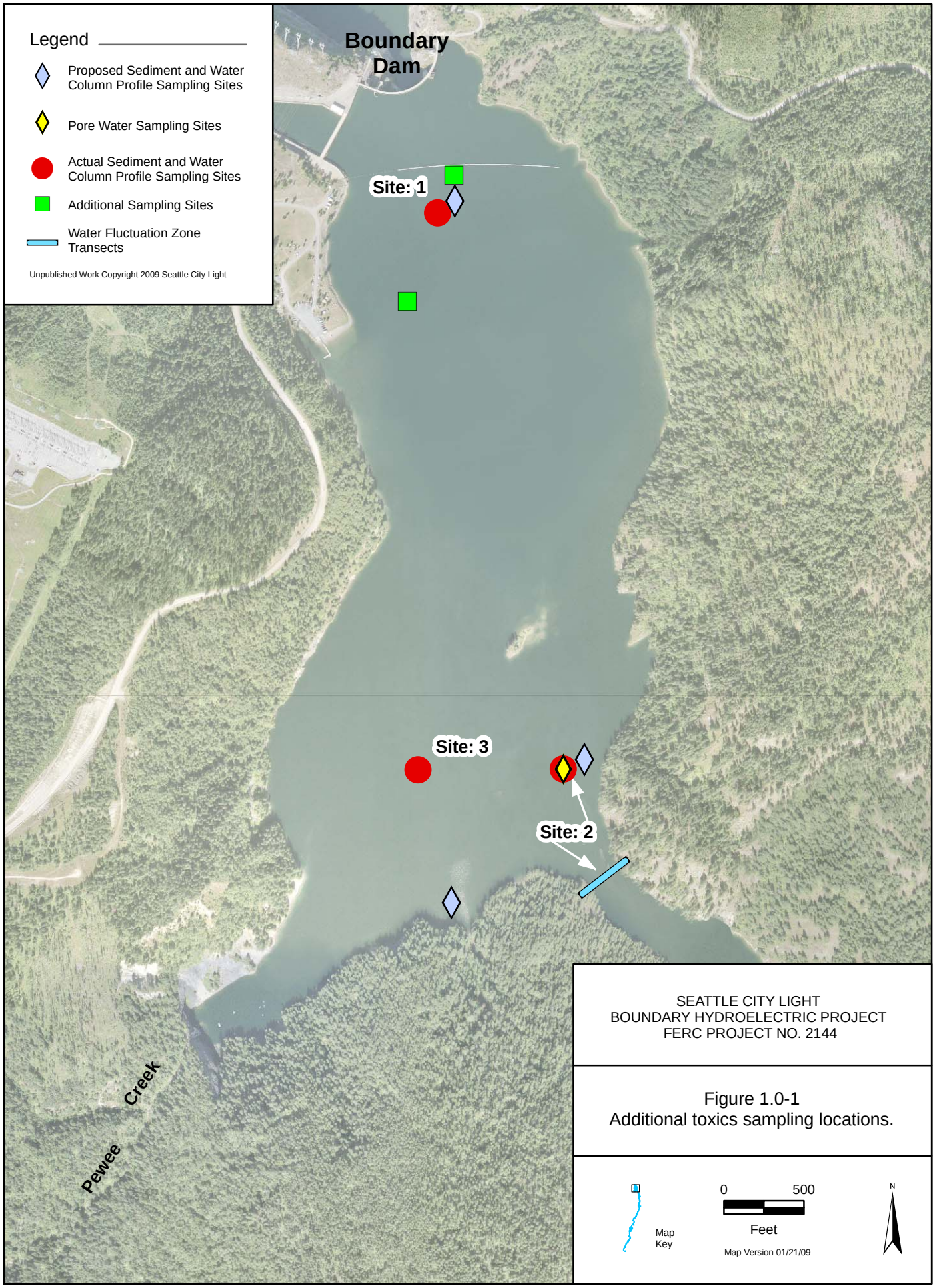
Study 4 Appendix 6
Final Assessment of Additional Sampling
Final Report
Boundary Hydroelectric Project (FERC No. 2144)

1 INTRODUCTION

The primary goal for the November 2007 and March 2008 toxics sampling for Study 4 was to determine if toxics were present in Boundary Reservoir, and if so, whether Project operations increased their bioavailability. As described in the Toxics Assessment: Evaluation of Contaminant Pathways Interim Report ("Interim Report") (SCL, 2008), the multiple lines of evidence developed from analytical tools used to answer this question indicated that Project operations do not influence bioavailability and mobility of toxics. However, to validate the original results and verify the extent of toxics presence, exceedances of surface water criteria in one of three replicates from pore water sampling at sites 5 and 8 for zinc and at site 5 for lead were re-examined, through additional sampling (October 2008). In addition, new samples were obtained from sampling locations 1 and 14 in October 2008 and compared to the new samples from locations 5 and 8 to confirm the localized nature of toxics at sites 5 and 8.

As provided in the Interim Report, additional samples were collected in October 2008 at select sites throughout the Boundary Reservoir (as cited above, sites 1, 5, 8, and 14 were revisited for more extensive sampling of sediments, pore water, and the water column). Sampling was conducted at these original sites visited in March 2008 with additional collection both upstream and downstream of these locations wherever sampleable sediments were found. The specific sampling locations are shown in Figures 1.0-1 through 1.0-4.


Legend
Proposed Sediment and Water Column Profile Sampling Sites
Pore Water Sampling Sites
Actual Sediment and Water Column Profile Sampling Sites
Additional Sampling Sites
Water Fluctuation Zone Transects
Unpublished Work Copyright 2009 Seattle City Light
Boundary Dam
Site: 1
Site: 3
Site: 2
Pewee Creek
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure 1.0-1
Additional toxics sampling locations.
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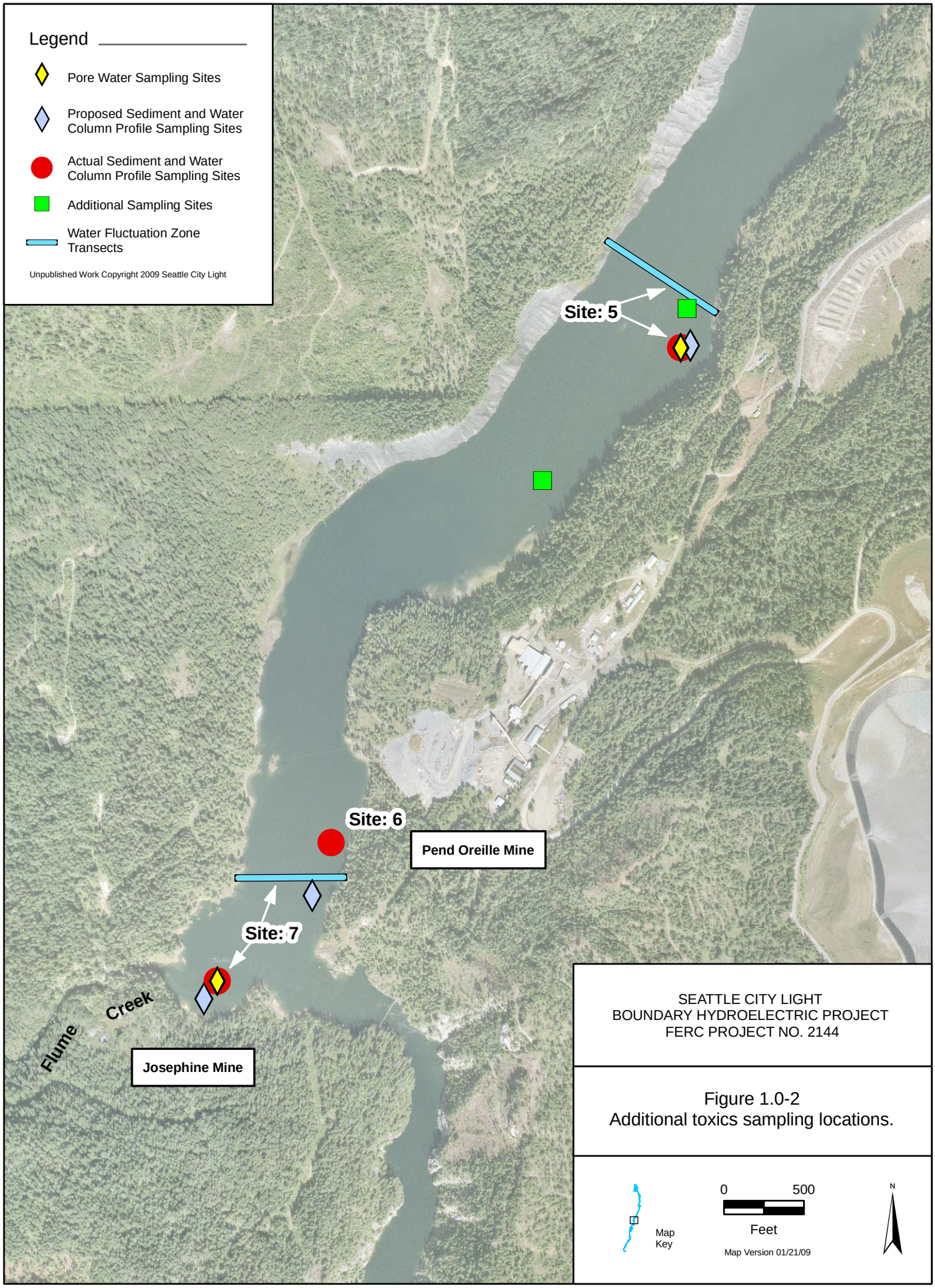

Figure 1.0-2
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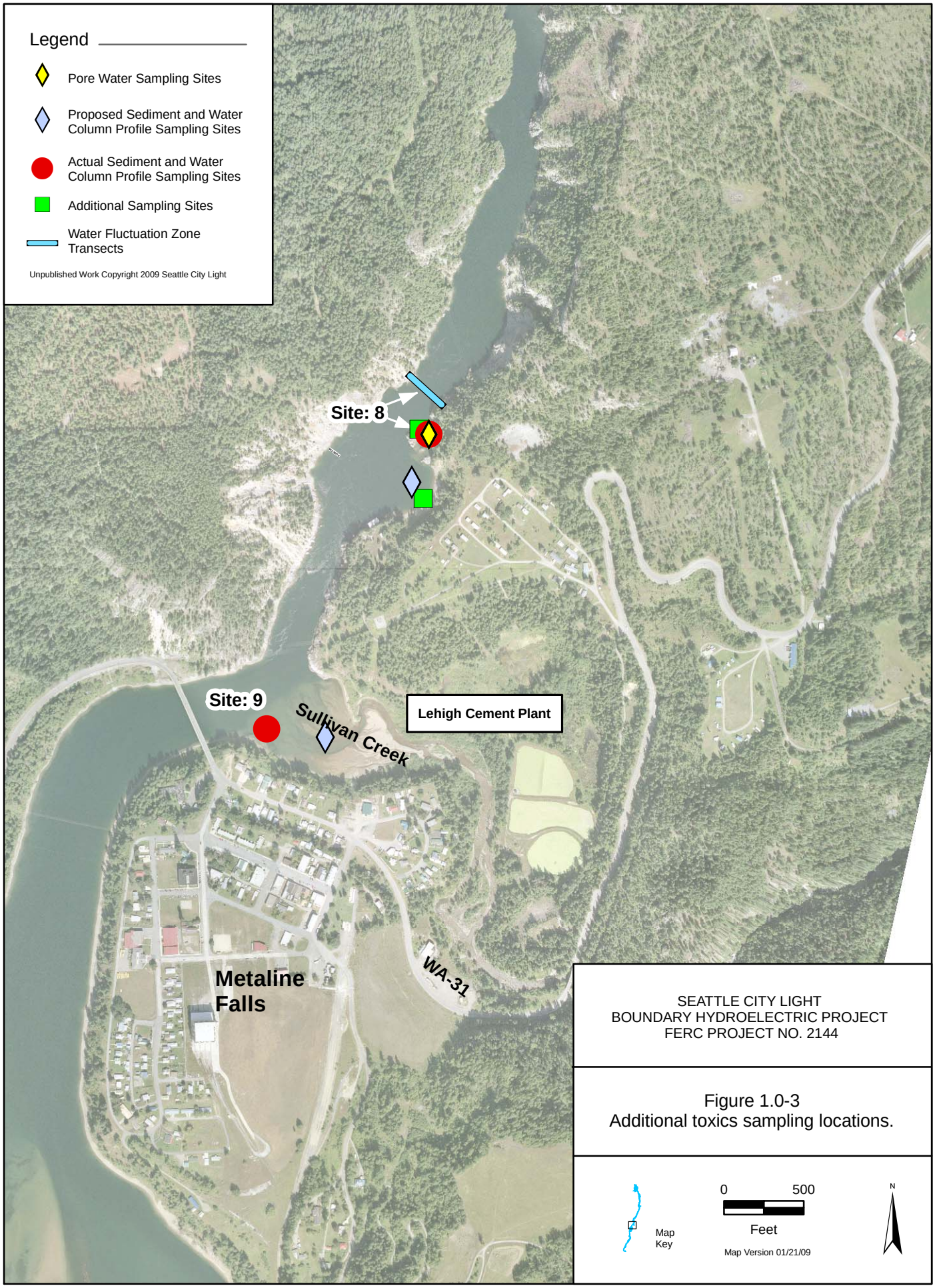

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FERC PROJECT NO. 2144

Figure 1.0-3
Additional toxics sampling locations.

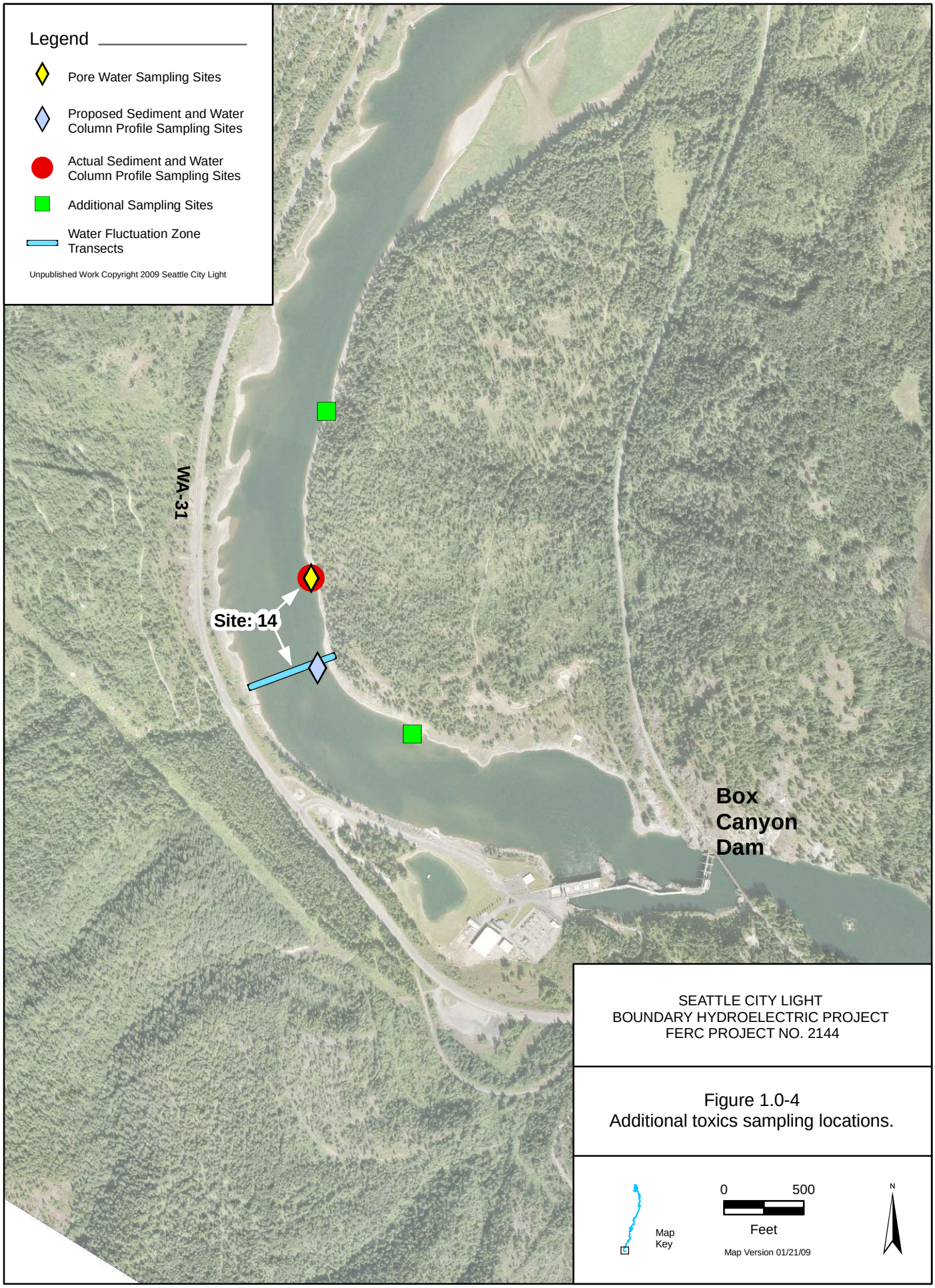

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Figure 1.0-4
Additional toxics sampling locations.

2 METHODS

The purpose of additional sampling conducted in October 2008 was to re-examine exceedances of surface water criteria in one of three replicates from pore water sampling at sites 5 and 8 for zinc and site 5 for lead, which were collected in March 2008. Secondary purposes of this additional sampling were to verify the presence and spatial extent of zinc and lead concentrations at the sites where pore water exceedances were detected in March 2008 as well as to compare concentrations of toxics within the upper reservoir and the forebay zones of Boundary Reservoir.

2.1. Validation of Results at Select Sampling Locations

Sampling at sites 5 and 8 was originally collected in March 2008 and included water column, pore water, and sediment samples using the procedures described in the Sampling and Analysis Plan (SAP) (SCL 2007). Three replicate sediment samples were collected and used for analyzing sediment and pore water concentrations of lead and zinc, as well as other toxics parameters (i.e., arsenic, cadmium, and mercury). In addition, water column samples were collected at these locations from the surface, middle, and bottom for each sample set.

The purpose of additional sampling (October 2008) was to validate original results (March 2008) and reconfirm the apparent influence of localized source effects and/or determine if the spatial extent of toxics presence was related to small-scale effects such as groundwater inflow or biological activity of burrowing benthic macroinvertebrates. Observations of aquatic life entrained in sampled sediments may serve as indicators of potential bioavailability due to site-specific conditions. Expanded sampling area, upstream and downstream at each of these sites was conducted to determine the extent of toxics presence (see Section 2.2).

2.2. Verification of Longitudinal Extent of Toxics Presence

Longitudinal sampling was designed to address the extent of toxics presence along a transect parallel to the direction of the current and that represented the influence of moving water on sediment transport. The purpose of collecting these additional replicates was to verify presence and spatial extent of zinc and lead concentrations at sites where exceedances had been detected. In addition to validation of the original sampling results, a total of three sets of three replicates at each of sampling locations 5 and 8 were collected for analysis of lead and zinc as well as other toxics parameters (similar to parameters sampling in March 2008). Sampling locations included the original site (three replicates) as identified by Global Positioning System (GPS) coordinates and one set of samples collected upstream (three replicates) and one downstream (three replicates) of the original site.

Sediment, pore water, and water column samples were collected beginning downstream and moving in an upstream direction. Three replicates were collected from the original site first, then the downstream site next, and finally the farthest upstream site. Past search efforts for sediment were difficult at these locations because of the low availability of samples meeting high quality sample requirements outlined in the SAP (SCL 2007). As a result, the three sets of additional samples (each set represented by three replicates) were not spaced equally or at incremental distances from each other, but far enough apart to represent distinct observations. Given the

difficulties in finding sediment at sites 5 and 8, sampling occurred as near to the original sites as possible to ensure high quality samples. The locations of all sediment samples were carefully documented using GPS and recorded on aerial photographs as shown in Figures 1.0-1 through 1.0-4.

2.3. Comparison to Upper and Lower Reservoir Conditions

Samples were also collected at sites 1 (forebay above Boundary Dam) and 14 (Box Canyon tailrace) to establish the toxics concentrations received by Boundary Reservoir from Box Canyon Reservoir and those potentially deposited in the forebay of Boundary Reservoir. The toxics concentrations from the other sites (5 and 8) were compared to those representing the reference condition (site 14) and the deepest zone (site 1) where transported fines are expected to settle. This comparison provided a perspective on physicochemical conditions at sites 5 and 8 to determine potential similarity they may have to either upstream or downstream locations in the reservoir. Comparing the results from sites 5 and 8 to sites 1 and 14 was useful for determining what characteristics of the sampling locations contribute to toxics presence, such as proximity to known upland mining and industrial sources.

Three sediment, pore water, and water column samples (each consisting of three replicates) were collected at sampling sites 1 and 14, beginning from downstream and moving in an upstream direction. Samples were analyzed for zinc and lead as well as other toxics parameters, similar to those parameters sampled for in March 2008 (i.e., arsenic, cadmium, and mercury). The original site set of three replicates was collected first, then the furthest downstream site visited next, and then the farthest upstream set of replicates collected last using the procedures described in the SAP (SCL 2007). Water column samples were collected from the surface, middle, and bottom for each sample set.

2.4. Schedule for Additional Sampling and Analysis

To provide information in a timely manner for preparation of the final report, SCL initiated the plan for additional sampling and analysis immediately upon approval from the Federal Energy Regulatory Commission (FERC). Based on FERC's September 24, 2008, determination, additional sample gathering was completed in October 2008.

3 SEDIMENT SAMPLING RESULTS

Sediment samples were collected in October 2008 at four of the original sites visited in March 2008 and at two additional locations at each site: one downstream of the original site and one upstream of the original site. Sites 1, 5, 8, and 14 were visited to describe sediment toxics characteristics at, above and below the original sites, in part to determine if a source for toxics in sediments could be identified.

3.1. Verification and Validation of Data Quality Elements

Laboratory performance of sample analysis is measured by several quality assurance analytical procedures that are outlined in SCL (2007). Quality assurance results for the sediment samples are presented in Attachment A. All quality assurance components were met for sediment

analysis except for re-analysis of duplicate samples based on laboratory homogenization and sample split. Analytical results from laboratory duplicate samples for arsenic, zinc, lead, and cadmium were slightly higher than outlined. However, concentrations for these duplicate samples were sufficiently low that this variance would not have resulted in the determination of a threshold exceedance.

3.2. Analytical Results from Sediment Sampling Sites

Concentrations for sediment toxics from the October 2008 sampling in Boundary Reservoir are summarized in Table 3.2-1. Complete results for sediment toxics sampling are provided in Attachment A. The data summary in Table 3.2-1 includes all observations made from each site (e.g., three replicate samples at each location). Sediment observations from each site that resulted in non-detectable concentrations are indicated in the Table by a "<" symbol. When a range for concentrations is included for a site, the second expression indicates the presence of a detectable sediment concentration. Primary and secondary lowest apparent effects thresholds (LAETs) are included at the bottom of the table for each of the metals. Figures 3.2-1 through 3.2-5 show the average toxics concentration and standard deviation observed in the three replicate sediment samples taken at each sampling location as compared to primary and secondary LAETs. Figure 3.2-6 shows the values of lead concentrations for replicate samples at each sampling location.

Concentrations of sediment toxics are generally very low at all sites sampled, except for lead in one of nine sediment samples collected at site 8. Lead concentrations were similar in sediment samples collected at site 1 (forebay) and at site 5 (downstream of Pend Oreille Mine), including the additional upstream and downstream locations at each of these sites. However, one of nine sediment samples collected from the original site 8, which is adjacent to the historic Grandview Mine Site, exceeded the primary LAET threshold for lead (Figure 3.2-6). The average lead concentration estimated for sediments at original site 8 did not exceed either of the sediment thresholds (Figure 3.2-2).

Table 3.2-1. Range of October 2008 results for sediment concentrations of toxics in Boundary Reservoir (dry weight).

Site No.	Arsenic (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	Lead (mg/kg)
1	7.28 – 10.9	0.37 – 0.51	0.07 – 0.08	129 – 153	23.9 – 27.7
1 upstream	5.45 – 6.98	0.32 – 0.45	0.06 – 0.09	125 – 145	20.2 – 24.4
1 downstream	8.13 – 11.1	0.35 – 0.41	0.04 – 0.05	131 – 137	22.5 – 23.3
5	2.82 – 3.09	0.29 – 0.42	<0.01 – 0.02	117 – 138	14.8 – 20.6
5 upstream	2.60 – 3.91	0.20 – 0.39	<0.01	93.6 – 219	15.6 – 27.6
5 downstream	2.87 – 3.56	0.18 – 0.29	<0.01	110 – 572	18.7 – 21.8
8	2.59 – 4.25	0.11 – 0.14	<0.01 – 0.08	66.3 – 74.9	25.5 – 344
8 upstream	2.80 – 3.63	0.12 – 0.31	<0.01	30.6 – 50.9	4.59 – 5.51
8 downstream	2.61 – 4.22	0.18 – 0.29	<0.01	56.6 – 117	16.4 – 43.5
14	2.30 – 3.30	0.07 – 0.45	<0.01	36.2 – 43.8	4.89 – 7.04
14 upstream	1.34 – 2.21	0.03 – 0.05	<0.01	25.6 – 46.3	2.18 – 2.87
14 downstream	2.60 – 3.36	0.10 – 0.17	<0.01	35.4 – 40.5	4.44 – 4.68
LAET	31.4	2.39	0.8	683	335
Second LAET	50.9	2.9	3.04	1,080	431

Notes:
mg/kg – milligram per kilogram
LAET – lowest apparent effects threshold

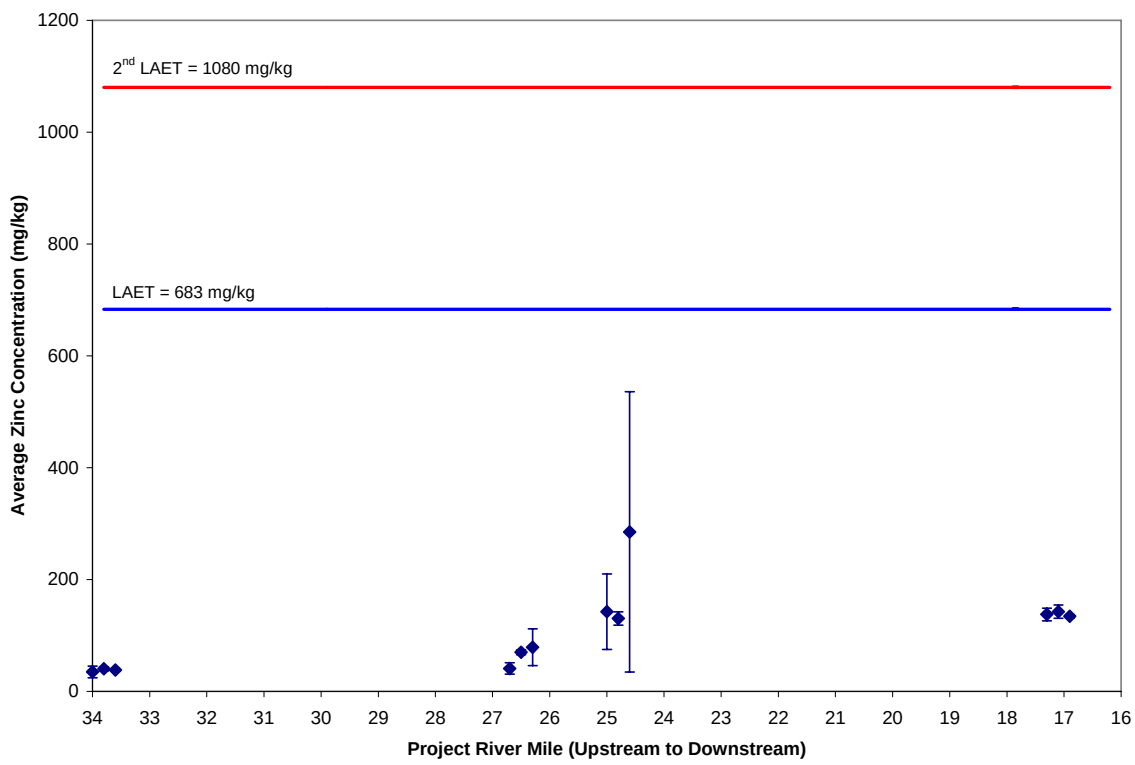

Figure 3.2-1. Average sediment zinc concentrations in Boundary Reservoir, October 2008.

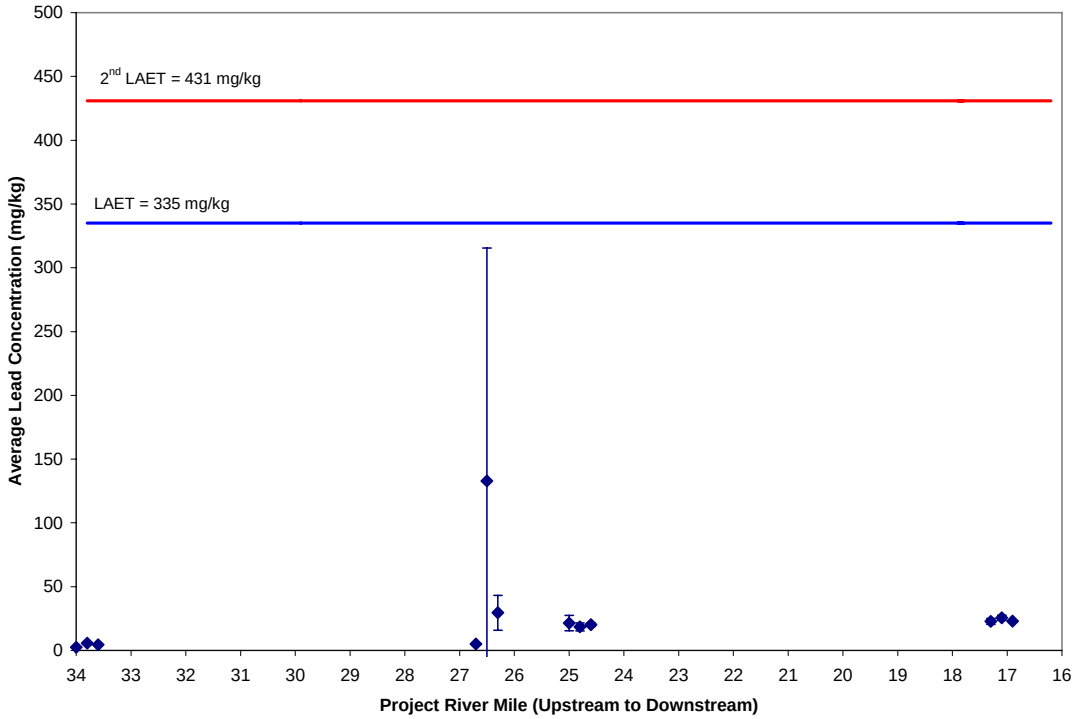

Figure 3.2-2. Average sediment lead concentrations in Boundary Reservoir, October 2008.

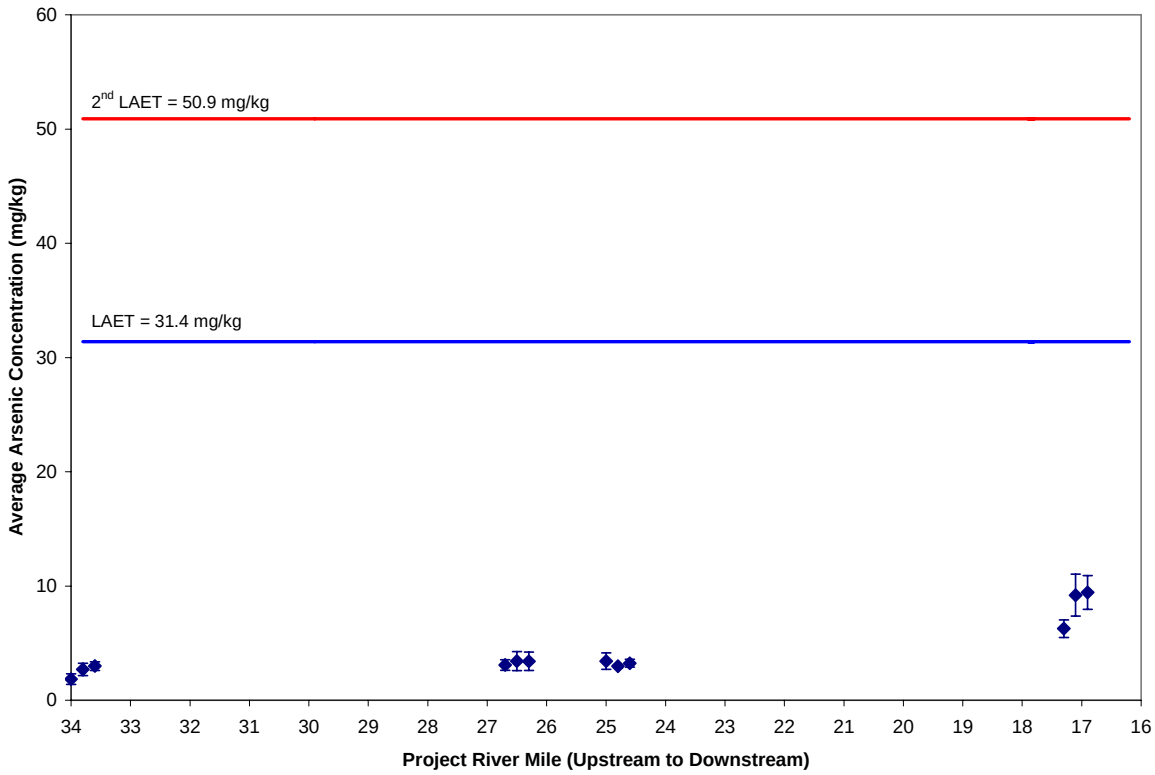

Figure 3.2-3. Average sediment arsenic concentrations in Boundary Reservoir, October 2008.

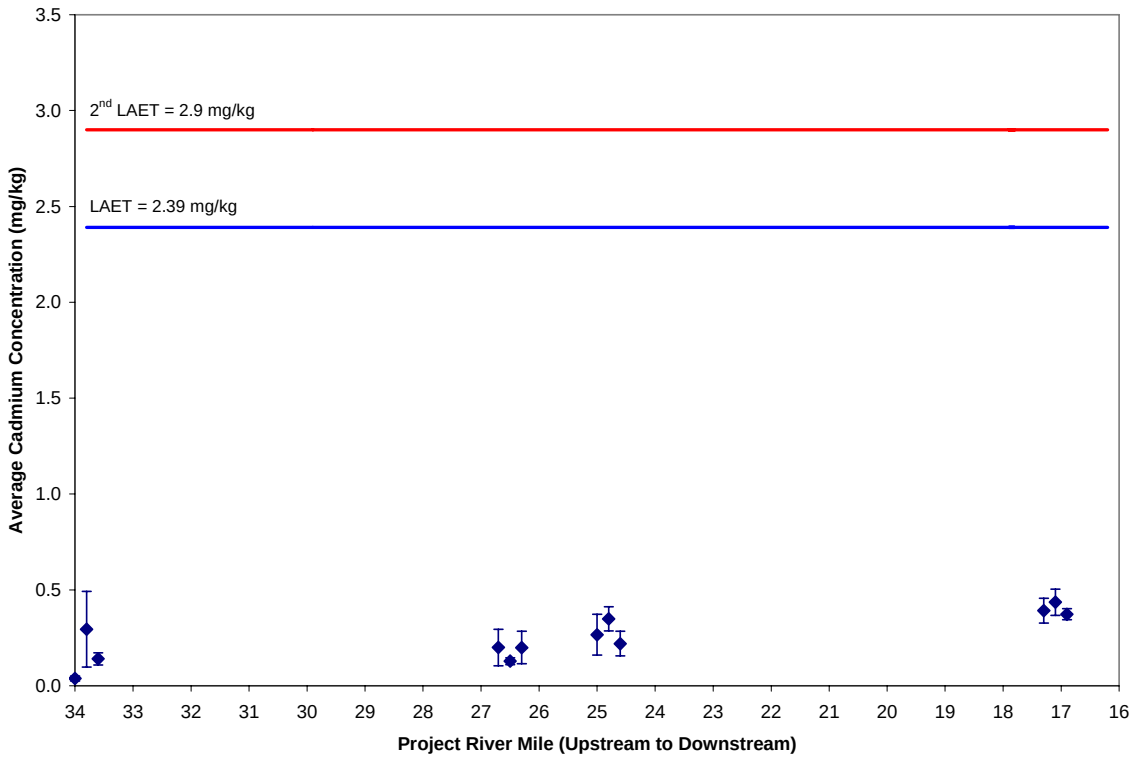

Figure 3.2-4. Average sediment cadmium concentrations in Boundary Reservoir, October 2008.

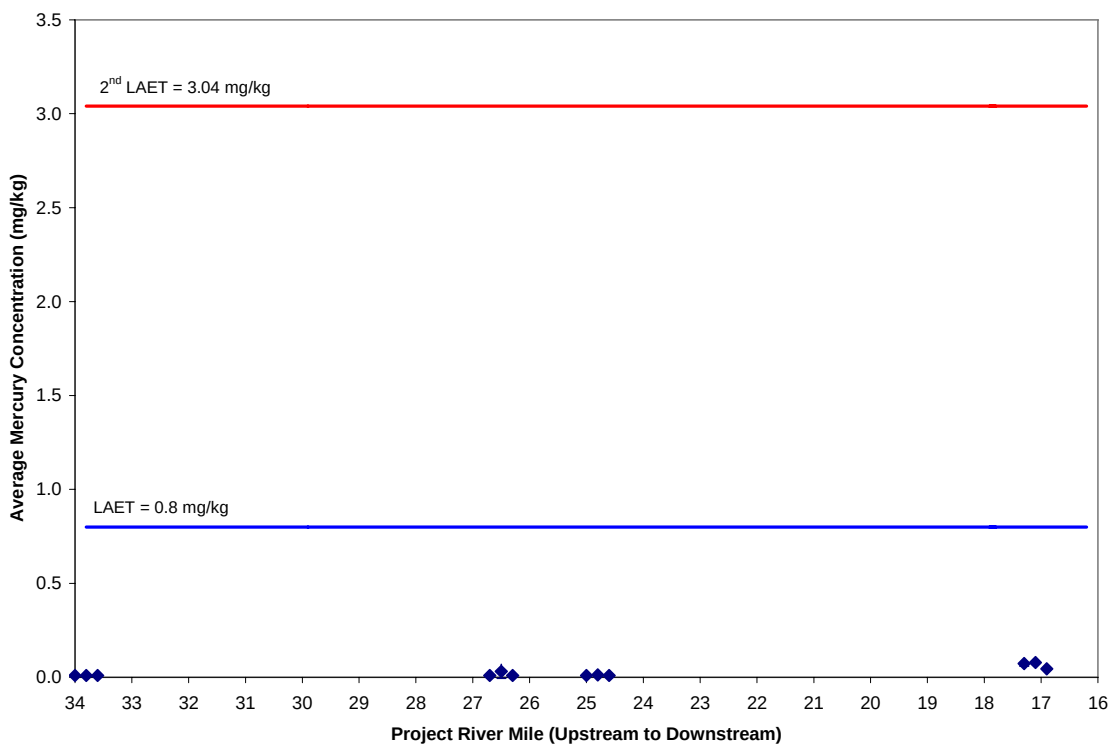

Figure 3.2-5. Average sediment mercury concentrations in Boundary Reservoir, October 2008.

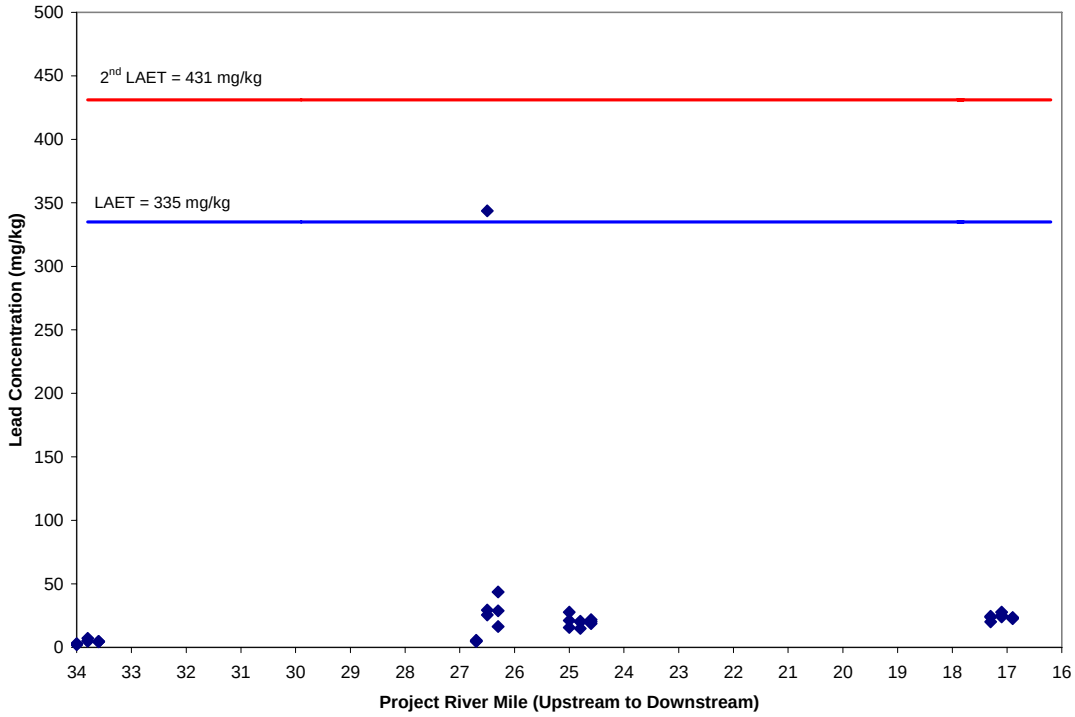

Figure 3.2-6. Sediment lead concentrations in Boundary Reservoir, October 2008.

Physical and chemical sediment characteristics determine, in part, the potential for toxics to become bioavailable and impair aquatic life. Measurements of general chemistry concentrations and composition of sediment samples are summarized in Table 3.2-2. Complete results for sediment samples are provided in Attachment A. The data summary in Table 3.2-2 includes all observations made from each of the site samples (e.g., three replicates at each location). Figures 3.2-7 through 3.2-9 show average sediment content, total organic carbon (TOC), and sulfide concentration, respectively.

Physical properties of the sediment changed from upstream (site 14 in Box Canyon Tailrace) to downstream (site 1 in the forebay). The sediment water content was greater in Canyon and Forebay zones. Sediment particle size at site 1 in Boundary forebay was dominated by silt/clay size fractions (51-76 percent) and shifted toward sand size fractions (81–100 percent) at site 5 downstream of the Pend Oreille Mine in the Canyon Reach. Sediment size fractions at site 8, adjacent to Grandview Mine, represented a transition from sand (48–99 percent) to a mix of sand and gravel portions. Gravel was co-dominant with sand at the site 8 upstream sample (collected from the bay below the old powerhouse). Sediment composition at site 8 represented the coarser size classes in contrast to the site 1 forebay sediments represented by fines. Site 14 had similar sediment size fraction characteristics as site 8 with sand (48–97 percent), either co-dominant with gravel or dominating other size classes. Coarse sediment size fractions do not absorb toxics as readily as fine fractions (e.g., silt and muck). Sediment characteristics were similar for sites 14 and 8, where a small fraction of entrained organics (0.1–0.3 percent) was either introduced from upstream sources or from outside of the reservoir (e.g., erosion of sand into the channel;

Grandview Mine materials). Sediments from sites 8 and 14 represent material that was likely not resident for extended periods of time. Organics accumulate in higher concentrations when sediments are resident for a longer period of time at a location, similar to those conditions found at sites 1 and 5 (0.2–3.8 percent).

Organics that compete for binding of divalent (lead, zinc, cadmium) and organometals (arsenic and mercury) are measured by TOC or sulfides. Organic carbon will adsorb toxics, and sulfides will bind the positively charged metals ions and make them unavailable for binding to respiratory tissues in aquatic organisms. Very low percentages of organic carbon are entrained in sediments at all sites in Boundary Reservoir and therefore are not a major factor in making toxics biologically available through respiratory tissues. Additionally, direct consumption of organic carbon is not a likely pathway for significant bioaccumulation from the low concentration of toxics in sediments.

Sulfide concentrations were found in much larger concentrations at site 1 (forebay) and site 5 (downstream of the Pend Oreille Mine) compared to sites 8 (adjacent Grandview Mine) and 14 (Box Canyon tailrace). These concentration levels can actively bind to toxics ions and make them biologically unavailable to aquatic life inhabiting sediments at these sites. The high sulfide concentrations are an indicator of longer residence time of fine sediments and bacteriological decay of organic material that produces sulfide concentrations as a by-product of metabolism. The finer sediment-size fractions and high sulfide concentrations at both sites 1 and 5 indicate the relative stability of deposited sediments in these areas and the low potential for bioavailability of toxics.

Table 3.2-2. Range of October 2008 results for general chemistry concentrations and measurements collected from sediment sites in Boundary Reservoir.

Site No.	Total Solids (%)	Water (%)	Total Organic Carbon (%)	Sulfides (mg/kg)
1	30.1 – 31.9	68.1 – 69.9	3.67 – 3.83	2.16 – 5.68
1 upstream	35.6 – 41.2	68.8 – 64.4	2.26 – 3.24	10.1 – 13.4
1 downstream	32.1 – 32.8	67.2 – 67.9	3.23 – 3.54	2.73 – 8.97
5	55.7 – 57.5	42.5 – 44.3	0.81 – 1.24	<0.2 – 5.84
5 upstream	52.1 – 74.2	25.8 – 47.9	0.25 – 1.44	<0.2 – 22.6
5 downstream	65.7 – 73.0	27.0 – 34.3	0.46 – 0.88	<0.2 – 0.55
8	77.1 – 82.2	17.8 – 22.9	0.21 – 0.34	<0.2
8 upstream	83.9 – 90.1	9.85 – 16.1	0.11 – 0.21	<0.2
8 downstream	78.6 – 80.4	19.6 – 21.4	0.23 – 0.26	<0.2
14	73.9 – 86.4	13.6 – 26.1	0.04 – 0.22	<0.2 – 3.16
14 upstream	77.8 – 86.7	13.3 – 22.2	0.08 – 0.12	<0.2
14 downstream	80.6 – 82.0	18.0 – 19.4	0.05 – 0.09	<0.2

Note:
mg/kg – milligram per kilogram

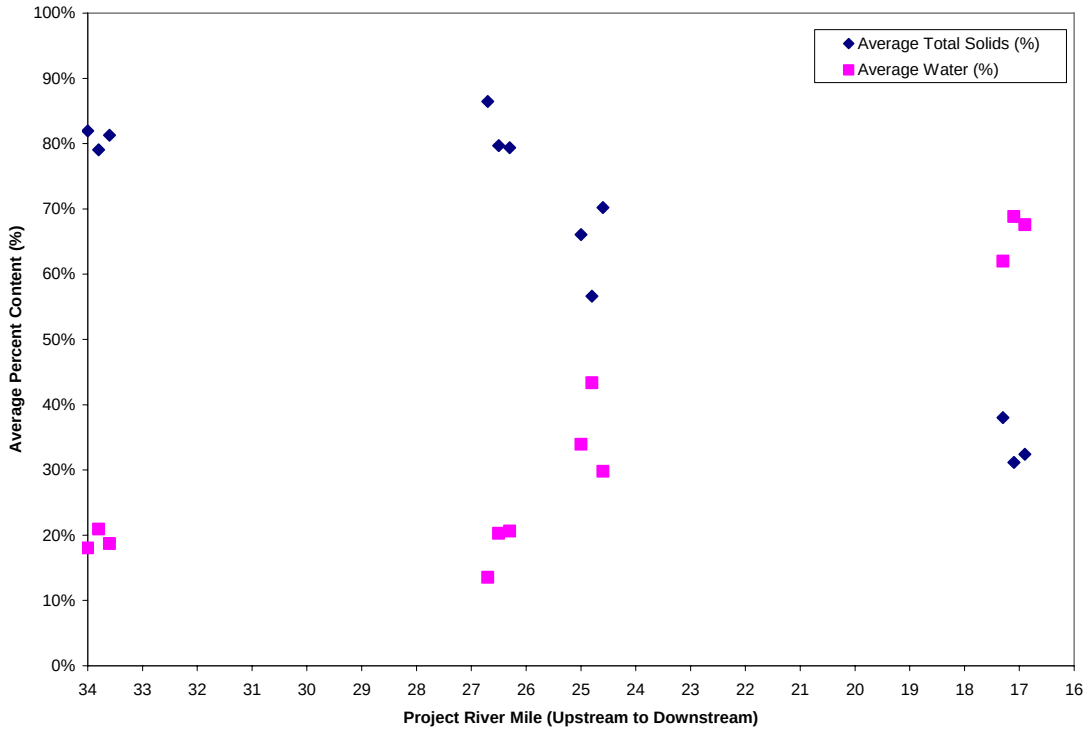

Figure 3.2-7. Average sediment percent content in Boundary Reservoir, October 2008.

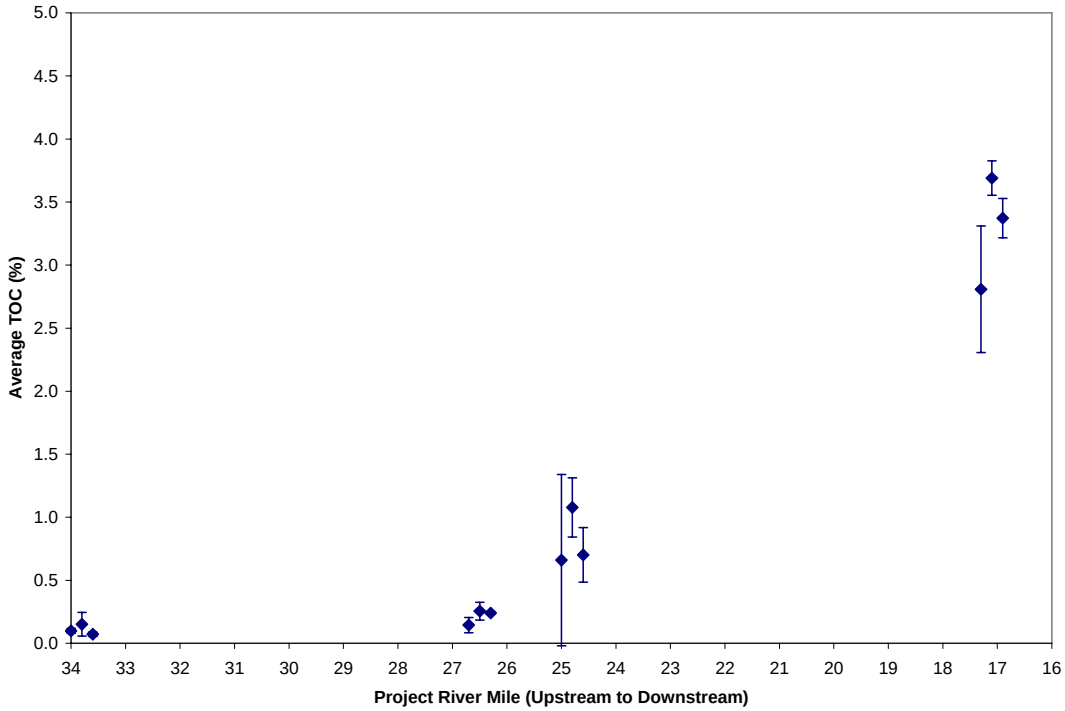

Figure 3.2-8. Average sediment TOC percentage in Boundary Reservoir, October 2008.

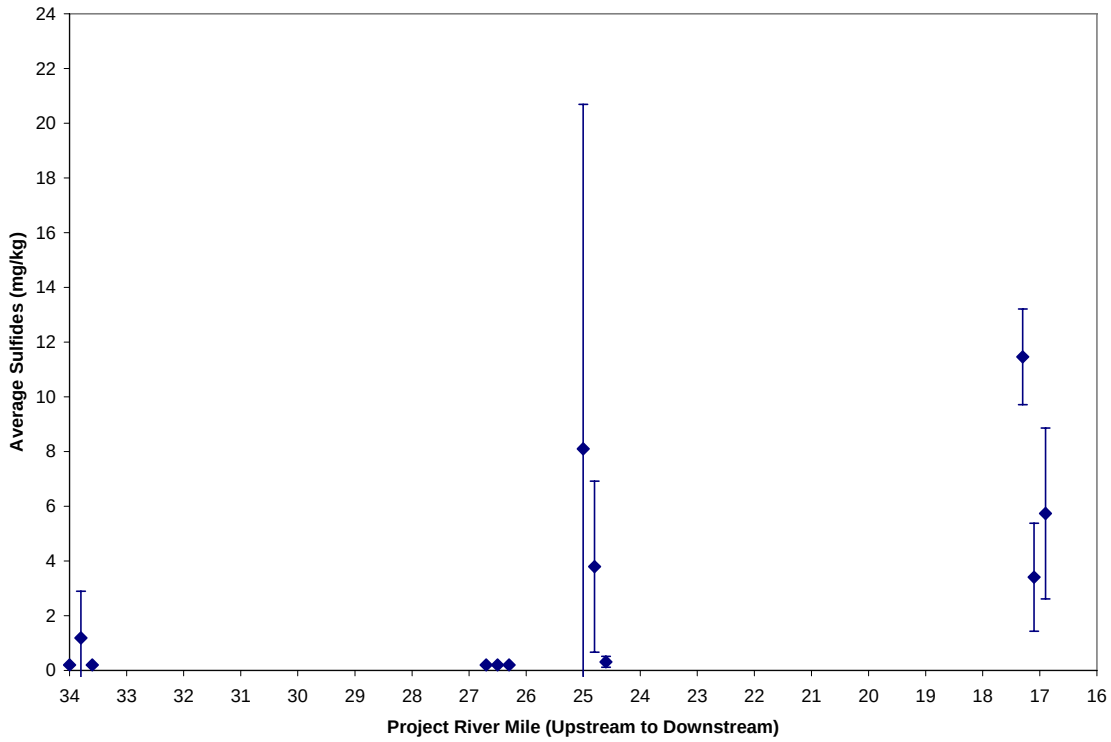

Figure 3.2-9. Average sediment sulfides concentration in Boundary Reservoir, October 2008.

4 PORE WATER SAMPLING RESULTS

Pore water samples were collected along with sediment samples in October 2008 at four of the original sites visited in March 2008 and at two additional locations at each site: one downstream of the original site and one upstream of the original site. Sites 1, 5, 8, and 14 were visited to describe pore water toxics characteristics at, above and below the original sites, in part, to determine if toxics presence in pore water could be explained through comparison with other nearby physicochemical conditions.

4.1. Verification and Validation of Data Quality Elements

Laboratory performance of sample analysis is measured by several quality assurance analytical procedures that are outlined in SCL (2007). Quality assurance results for the pore water samples are presented in Attachment B. All quality assurance components were met for pore water analysis except for re-analysis of duplicate samples based on laboratory homogenization and sample split. Analytical results from laboratory duplicate samples for lead were slightly higher than outlined. However, concentrations for these duplicate samples were sufficiently low that this variance would not have resulted in the determination of a surface water criteria exceedance.

4.2. Analytical Results from Pore Water Sampling Sites

Concentrations for dissolved toxics from the October 2008 pore water sampling are summarized in Table 4.2-1. Complete results for dissolved toxics sampling are provided in Attachment B. The data summary in Table 4.2-1 includes all observations made from each of the sampling locations (e.g., three replicate samples at each location). When a range of concentrations is included for a sampling site, the second expression indicates the presence of a detectable dissolved metal concentration. Chronic and acute surface water criteria are included at the bottom of the table for each of the metals. Figures 4.2-1 through 4.2-5 show the average and standard deviation of toxics concentrations observed in the three replicate pore water samples taken at each sampling location as compared to Washington State surface water quality standards. Figure 4.2-6 shows the values of lead concentrations for replicate samples at each sampling location.

Concentrations of toxics are generally very low at all sites sampled, except for lead in pore water samples collected at site 8. Dissolved lead concentrations in pore water were higher than chronic criteria established for surface water in four of nine samples collected from site 8 (one sample in site 8 downstream and all three samples at the original site 8). The average concentration for dissolved lead at the original site 8 exceeded chronic criteria for surface water (Figure 4.2-5). As discussed in Section 3.2, lead concentrations in October 2008 sediment samples collected from original site 8 (adjacent Grandview Mine Site) also exceeded the LAET threshold in one of three replicates. The average concentration estimated in sediment at the original site 8 location corresponded with the average pore water concentration that exceeded chronic criteria.

Table 4.2-1. Range of October, 2008 results for dissolved concentrations of toxics from pore water at sites in Boundary Reservoir.

Site No.	Arsenic (µg/L)	Cadmium (µg/L)	Zinc (µg/L)	Lead (µg/L)	Methyl Mercury (µg/L)	Total Diss. Mercury (µg/L)
1	15.1 – 29.3	<0.2	14.7 – 30.6	<0.2	0.00011 – 0.00019	0.00178–0.00249
1 upstream	7.16 – 12.6	<0.2 – 0.21	18.0 – 39.6	0.87 – 1.35	0.00011	0.00186–0.0134
1 downstream	17.6 – 16.4	<0.2	15.4 – 28.2	<0.2 – 0.29	0.00013 – 0.00016	0.00178–0.00227
5	1.04 – 2.23	<0.2	14.4 – 21.0	<0.2 – 0.51	0.00008 – 0.00012	0.00063–0.00134
5 upstream	1.02 – 2.86	<0.2	19.6 – 28.9	<0.2 – 0.21	0.00009 – 0.0001	0.00038–0.00042
5 downstream	1.03 – 1.22	<0.2	16.0 – 20.0	<0.2 – 0.78	0.00008 – 0.0001	0.00045–0.00059
8	<1.0	<0.2	23.2 – 32.6	2.41 – 5.31	0.00008 – 0.00009	0.00055–0.00088
8 upstream	1.07 – 1.1	<0.2	18.6 – 27.0	<0.2 – 0.33	0.00008 – 0.00009	0.00045–0.00075
8 downstream	1.02 – 1.11	<0.2	22.0 – 25.4	0.27 – 4.05	0.00007 – 0.000058	0.00043–0.00077
14	<1.0 – 1.26	<0.2	9.49 – 18.88	<0.2 – 1.02	0.00007 – 0.00022	0.00047–0.00151
14 upstream	1.0 – 1.23	<0.2	14.7 – 21.6	<0.2 – 1.09	0.00008 – 0.00009	0.00054–0.00127
14 downstream	1.09 – 1.25	<0.2	13.3 – 16.6	<0.2	0.00011 – 0.00017	0.00090–0.00302
Chronic Criteria (µg/L)	190	1.03	86.5	2	N/A	N/A
Acute Criteria (µg/L)	360	3.7	94.7	51	N/A	2.1

Notes:
µg/L – microgram per liter
N/A – criteria not available
ng/L – nanogram per liter
(Source for criteria: Ecology 2006)

Pore water sample concentrations that exceeded surface water criteria were re-analyzed to confirm initial analytical results. Table 4.2-2 reports results from the laboratory re-analysis confirming that original analysis and re-analysis were almost identical.

Table 4.2-2. Results comparing analysis and re-analysis of pore water samples exceeding surface water criteria from October 2008 verification sampling for toxics in Boundary Reservoir.

Re-Analysis of Pore Water Samples for Lead Exceedance: Boundary Reservoir		
Site Number	**Original Analysis (µg/L)**	**Re-Analysis (µg/L)**
8-Down-PW-2	4.05	4.02
8-PW-1	3.87	4.11
8-PW-2	2.41	2.45
8-PW-3	5.31	5.69

Toxics in pore water may migrate back and forth between sediment-bound and dissolved forms depending on factors that promote movement. In addition to evaluating the potential for bioavailability through direct contact (comparison to surface water criteria), sediment toxics from the same sample are compared to the LAETs so that both routes of bioaccumulation are considered in evaluation for potential bioavailability. Results summarized in Table 4.2-3 are the basis for evaluating potential for bioavailability.

Table 4.2-3. Range of results for sediment concentrations of toxics in Boundary Reservoir (dry weight).

Site No.	Arsenic (mg/kg)	Cadmium (mg/kg)	Mercury (mg/kg)	Zinc (mg/kg)	Lead (mg/kg)
1	7.28 – 10.9	0.37 – 0.51	0.07 – 0.08	129 – 153	23.9 – 27.7
1 upstream	5.45 – 6.98	0.32 – 0.45	0.06 – 0.09	125 – 145	20.2 – 24.4
1 downstream	8.13 – 11.1	0.35 – 0.41	0.04 – 0.05	131 – 137	22.5 – 23.3
5	2.82 – 3.09	0.29 – 0.42	<0.01 – 0.02	117 – 138	14.8 – 20.6
5 upstream	2.60 – 3.91	0.20 – 0.39	<0.01	93.6 – 219	15.6 – 27.6
5 downstream	2.87 – 3.56	0.18 – 0.29	<0.01	110 – 572	18.7 – 21.8
8	2.59 – 4.25	0.11 – 0.14	<0.01 – 0.08	66.3 – 74.9	25.5 – 344
8 upstream	2.80 – 3.63	0.12 – 0.31	<0.01	30.6 – 50.9	4.59 – 5.51
8 downstream	2.61 – 4.22	0.18 – 0.29	<0.01	56.6 – 117	16.4 – 43.5
14	2.30 – 3.30	0.07 – 0.45	<0.01	36.2 – 43.8	4.89 – 7.04
14 upstream	1.34 – 2.21	0.03 – 0.05	<0.01	25.6 – 46.3	2.18 – 2.87
14 downstream	2.60 – 3.36	0.10 – 0.17	<0.01	35.4 – 40.5	4.44 – 4.68
LAET	31.4	2.39	0.8	683	335
Second LAET	50.9	2.9	3.04	1,080	431

Notes:
LAET – lowest apparent effects threshold
mg/kg – milligram per kilogram
PCBs – polychlorinated biphenyls

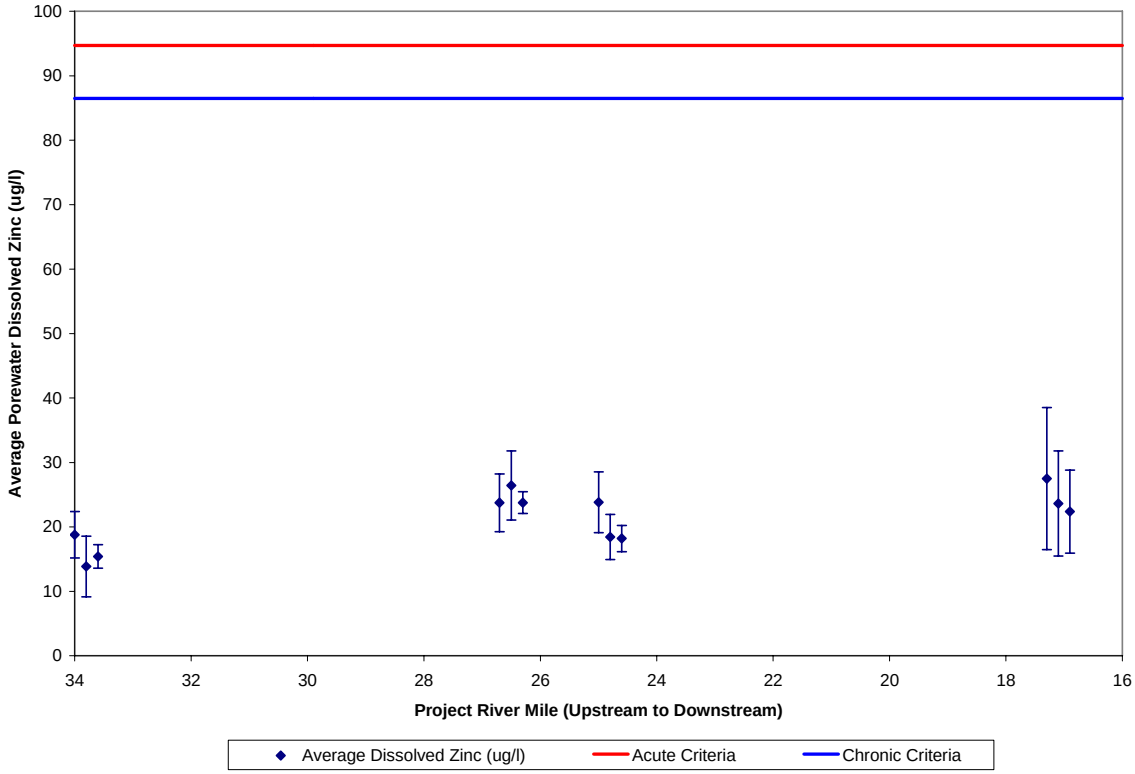

Figure 4.2-1. Average pore water dissolved zinc concentrations in Boundary Reservoir, October 2008.

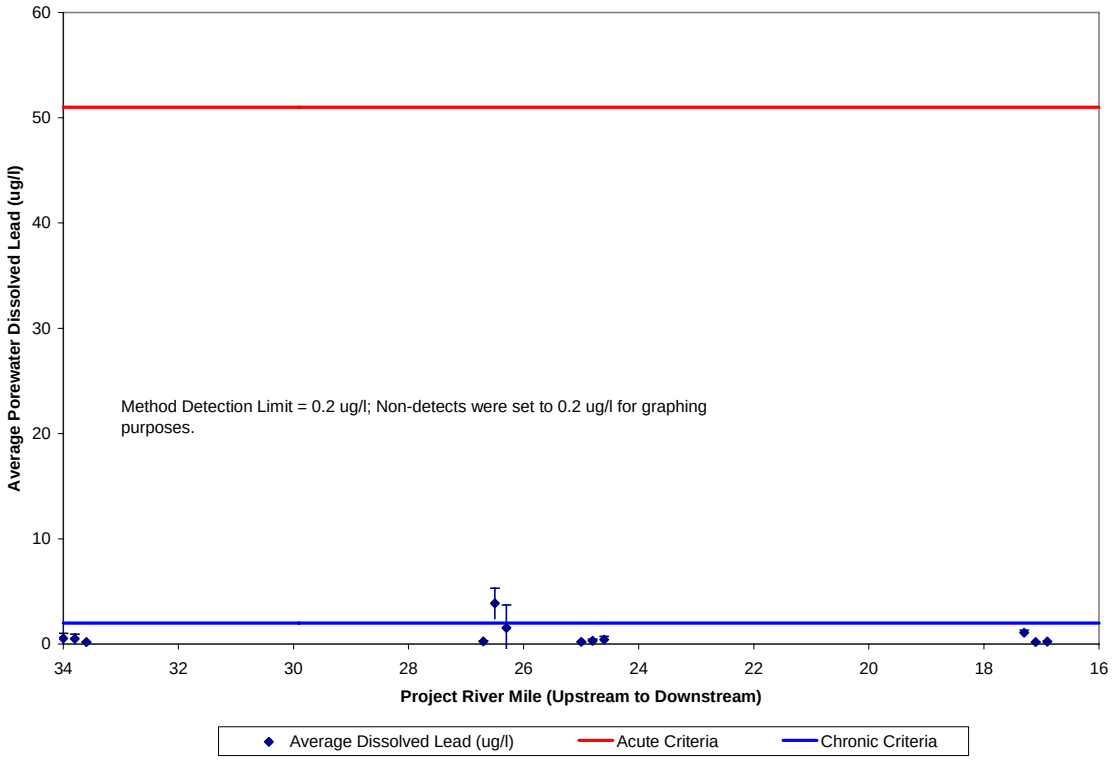

Figure 4.2-2. Average pore water dissolved lead concentrations in Boundary Reservoir, October 2008.

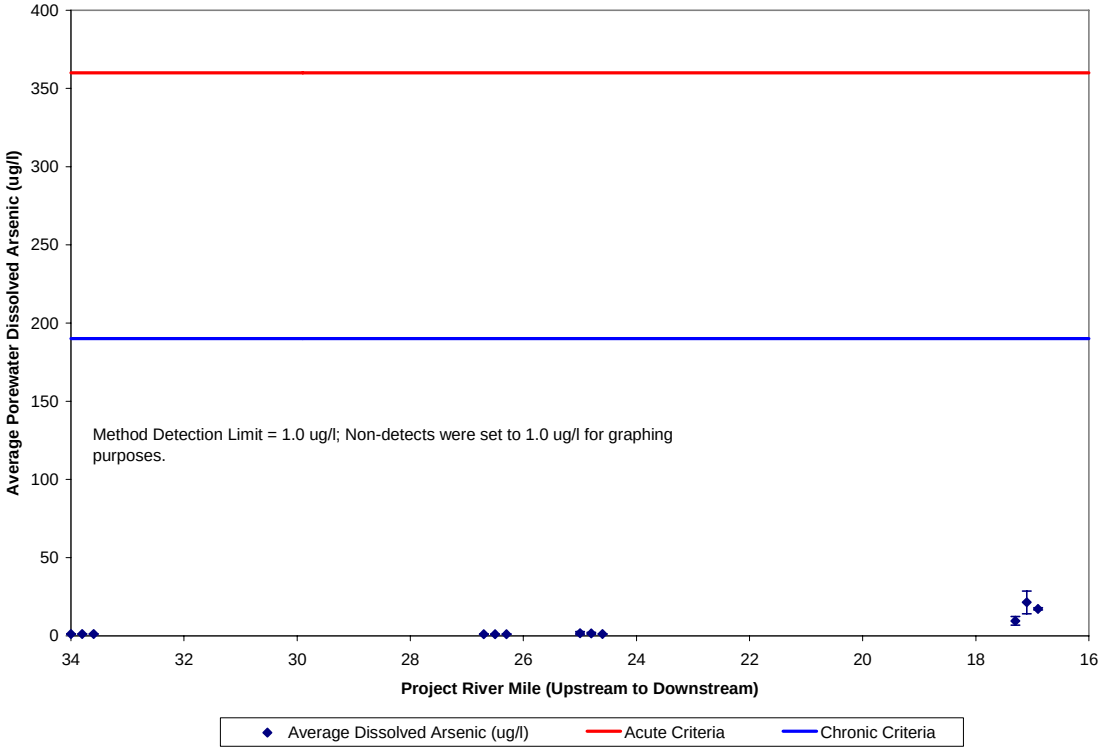

Figure 4.2-3. Average pore water dissolved arsenic concentrations in Boundary Reservoir, October 2008.

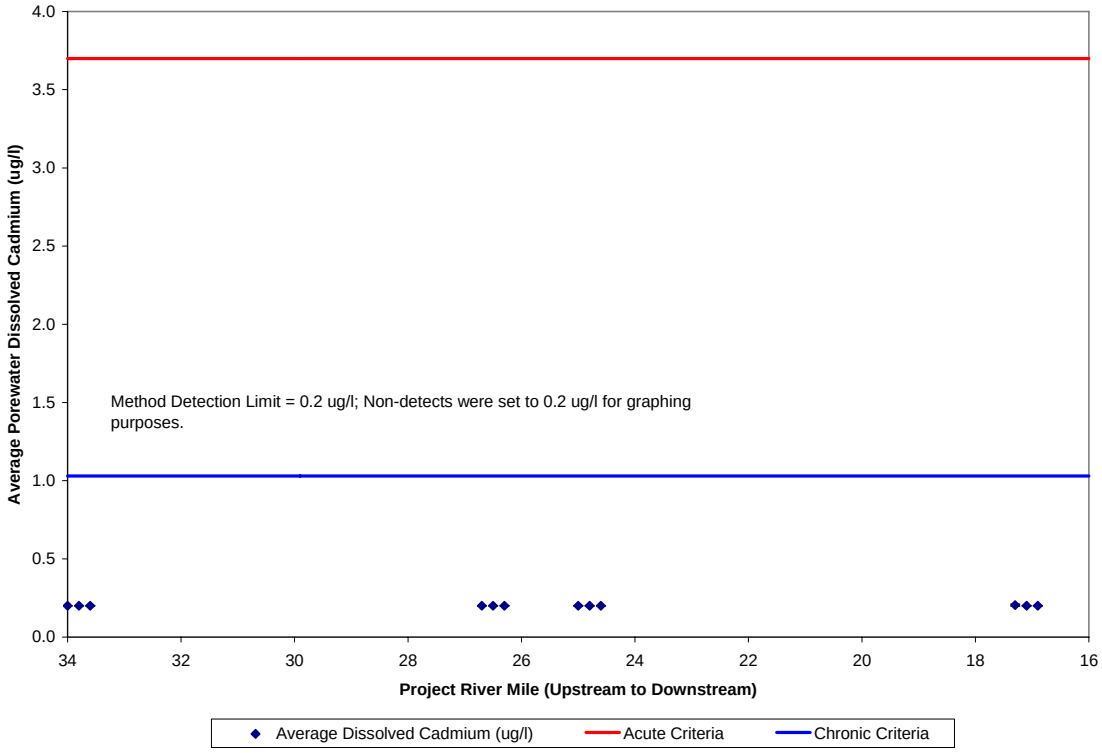

Figure 4.2-4. Average pore water dissolved cadmium concentrations in Boundary Reservoir, October 2008.

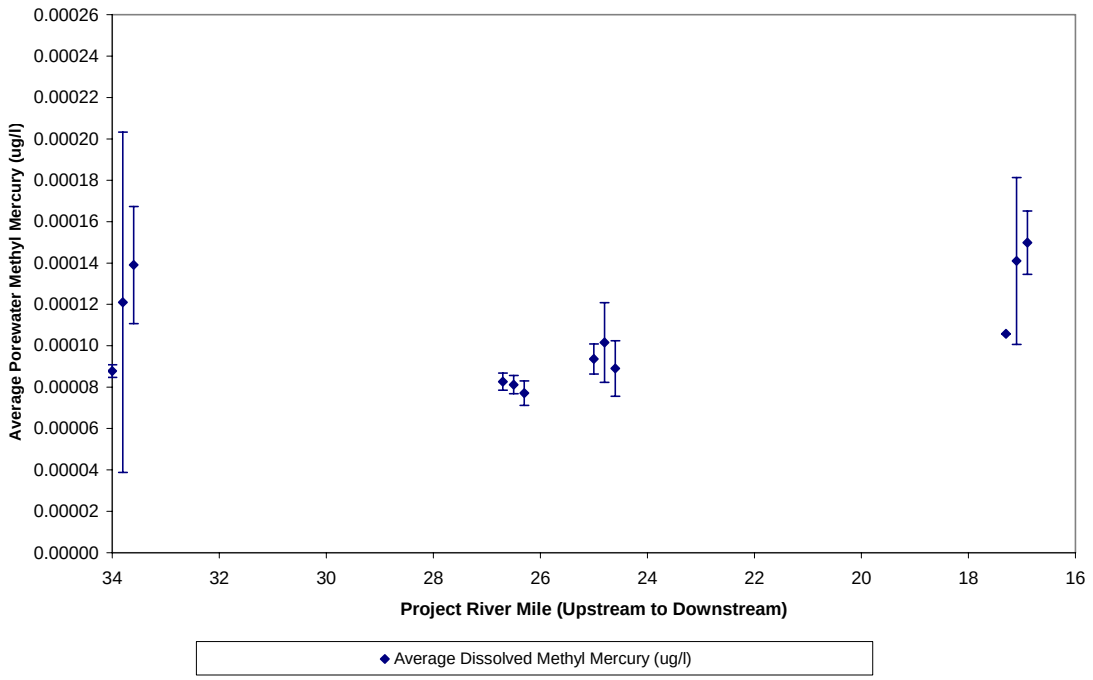

Figure 4.2-5. Average pore water methyl mercury concentrations in Boundary Reservoir, October 2008.

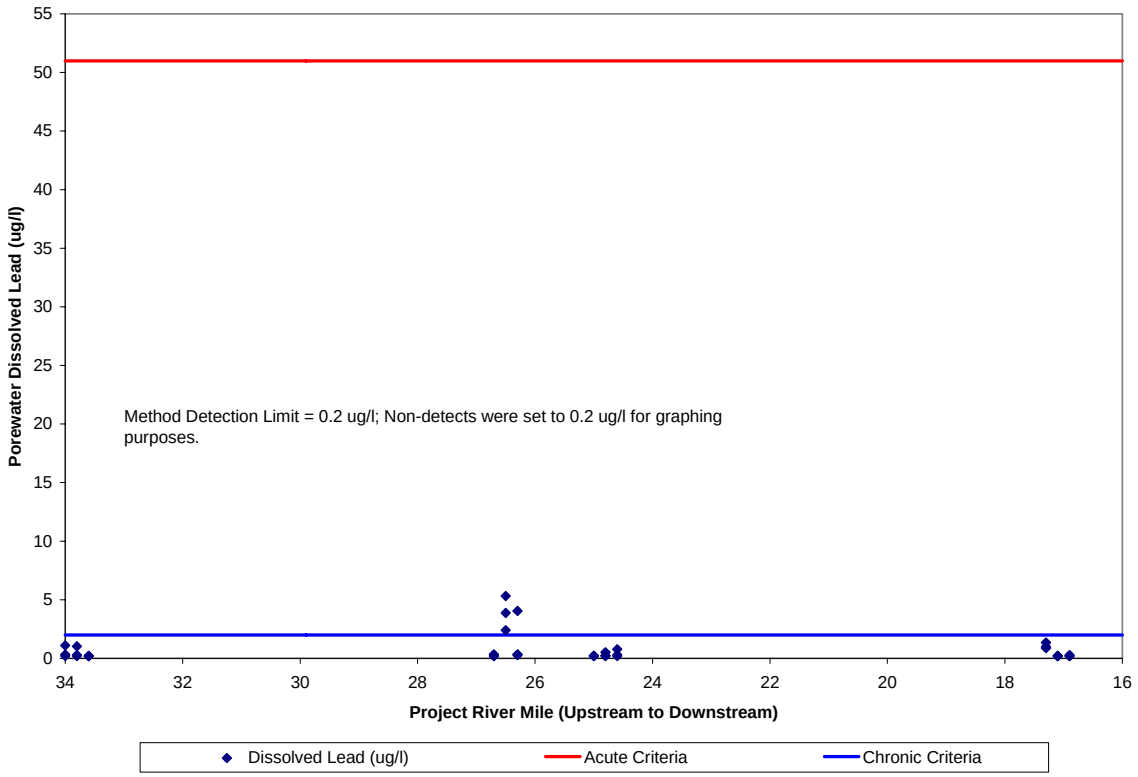

Figure 4.2-6. Pore water dissolved lead concentrations in Boundary Reservoir, October 2008.

Sediment and pore water samples that exceeded LAET and the chronic criterion, respectively, were collected from the location pictured in Figure 4.2-7. The source of sediment may have been a location just upstream from this depositional area and transferred through the opening in the rock outcropping (pictured in Figure 4.2-8). Erosion materials from the hillslope (pictured in Figure 4.2-9) may have been carried toward the opening in the rock outcropping and trapped in this depositional area. The sediment size fractions are coarse in this depositional area and resemble the particle size of the erosional material on the bank above the reservoir.

Figure 4.2-7. Site 8 (original location) depositional sand within the rock outcropping (sediment deposition was not present at this location in March 2008).

Figure 4.2-8. Opening upstream of the rock outcropping at Site 8 (old powerhouse in the upper right background).

Figure 4.2-9. Erosional material upstream of the rock outcropping (approximately 125 feet away from the sediment/pore water with elevated lead concentrations).

Concentrations for general chemistry parameters from October 2008 pore water sampling are summarized in Table 4.2-4. Complete results for general chemistry sampling are provided in Attachment D. The data summary in Table 4.2-4 includes all observations made from each of the sites (e.g., three replicate samples at each location).

Organics that compete for binding of divalent (lead, zinc, cadmium) and organometals (arsenic and mercury) are measured by dissolved organic carbon (DOC) or soluble reactive phosphorus (SRP). DOC and SRP will adsorb toxics and make them unavailable for binding to respiratory tissues in aquatic organisms. Figures 4.2-10 through 4.2-14 show the general chemistry makeup of pore water samples collected. DOC in pore water had the highest concentrations at sites 1 and 5. These concentrations were much higher in pore water than found at sites 8 and 14. The presence of the highest DOC and SRP concentrations in the forebay and canyon sites is an indication that biological cycling of nutrients is occurring at a greater rate. The DOC concentrations at the upper two sites were consistently low and well below those concentrations found in the pore water at sites 5 and 1.

Water hardness diminishes the toxicity of metals exposure to aquatic life. Hardness concentrations in pore water were moderate at most sites (5, 8, and 14), but were very high in pore water collected from site 1. The component cations comprising hardness are calcium and magnesium. Both cation concentrations were high at site 1 in the forebay indicating a substantial precipitation or sedimentation of these elements in this reach. Sediment samples collected from site 1 in the forebay had a grayish coloration indicating marl (limestone-based muck or clay, see Figure 4.2-15).

Table 4.2-4. Range of October 2008 results for general chemistry concentrations and measurements collected from pore water at sites in Boundary Reservoir.

Site No.	pH (units)	DOC (mg/L)	SRP (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg $CaCO_3$/L)
1	7.91 – 8.13	16.1 – 20.9	0.01 – 0.04	106 - 129	24.1 – 32.3	380 – 456
1 upstream	7.54 – 7.85	4.02 – 11.0	0.10 – 0.17	21.7 – 25.2	6.80 – 8.99	82.1 – 88.5
1 downstream	6.70 – 7.95	17.7 – 23.5	0.12 – 0.19	102 - 127	23.4 – 28.4	354 – 435
5	7.30 – 7.68	2.23 – 4.59	0.003 – 0.01	16.7 – 19.1	5.45 – 6.03	64.0 – 72.5
5 upstream	7.26 – 7.69	1.15 – 7.99	0.001 – 0.009	18.8 – 20.8	4.79 – 5.53	69.8 – 71.6
5 downstream	7.55 – 7.98	1.05 – 3.20	0.002 – 0.006	18.1 – 19.3	4.65 – 4.85	64.8 – 68.0
8	7.54 – 7.63	0.98 – 1.01	0.007 – 0.009	22.1 – 23.9	5.12 – 5.50	76.3 – 82.8
8 upstream	7.70 – 7.86	1.27 – 1.89	0.001 – 0.002	18.6 – 19.6	5.43 – 5.74	70.2 – 70.7
8 downstream	7.69 – 7.85	1.19 – 1.48	0.002	17.5 – 18.5	5.71 – 5.98	67.9 – 70.9
14	7.59 – 7.74	1.18 – 1.74	0.002 – 0.036	18.3 – 19.4	4.89 – 5.31	65.8 – 70.4
14 upstream	7.59 – 7.74	1.28 – 1.55	0.002 – 0.011	14.9 – 17.9	4.48 – 6.02	55.7 – 68.4
14 downstream	7.74 – 7.90	1.34 – 1.62	0.003 – 0.007	18.2 – 19.6	4.26 – 4.70	64.7 – 66.6

Notes:
$CaCO_3$ – calcium carbonate
DOC – dissolved organic carbon
mg/L – milligram per liter
SRP – soluble reactive phosphorous

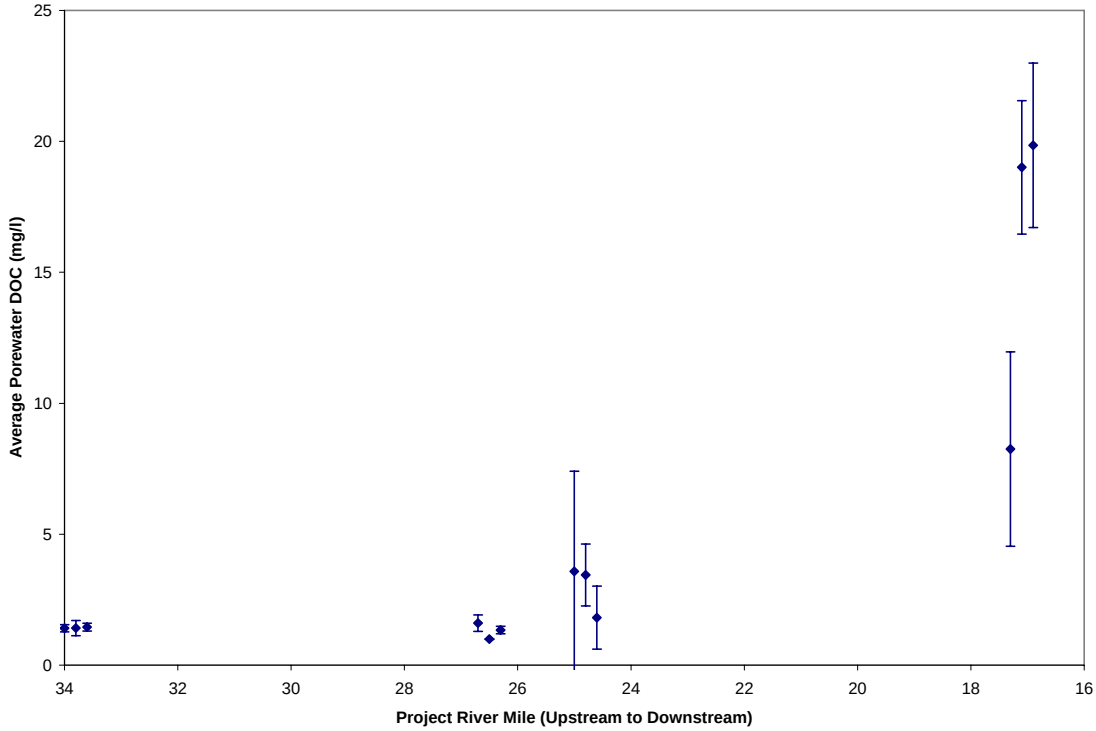

Figure 4.2-10. Average pore water DOC concentrations in Boundary Reservoir, October 2008.

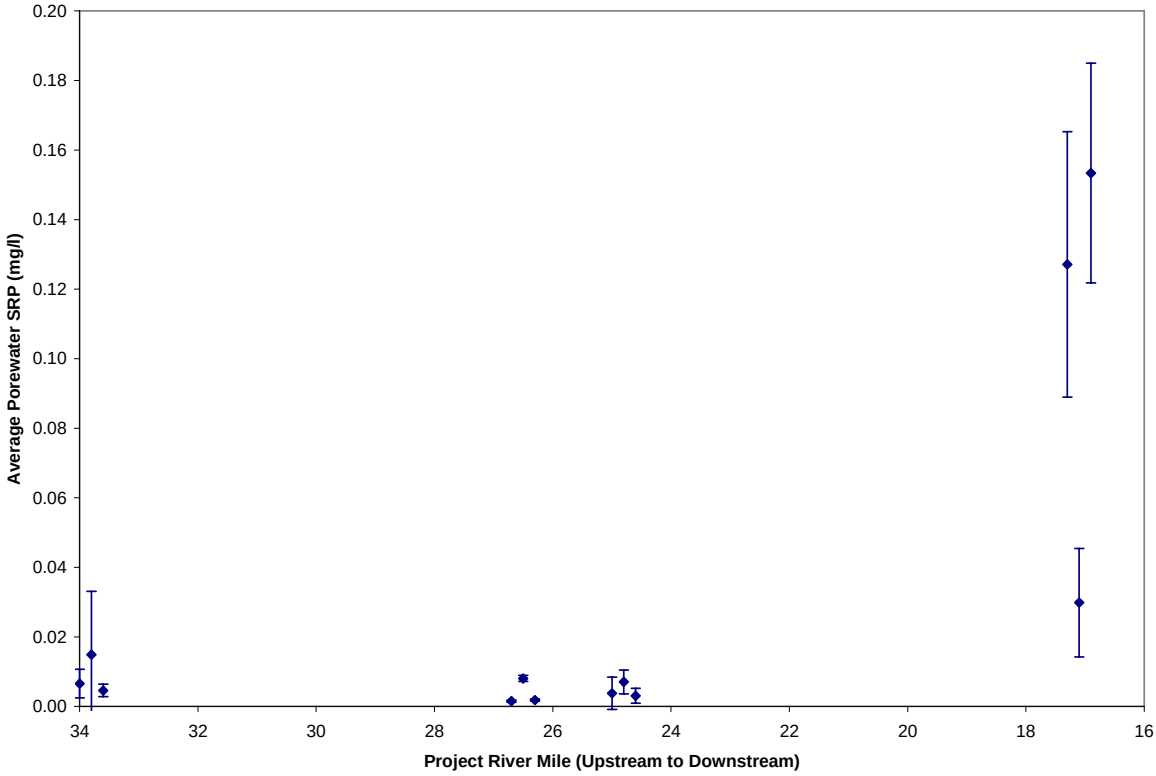

Figure 4.2-11. Average pore water SRP concentrations in Boundary Reservoir, October 2008.

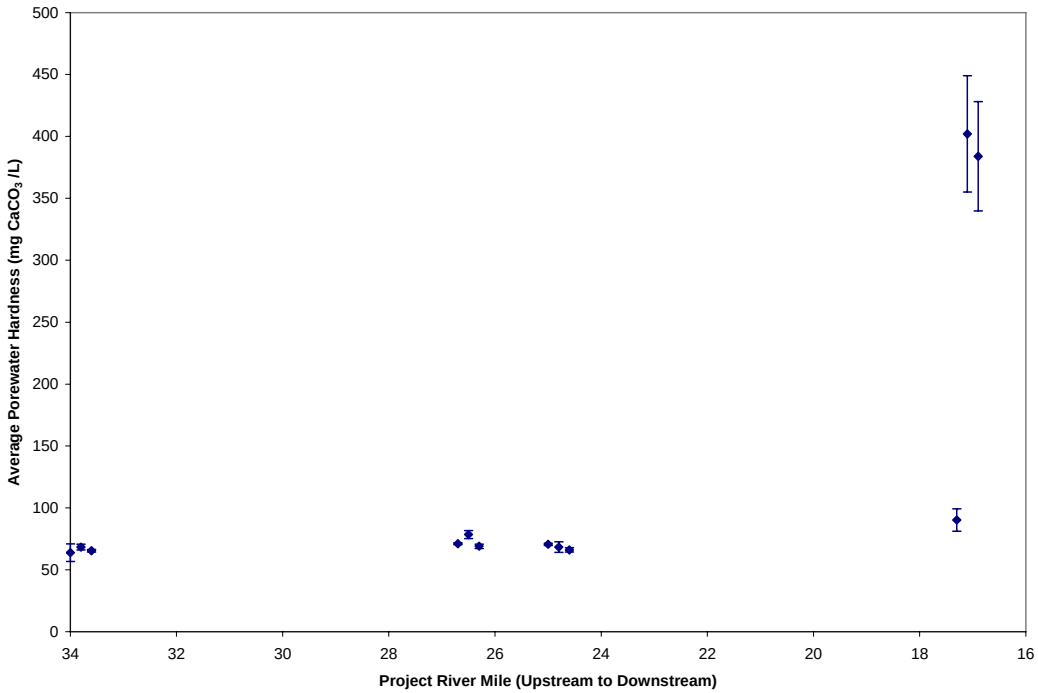

Figure 4.2-12. Average pore water hardness in Boundary Reservoir, October 2008.

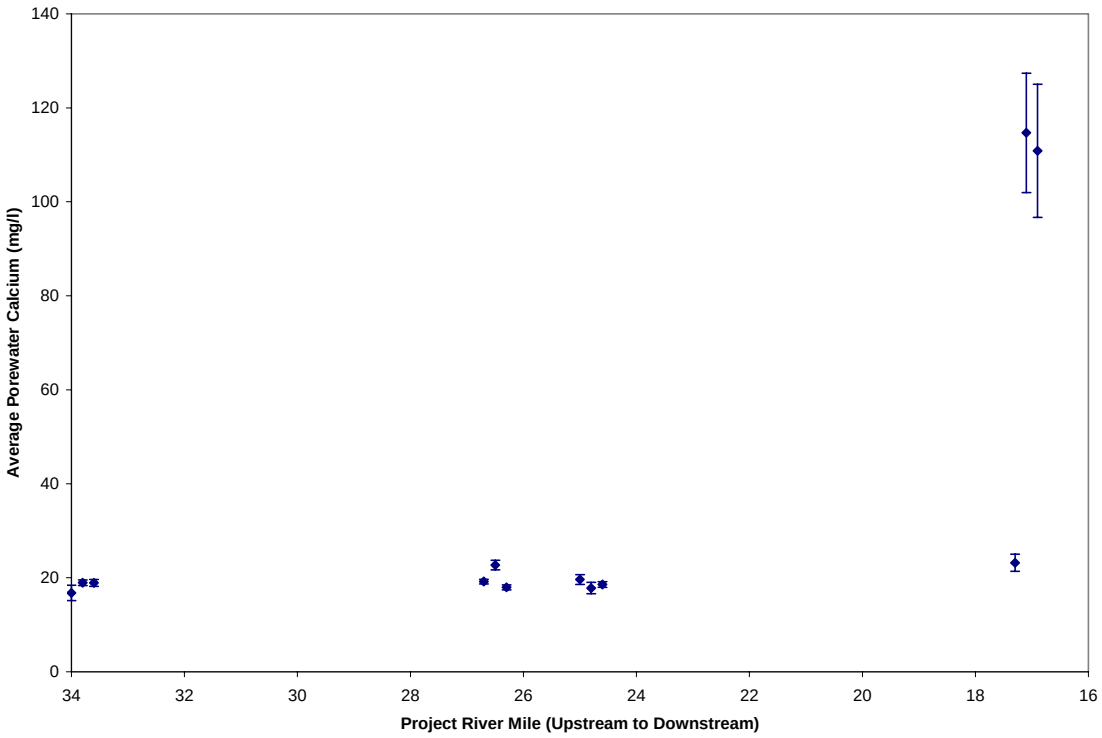

Figure 4.2-13. Average pore water calcium concentrations in Boundary Reservoir, October 2008.

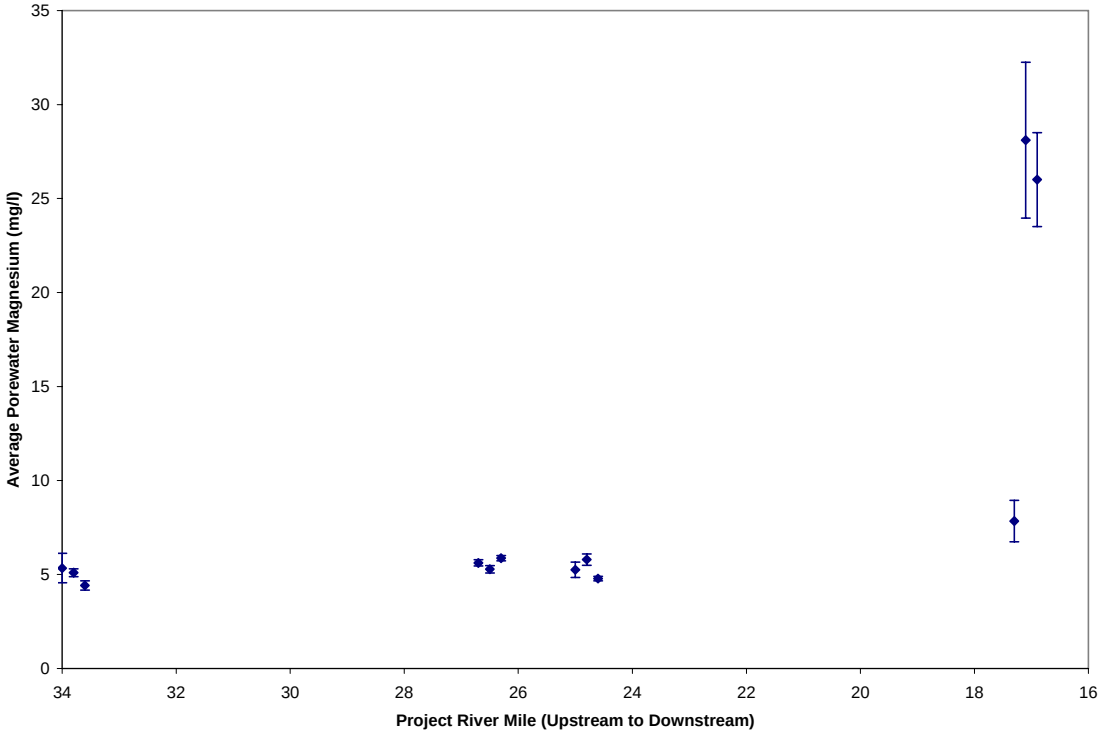

Figure 4.2-14. Average pore water magnesium concentrations in Boundary Reservoir, October 2008.

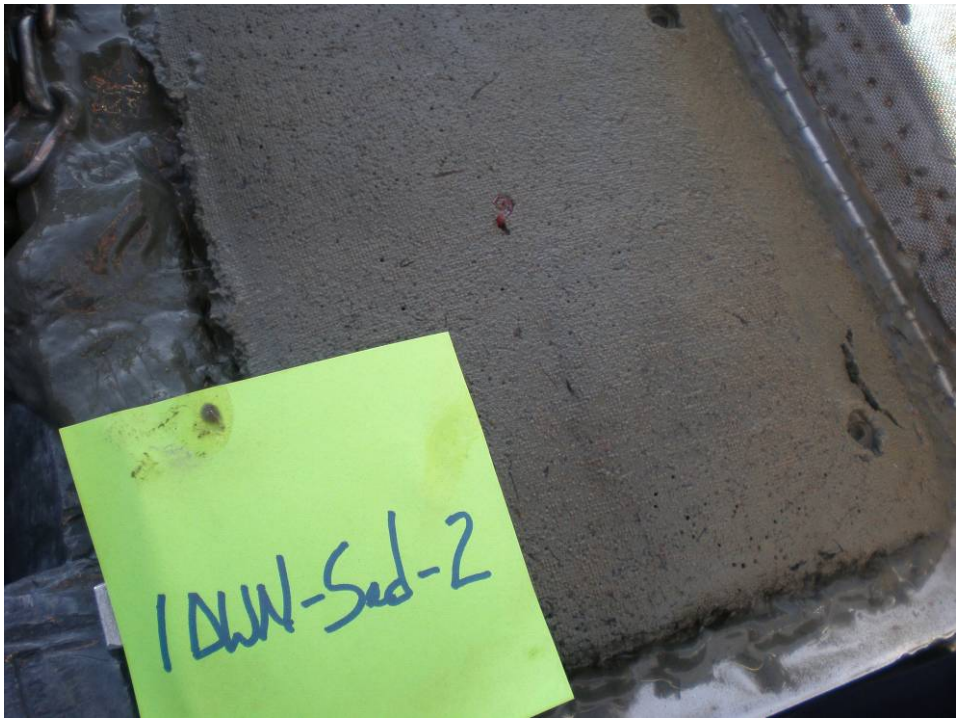

Figure 4.2-15. Site 1 sediment sample, October 2008 (note color and fine size fraction).

5 WATER COLUMN SAMPLING RESULTS

Water column water samples were collected along with sediment samples in October 2008 at four of the original sites visited in March 2008 and at two additional locations at each site; one downstream of the original site and one upstream of the original site. Sites 1, 5, 8, and 14 were visited to describe toxics characteristics at, above and below the original sites, in part, to determine if toxics presence in the water column could be explained through comparison with other nearby physicochemical conditions.

5.1. Verification and Validation of Data Quality Elements

Laboratory performance in analyzing samples is measured by several quality assurance analytical procedures that are outlined in SCL (2007). Quality assurance results for the water column samples are presented in Attachment C. Matrix spike and recovery limits were slightly above the prescribed range for arsenic and zinc and higher than actual concentration. All other quality assurance components were met for water column profile samples (Table 5.1-1).

Table 5.1-1. Summary of data quality objectives that meet field and laboratory performance expectations.

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Samples RPD	Matrix Spikes % Recovery Limits	Required Reporting Limit
Arsenic	Water	✓	✓	♦	✓
Cadmium	Water	✓	✓	✓	✓
Lead	Water	✓	✓	✓	✓
Mercury	Water	✓	✓	✓	✓
Zinc	Water	✓	✓	♦	✓
Dissolved Organic Carbon	Water	✓	✓	✓	✓
Alkalinity	Water	✓	NA	✓	✓
Hardness	Water	✓	NA	✓	✓
Dissolved Oxygen	Water	✓	NA	✓	✓
pH	Water	✓	NA	✓	✓
Temperature	Water	✓	NA	✓	✓
Conductivity	Water	✓	NA	✓	✓
Turbidity	Water	✓	✓	✓	✓

Notes:
LCS – laboratory control sample
NA – not applicable
RPD – relative percent difference
♦ – higher recovery than maximum expected for this analyte (blank samples are slightly higher than maximum allowable concentration range); laboratory performance may have slightly overestimated concentrations for these elements in surface water samples.

5.2. Analytical Results from Water Column Profile Sampling Sites

Dissolved toxics concentrations from the October 2008 water column profile sites are summarized in Table 5.2-1. Concentrations for total recoverable toxics from the October 2008 water column profile sites are summarized in Table 5.2-2. Complete results for dissolved and total toxics sampling are provided in Attachment D. The data summary tables include all observations made from each of the sampling sites (e.g., three depths at each location: bottom, middle, and surface). Most of the water quality observations from the sampling sites resulted in non-detectable concentrations (indicated by a "<" symbol). When a range of concentrations was included at a sampling site, the second expression indicated the presence of a detectable dissolved metal concentration. Chronic and acute surface water criteria are included at the bottom of Table 5.2-1 (dissolved toxics) for each of the metals.

Figures 5.2-1 through 5.2-5 show dissolved toxics concentrations from surface water at three locations in the water column throughout the Boundary Reservoir. Concentrations of dissolved toxics in surface water are generally very low at all sites sampled. Concentrations of dissolved toxics in surface water can affect aquatic life by absorption through respiratory tissues (e.g., gills). Dissolved toxics may originate through diffusion from pore water in sediments and follow a concentration gradient (i.e., from areas of lower concentration to a more concentrated area).

Samples collected from the water column at all sites (including the downstream, original, and upstream locations) did not have measurable concentrations of dissolved toxics (e.g., lead, zinc, cadmium, arsenic, and mercury) or were just above detectable concentrations. Results from October 2008 water column sampling for dissolved toxics were predominantly at or below detection limits for each of the parameters. The low or undetectable concentrations of each toxic indicated that presence in sediment or pore water did not diffuse into the overlying surface water. In addition, water quality characteristics (e.g., hardness and DOC) diminished the potential for bioavailability of dissolved toxics.

Table 5.2-1. Range of results for October 2008 dissolved concentrations of toxics from water column profile sites in Boundary Reservoir.

Site No.	Arsenic (µg/L)	Cadmium (µg/L)	Mercury (µg/L)	Zinc (µg/L)	Lead (µg/L)
1	1.02 – 1.12	<0.20	0.0007 – 0.001	<3.0	<0.20
1 upstream	1.12 – 1.20	<0.20	0.0006 – 0.0008	<3.0	<0.20
1 downstream	1.09 – 1.23	<0.20	0.0004 – 0.001	<3.0	<0.20
5	<1.0 – 1.04	<0.20	0.0006 – 0.001	<3.0	<0.20
5 upstream	<1.0 – 1.09	<0.20	0.0005 – 0.001	<3.0	<0.20
5 downstream	1.03 – 1.19	<0.20	0.0005 – 0.0012	<3.0	<0.20
8	1.03 – 1.11	<0.20	0.0006 – 0.0008	<3.0	<0.20
8 upstream	1.07 – 1.13	<0.20	0.0007 – 0.0008	<3.0	<0.20
8 downstream	1.04 – 1.12	<0.20	0.0003 – 0.0008	<3.0	<0.20
14	1.05 – 1.14	<0.20	0.0004 – 0.001	<3.0	<0.20
14 upstream	1.05 – 1.19	<0.20	0.0004 – 0.0005	<3.0	<0.20
14 downstream	1.02 – 1.14	<0.20	0.0004 – 0.0015	<3.0	<0.20 – 0.55
Chronic Criteria (µg/L)	190	1.03	N/A	86.5	2
Acute Criteria (µg/L)	360	3.7	2.1 (µg/L)	94.7	51

Notes:
µg/L – microgram per liter
*Surface methyl-Hg sample
N/A – criteria not available
(Source for criteria: Ecology 2006)

Results for total recoverable concentrations of toxics were also low (Table 5.2-2). These concentrations represent toxics concentrations associated with particulates as well as dissolved fractions in the water column. There were no detectable concentrations of cadmium in water column samples. However, small concentrations of arsenic, zinc and lead were detected that were well below surface water criteria for dissolved fractions, and so do not represent a potential for bioaccumulation from a food source that would harm aquatic life.

Table 5.2-2. Range of results for total recoverable concentrations of toxics from water column profile sites in Boundary Reservoir.

Site No.	Arsenic (µg/L)	Cadmium (µg/L)	Zinc (µg/L)	Lead (µg/L)
1	1.19 – 1.26	<0.20	<3.0 – 3.14	<0.20 – 1.94
1 upstream	1.11 – 1.17	<0.20	<3.0	<0.20
1 downstream	1.15 – 1.19	<0.20	<3.0	<0.20
5	1.19 – 1.26	<0.20	<3.0	<0.20
5 upstream	1.11 – 1.16	<0.20	<3.0	<0.20
5 downstream	1.17 – 1.24	<0.20	<3.0	<0.20
8	1.02 – 1.15	<0.20	<3.0 – 7.84	<0.20
8 upstream	1.07 – 1.12	<0.20	<3.0	<0.20
8 downstream	1.07 – 1.20	<0.20	<3.0	<0.20
14	1.08 – 1.26	<0.20	<3.0	<0.20
14 upstream	1.05 – 1.29	<0.20	<3.0	<0.20 – 0.21
14 downstream	1.06 – 1.19	<0.20	<3.0	<0.20

Note:
µg/L – microgram per liter

Figure 5.2-1. Water column dissolved arsenic concentrations in Boundary Reservoir, October 2008.

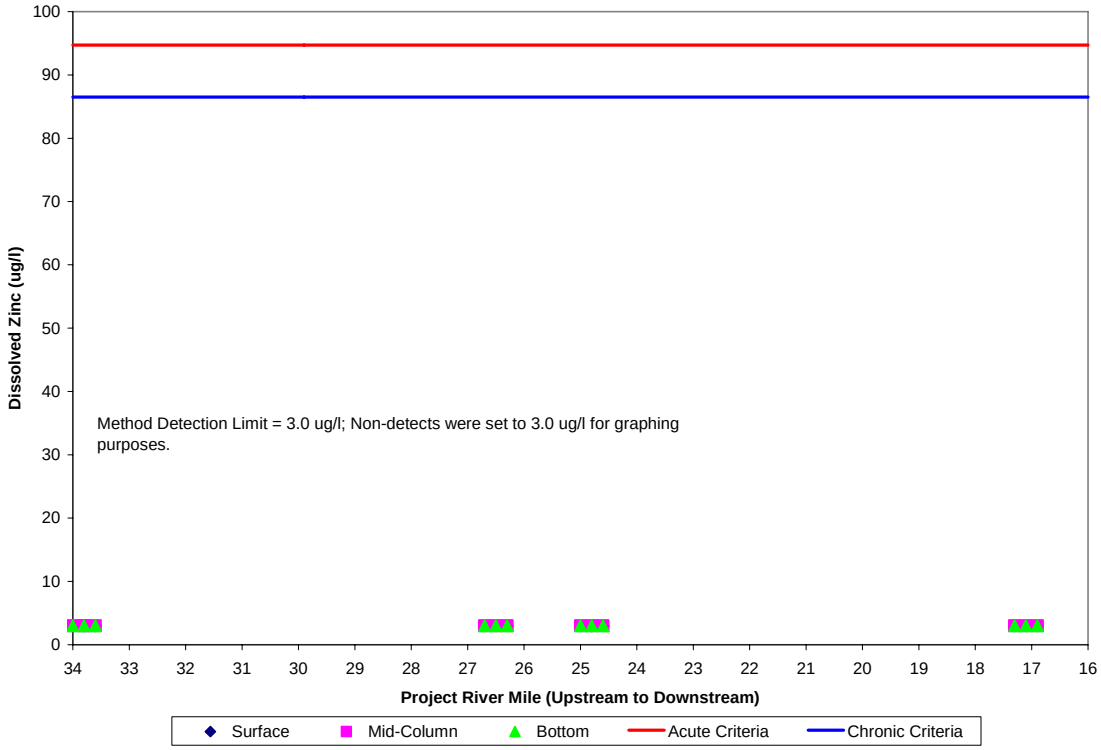

Figure 5.2-2. Water column dissolved zinc concentrations in Boundary Reservoir, October 2008.

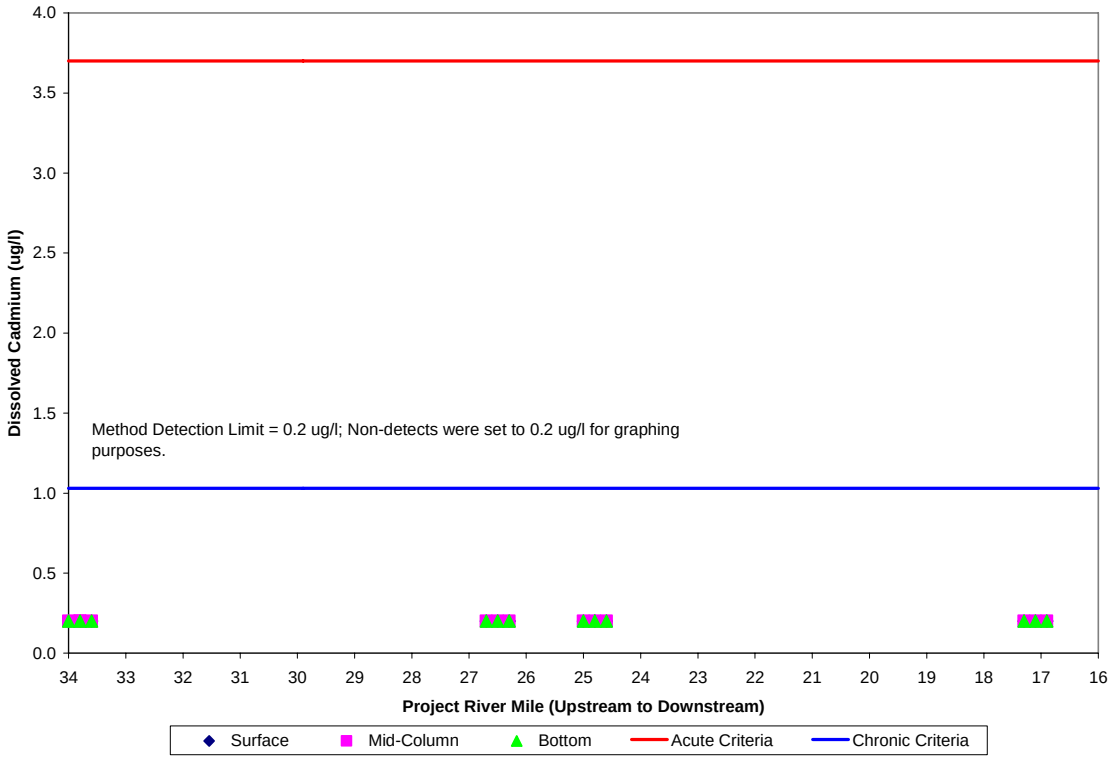

Figure 5.2-3. Water column dissolved cadmium concentrations in Boundary Reservoir, October 2008.

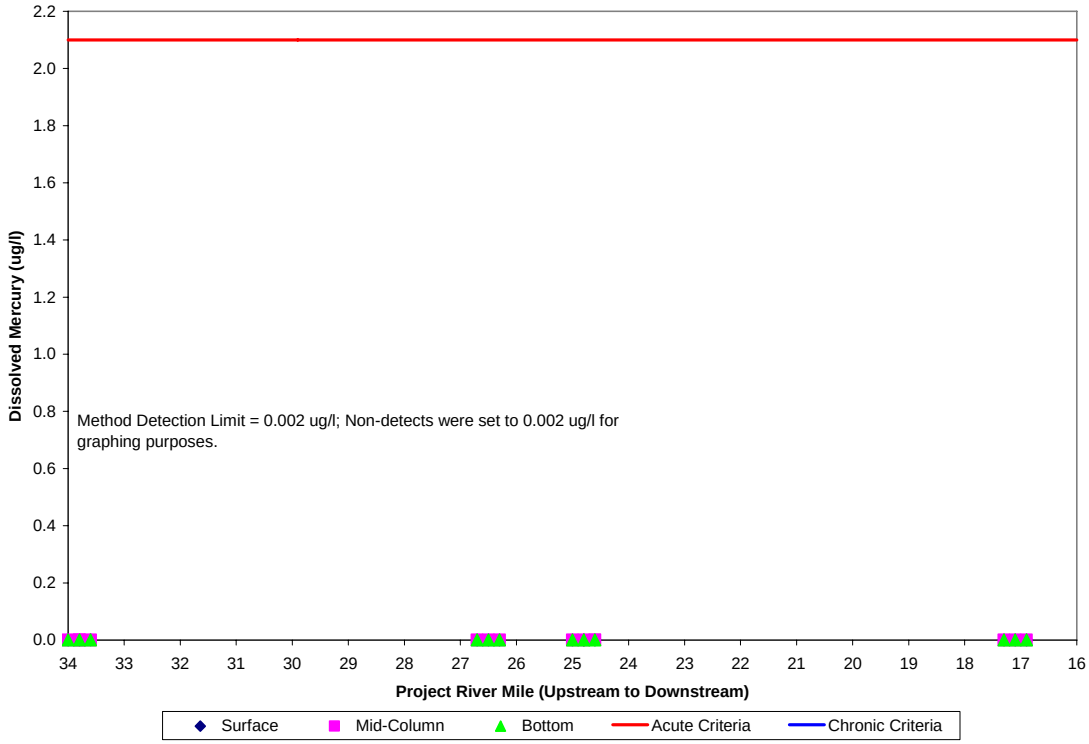

Figure 5.2-4. Water column dissolved mercury concentrations in Boundary Reservoir, October 2008.

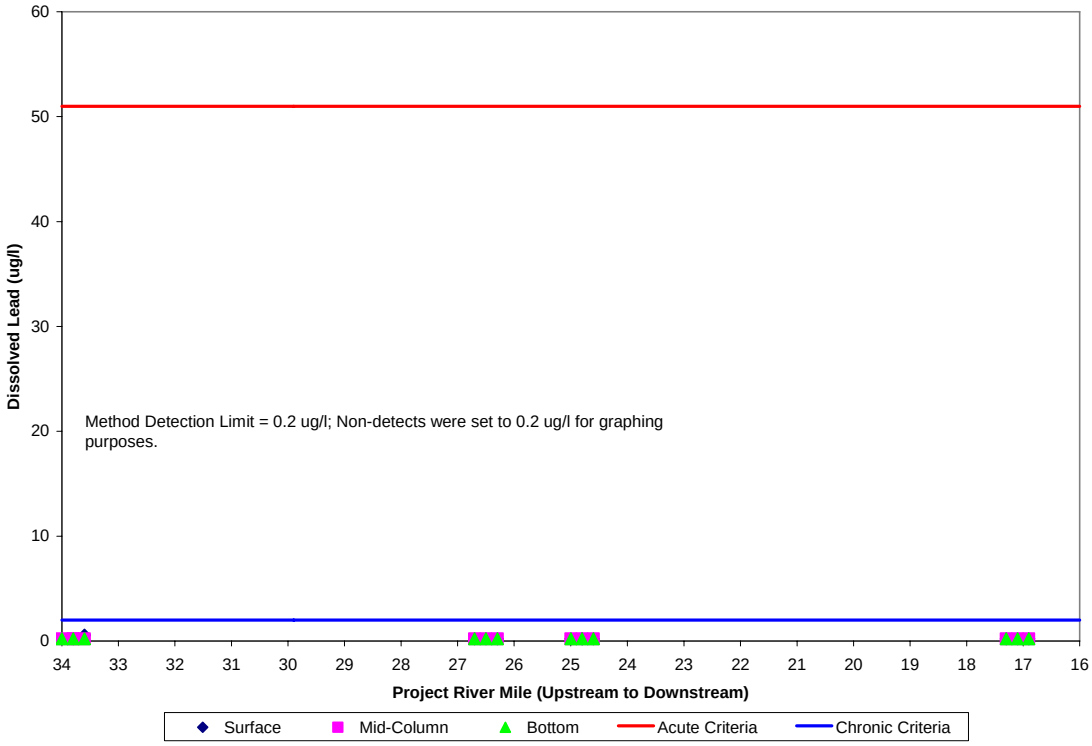

Figure 5.2-5. Water column dissolved lead concentrations in Boundary Reservoir, October 2008.

Field parameters were recorded at each of the three depths at each sample location and are summarized in Table 5.2-3. Complete results of field parameter sampling are provided in Attachment D (Table D-1). The data summary in Table 5.2-3 includes all observations made from each of the sample locations (e.g., three depths at each location: bottom, mid, and surface). The range of observations measured at each location and for each parameter showed low variability.

Table 5.2-3. Range of results for October 2008 field parameters collected from water column profile sites in Boundary Reservoir.

Site No.	Temperature (ºC)	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (µmhos/cm)	Redox (mV)
1	10.57 – 10.64	10.2 – 10.4	7.58 – 7.91	155.5 - 156	389 - 391
1 upstream	10.63	10.3 – 10.4	7.76 – 7.87	155.3 – 155.9	386 – 388
1 downstream	10.6 – 10.73	10.2 – 10.3	7.56 – 7.77	155.3 – 156.5	415 – 417
5	10.31 – 10.34	10.5	7.93	155.8 - 156	372 - 375
5 upstream	10.38 – 10.4	10.5 – 10.6	7.88 – 7.92	155.3 – 155.6	364 – 370
5 downstream	10.39 – 10.41	10.5 – 10.6	7.94 – 7.95	155.4 – 155.6	377 – 381
8	10.43	10.7	7.91 – 7.93	155.4 – 155.7	372 – 374
8 upstream	10.36 – 10.39	10.6 – 10.7	7.85 – 7.93	155.3 – 155.7	383 – 385
8 downstream	10.4 – 10.5	10.6	7.83 – 7.92	155.1 – 155.4	375 - 377
14	10.73 – 10.89	10.5	7.59 – 7.66	152.4 – 152.7	380 - 381
14 upstream	10.73	10.5	7.52 – 7.65	152.7 – 153.1	395 - 398
14 downstream	10.7 – 10.74	10.5 – 10.6	7.46 – 7.85	152.7 – 153.2	376 - 421

Notes:
µmhos/cm – micromhos per centimeter
mg/L – milligram per liter
mV – millivolt

Concentrations for general chemistry parameters from the water column profile sites are summarized in Table 5.2-4. Complete results for general chemistry sampling are provided in Attachment D (Table D-2). The data summary in Table 5.2-3 includes all observations made from each of the sample locations (e.g., three depths at each location: bottom, middle, and surface). Figures 5.2-6 through 5.2-8 show the general chemistry results for sites in Boundary Reservoir. The range of observations measured at each location and for each parameter showed low variability from surface to bottom depths. The transfer of toxics from deposited sediments, dissolution in pore water, and diffusion into overlying surface water was the model used to determine source, transfer, and potential for bioavailability.

Several factors in surface water influence level of toxicity and potential for bioavailability to aquatic life. The components comprising hardness in water (calcium and magnesium concentrations) reduce toxicity of toxics to aquatic life. These cations compete with divalent metals (lead, zinc, and cadmium) for binding sites on respiratory tissues on aquatic organisms (e.g., gills). Hardness in samples collected from surface, middle, and bottom samples were

similar within and among all sites. The hardness concentration is moderate-high and a primary factor in reducing toxicity of metals. The DOC concentrations were low and showed some minor variability among the surface, middle, and bottom samples. DOC will adsorb the toxics to the surface and settle in a depositional area.

Table 5.2-4. Range of results for October 2008 general chemistry concentrations and measurements collected from water column profile sites in Boundary Reservoir.

Site No.	Turbidity (NTU)	Alkalinity (mg $CaCO_3$/L)	DOC (mg/L)	Hardness (mg $CaCO_3$/L)
1	0.39 – 6.6	86.0 – 87.5	1.26 – 2.09	73.9 – 74.9
1 upstream	0.43 – 0.45	86.0 – 87.7	1.29 – 1.61	75.2 – 76.2
1 downstream	0.42 – 0.50	85.6 – 87.5	1.14 – 1.41	74.1 – 75.2
5	0.38 – 0.43	86.1 – 87.8	1.14 – 1.21	74.9 – 76.2
5 upstream	0.39 – 0.47	82.6 – 86.3	1.22 – 1.34	74.7 – 75.8
5 downstream	0.34 – 0.40	84.5 – 85.7	1.15 – 1.46	74.5 – 75.0
8	0.38 – 0.40	83.8 – 87.6	1.17 – 1.82	75.2 – 76.2
8 upstream	0.37 – 0.39	85.3 – 86.4	1.14 – 1.63	74.1 – 75.8
8 downstream	0.36 – 0.41	85.8 – 87.2	1.15 – 1.31	73.7 – 76.0
14	0.36 – 0.41	86.4 – 88.0	1.21 – 1.40	74.5 – 75.6
14 upstream	0.38 – 0.41	85.9 – 88.6	1.23 – 1.58	74.7 – 75.6
14 downstream	0.40 – 0.43	85.8 – 87.1	1.19 – 1.85	74.7 – 76.0

Notes:
$CaCO_3$ – calcium carbonate
DOC – dissolved organic carbon
mg/L – milligram per liter
NTU – nephelometric turbidity unit

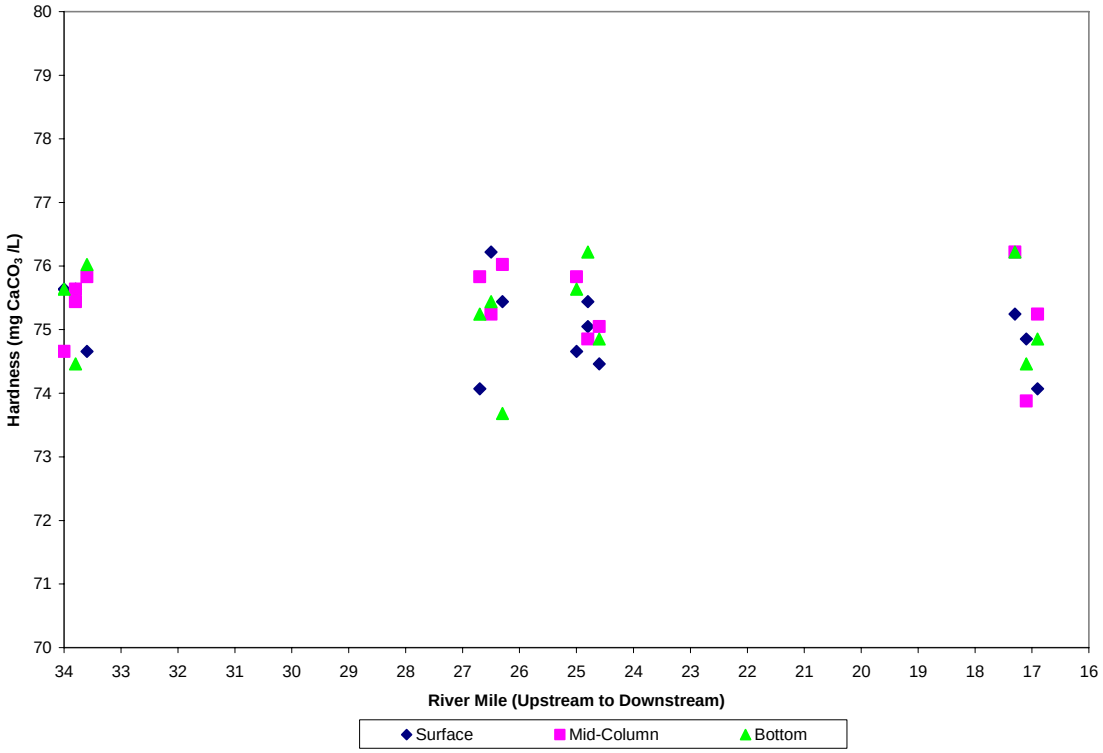

Figure 5.2-6. Water column hardness in Boundary Reservoir, October 2008.

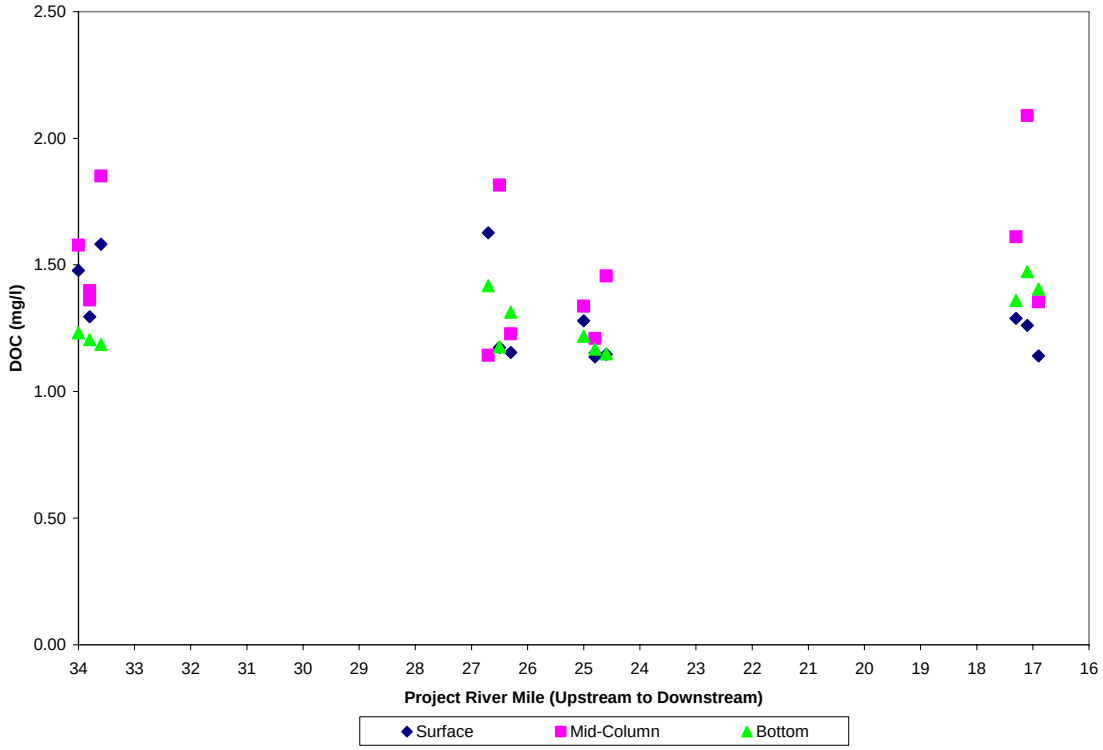

Figure 5.2-7. Water column DOC concentrations in Boundary Reservoir, October 2008.

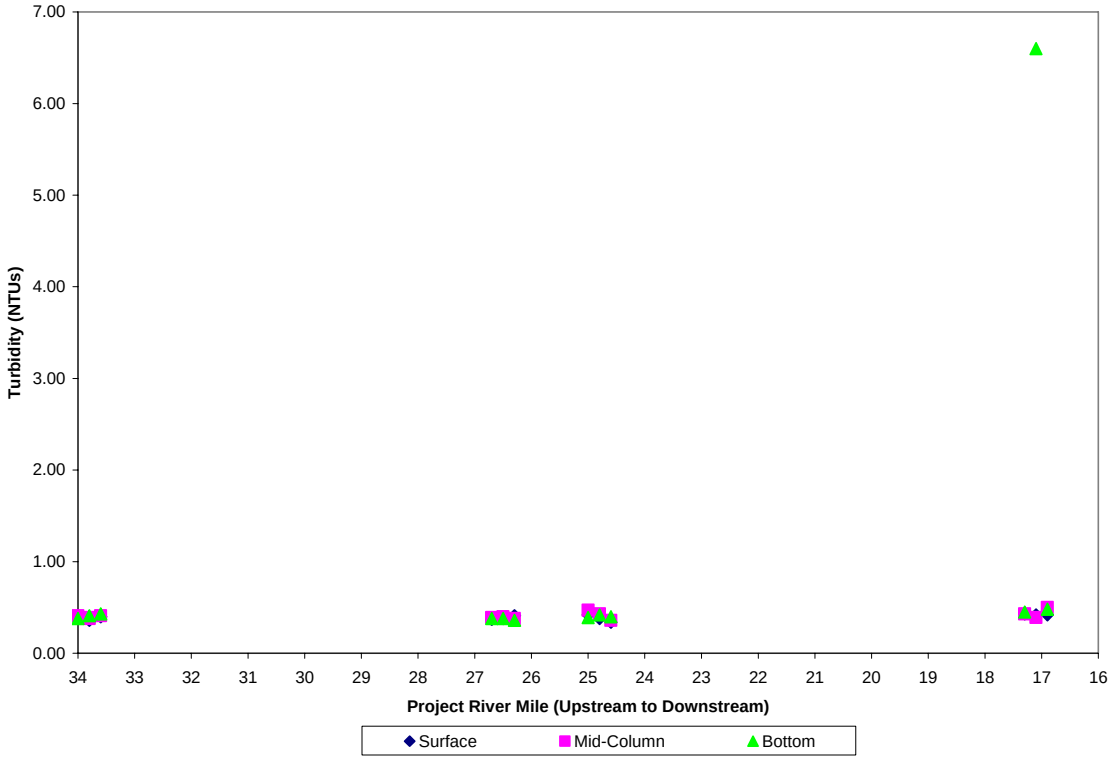

Figure 5.2-8. Water column turbidity in Boundary Reservoir, October 2008.

6 REFERENCES

Ecology (Washington State Department of Ecology). 2006. Water Quality Standards for Surface Waters of the State of Washington: Chapter 173-201A-240 WAC. Publication No. 06-10-091. Olympia, Washington.

SCL (Seattle City Light). 2007. Study 4 – Toxics Assessment: Evaluation of Contaminant Pathways, Final Phase 2 Sampling and Analysis Plan for the Boundary Hydroelectric Project (FERC No. 2144). Prepared by Tetra Tech. Seattle, Washington. July 2007, as modified by SCL's September 28, 2007, response to comments.

SCL. 2008. Study 4 – Toxics Assessment: Evaluation of Contaminant Pathways Interim Report for the Boundary Hydroelectric Project (FERC No. 2144). Prepared by Tetra Tech. August, 2008.

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Attachment A: Sediment Data

AQUATIC RESEARCH INCORPORATED

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CASE FILE NUMBER: TET006-79 **PAGE 1**
REPORT DATE: 12/08/08
DATE SAMPLED: 10/21/08 **DATE RECEIVED:** 10/24/08
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM TETRA TECH

CASE NARRATIVE

Thirty six sediment samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on the subsequent p

SAMPLE DATA

SAMPLE ID	TOTAL SOLIDS (%)	WATER (%)	TOC (%)	ARSENIC (mg/kg)	ZINC (mg/kg)	MERCURY (mg/kg)
1-SED-1	31.9%	68.1%	3.67	9.38	129	0.073
1-SED-2	30.1%	69.9%	3.56	7.28	153	0.080
1-SED-3	31.5%	68.5%	3.83	10.9	145	0.084
1 UPS-SED-1	37.2%	62.8%	2.92	6.37	145	0.085
1 UPS-SED-2	35.6%	64.4%	3.24	6.98	143	0.077
1 UPS-SED-3	41.2%	58.8%	2.26	5.45	125	0.057
1 DWN-SED-1	32.1%	67.9%	3.35	8.13	135	0.040
1 DWN-SED-2	32.3%	67.7%	3.54	9.12	131	0.046
1 DWN-SED-3	32.8%	67.2%	3.23	11.1	137	0.049
5-SED-1	56.7%	43.3%	0.809	3.02	136	0.019
5-SED-2	57.5%	42.5%	1.24	2.82	117	<0.014
5-SED-3	55.7%	44.3%	1.18	3.09	138	<0.014
5 UPS-SED-1	52.1%	47.9%	1.44	3.77	93.6	<0.015
5 UPS-SED-2	71.8%	28.2%	0.247	3.91	219	<0.011
5 UPS-SED-3	74.2%	25.8%	0.287	2.60	114	<0.011
5 DWN-SED-1	72.0%	28.0%	0.756	3.56	110	<0.011
5 DWN-SED-2	73.0%	27.0%	0.463	2.87	172	<0.011
5 DWN-SED-3	65.7%	34.3%	0.884	3.31	572	<0.012
8-SED-1	82.2%	17.8%	0.222	2.59	74.9	<0.010
8-SED-2	79.8%	20.2%	0.336	3.42	66.3	0.075
8-SED-3	77.1%	22.9%	0.209	4.25	68.5	<0.010
8 UPS-SED-1	83.9%	16.1%	0.110	3.63	40.8	<0.010
8 UPS-SED-2	90.1%	9.85%	0.214	2.80	50.9	<0.010
8 UPS-SED-3	85.3%	14.7%	0.111	2.85	30.6	<0.010
8 DWN-SED-1	78.6%	21.4%	0.234	4.22	117	<0.010
8 DWN-SED-2	80.4%	19.6%	0.235	2.61	63.1	<0.010
8 DWN-SED-3	79.1%	20.9%	0.255	3.41	56.6	<0.010
14-SED-1	86.4%	13.6%	0.217	2.48	43.8	<0.010
14-SED-2	76.9%	23.1%	0.044	3.30	36.2	<0.010
14-SED-3	73.9%	26.1%	0.192	2.30	41.0	<0.011
14 UPS-SED-1	77.8%	22.2%	0.119	1.34	31.9	<0.010
14 UPS-SED-2	81.4%	18.6%	0.080	2.21	46.3	<0.010
14 UPS-SED-3	86.7%	13.3%	0.098	2.02	25.6	<0.010
14 DWN-SED-1	81.3%	18.7%	0.054	2.60	35.4	<0.010
14 DWN-SED-2	80.6%	19.4%	0.088	3.36	40.5	<0.010
14 DWN-SED-3	82.0%	18.0%	0.075	3.03	38.6	<0.010

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CASE FILE NUMBER: **TET006-79**
REPORT DATE: **12/08/08**
DATE SAMPLED: **10/21/08** **DATE RECEIVED:** **10/24/08**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM TETRA TECH

SAMPLE DATA

SAMPLE ID	TOTAL SOLIDS (%)	WATER (%)	LEAD (mg/kg)	CADMIUM (mg/kg)	SULFIDE (mg/kg)
1-SED-1	31.9%	68.1%	23.9	0.367	2.37
1-SED-2	30.1%	69.9%	27.7	0.435	5.68
1-SED-3	31.5%	68.5%	25.1	0.505	2.16
1 UPS-SED-1	37.2%	62.8%	24.4	0.452	10.1
1 UPS-SED-2	35.6%	64.4%	23.9	0.401	13.4
1 UPS-SED-3	41.2%	58.8%	20.2	0.323	10.9
1 DWN-SED-1	32.1%	67.9%	23.3	0.352	8.97
1 DWN-SED-2	32.3%	67.7%	22.5	0.405	5.51
1 DWN-SED-3	32.8%	67.2%	23.3	0.360	2.73
5-SED-1	56.7%	43.3%	14.8	0.344	5.84
5-SED-2	57.5%	42.5%	19.9	0.288	5.34
5-SED-3	55.7%	44.3%	20.6	0.415	<0.507
5 UPS-SED-1	52.1%	47.9%	15.6	0.203	22.6
5 UPS-SED-2	71.8%	28.2%	21.1	0.388	1.46
5 UPS-SED-3	74.2%	25.8%	27.6	0.206	<0.257
5 DWN-SED-1	72.0%	28.0%	21.8	0.179	<0.236
5 DWN-SED-2	73.0%	27.0%	20.2	0.293	<0.266
5 DWN-SED-3	65.7%	34.3%	18.7	0.186	0.546
8-SED-1	82.2%	17.8%	25.5	0.131	<0.224
8-SED-2	79.8%	20.2%	29.4	0.144	<0.249
8-SED-3	77.1%	22.9%	344	0.109	<0.248
8 UPS-SED-1	83.9%	16.1%	5.51	0.305	<0.218
8 UPS-SED-2	90.1%	9.85%	4.59	0.172	<0.214
8 UPS-SED-3	85.3%	14.7%	4.97	0.121	<0.210
8 DWN-SED-1	78.6%	21.4%	43.5	0.286	<0.248
8 DWN-SED-2	80.4%	19.6%	28.8	0.117	<0.208
8 DWN-SED-3	79.1%	20.9%	16.4	0.193	<0.240
14-SED-1	86.4%	13.6%	4.89	0.073	<0.209
14-SED-2	76.9%	23.1%	4.99	0.453	<0.235
14-SED-3	73.9%	26.1%	7.04	0.359	3.16
14 UPS-SED-1	77.8%	22.2%	2.87	0.033	<0.210
14 UPS-SED-2	81.4%	18.6%	2.38	0.053	<0.222
14 UPS-SED-3	86.7%	13.3%	2.18	0.028	<0.228
14 DWN-SED-1	81.3%	18.7%	4.50	0.103	<0.200
14 DWN-SED-2	80.6%	19.4%	4.68	0.151	<0.214
14 DWN-SED-3	82.0%	18.0%	4.44	0.165	<0.240

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CASE FILE NUMBER: TET006-79 **PAGE 3**
REPORT DATE: 01/21/09
DATE SAMPLED: 10/21/08 **DATE RECEIVED:** 10/24/08
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM TETRA TECH

QA/QC DATA

QC PARAMETER	TOTAL SOLIDS (%)	TOC (%)	TOC (%)	TOC (%)	ARSENIC (mg/kg)	ARSENIC (mg/kg)
METHOD	EPA 160.1	EPA 9060	EPA 9060	EPA 9060	SM 3113B	SM3113B
DATE ANALYZED	11/18/08	12/04/08	12/04/08	12/05/08	12/03/08	12/03/08
DETECTION LIMIT	1.00	0.01	0.01	0.01	0.250	0.250
DUPLICATE						
SAMPLE ID	14 DWN-SED-3	1-SED-1	5 DWN-SED-3	8-SED-3	5 UPS-SED-2	14 UPS-SED-3
ORIGINAL	82.0%	3.67	0.884	0.209	3.91	2.02
DUPLICATE	80.8%	3.92	0.742	0.207	4.69	1.79
RPD	1.46%	4.57%	12.34%	0.75%	18.26%	12.12%
SPIKE SAMPLE						
SAMPLE ID					5 UPS-SED-2	14 UPS-SED-3
ORIGINAL					3.91	2.02
SPIKED SAMPLE					7.07	5.26
SPIKE ADDED					3.48	2.88
% RECOVERY	NA	NA	NA	NA	90.84%	112.48%
QC CHECK						
					mg/l	mg/l
FOUND		3.45	3.45	3.44	1.05	1.05
TRUE		3.35	3.35	3.35	1.00	1.00
% RECOVERY	NA	102.87%	102.87%	102.78%	104.55%	104.55%
BLANK	NA	<0.01	<0.01	<0.01	<0.250	<0.250

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NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIM
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATIO

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PHONE: (206) 632-2715 FAX: (206) 632-2417

CASE FILE NUMBER: TET006-79 **PAGE 4**
REPORT DATE: 12/08/08
DATE SAMPLED: 10/21/08 **DATE RECEIVED:** 10/24/08
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM TETRA TECH

QA/QC DATA

QC PARAMETER	ZINC (mg/kg)	ZINC (mg/kg)	MERCURY (mg/kg)	MERCURY (mg/kg)
METHOD	EPA 200.7	EPA 200.7	EPA 245.2	EPA 245.2
DATE ANALYZED	10/29/08	10/29/08	11/07/08	11/07/08
DETECTION LIMIT	1.00	1.00	0.010	0.010
DUPLICATE				
SAMPLE ID	5 UPS-SED-2	14 UPS-SED-3	5 UPS-SED-2	14 UPS-SED-3
ORIGINAL	219	25.6	<0.011	<0.010
DUPLICATE	233	22.8	<0.011	<0.010
RPD	6.19%	11.73%	NC	NC
SPIKE SAMPLE				
SAMPLE ID	5 UPS-SED-2	14 UPS-SED-3	5 UPS-SED-2	14 UPS-SED-3
ORIGINAL	219	25.6	<0.011	<0.010
SPIKED SAMPLE	336	128	0.124	0.200
SPIKE ADDED	139	115	0.139	0.231
% RECOVERY	83.77%	88.81%	88.80%	86.60%
QC CHECK				
mg/l	mg/l	mg/l	mg/l	mg/l
FOUND	0.954	0.954	0.00533	0.00533
TRUE	1.00	1.00	0.00500	0.00500
% RECOVERY	95.35%	95.35%	106.60%	106.60%
BLANK	<1.00	<1.00	<0.010	<0.010

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OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATIO

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CASE FILE NUMBER: TET006-79 **PAGE 5**
REPORT DATE: 12/08/08
DATE SAMPLED: 10/21/08 **DATE RECEIVED:** 10/24/08
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM TETRA TECH

QA/QC DATA

QC PARAMETER	LEAD (mg/kg)	LEAD (mg/kg)	CADMIUM (mg/kg)	CADMIUM (mg/kg)
METHOD	EPA 200.7	EPA 200.7	SM3113B	SM3113B
DATE ANALYZED	10/29/08	10/29/08	10/29/08	10/30/08
DETECTION LIMIT	1.00	1.00	0.025	0.025
DUPLICATE				
SAMPLE ID	5 UPS-SED-2	14 UPS-SED-3	5 UPS-SED-2	14 UPS-SED-3
ORIGINAL	21.1	2.18	0.388	0.028
DUPLICATE	23.9	2.16	0.316	0.030
RPD	12.41%	1.06%	20.55%	8.00%
SPIKE SAMPLE				
SAMPLE ID	5 UPS-SED-2	14 UPS-SED-3	5 UPS-SED-2	14 UPS-SED-3
ORIGINAL	21.1	2.18	0.388	0.028
SPIKED SAMPLE	166	107	0.540	0.178
SPIKE ADDED	139	115	0.174	0.144
% RECOVERY	104.24%	91.19%	87.20%	104.00%
QC CHECK				
mg/l	mg/l	mg/l	mg/l	mg/l
FOUND	0.961	0.961	0.00122	0.00117
TRUE	1.00	1.00	0.00125	0.00125
% RECOVERY	96.08%	96.08%	97.60%	93.60%
BLANK	<1.00	<1.00	<0.025	<0.025

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OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATIO

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CASE FILE NUMBER: **TET006-79** **PAGE 6**
REPORT DATE: **12/08/08**
DATE SAMPLED: **10/21/08** **DATE RECEIVED:** **10/24/08**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON SEDIMENT SAMPLES FROM TETRA TECH

QA/QC DATA

QC PARAMETER	SULFIDE (mg/kg)	SULFIDE (mg/kg)	SULFIDE (mg/kg)
METHOD	EPA 9030B	EPA 9030B	EPA 9030B
DATE ANALYZED	10/29/08	10/29/08	10/29/08
DETECTION LIMIT	0.200	0.200	0.200
DUPLICATE			
SAMPLE ID	1-SED-1	8-SED-2	14 DWN-SED-3
ORIGINAL	2.37	<0.249	<0.240
DUPLICATE	2.50	<0.245	<0.217
RPD	5.25%	NC	NC
SPIKE SAMPLE			
SAMPLE ID			
ORIGINAL			
SPIKED SAMPLE			
SPIKE ADDED			
% RECOVERY	NA	NA	NA
QC CHECK			
FOUND			
TRUE			
% RECOVERY	NA	NA	NA
BLANK	<0.200	<0.200	<0.200

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SUBMITTED BY:

Steven Lazoff
Laboratory Director

Attachment B: Pore Water Data

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CASE FILE NUMBER: TET006-78A **PAGE 1**
REPORT DATE: 11/22/2008 REVISED 12/01/08
DATE SAMPLED: 10/21,22/08 **DATE RECEIVED:** 10/24/08
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM TETRA TECH

CASE NARRATIVE

Thirty six pore water samples were received by the laboratory in good condition and analyzed according to the chain of custody. No difficulties were encountered in the preparation or analysis of these samples. Sample data follows while QA/QC data is contained on subsequent pages. Samples 8 DN-PW-2, 8-PW-1, 8-PW-2, and 8-PW-3 were reanalyzed to confirm the lead results. The lead values from the reanalysis on 10/28/08 were 0.00402, 0.00411, 0.00245, and 0.00569 mg/l, for samples 8 DN-PW-2, 8-PW-1, 8-PW-2, and 8-PW03, respectively.

SAMPLE DATA

	DISSOLVED METALS			
SAMPLE ID	ARSENIC (mg/l)	CADMIUM (mg/l)	LEAD (mg/l)	ZINC (mg/l)
1 UPS-PW-3	0.0126	<0.00020	0.00135	0.018
1 UPS-PW-2	0.0072	0.00021	0.00087	0.040
1 UPS-PW-1	0.0088	<0.00020	0.00100	0.025
5-PW-1	0.0022	<0.00020	<0.00020	0.020
5-PW-2	0.0015	<0.00020	0.00051	0.014
5-PW-3	0.0010	<0.00020	0.00023	0.021
8 DN-PW-1	0.0011	<0.00020	0.00033	0.025
8 DN-PW-2	0.0011	<0.00020	0.00405	0.022
8 DN-PW-3	0.0010	<0.00020	0.00027	0.024
14 UP-PW-1	0.0011	<0.00020	0.00032	0.022
14 UP-PW-2	0.0010	<0.00020	<0.00020	0.015
14 UP-PW-3	0.0012	<0.00020	0.00109	0.020
8 UP-PW-1	0.0011	<0.00020	0.00033	0.027
8 UP-PW-2	0.0011	<0.00020	<0.00020	0.026
8 UP-PW-3	0.0011	<0.00020	<0.00020	0.019
8-PW-1	<0.0010	<0.00020	0.00387	0.023
8-PW-2	<0.0010	<0.00020	0.00241	0.023
8-PW-3	<0.0010	<0.00020	0.00531	0.033
14-PW-1	<0.0010	<0.00020	0.00102	0.019
14-PW-2	0.0013	<0.00020	<0.00020	0.013
14-PW-3	0.0012	<0.00020	0.00027	0.009
5 UP-PW-1	0.0010	<0.00020	<0.00020	0.020
5 UP-PW-2	0.0010	<0.00020	<0.00020	0.023
5 UP-PW-3	0.0029	<0.00020	0.00021	0.029
5 DN-PW-1	0.0012	<0.00020	0.00078	0.020
5 DN-PW-2	0.0012	<0.00020	0.00031	0.019
5 DN-PW-3	0.0010	<0.00020	<0.00020	0.016
14 DN-PW-1	0.0011	<0.00020	<0.00020	0.016
14 DN-PW-2	0.0011	<0.00020	<0.00020	0.017
14 DN-PW-3	0.0012	<0.00020	<0.00020	0.013
1-PW-1	0.0151	<0.00020	<0.00020	0.031
1-PW-2	0.0293	<0.00020	<0.00020	0.015
1-PW-3	0.0199	<0.00020	<0.00020	0.026
1 DN-PW-1	0.0176	<0.00020	0.00029	0.023
1 DN-PW-2	0.0164	<0.00020	<0.00020	0.028
1 DN-PW-3	0.0177	<0.00020	<0.00020	0.015

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CASE FILE NUMBER: TET006-78A **PAGE 2**
REPORT DATE: 11/22/2008 REVISED 12/01/08
DATE SAMPLED: 10/21,22/08 **DATE RECEIVED:** 10/24/08
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM TETRA TECH

QA/QC DATA

	DISSOLVED METALS					
QC PARAMETER	ARSENIC (mg/l)	ARSENIC (mg/l)	CADMIUM (mg/l)	CADMIUM (mg/l)	LEAD (mg/l)	LEAD (mg/l)
METHOD	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8	EPA 200.8
DATE ANALYZED	10/27/08	10/27/08	10/27/08	10/27/08	10/27/08	10/27/08
DETECTION LIMIT	0.0010	0.0010	0.00020	0.00020	0.00020	0.00020
DUPLICATE						
SAMPLE ID	5 UP-PW-2	14 DN-PW-1	5 UP-PW-2	14 DN-PW-1	5 UP-PW-2	5 DN-PW-2
ORIGINAL	0.0010	0.0011	<0.00020	<0.00020	<0.00020	0.00031
DUPLICATE	0.0010	0.0011	<0.00020	<0.00020	<0.00020	0.00036
RPD	0.69%	2.13%	NC	NC	NC	16.21%
SPIKE SAMPLE						
SAMPLE ID	5 UP-PW-2	14 DN-PW-1	5 UP-PW-2	14 DN-PW-1	5 UP-PW-2	5 DN-PW-2
ORIGINAL	0.0010	0.0011	<0.00020	<0.00020	<0.00020	0.00031
SPIKED SAMPLE	0.0522	0.0577	0.04906	0.04964	0.05076	0.05217
SPIKE ADDED	0.0500	0.0500	0.05000	0.05000	0.05000	0.05000
% RECOVERY	102.25%	113.28%	98.12%	99.28%	101.52%	103.73%
QC CHECK						
FOUND	0.0515	0.0515	0.05225	0.05225	0.0519	0.0519
TRUE	0.0500	0.0500	0.05000	0.05000	0.0500	0.0500
% RECOVERY	103.06%	103.06%	104.50%	104.50%	103.78%	103.78%
BLANK	<0.0010	<0.0010	<0.00020	<0.00020	<0.00020	<0.00020

RPD = RELATIVE PERCENT DIFFERENCE.
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NC = NOT CALCULABLE DUE TO ONE OR MORE VALUES BEING BELOW THE DETECTION LIMIT.
OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

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CASE FILE NUMBER: **TET006-78A** **PAGE 3**
REPORT DATE: **11/22/2008 REVISED 12/01/08**
DATE SAMPLED: **10/21,22/08** **DATE RECEIVED:** **10/24/08**
FINAL REPORT, LABORATORY ANALYSIS OF SELECTED PARAMETERS ON WATER SAMPLES FROM TETRA TECH

QA/QC DATA

	DISSOLVED METALS	
QC PARAMETER	ZINC (mg/l)	ZINC (mg/l)
METHOD	EPA 200.8	EPA 200.8
DATE ANALYZED	10/27/08	10/27/08
DETECTION LIMIT	0.003	0.003
DUPLICATE		
SAMPLE ID	5 UP-PW-2	14 DN-PW-1
ORIGINAL	0.023	0.016
DUPLICATE	0.023	0.018
RPD	0.61%	7.12%
SPIKE SAMPLE		
SAMPLE ID	5 UP-PW-2	14 DN-PW-1
ORIGINAL	0.023	0.016
SPIKED SAMPLE	0.072	0.073
SPIKE ADDED	0.050	0.050
% RECOVERY	98.26%	112.84%
QC CHECK		
FOUND	0.051	0.051
TRUE	0.050	0.050
% RECOVERY	101.72%	101.72%
BLANK	<0.003	<0.003

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OR = RECOVERY NOT CALCULABLE DUE TO SPIKE SAMPLE OUT OF RANGE OR SPIKE TOO LOW RELATIVE TO SAMPLE CONCENTRATION.

SUBMITTED BY:

Steven Lazoff
Laboratory Director

Attachment C: Data Verification and Validation

Table C-1. Measurement quality objectives for laboratory analysis of water column profile samples (values in parentheses are actual results) for October 2008.

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Sample Relative Percent Difference	Matrix Spikes % Recovery Limits	Matrix Spike-Duplicates Relative Percent Difference	Surrogate Standards % Recovery Limits	Lowest Concentrations of Interest, Units of Concentration
WATER							
Arsenic	Water	±10 (+8.48%)	±10[1] (4.96%)	85-115[1] (118.05%)	±10[1]	±10[2]	Reporting Limit, µg/L
Cadmium	Water	±10 (+4.64%)	±10[1] (NC)	85-115[1] (114.88%)	±10[1]	±10[2]	Reporting Limit, µg/L
Lead	Water	±10 (+7.46%)	±10[1] (NC)	85-115[1] (112.06%)	±10[1]	±10[2]	Reporting Limit, µg/L
Mercury	Water	±10 (+2.8%)	<20 (8.51%)	85-115 (107.64%)	18	N/A	Reporting Limit, µg/L
Zinc	Water	±10 (+5.38%)	±10[1](NC)	85-115[1] (117.04%)	±10[1]	±10[2]	Reporting Limit, µg/L
Alkalinity	Water	±5 (-0.6%)	±10 (0.88%)	N/A	N/A	N/A	1.0 mg/L
Hardness	Water	±2 (-1.3%)	±3 (0.25%)	N/A	N/A	N/A	2.0 mg/L
Dissolved Oxygen (DO)[3]	Water	0.1 mg DO/L	0.05 mg DO/L	N/A	N/A	N/A	0 mg/L
pH [3]	Water	±0.1 pH unit	±0.1 pH unit	N/A	N/A	N/A	N/A
Temperature[3]	Water	±0.1ºC	±0.1ºC	N/A	N/A	N/A	N/A
Conductivity[3]	Water	<5 of second calibration standard in range on interest at 25ºC	5 at ≤ 100 µS/cm; 3 >100 µS/cm at 25ºC	N/A	N/A	N/A	10 µS/cm
Turbidity	Water	±5, greater at low levels (-3.75%)	±5, greater at low levels (8.0%)	N/A	N/A	N/A	Reporting Limit, NTU

Notes:
This table is constructed with the same units used to report results for laboratory QC analyses. Information on the default QC sample types and QC limits was obtained from the laboratory that performed the analyses. An exception is pH, which was analyzed in the field.
Surrogate recoveries are compound-specific.
1 The overall performance expectation for method 200.8 for this analyte.
2 Calibration blank and calibration standard are used as surrogate samples immediately after each calibration routine, after every 10 analyses, and at the end of the sample run.
3 This is a field measurement.

LCS – laboratory control sample
µg/L – microgram per liter
N/A – not applicable
NC – not calculable (one or more values below detection limit)
mg/L – milligram per liter
µS/cm – microsiemen per centimeter

Table C-2. Measurement quality objectives for laboratory analysis of pore water samples (values in parentheses are actual results) for October 2008.

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Sample Relative Percent Difference	Matrix Spikes % Recovery Limits	Matrix Spike-Duplicates Relative Percent Difference	Surrogate Standards % Recovery Limits	Lowest Concentrations of Interest, Units of Concentration
Arsenic	Water	±10 (+3.06%)	±10[1] (2.13%)	85-115[1] (113.28%)	±10[1]	±10[2]	Reporting Limit, µg/L
Cadmium	Water	±10 (+4.5%)	±10[1] (NC)	85-115[1] (99.28%)	±10[1]	±10[2]	Reporting Limit, µg/L
Lead	Water	±10 (+3.78%)	±10[1] (16.21%)	85-115[1] (103.73%)	±10[1]	±10[2]	Reporting Limit, µg/L
Mercury	Water	±10 (+4.0%)	<20 (16.39%)	85-115 (100.2%)	18	N/A	Reporting Limit, µg/L
Zinc	Water	±10 (+1.72%)	±10[1](7.12)	85-115[1] (112.84%)	±10[1]	±10[2]	Reporting Limit, µg/L
Dissolved Organic Carbon	Water	±20 (-2.47%)	±20 (4.94%)	70-130 (102.91%)	±20	N/A	0.25 mg/L
Hardness	Water	±2 (+2.05%)	±3 (4.6%)	N/A	N/A	N/A	0.7 mg/L
Ca	Water	±2 (-1.04%)	±3 (7.6%)	N/A	N/A	N/A	0.1 mg/L
Mg	Water	±2 (+3.93%)	±3 (2.08%)	N/A	N/A	N/A	0.1 mg/L
SRP	Water	±20 (+0.11%)	±20 (11.2%)	±10 (100.34%)	±20	< RL	1.0 µg/L
pH[3]	Water	±0.1 pH unit	±0.1 pH unit		N/A	N/A	N/A

Notes:
This table is constructed with the same units used to report results for laboratory QC analyses. Information on the default QC sample types and QC limits was obtained from the laboratory that performed the analyses. An exception is pH, which was analyzed in the field.
Surrogate recoveries are compound-specific.
1 The overall performance expectation for method 200.8 for this analyte.
2 Calibration blank and calibration standard are used as surrogate samples immediately after each calibration routine, after every 10 analyses, and at the end of the sample run.
3 This is a field measurement.

LCS – laboratory control sample
µg/L – microgram per liter
N/A – not applicable
NC – not calculable (one or more values below detection limit)
mg/L – milligram per liter
µS/cm – microsiemen per centimeter

Table C-3. Measurement quality objectives for laboratory analysis of sediment samples (values in parentheses are actual results) for October 2008.

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Sample Relative Percent Difference	Matrix Spikes % Recovery Limits	Matrix Spike-Duplicates Relative Percent Difference	Surrogate Standards % Recovery Limits	Lowest Concentrations of Interest, Units of Concentration
Arsenic	Sediment	±10 (+4.55%)	±10 (18.26%)	85-115 (112.48%)	±10	±10	Reporting Limit, mg/kg
Cadmium	Sediment	±10 (-2.4%)	±10 (20.55%)	85-115 (104%)	±10	±10	Reporting Limit, mg/kg
Lead	Sediment	±10 (-3.92%)	±10 (12.41%)	85-115 (104.24%)	±10	±10	Reporting Limit, mg/kg
Mercury	Sediment	80-120 (+6.6%)	(NC)	75-125 (88.8%)	±25 (not given in method)	N/A	Reporting Limit, mg/kg
Zinc	Sediment	±10 (-4.65%)	±10 (11.73%)	85-115 (88.81%)	±10	±10	Reporting Limit, mg/kg
PCBs	Sediment	40-140 (83%)	<30% (NC)	40-140 (80%)	<50	30-150	Reporting Limit, mg/kg
Total Organic Carbon	Sediment	±20 (5.37%)	<20 (4.35%) For samples >5X the CRDL; ± CRDL for samples <5X CRDL	N/A	Not in method	N/A	0.01%
Sulfide	Sediment	See Note 4	Acid soluble sulfide: 1-45 (NC) Acid insoluble sulfide: 1.2-42	Acid soluble sulfide: 77-92 Acid insoluble sulfide: 21-81	N/A	N/A	Reporting limit, mg/kg
Total Solids	Sediment	N/A	±20 (.35%)	N/A	N/A	N/A	1.0 %

Notes:
This table is constructed with the same units used to report results for laboratory QC analyses. Information on the default QC sample types and QC limits was obtained from the laboratory that performed the
Surrogate recoveries are compound-specific.

1 The overall performance expectation for method 200.8 for this analyte.
2 Calibration blank and calibration standard are used as surrogate samples immediately after each calibration routine, after every 10 analyses, and at the end of the sample run.
3 This is a field measurement.
4 Recovery depends on concentration of the check standard and matrix: for sediments, low level matrix spikes for lead and zinc may be below background levels.

LCS – laboratory control sample
NC – not calculable (one or more values below detection limit)
µg/L – microgram per liter
mg/L – milligram per liter
N/A – not applicable
µS/cm – microsiemen per centimeter
CRDL – Contract Required Detection Limit

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Attachment D: Water Column Profile Data

Table D-1. Laboratory results for dissolved metals concentrations from water column profile sites in Boundary Reservoir (October 2008 sampling).

Sample ID	Dissolved Arsenic (mg/L)	Dissolved Cadmium (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	Dissolved Mercury (mg/L)	Total Arsenic (mg/L)	Total Cadmium (mg/L)	Total Lead (mg/L)	Total Zinc (mg/L)
1 DWN-BOT	1.1540	<0.00020	<0.00020	<0.003	0.47	1.1530	<0.00020	<0.00020	<0.003
1 DWN-MID	1.2260	<0.00020	<0.00020	<0.003	0.97	1.1860	<0.00020	<0.00020	<0.003
1 DWN-SURF	1.0900	<0.00020	<0.00020	<0.003	0.43	1.1680	<0.00020	<0.00020	<0.003
1-BOT	1.1230	<0.00020	<0.00020	<0.003	0.97	1.2580	<0.00020	1.93900	3.135
1-MID	1.0170	<0.00020	<0.00020	<0.003	0.69	1.2170	<0.00020	<0.00020	<0.003
1-SURF	1.1220	<0.00020	<0.00020	<0.003	0.69	1.1920	<0.00020	<0.00020	<0.003
1 UPS-BOT	1.1970	<0.00020	<0.00020	<0.003	0.64	1.1730	<0.00020	<0.00020	<0.003
1 UPS-MID	1.1210	<0.00020	<0.00020	<0.003	0.75	1.1050	<0.00020	<0.00020	<0.003
1 UPS-SURF	1.1240	<0.00020	<0.00020	<0.003	0.73	1.1270	<0.00020	<0.00020	<0.003
14 UPS-BOT	1.1080	<0.00020	<0.00020	<0.003	0.45	1.1910	<0.00020	<0.00020	<0.003
14 UPS-MID	1.1910	<0.00020	<0.00020	<0.003	0.44	1.0640	<0.00020	<0.00020	<0.003
14 UPS-SURF	1.0460	<0.00020	<0.00020	<0.003	0.47	1.1090	<0.00020	<0.00020	<0.003
14-BOT	1.1320	<0.00020	<0.00020	<0.003	0.49	1.1670	<0.00020	<0.00020	<0.003
14-MID	1.0510	<0.00020	<0.00020	<0.003	1.00	1.0780	<0.00020	<0.00020	<0.003
14-MID-DUP	1.0550	<0.00020	<0.00020	<0.003	0.96	1.2620	<0.00020	<0.00020	<0.003
14-SURF	1.0680	<0.00020	<0.00020	<0.003	0.43	1.0850	<0.00020	<0.00020	<0.003
14 DWN-BOT	1.1420	<0.00020	<0.00020	<0.003	0.83	1.1010	<0.00020	0.20560	<0.003
14 DWN-MID	1.0960	<0.00020	<0.00020	<0.003	0.35	1.2850	<0.00020	<0.00020	<0.003
14 DWN-SURF	1.0210	<0.00020	0.54540	<0.003	1.50	1.0470	<0.00020	<0.00020	<0.003
5 DWN-BOT	1.1510	<0.00020	<0.00020	<0.003	0.68	1.2360	<0.00020	<0.00020	<0.003
5 DWN-MID	1.1920	<0.00020	<0.00020	<0.003	1.23	1.1710	<0.00020	<0.00020	<0.003
5 DWN-SURF	1.0340	<0.00020	<0.00020	<0.003	0.52	1.2200	<0.00020	<0.00020	<0.003
5-BOT	<0.0010	<0.00020	<0.00020	<0.003	0.67	1.2010	<0.00020	<0.00020	<0.003
5-MID	<0.0010	<0.00020	<0.00020	<0.003	0.95	1.2560	<0.00020	<0.00020	<0.003
5-SURF	1.0140	<0.00020	<0.00020	<0.003	0.58	1.1930	<0.00020	<0.00020	<0.003
5 SURF-DUP	1.0360	<0.00020	<0.00020	<0.003	0.56	1.2110	<0.00020	<0.00020	<0.003

Table D-1, continued…

Sample ID	Dissolved Arsenic (mg/L)	Dissolved Cadmium (mg/L)	Dissolved Lead (mg/L)	Dissolved Zinc (mg/L)	Dissolved Mercury (mg/L)	Total Arsenic (mg/L)	Total Cadmium (mg/L)	Total Lead (mg/L)	Total Zinc (mg/L)
5 UPS-BOT	1.0470	<0.00020	<0.00020	<0.003	0.98	1.1100	<0.00020	<0.00020	<0.003
5 UPS-MID	1.0920	<0.00020	<0.00020	<0.003	0.58	1.1620	<0.00020	<0.00020	<0.003
5 UPS-SURF	<0.0010	<0.00020	<0.00020	<0.003	0.49	1.1370	<0.00020	<0.00020	<0.003
8 DWN-BOT	1.0410	<0.00020	<0.00020	<0.003	0.84	1.0720	<0.00020	<0.00020	<0.003
8 DWN-MID	1.1240	<0.00020	<0.00020	<0.003	0.58	1.0960	<0.00020	<0.00020	<0.003
8 DWN-SURF	1.0650	<0.00020	<0.00020	<0.003	0.60	1.1980	<0.00020	<0.00020	<0.003
8-BOT	1.0270	<0.00020	<0.00020	<0.003	0.68	1.0210	<0.00020	<0.00020	7.835
8-MID	1.1140	<0.00020	<0.00020	<0.003	0.60	1.0820	<0.00020	<0.00020	<0.003
8-SURF	1.1020	<0.00020	<0.00020	<0.003	0.84	1.1520	<0.00020	<0.00020	<0.003
8 UPS-BOT	1.0650	<0.00020	<0.00020	<0.003	0.70	1.1230	<0.00020	<0.00020	<0.003
8 UPS-MID	1.1250	<0.00020	<0.00020	<0.003	0.65	1.0760	<0.00020	<0.00020	<0.003
8 UPS-SURF	1.0780	<0.00020	<0.00020	<0.003	0.83	1.0720	<0.00020	<0.00020	<0.003
LOWER BLNK	<0.0010	<0.00020	<0.00020	<0.003	0.39	<0.0010	<0.00020	<0.00020	<0.003
UPPER BLNK	<0.0010	<0.00020	<0.00020	<0.003	0.20	<0.0010	<0.00020	<0.00020	<0.003

Notes:
mg/L – milligram per liter

Table D-2. Water Column Profile – October 2008.

Station No.	Date and Time	Water Column Location	Depth (m)	Temperature (°Celsius)	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (µmhos/cm)	Redox Potential mV
1	10/23/2008 10:22	Surface	0.2	10.64	10.41	7.58	156	391
1	10/23/2008 10:28	Mid	27.2	10.59	10.33	7.91	155.6	390
1	10/23/2008 10:26	Bottom	50.4	10.57	10.22	7.86	155.5	389
1DWN	10/23/2008 9:14	Surface	0.1	10.73	10.34	7.56	156.5	415
1DWN	10/23/2008 9:19	Mid	30.3	10.61	10.33	7.77	155.3	417
1DWN	10/23/2008 9:17	Bottom	63.3	10.6	10.18	7.72	156	417
1UPS	10/23/2008 10:32	Surface	0.1	10.63	10.44	7.76	155.3	388
1UPS	10/23/2008 10:35	Mid	14.8	10.63	10.37	7.9	155.6	386
1UPS	10/23/2008 10:34	Bottom	28.4	10.63	10.33	7.87	155.9	386
5	10/23/2008 12:20	Surface	0.1	10.31	10.52	7.93	155.8	372
5	10/23/2008 12:21	Mid	6.1	10.33	10.47	7.93	156	374
5	10/23/2008 12:21	Bottom	10	10.34	10.47	7.93	156	375
5DWN	10/23/2008 12:34	Surface	0.1	10.41	10.58	7.94	155.6	377
5DWN	10/23/2008 12:35	Mid	6.1	10.4	10.56	7.95	155.6	379
5DWN	10/23/2008 12:36	Bottom	12.2	10.39	10.54	7.94	155.4	381
5UPS	10/23/2008 12:05	Surface	0	10.4	10.57	7.88	155.6	364
5UPS	10/23/2008 12:06	Mid	5	10.39	10.58	7.92	155.3	366
5UPS	10/23/2008 12:07	Bottom	10.5	10.38	10.54	7.9	155.6	370
8	10/23/2008 11:42	Surface	0.1	10.43	10.67	7.91	155.4	372
8	10/23/2008 11:43	Mid	0.5	10.43	10.66	7.93	155.7	374
8	10/23/2008 11:43	Bottom	1.1	10.43	10.67	7.92	155.5	373
8DWN	10/23/2008 11:51	Surface	0.1	10.47	10.62	7.83	155.4	375
8DWN	10/23/2008 11:53	Mid	0.5	10.44	10.64	7.92	155.1	377
8DWN	10/23/2008 11:51	Bottom	1	10.46	10.64	7.86	155.3	377
8UPS	10/23/2008 11:27	Surface	0.1	10.36	10.63	7.85	155.7	383
8UPS	10/23/2008 11:29	Mid	0.7	10.39	10.63	7.93	155.6	385
8UPS	10/23/2008 11:28	Bottom	1.5	10.39	10.65	7.91	155.3	383

Table D-2, continued…

Station No.	Date and Time	Water Column Location	Depth (m)	Temperature (°Celsius)	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (µmhos/cm)	Redox Potential mV
14	10/22/2008 14:07	Surface	0	10.89	10.48	7.59	152.4	380
14	10/22/2008 14:08	Mid	0.4	10.76	10.5	7.63	152.6	380
14	10/22/2008 14:08	Bottom	1	10.73	10.5	7.66	152.7	381
14DWN	10/22/2008 13:20	Surface	0.1	10.7	10.58	7.46	153.2	421
14DWN	10/22/2008 14:41	Mid	0.4	10.73	10.52	7.74	152.7	376
14DWN	10/22/2008 14:42	Bottom	1.5	10.74	10.5	7.85	153.1	376
14UPS	10/22/2008 14:17	Surface	0.1	10.73	10.52	7.52	152.8	398
14UPS	10/22/2008 14:18	Mid	0.6	10.73	10.5	7.57	153.1	398
14UPS	10/22/2008 14:19	Bottom	1.2	10.73	10.5	7.65	152.7	395

Notes:
µmhos/cm – micromhos per centimeter
m – meter
mg/L – milligram per liter
mV – millivolt

Appendix 2: Sediment Data

Appendix 2a. Data Tables

Appendix 2b. Sediment Sampling Effort

Appendix 2a. Data Tables

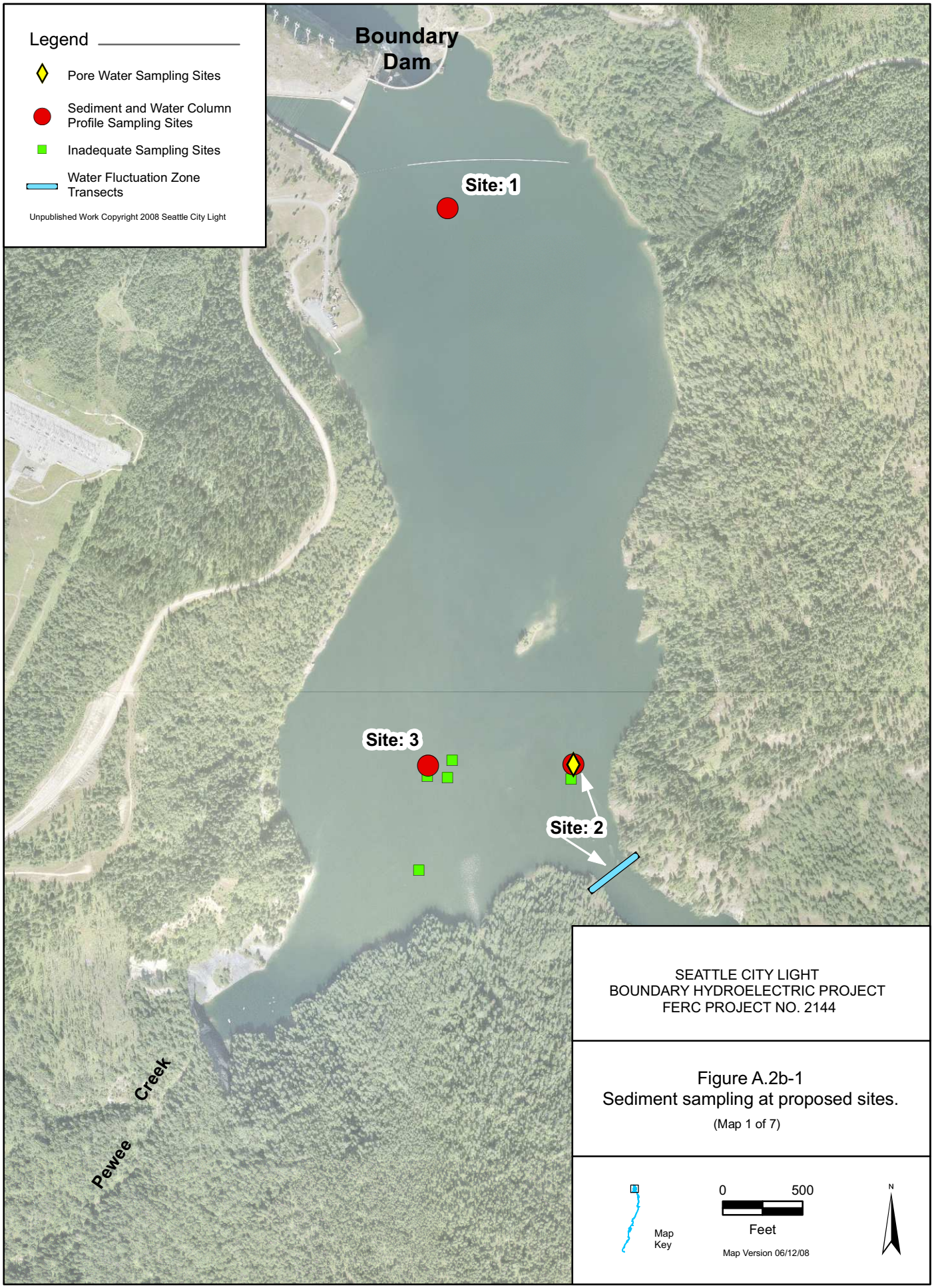
Table A.2a-1. Laboratory results describing the inorganic and organic fraction and toxics content (dry weight) of sediment samples at sites in Boundary Reservoir (March 2008 sampling).

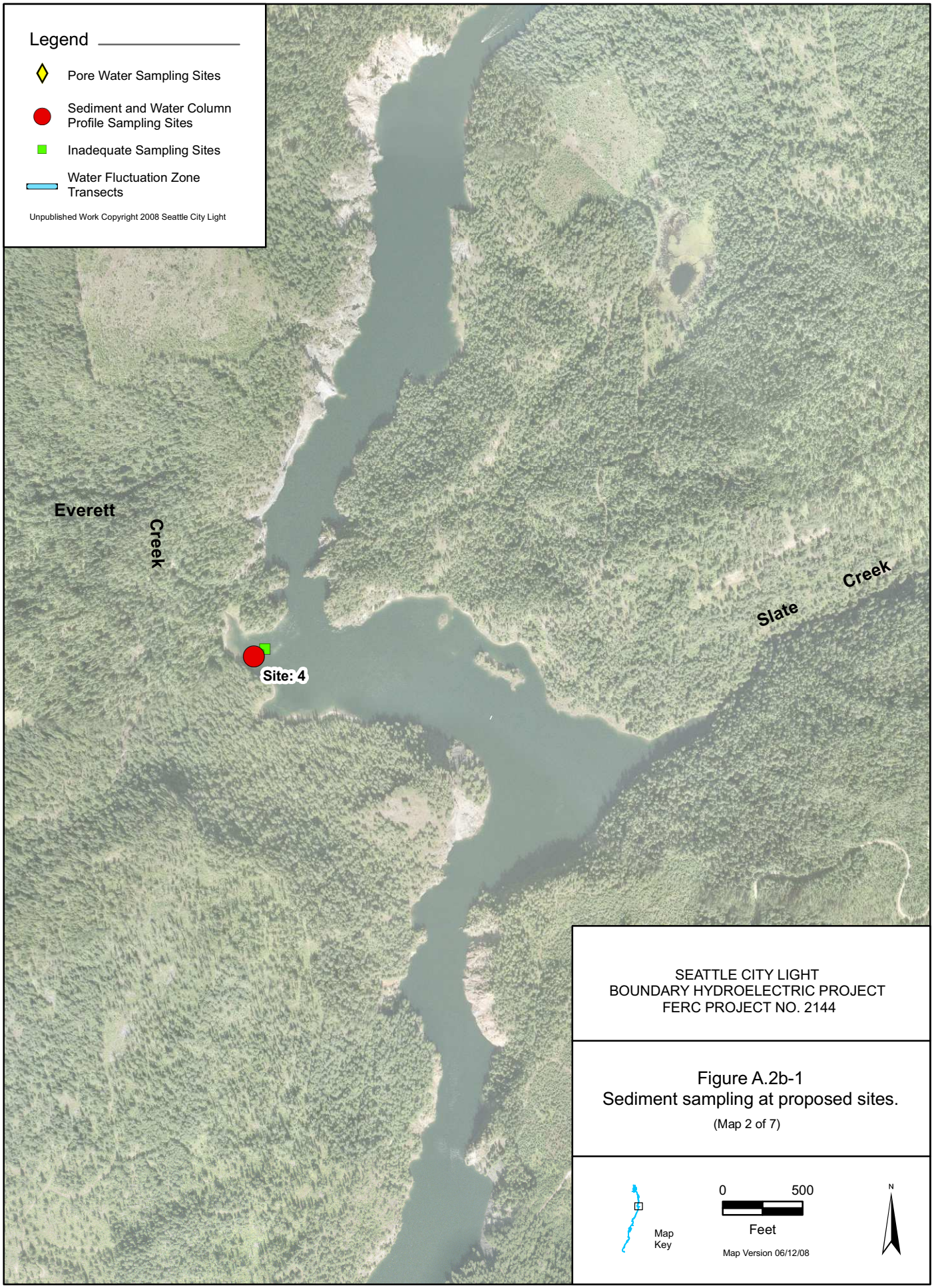
Sample ID	Percent Total Solids (%)	Percent Water (%)	Total Organic Carbon (TOC) (%)	Sulfide (mg/kg)
1-SED-1	31.35	68.65	2.76	1.66
1-SED-2	34.36	65.64	2.60	1.22
1-SED-3	33.46	66.54	2.70	2.37
2-SED-1	46.78	53.22	2.67	0.87
2-SED-2	34.32	65.68	3.35	9.06
2-SED-3	38.90	61.10	2.96	11.64
3-SED-1	31.89	68.11	2.97	11.23
3-SED-2	32.27	67.73	3.00	15.14
3-SED-3	32.47	67.53	2.93	12.80
4-SED-1	43.31	56.69	2.77	9.11
4-SED-2	46.77	53.23	2.45	6.11
4-SED-3	39.36	60.64	2.72	1.18
5-SED-1	65.50	34.50	1.37	5.58
5-SED-2	65.53	34.47	1.73	3.81
5-SED-3	72.17	27.83	1.12	0.59
6-SED-1	81.21	18.79	0.755	0.48
6-SED-2	79.29	20.71	1.29	0.51
6-SED-3	79.30	20.70	1.26	0.51
7-SED-1	75.36	24.64	0.528	1.15
7-SED-2	30.61	69.39	11.6	1.36
7-SED-3	83.41	16.59	1.13	0.49
8-SED-1	72.85	27.15	1.74	2.59
8-SED-2	72.26	27.74	1.92	0.58
8-SED-3	74.27	25.73	2.98	0.62
9-SED-1	52.64	47.36	2.04	0.82
9-SED-2	68.60	31.40	1.41	0.64
9-SED-3	75.12	24.88	1.22	0.58
10-SED-1	70.74	29.26	0.396	0.45
10-SED-2	67.65	32.35	0.631	0.62
10-SED-3	72.43	27.57	0.496	0.52
11-SED-1	72.59	27.41	0.519	0.47
11-SED-2	68.14	31.86	0.975	0.42
11-SED-3	58.80	41.20	1.59	0.62
12-SED-1	69.91	30.09	0.688	0.47
12-SED-2	73.66	26.34	0.610	0.37
12-SED-3	75.71	24.29	0.495	0.39
13-SED-1	72.58	27.42	0.669	0.39
13-SED-2	82.20	17.80	0.565	0.34
13-SED-3	79.81	20.19	0.671	0.30
14-SED-1	75.80	24.20	1.17	0.37
14-SED-2	67.15	32.85	1.49	0.44
14-SED-3	78.39	21.61	0.936	0.31

Table A.2a-1, continued…

Sample ID	Arsenic (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)	Lead (mg/kg)	Cadmium (mg/kg)	PCBs (mg/kg)
1-SED-1	14.3	145	0.0559851	33.7	0.629	
1-SED-2	13.2	117	0.0518046	29.6	0.450	
1-SED-3	14.0	135	0.0615431	31.4	0.571	
2-SED-1	9.41	126	0.0447718	24.9	0.476	<0.05
2-SED-2	11.7	146	0.0456153	33.5	0.609	<0.05
2-SED-3	11.7	136	0.0454629	26.6	0.543	<0.05
3-SED-1	15.6	151	0.0639305	33.2	0.666	
3-SED-2	14.7	127	0.0573835	27.2	0.512	
3-SED-3	11.8	128	0.057693	29.3	0.606	
4-SED-1	9.46	137	0.0422495	31.2	0.558	<0.05
4-SED-2	10.1	151	0.0433811	26.5	0.625	<0.05
4-SED-3	10.8	150	0.0593065	32.7	0.675	<0.05
5-SED-1	7.17	110	0.0154503	17.5	0.340	
5-SED-2	6.94	196	0.0196636	30.1	0.702	
5-SED-3	5.10	130	0.0160845	19.1	0.372	
6-SED-1	5.78	71.3	<0.01	17.8	0.192	
6-SED-2	4.48	67.8	<0.01	14.5	0.155	
6-SED-3	3.75	52.4	<0.01	17.6	0.169	
7-SED-1	3.85	360	0.0285571	147	1.12	<0.05
7-SED-2	5.78	299	0.0355452	56.9	0.996	<0.05
7-SED-3	5.85	386	0.0146588	67.7	0.971	<0.05
8-SED-1	3.97	518	0.0145871	115	0.917	
8-SED-2	4.18	518	0.0188006	278	0.791	
8-SED-3	3.80	461	<0.01	291	0.816	
9-SED-1	4.48	65.4	0.0116806	26.6	0.258	
9-SED-2	5.52	56.4	0.0116624	10.9	0.208	
9-SED-3	2.06	34.1	<0.01	10.0	0.108	
10-SED-1	6.18	77.3	0.0214352	14.6	0.244	
10-SED-2	9.11	101	0.0301538	19.2	0.298	
10-SED-3	5.05	86.1	0.02336	15.4	0.238	
11-SED-1	6.11	102	0.0148671	9.85	0.324	
11-SED-2	8.90	147	0.0213099	15.8	0.455	
11-SED-3	6.74	150	0.0253482	13.5	0.447	
12-SED-1	6.03	78.8	<0.01	19.1	0.246	
12-SED-2	5.04	96.7	0.0157929	19.4	0.286	
12-SED-3	3.74	68.6	<0.01	18.0	0.181	
13-SED-1	4.44	40.2	<0.01	7.44	0.286	<0.05
13-SED-2	2.02	25.1	<0.01	4.26	0.242	<0.05
13-SED-3	3.97	37.4	<0.01	6.64	0.539	<0.05
14-SED-1	3.68	45.2	<0.01	7.15	0.126	
14-SED-2	3.56	41.0	<0.01	4.76	0.097	
14-SED-3	2.89	39.1	<0.01	5.22	0.096	

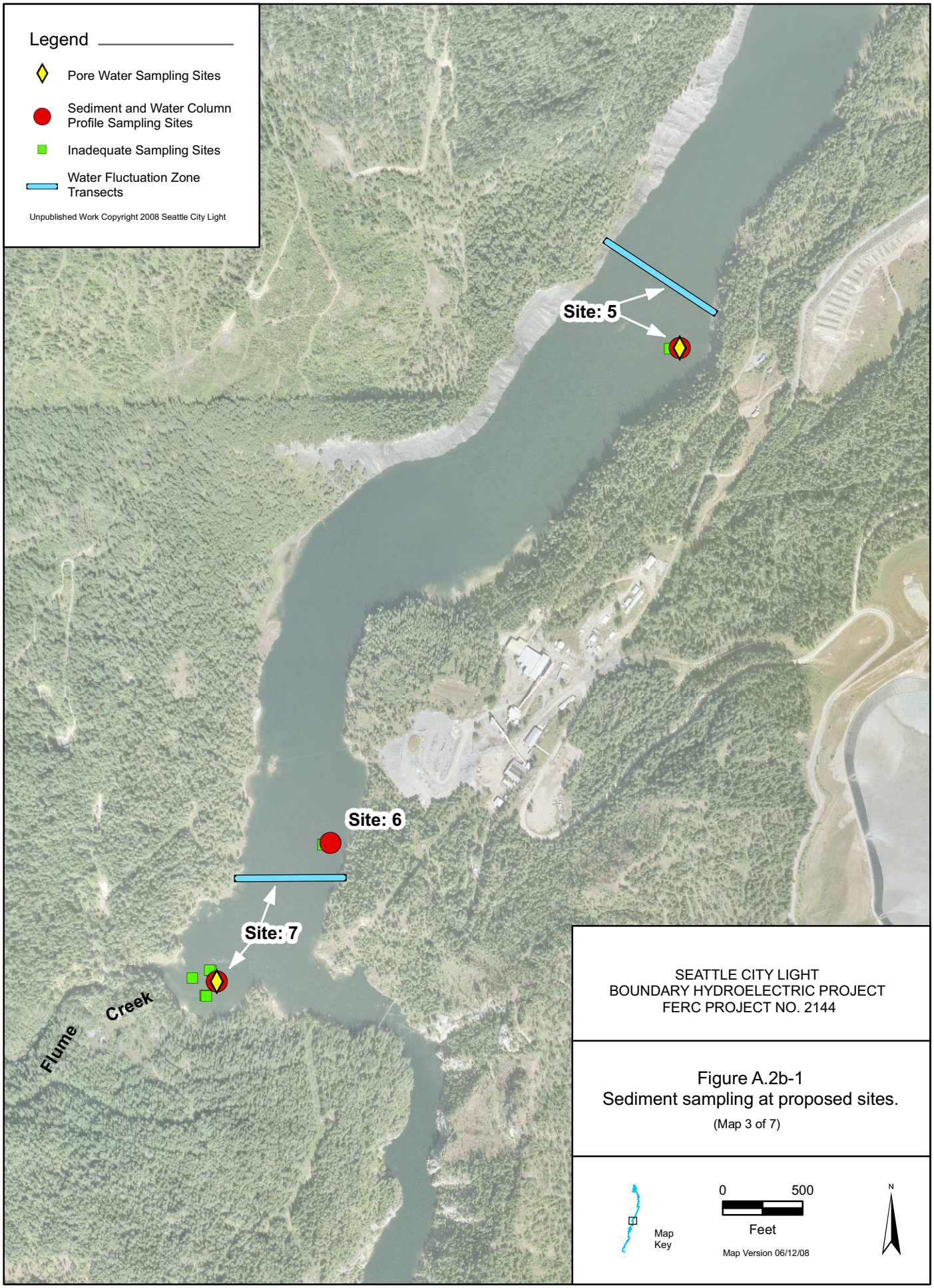
Appendix 2b. Sediment Sampling Effort


Legend
Pore Water Sampling Sites
Sediment and Water Column Profile Sampling Sites
Inadequate Sampling Sites
Water Fluctuation Zone Transects
Unpublished Work Copyright 2008 Seattle City Light
Boundary Dam
Site: 1
Site: 3
Site: 2
Pewee Creek
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure A.2b-1
Sediment sampling at proposed sites.
(Map 1 of 7)
Map Key
0
500
Feet
Map Version 06/12/08
N



SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144

Figure A.2b-1
Sediment sampling at proposed sites.
(Map 2 of 7)



SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
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Figure A.2b-1
Sediment sampling at proposed sites.
(Map 3 of 7)

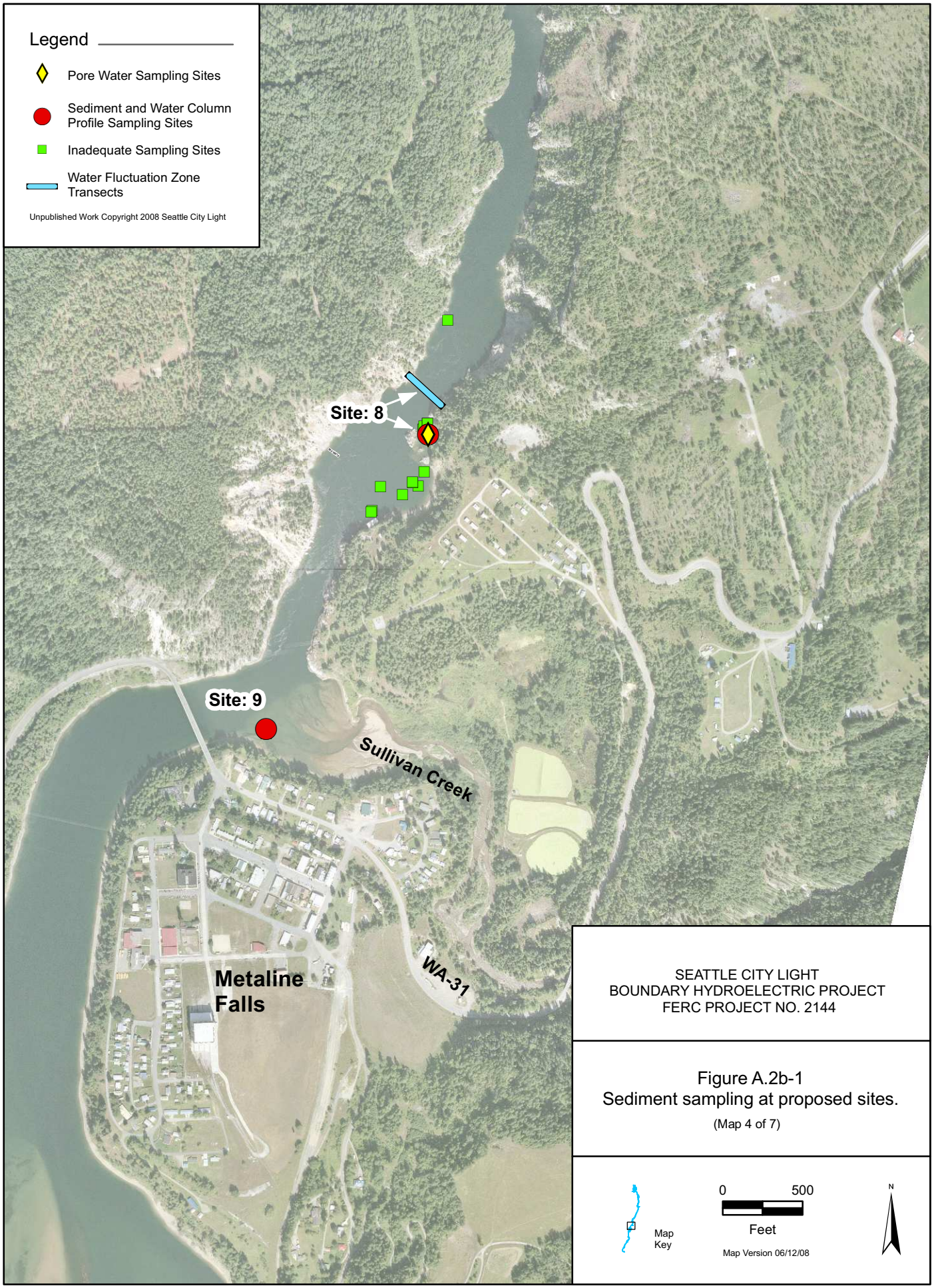

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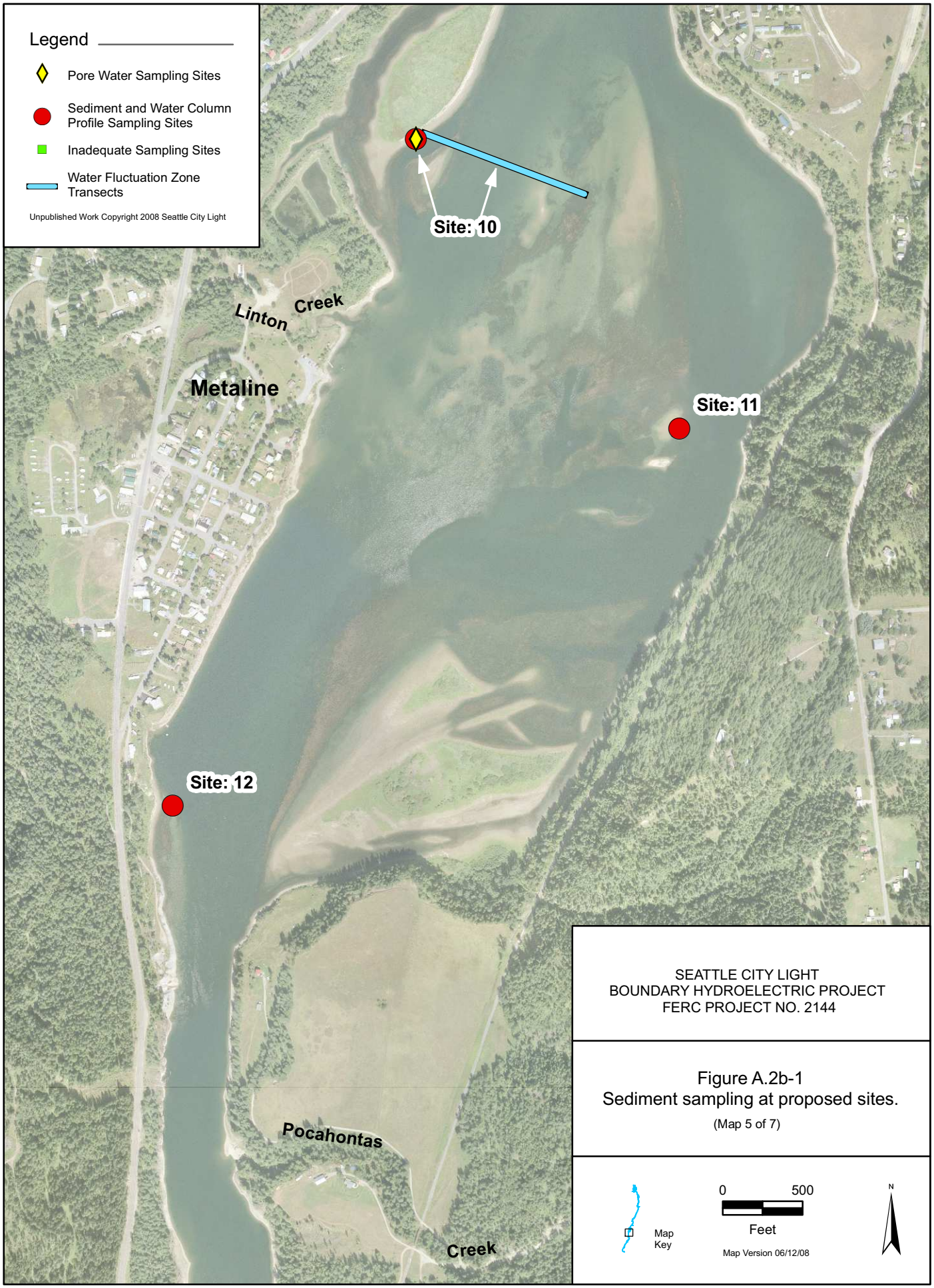
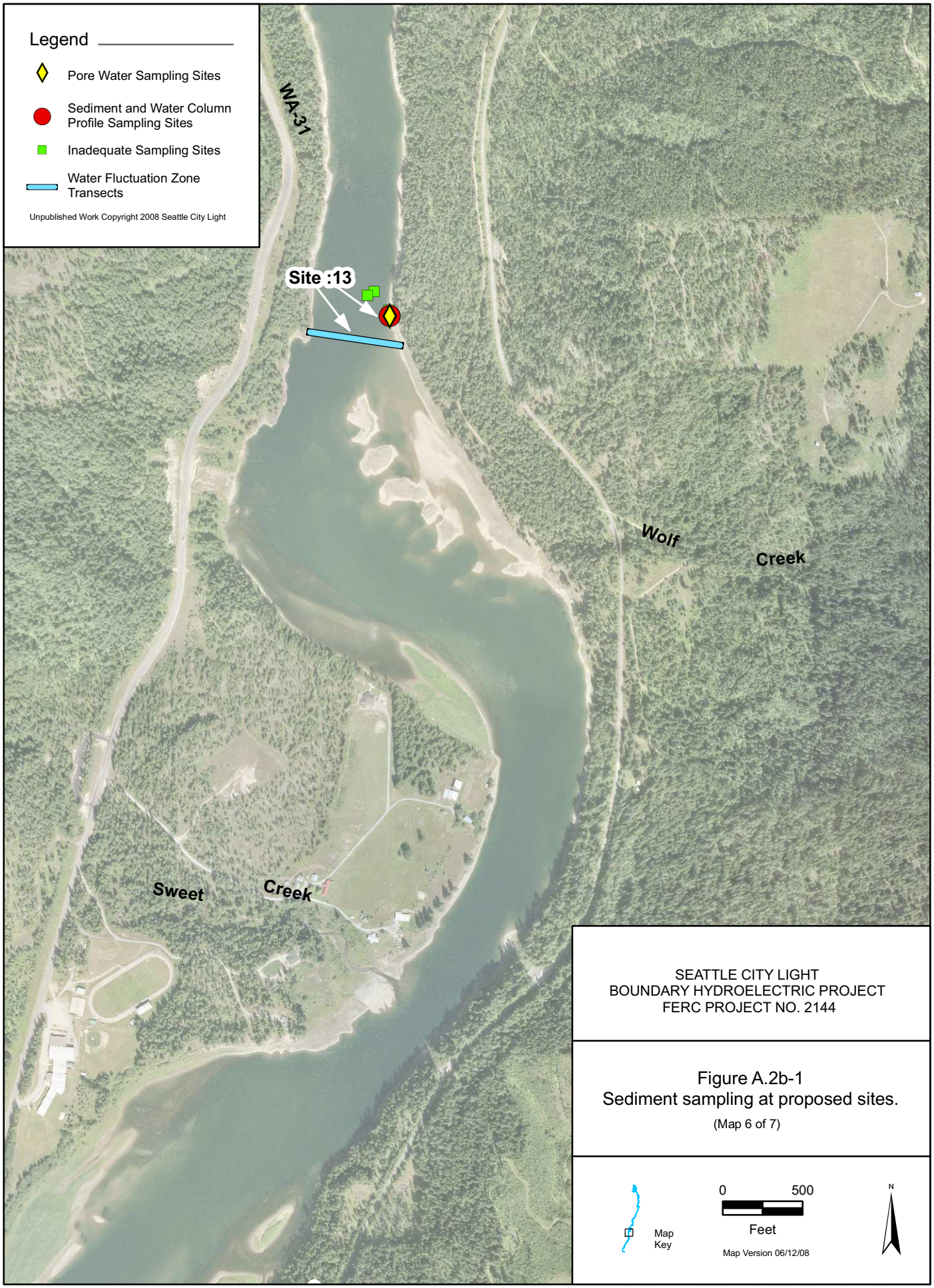
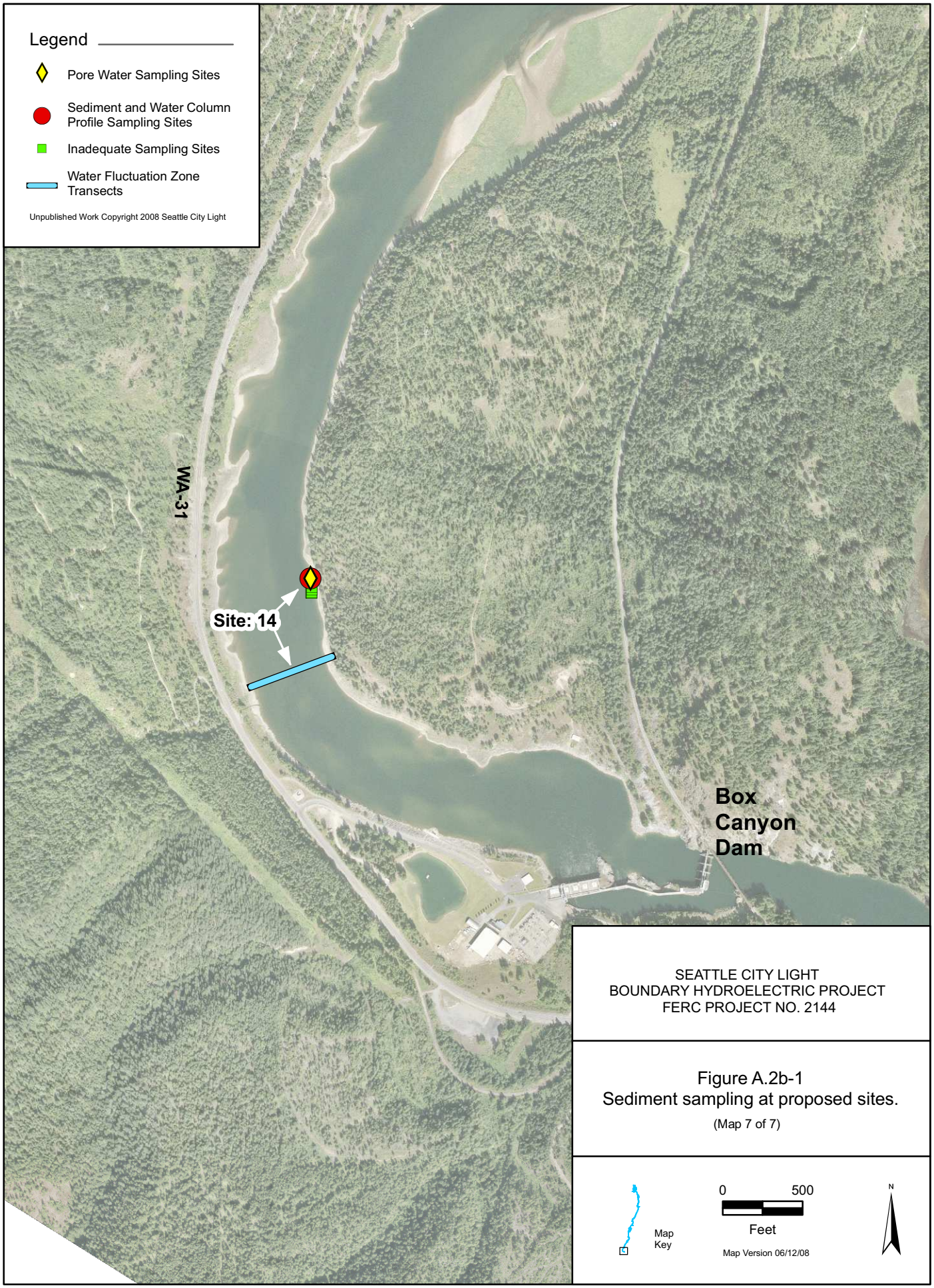
Figure A.2b-1
Sediment sampling at proposed sites.
(Map 4 of 7)


Legend
Pore Water Sampling Sites
Sediment and Water Column Profile Sampling Sites
Inadequate Sampling Sites
Water Fluctuation Zone Transects
Unpublished Work Copyright 2008 Seattle City Light
Site: 10
Linton Creek
Metaline
Site: 11
Site: 12
Pocahontas
Creek
SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144
Figure A.2b-1
Sediment sampling at proposed sites.
(Map 5 of 7)
Map Key
0
500
Feet
Map Version 06/12/08
N



SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144

Figure A.2b-1
Sediment sampling at proposed sites.
(Map 6 of 7)



SEATTLE CITY LIGHT
BOUNDARY HYDROELECTRIC PROJECT
FERC PROJECT NO. 2144

Figure A.2b-1
Sediment sampling at proposed sites.
(Map 7 of 7)

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Appendix 3: Quality Assurance Results Summary

Appendix 3a. Measurement Quality Objectives

Appendix 3b. Forms

Appendix 3a. Measurement Quality Objectives

Data generated from collection of field samples were analyzed by the contract laboratory (Aquatic Research Incorporated, Seattle, Washington) within holding times specified for each parameter. Quality assurance (QA) results were generated for laboratory performance of analytical procedures and for variability between duplicate samples collected in the field. Table A.3a-1 outlines QA performance requirements and results for sources of variability from both field and laboratory collection and analysis, respectively.

Table A.3a-1. Measurement quality objectives for laboratory analysis of surface water for the water fluctuation zone samples collected in November 2007 (values in parentheses are actual results).

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Sample Relative Percent Difference	Matrix Spikes % Recovery Limits	Matrix Spike-Duplicates Relative Percent Difference	Surrogate Standards % Recovery Limits	Lowest Concentrations of Interest, Units of Concentration
WATER							
Arsenic	Water	±10 (-13.0%)	±10[1] (9.6%)	85-115[1] (90%)	±10[1]	±10[2]	Reporting Limit, µg/L
Cadmium	Water	±10 (-12.0%)	±10[1] (NC)	85-115[1] (93%)	±10[1]	±10[2]	Reporting Limit, µg/L
Lead	Water	±10 (-5.0%)	±10[1] (NC)	85-115[1] (99%)	±10[1]	±10[2]	Reporting Limit, µg/L
Mercury	Water	±10 (+3.70%)	<20 (NC)	85-115 (95.51%)	18	N/A	Reporting Limit, µg/L
Zinc	Water	±10 (+3.48%)	±10[1](5.50%)	85-115[1] (107.79%)	±10[1]	±10[2]	Reporting Limit, µg/L
Dissolved Organic Carbon	Water	±20 (-0.5%)	±20 (2.22%)	70-130 (103.20%)	±20	N/A	0.5 mg/L
Alkalinity	Water	±5 (+0.8%)	±10 (0.13%)	N/A	N/A	N/A	10 mg/L
Hardness	Water	±2 (-0.33%)	±3 (0.26%)	N/A	N/A	N/A	5 mg/L
Dissolved Oxygen (DO)[3]	Water	0.1 mg DO/L	0.05 mg DO/L	N/A	N/A	N/A	0 mg/L
pH[3]	Water	±0.1 pH unit	±0.1 pH unit	N/A	N/A	N/A	N/A
Temperature[3]	Water	±0.1ºC	±0.1ºC	N/A	N/A	N/A	N/A
Conductivity[3]	Water	<5 of second calibration standard in range on interest at 25ºC	5 at ≤ 100 µS/cm; 3 >100 µS/cm at 25ºC	N/A	N/A	N/A	10 µS/cm
Turbidity	Water	±5, greater at low levels (-3.75%)	±5, greater at low levels (8.0%)	N/A	N/A	N/A	Reporting Limit, NTU

Notes:
This table is constructed with the same units used to report results for laboratory QC analyses. Information on the default QC sample types and QC limits was obtained from the laboratory that performed the analyses. An exception is pH, which was analyzed in the field.
Surrogate recoveries are compound-specific.
1 The overall performance expectation for method 200.8 for this analyte.
2 Calibration blank and calibration standard are used as surrogate samples immediately after each calibration routine, after every 10 analyses, and at the end of the sample run.
3 This is a field measurement.

LCS – laboratory control sample
µg/L – microgram per liter
N/A – not applicable
NTU – nephelometric turbidity unit
NC – not calculable (one or more values below detection limit)
mg/L – milligram per liter
µS/cm – microsiemen per centimeter

Table A.3a-2. Measurement quality objectives for laboratory analysis of water column profile samples (values in parentheses are actual results).

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Sample Relative Percent Difference	Matrix Spikes % Recovery Limits	Matrix Spike-Duplicates Relative Percent Difference	Surrogate Standards % Recovery Limits	Lowest Concentrations of Interest, Units of Concentration
WATER							
Arsenic	Water	±10 (-10.0%)	±10[1] (2.35%)	85-115[1] (113%)	±10[1]	±10[2]	Reporting Limit, µg/L
Cadmium	Water	±10 (-0.8%)	±10[1] (NC)	85-115[1] (116%)	±10[1]	±10[2]	Reporting Limit, µg/L
Lead	Water	±10 (+3.0%)	±10[1] (0.0)	85-115[1] (94.7%)	±10[1]	±10[2]	Reporting Limit, µg/L
Mercury	Water	±10 (+4.6%)	<20 (16.39%)	85-115 (111.6%)	18	N/A	Reporting Limit, µg/L
Zinc	Water	±10 (+0.2%)	±10[1](NC)	85-115[1] (112.68%)	±10[1]	±10[2]	Reporting Limit, µg/L
Alkalinity	Water	±5 (-0.6%)	±10 (0.88%)	N/A	N/A	N/A	1.0 mg/L
Hardness	Water	±2 (-1.3%)	±3 (0.25%)	N/A	N/A	N/A	2.0 mg/L
Dissolved Oxygen (DO)[3]	Water	0.1 mg DO/L	0.05 mg DO/L	N/A	N/A	N/A	0 mg/L
pH[3]	Water	±0.1 pH unit	±0.1 pH unit	N/A	N/A	N/A	N/A
Temperature[3]	Water	±0.1ºC	±0.1ºC	N/A	N/A	N/A	N/A
Conductivity[3]	Water	<5 of second calibration standard in range on interest at 25ºC	5 at ≤ 100 µS/cm; 3 >100 µS/cm at 25ºC	N/A	N/A	N/A	10 µS/cm
Turbidity	Water	±5, greater at low levels (-3.75%)	±5, greater at low levels (8.0%)	N/A	N/A	N/A	Reporting Limit, NTU

Notes:
This table is constructed with the same units used to report results for laboratory QC analyses. Information on the default QC sample types and QC limits was obtained from the laboratory that performed the analyses. An exception is pH, which was analyzed in the field.
Surrogate recoveries are compound-specific.
1 The overall performance expectation for method 200.8 for this analyte.
2 Calibration blank and calibration standard are used as surrogate samples immediately after each calibration routine, after every 10 analyses, and at the end of the sample run.
3 This is a field measurement.

LCS – laboratory control sample
µg/L – microgram per liter
N/A – not applicable
NC – not calculable (one or more values below detection limit)
mg/L – milligram per liter
µS/cm – microsiemen per centimeter

Table A.3a-3. Measurement quality objectives for laboratory analysis of pore water samples (values in parentheses are actual results).

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Sample Relative Percent Difference	Matrix Spikes % Recovery Limits	Matrix Spike-Duplicates Relative Percent Difference	Surrogate Standards % Recovery Limits	Lowest Concentrations of Interest, Units of Concentration
Arsenic	Water	±10 (-9.0%)	±10[1] (NC)	85-115[1] (99.0%)	±10[1]	±10[2]	Reporting Limit, µg/L
Cadmium	Water	±10 (-0.4%)	±10[1] (NC)	85-115[1] (111.2%)	±10[1]	±10[2]	Reporting Limit, µg/L
Lead	Water	±10 (+4.0%)	±10[1] (0.00%)	85-115[1] (95.1%)	±10[1]	±10[2]	Reporting Limit, µg/L
Mercury	Water	±10 (+4.0%)	<20 (16.39%)	85-115 (100.2%)	18	N/A	Reporting Limit, µg/L
Zinc	Water	±10 (+2.3%)	±10[1](0.92)	85-115[1] (106.99%)	±10[1]	±10[2]	Reporting Limit, µg/L
Dissolved Organic Carbon	Water	±20 (-2.47%)	±20 (4.94%)	70-130 (102.91%)	±20	N/A	0.25 mg/L
Hardness	Water	±2 (+2.05%)	±3 (4.6%)	N/A	N/A	N/A	0.7 mg/L
Ca	Water	±2 (-1.04%)	±3 (7.6%)	N/A	N/A	N/A	0.1 mg/L
Mg	Water	±2 (+3.93%)	±3 (2.08%)	N/A	N/A	N/A	0.1 mg/L
SRP	Water	±20 (+0.11%)	±20 (11.2%)	±10 (100.34%)	±20	< RL	1.0 µg/L
pH [3]	Water	±0.1 pH unit	±0.1 pH unit		N/A	N/A	N/A

Notes:
This table is constructed with the same units used to report results for laboratory QC analyses. Information on the default QC sample types and QC limits was obtained from the laboratory that performed the analyses. An exception is pH, which was analyzed in the field.
Surrogate recoveries are compound-specific.
1 The overall performance expectation for method 200.8 for this analyte.
2 Calibration blank and calibration standard are used as surrogate samples immediately after each calibration routine, after every 10 analyses, and at the end of the sample run.
3 This is a field measurement.

LCS – laboratory control sample
µg/L – microgram per liter
N/A – not applicable
NC – not calculable (one or more values below detection limit)
mg/L – milligram per liter
µS/cm – microsiemen per centimeter

Table A.3a-4. Measurement quality objectives for laboratory analysis of sediment samples (values in parentheses are actual results).

Parameter	Sample Matrix	Check Standard (LCS) % Recovery Limits	Duplicate Sample Relative Percent Difference	Matrix Spikes % Recovery Limits	Matrix Spike-Duplicates Relative Percent Difference	Surrogate Standards % Recovery Limits	Lowest Concentrations of Interest, Units of Concentration
Arsenic	Sediment	±10 (+4.55%)	±10 (2.71%)	85-115 (91.37%)	±10	±10	Reporting Limit, mg/kg
Cadmium	Sediment	±10 (-1.6%)	±10 (6.93%)	85-115 (97.87%)	±10	±10	Reporting Limit, mg/kg
Lead	Sediment	±10 (+3.10%)	±10 (7.11%)	85-115 (88.51%)	±10	±10	Reporting Limit, mg/kg
Mercury	Sediment	80-120 (-0.8%)	<±35 for (5.88%) samples >5X CRDL; ± 2xCRDL for samples <5X CRDL	75-125 (97.16%)	±25 (not given in method)	N/A	Reporting Limit, mg/kg
Zinc	Sediment	±10 (+0.83%)	±10 (7.41%)	85-115 (90.78%)	±10	±10	Reporting Limit, mg/kg
PCBs	Sediment	40-140 (83%)	<30% (NC)	40-140 (80%)	<50	30-150	Reporting Limit, mg/kg
Total Organic Carbon	Sediment	±20 (5.37%)	<20 (4.35%) For samples >5X the CRDL; ± CRDL for samples <5X CRDL	N/A	Not in method	N/A	0.01%
Sulfide	Sediment	See Note 4	Acid soluble sulfide: 1-45 (NC) Acid insoluble sulfide: 1.2-42	Acid soluble sulfide: 77-92 Acid insoluble sulfide: 21-81	N/A	N/A	Reporting limit, mg/kg
Total Solids	Sediment	N/A	±20 (.35%)	N/A	N/A	N/A	1.0 %

Notes:
This table is constructed with the same units used to report results for laboratory QC analyses. Information on the default QC sample types and QC limits was obtained from the laboratory that performed the analyses. An exception is pH, which was analyzed in the field.
Surrogate recoveries are compound-specific.

1 The overall performance expectation for method 200.8 for this analyte.
2 Calibration blank and calibration standard are used as surrogate samples immediately after each calibration routine, after every 10 analyses, and at the end of the sample run.
3 This is a field measurement.
4 Recovery depends on concentration of the check standard and matrix: for sediments, low level matrix spikes for lead and zinc may be below background levels.

LCS – laboratory control sample
µg/L – microgram per liter
N/A – not applicable
CRDL – Contract Required Detection Limit
NC – not calculable (one or more values below detection limit)
mg/L – milligram per liter
µS/cm – microsiemen per centimeter

Appendix 3b. Forms

Run: **Boundary Dam Relicense** Date: **11/13/04**

Meter Calibration Log Form

Cond Meter# _____ Initial Cell Constant _____ Standard _____ µmhos/cm Meter _____ µmhos/cm

pH Meter # _____ pH Probe # _____

Thermistor # _____ Thermistor _____ °C Thermometer _____ °C Correction _____

DAY 1

Low Ionic Strength pH Value vs. Temp. °C

	7	10
10	7.01	9.27
15	6.99/7.00	9.23
20	6.98	9.19

Slope _____ 92-102%
mv @ pH 7 _____ ± 30 mv
mv @ pH 4/10 _____ Difference between mv @ pH7 160-180
Response Time _____ < 90 seconds
Time of Day _____

Depth = 0 rm

	true pH	meter	time of day		
T = 18.85 ˚C QA Check #1	**7.02**	**7.22 set to 7.02**	**0524**	Recalibrated	Y / N **- 1st cal.**
T = 18.72 QA Check #2	**10.07**	**10.17 set to 10.07**	**0530**	Recalibrated	Y / N **- 2nd cal. Check w/ 7 ✓**
T = 19.16 QA Check #3	**7.02**	**7.05 ✓**	**0855 11/14**	Recalibrated	Y / N

If meter pH is not within 0.10 pH units of true value in pH 7 buffer, then recalibrate & re-read sample.

Conductivity Standard **1412** µmhos/cm Meter _____ µmhos/cm

DAY 2 (11/14/04) BP = 713 DO = 100% ORP = 443 T = 18.43 ˚ C ORP M = 435

Initial Cell Constant _____ Standard _____ µmhos/cm Meter _____ µmhos/cm

Slope _____ 92-102%
mv @ pH 7 _____ ± 30 mv
mv @ pH 4/10 _____ Difference between mv @ pH7 160-180
Response Time _____ < 90 seconds
Time of Day _____

	true pH	meter	time of day		
T = 19.16 QA Check #1	**7.02**	**7.05**	**0855**	Recalibrated	**Y** / N
T = 19.18 QA Check #2	**10.06**	**10.06**		Recalibrated	Y / **N**
QA Check #3				Recalibrated	Y / N

If meter pH is not within 0.10 pH units of true value in pH 7 buffer, then recalibrate & re-read sample.

Conductivity Standard **1412** µmhos/cm Meter **1404** µmhos/cm **- Ycal.**

DAY 3 BP = DO = 100% ORP cal = 441 T = 18.90 ˚ C ORP M = 440

Initial Cell Constant _____ Standard _____ µmhos/cm Meter _____ µmhos/cm

Slope _____ 92-102%
mv @ pH 7 _____ ± 30 mv
mv @ pH 4/10 _____ Difference between mv @ pH7 160-180
Response Time _____ < 90 seconds
Time of Day _____

	true pH	meter	time of day		
QA Check #1				Recalibrated	Y / N
QA Check #2				Recalibrated	Y / N
QA Check #3				Recalibrated	Y / N

If meter pH is not within 0.10 pH units of true value in pH 7 buffer, then recalibrate & re-read sample.

Conductivity Standard _____ µmhos/cm Meter _____ µmhos/cm

1ET006.55

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3927 Aurora Avenue N, Seattle, WA 98103
P 206.632.2715 | F 206.632.2417

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SHEET 1 OF 1

CHAIN-OF-CUSTODY RECORD

CLIENT:
SAMPLING DATE: 11/13/07
SAMPLERS: SB, RP

PROJECT ID: Boundary Toxics (B.T.)
CASE FILE NO.:
DATA RECORDED BY:

SAMPLE INFORMATION

PARAMETERS

SAMPLE ID	DATE/TIME COLLECTED	Turbidity	Alk	Hardness	DOC	Total Metals	Dis. Metals	Methyl Hg	Total Hg	Dis. Hg	BOTT #	NOTES
02-R-Ø	11/13/02	X	X	X	X	X	X	X	X	X	6	
02-L-10	"	X	X	X	X	X	X			X	5	
02-L-Ø-DUP	"	X	X	X	X	X	X			X	5	
02-R-10	"	X	X	X	X	X	X			X	5	
02-M-10	"	X	X	X	X	X	X			X	5	
02-L-Ø	"	X	X	X	X	X	X			X	5	
02-M-Ø	"	X	X	X	X	X	X	X	X	X	6	
02-Blank	"	X	X	X	X	X	X			X	5	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name	Shannon Bratton	11/15/07 9:47	Hansen Gadomski	11/16/07 9:25AM
Signature	Shannon Bratton		Hansen Gadomski	
Affiliation	Tetra Tech		ARI	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.):

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SHEET 1 OF 1

CHAIN-OF-CUSTODY RECORD

CLIENT:
SAMPLING DATE: 11/13/07
SAMPLERS: SB, RP

PROJECT ID: Boundary Toxics
CASE FILE NO.:
DATA RECORDED BY:

SAMPLE INFORMATION

SAMPLE ID	DATE/TIME COLLECTED	Turbidity	ALK	Hardness	DOC	Total Metals	Dis. Metals	Total Hg	Dis. Hg	BOTT #	NOTES
05-R-10	11/13/07	X	X	X	X	X	X		X	1	
05-M-0	"	X	X	X	X	X	X	X	X	2	
05-L-0	"	X	X	X	X	X	X		X	3	REFILTER DOC
05-R-0	"	X	X	X	X	X	X	X	X	4	DISS. Hg CONT. BROKE ~~[illegible]~~
05-M-0-DUP	"	X	X	X	X	X	X		X	5	
05-M-10	"	X	X	X	X	X	X		X	6	
05-L-10	"	X	X	X	X	X	X		X	7	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name	Shannon K. Bratkis	11/15/07 10:00	LAUREN GADOWSKI	11/16/07
Signature	Shannon K. Bratkis		Lauren Gadowski	
Affiliation	Tetra Tech		ARI	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.):

TCT006-22

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SHEET 1 OF 1

CHAIN-OF-CUSTODY RECORD

CLIENT:
SAMPLING DATE: 11/13/07
SAMPLERS: SB, RP

PROJECT ID: Boundary Toxics (B.T.)
CASE FILE NO.:
DATA RECORDED BY:

SAMPLE INFORMATION

PARAMETERS

SAMPLE ID	DATE/TIME COLLECTED	Turbidity	Alk	Hardness	DOC	Total Metals	Dis. Metals	Mercury Hg	Total Hg	Dis. Hg	BOTT #	NOTES
07-R-10	11/13/07	X	X	X	X	X	X			X	5	
07-R-Ø	"	X	X	X	X	X	X			X	5	
07-M-10	"	X	X	X	X	X	X			X	5	
07-R-Ø-DUP	"	X	X	X	X	X	X			X	5	
07-L-10	"	X	X	X	X	X	X			X	5	
07-L-Ø	"	X	X	X	X	X	X	X	X	X	6	
07-M-Ø	"	X	X	X	X	X	X	X	X	X	6	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name	Shannon K Bratton	11/15/07 9:37	JAMIEN GADOMSKI	11/16/07
Signature	Shannon K Bratton		Jamien Gadomski	7:40AM
Affiliation	Tetra Tech		ARI	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.):

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SHEET 1 OF 1

CHAIN-OF-CUSTODY RECORD

CLIENT:
SAMPLING DATE: 11-13-07
SAMPLERS: SB RP

PROJECT ID: BOUNDARY TOXICS (B.T.)
CASE FILE NO.:
DATA RECORDED BY:

SAMPLE INFORMATION

PARAMETERS

SAMPLE ID	DATE/TIME COLLECTED	ALK	HARD	HPB	TOTAL METALS	DISS METALS	METHYL/TOTAL HG	DISS HG	DOC	BOTT #	NOTES
8-L-0		X	X	X	X	X		X	X	5	
8-L-10		X	X	X	X	X		X	X	5	
8-M-0		X	X	X	X	X	X	X	X	6	
8-M-10		X	X	X	X	X		X	X	5	
8-R-0		X	X	X	X	X	X	X	X	6	
8-R-10		X	X	X	X	X		X	X	5	
8-L-10 DUP		X	X	X	X	X		X	X	5	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name	ROBERT ALDINKOFF	11-15-07	ALLEN GANDHSEE	11/16/07
Signature	[illegible]	10:02	[illegible]	7:40am
Affiliation	TETRA TECH		ARI	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.):

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TET006'55

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SHEET 1 OF 1

CHAIN-OF-CUSTODY RECORD

CLIENT:
SAMPLING DATE: 11-14-07
SAMPLERS: SB PP

PROJECT ID: Boundary Toxics (B.T.)
CASE FILE NO.:
DATA RECORDED BY:

SAMPLE INFORMATION

PARAMETERS

SAMPLE ID	DATE/TIME COLLECTED	Turbidity	ALK	Hardness	DOC	Total Metals	Dis. Metals	Methy Hg	Total Hg	Dis. Hg	BOTT #	NOTES
10-L-0		X	X	X	X	X	X	X	X	X	6	
10-L-10		X	X	X	X	X	X			X	5	
10-M-0		X	X	X	X	X	X	X	X	X	6	
10-M-10		X	X	X	X	X	X			X	5	
10-P-0		X	X	X	X	X	X			X	5	
10-P-10		X	X	X	X	X	X			X	5	
10-BLANK		X	X	X	X	X	X			X	5	
10-M-10 MP		X	X	X	X	X	X			X	5	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name	ROBERT PLOTNIKOFF	11-15-07 09:30	LARISEN GADOMSKI	11/16/07 9:25
Signature	[signature]		[signature]	
Affiliation	TETRA TECH		ARI	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.):

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SHEET 1 OF 1

CHAIN-OF-CUSTODY RECORD

CLIENT:
SAMPLING DATE: 11-14-07
SAMPLERS: SB RP

PROJECT ID: BOUNDARY TOXICS (B.T.)
CASE FILE NO.:
DATA RECORDED BY:

SAMPLE INFORMATION

PARAMETERS

SAMPLE ID	DATE/TIME COLLECTED	ALK.	HARDN.	TURBIDITY	DISS. METALS	TOTAL METALS	METHYL HG	TOTAL HG	DISS. HG	NO2	BOTT #	NOTES
13-L-0		X	X	X	X	X		X		X	5	DISS METALS - NP
13-M-0		X	X	X	X	X	X	X		X	6	DISS. METALS - NP
13-R-0		X	X	X	X	X	X	X		X	6	
13-L-10		X	X	X	X	X		X		X	5	DISS METALS - NP
13-M-10		X	X	X	X	X		X		X	5	DISS METALS - NP
13-R-10		X	X	X	X	X		X		X	5	DISS HG - NP
13-R-10 DUP		X	X	X	X	X		X		X	5	DISS HG - NP

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name	ROBERT ELOTRNIKOFF	11-15-07 09:47	JAMES GADOMSKI	11/16/07 9:30AM
Signature				
Affiliation	FETIRA TECH		ARI	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.):

01/16/2008 12:34 2066322417 AQUATIC RESEARCH PAGE 07/08

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SHEET 1 OF 1

CHAIN-OF-CUSTODY RECORD

CLIENT:
SAMPLING DATE: 11/14/07
SAMPLERS: SB, BD

PROJECT ID: Boundary Toxic (B.T.)
CASE FILE NO.:
DATA RECORDED BY:

SAMPLE INFORMATION

PARAMETERS

SAMPLE ID	DATE/TIME COLLECTED	Turbidity	ALK	Hardness	DOC	Total Metals	Dis. Metals	Mercury Hg	Total Hg	Dis. Hg	BOTT #	NOTES
14-R-10	11/14/07	X	X	X	X	X	X			X	5	
14-R-Ø	"	X	X	X	X	X	X	X	X	X	6	
14-L-Ø-DUP	"	X	X	X	X	X	X			X	5	
14-L-10	"	X	X	X	X	X	X			X	5	
14-L-Ø	"	X	X	X	X	X	X			X	5	
14-M-10	"	X	X	X	X	X	X			X	5	
14-M-Ø	"	X	X	X	X	X	X	X	X	X	6	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name	Shannon Bratcher	11/15/07 9:25	Jim Damien Gandhate	11/16/07 7:40AM
Signature	Shannon Bratcher		Damien Gandhate	
Affiliation	Tetra Tech		ARI	

	Relinquished By	Date/Time	Received By	Date/Time
Printed Name				
Signature				
Affiliation				

Miscellaneous Notes (Hazardous Materials, Quick turn-around time, etc.):

01/18/2008 12:34 2066322417 AQUATIC RESEARCH PAGE 08/08

Appendix 4: Water Fluctuation Zone Data

Table A.4-1. Field parameters measured at each site transect, three locations along a transect (L ~ left, M ~ middle, and R ~ right), and at four depths (0m, 1m, 2m, and 3m).

Sample ID	Date	Time	Depth (m)	Temperature (ºC)	pH (units)	Conductivity (µmhos/cm)	DO (mg/L)	Redox (mV)
02-L-0	11/13/2007	0806	0	7.89	10.86	8.14	162.5	411
02-M-0	11/13/2007	0806	0	7.9	10.92	8.12	162.5	396
02-R-0	11/13/2007	0806	0	7.84	11.4	8.08	162.8	400
02-L-1	11/13/2007	0806	1	7.93	10.83	8.17	162.6	410
02-M-1	11/13/2007	0806	1	7.91	10.84	8.14	162.5	396
02-R-1	11/13/2007	0806	1	7.88	11.01	8.1	162.5	400
02-L-2	11/13/2007	0806	2	7.94	10.86	8.17	162.6	411
02-M-2	11/13/2007	0806	2	7.93	10.86	8.15	162.6	397
02-R-2	11/13/2007	0806	2	7.88	10.89	8.12	162.2	400
02-L-3	11/13/2007	0806	3	7.94	10.84	8.18	162.6	410
02-M-3	11/13/2007	0806	3	7.93	10.84	8.15	162	398
02-R-3	11/13/2007	0806	3	7.88	10.88	8.13	162.1	399
05-L-0	11/13/2007	0946	0	7.57	11.21	7.99	161.6	398
05-M-0	11/13/2007	0946	0	7.53	11.15	8.03	161.3	400
05-R-0	11/13/2007	0946	0	7.53	10.95	7.99	161.5	396
05-L-1	11/13/2007	0946	1	7.59	10.81	8.04	161.7	396
05-M-1	11/13/2007	0946	1	7.59	10.8	8.06	161.1	399
05-R-1	11/13/2007	0946	1	7.51	10.82	8.04	161.5	395
05-L-2	11/13/2007	0946	2	7.59	10.77	8.06	161.6	396
05-M-2	11/13/2007	0946	2	7.56	10.77	8.07	160.9	399
05-R-2	11/13/2007	0946	2	7.58	10.79	8.05	161.1	396
05-L-3	11/13/2007	0946	3	7.61	10.76	8.07	161.7	396
05-M-3	11/13/2007	0946	3	7.6	10.75	8.09	161	400
05-R-3	11/13/2007	0946	3	7.57	10.77	8.07	161.3	396
07-L-0	11/13/2007	1038	0	7.5	10.97	8	162.5	401
07-M-0	11/13/2007	1038	0	7.48	11.21	7.98	162.8	395
07-R-0	11/13/2007	1038	0	7.51	11.18	7.96	161.5	393
07-L-1	11/13/2007	1038	1	7.48	10.78	8.04	162.5	401
07-M-1	11/13/2007	1038	1	7.5	10.81	8.02	162.3	395
07-R-1	11/13/2007	1038	1	7.52	10.84	8	161.9	392
07-L-2	11/13/2007	1038	2	7.5	10.75	8.05	162.5	401
07-M-2	11/13/2007	1038	2	7.5	10.76	8.04	162.3	395
07-R-2	11/13/2007	1038	2	7.51	10.79	8.02	161.6	392
07-L-3	11/13/2007	1038	3	7.51	10.71	8.06	162	401
07-M-3	11/13/2007	1038	3	7.51	10.73	8.07	162.2	395
07-R-3	11/13/2007	1038	3	7.52	10.76	8.04	161.6	393
08-L-0	11/13/2007	1200	0	7.51	11.14	8	162.7	393
08-M-0	11/13/2007	1200	0	7.54	11.15	8.05	162	413
08-R-0	11/13/2007	1200	0	7.54	10.93	8.06	162	420
08-L-1	11/13/2007	1200	1	7.52	10.91	8.04	162.6	392
08-M-1	11/13/2007	1200	1	7.54	10.9	8.07	162.4	412
08-R-1	11/13/2007	1200	1	7.54	10.87	8.08	162.6	420
08-L-2	11/13/2007	1200	2	7.53	10.83	8.05	162.2	393

Table A.4-1, continued…

Sample ID	Date	Time	Depth (m)	Temperature (ºC)	pH (units)	Conductivity (µmhos/cm)	DO (mg/L)	Redox (mV)
08-M-2	11/13/2007	1200	2	7.54	10.83	8.09	163	412
08-R-2	11/13/2007	1200	2	7.55	10.85	8.09	162.3	419
08-L-3	11/13/2007	1200	3	7.54	10.8	8.08	162	393
08-M-3	11/13/2007	1200	3	7.54	10.82	8.09	162.4	412
08-R-3	11/13/2007	1200	3	7.54	10.82	8.09	162.1	419
10-L-0	11/14/2007	1115	0	7.29	11.05	7.95	165.3	467
10-M-0	11/14/2007	1115	0	7.29	11.45	8.04	165.3	464
10-R-0	11/14/2007	1115	0	7.3	11.16	7.99	165.2	460
10-L-1	11/14/2007	1115	1	7.3	10.99	7.98	164.7	466
10-M-1	11/14/2007	1115	1	7.3	11.02	8.06	164.7	463
10-R-1	11/14/2007	1115	1	7.3	11	8.02	165.3	460
10-L-2	11/14/2007	1115	2	7.3	10.97	8.02	165	466
10-M-2	11/14/2007	1115	2	7.29	11	8.08	164.7	463
10-R-2	11/14/2007	1115	2	7.3	10.99	8.04	164.7	459
10-L-3	11/14/2007	1115	3	7.31	10.97	8.07	165	465
10-M-3	11/14/2007	1115	3	7.29	10.98	8.08	165.2	463
10-R-3	11/14/2007	1115	3	7.3	10.99	8.05	164.7	459
13-L-0	11/14/2007	1300	0	7.33	11.07	7.99	164.7	466
13-M-0	11/14/2007	1300	0	7.34	11.12	7.99	165.4	463
13-R-0	11/14/2007	1300	0	7.33	11.19	7.97	164.6	454
13-L-1	11/14/2007	1300	1	7.33	11.02	8.01	164.7	466
13-M-1	11/14/2007	1300	1	7.33	11.05	8.02	165	462
13-R-1	11/14/2007	1300	1	7.34	11.08	8.01	164.7	454
13-L-2	11/14/2007	1300	2	7.33	11.02	8.03	165	465
13-M-2	11/14/2007	1300	2	7.34	11.04	8.03	164.7	462
13-R-2	11/14/2007	1300	2	7.34	11.06	8.02	164.7	453
13-L-3	11/14/2007	1300	3	7.33	11.01	8.04	165	465
13-M-3	11/14/2007	1300	3	7.34	11.02	8.03	165.1	462
13-R-3	11/14/2007	1300	3	7.34	11.04	8.03	164.8	453
14-L-0	11/14/2007	1400	0	7.29	11.06	7.99	164.8	474
14-M-0	11/14/2007	1400	0	7.29	11.11	8.01	165	473
14-R-0	11/14/2007	1400	0	7.28	11.09	7.97	165.2	465
14-L-0.7	11/14/2007	1400	0.7	7.29	10.96	8.04	165.3	473
14-M-0.4	11/14/2007	1400	0.4	7.29	10.98	8.02	165.3	472
14-R-0.3	11/14/2007	1400	0.3	7.29	10.99	7.99	164.6	465
14-L-1.3	11/14/2007	1400	1.3	7.29	10.96	8.05	164.7	473
14-M-0.5	11/14/2007	1400	0.5	7.29	10.95	8.02	165.2	471
14-R-0.4	11/14/2007	1400	0.4	7.29	10.96	8	164.7	465
14-L-2.6	11/14/2007	1400	2.6	7.29	10.95	8.05	165	473
14-R-0.8	11/14/2007	1400	0.8	7.29	10.96	8.01	165	465

Table A.4-2. General chemistry parameters measured at each site transect, three locations along a transect (L ~ left, M ~ middle, and R ~ right), and at two depths (0 feet and 10 feet) (November 2007).

Sample ID	Depth (m)	Turbidity (NTU)	Alkalinity (mg $CaCO_3$/L)	DOC (mg/L)	Hardness (mg/L)
02-R-0	0	0.30	79.9	1.26	75.8
02-L-10	10	0.31	80.5	1.16	77.4
02-L-0-DUP	0	0.33	80.3	1.27	77.4
02-R-10	10	0.33	80.3	1.17	77.6
02-M-10	10	0.35	80.2	1.11	77.4
02-L-0	0	0.34	79.5	1.20	77.8
02-M-0	0	0.34	80.0	1.20	77.2
02-BLANK		<0.10	<1.00	<0.250	<2.00
05-R-10	10	0.33	78.6	1.14	77.4
05-M-0	0	0.34	79.1	1.16	75.8
05-L-0	0	0.27	79.1	1.14	76.6
05-R-0	0	0.34	80.2	1.26	76.0
05-M-0-DUP	0	0.27	79.7	1.17	76.2
05-M-10	10	0.32	79.9	1.63	77.8
05-L-10	10	0.29	78.5	1.29	76.4
07-R-10	10	0.31	79.7	1.15	76.6
07-R-0	0	0.36	79.6	1.17	77.0
07-M-10	10	0.33	79.4	1.33	77.2
07-R-0-DUP	0	0.34	79.5	1.33	78.0
07-L-10	10	0.32	79.8	1.55	76.4
07-L-0	0	0.34	79.8	1.24	75.4
07-M-0	0	0.38	79.7	1.28	75.8
8-L-0	0	0.32	81.0	1.29	77.4
8-L-10	10	0.35	79.8	1.55	77.0
8-M-0	0	0.36	79.8	1.23	75.2
8-M-10	10	0.26	80.0	1.32	76.2
8-R-0	0	0.29	80.5	1.28	76.6
8-R-10	10	0.31	80.1	1.28	76.2
8-L-10-DUP	10	0.33	80.5	1.37	76.4
10-L-0	0	0.31	80.8	1.29	77.0
10-L-10	10	0.32	80.9	1.20	76.4
10-M-0	0	0.41	81.5	1.20	76.2
10-M-10	10	0.38	80.5	1.25	75.6
10-R-0	0	0.36	80.2	1.21	76.2
10-R-10	10	0.31	81.4	1.27	77.2
10-BLANK		0.13	<1.00	<0.250	<2.00
10-M-10-DUP	10	0.34	80.0	1.32	75.4
13-L-0	0	0.30	80.8	1.22	75.8
13-M-0	0	0.31	80.7	1.38	76.4
13-R-0	0	0.31	80.7	1.18	76.2
13-L-10	10	0.28	81.5	1.18	76.6
13-M-10	10	0.28	81.0	1.17	76.6
13-R-10	10	0.28	79.7	1.67	78.0

Table A.4-2, continued…

Sample ID	Depth (m)	Turbidity (NTU)	Alkalinity (mg $CaCO_3$/L)	DOC (mg/L)	Hardness (mg/L)
13-R-10-DUP	10	0.30	79.8	1.28	77.6
14-R-10	10	0.29	80.5	1.20	78.8
14-R-0	0	0.31	81.0	1.18	76.4
14-L-0-DUP	0	0.23	80.0	1.21	77.4
14-L-10	10	0.27	80.3	1.68	77.2
14-L-0	0	0.27	80.7	1.46	77.0
14-M-10	10	0.27	80.6	1.45	77.0
14-M-0	0	0.26	79.7	1.38	76.6

Table A.4-3. Laboratory results for dissolved metals concentrations measured at each site transect, three locations along a transect (L ~ left, M ~ middle, and R ~ right), and at two depths (0 feet and 10 feet) (November 2007).

Sample ID	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Lead (µg/L)
02-R-0	<5.0	<0.002	1.2	<0.20	<0.20
02-L-10	<5.0	<0.002	1.0	<0.20	<0.20
02-L-0-DUP	<5.0	<0.002	<1.0	<0.20	<0.20
02-R-10	<5.0	<0.002	1.0	<0.20	<0.20
02-M-10	<5.0	<0.002	<1.0	<0.20	<0.20
02-L-0	<5.0	<0.002	1.2	<0.20	<0.20
02-M-0	<5.0	<0.002	1.1	<0.20	<0.20
02-BLANK	<5.0	<0.002	<1.0	<0.20	<0.20
05-R-10	<5.0	<0.002	<1.0	<0.20	<0.20
05-M-0	<5.0	<0.002	1.0	<0.20	<0.20
05-L-0	<5.0	<0.002	1.0	<0.20	<0.20
05-R-0	<5.0	BROKE IN TRANSIT	1.0	<0.20	<0.20
05-M-0-DUP	6.0	<0.002	<1.0	<0.20	<0.20
05-M-10	<5.0	<0.002	<1.0	<0.20	<0.20
05-L-10	<5.0	<0.002	<1.0	<0.20	<0.20
07-R-10	<5.0	<0.002	1.2	<0.20	<0.20
07-R-0	<5.0	<0.002	1.0	<0.20	<0.20
07-M-10	<5.0	<0.002	1.0	<0.20	<0.20
07-R-0-DUP	<5.0	<0.002	1.0	<0.20	<0.20
07-L-10	<5.0	<0.002	<1.0	<0.20	<0.20
07-L-0	<5.0	<0.002	<1.0	<0.20	<0.20
07-M-0	<5.0	<0.002	1.1	<0.20	<0.20
8-L-0	<5.0	<0.002	<1.0	<0.20	<0.20
8-L-10	<5.0	<0.002	<1.0	<0.20	<0.20
8-M-0	<5.0	<0.002	<1.0	<0.20	<0.20
8-M-10	<5.0	<0.002	<1.0	<0.20	<0.20
8-R-0	<5.0	<0.002	<1.0	<0.20	<0.20
8-R-10	<5.0	<0.002	1.0	<0.20	<0.20
8-L-10-DUP	<5.0	<0.002	<1.0	<0.20	<0.20
10-L-0	<5.0	<0.002	1.0	<0.20	<0.20
10-L-10	<5.0	<0.002	1.0	<0.20	<0.20
10-M-0	<5.0	<0.002	1.1	<0.20	<0.20
10-M-10	<5.0	<0.002	<1.0	<0.20	<0.20
10-R-0	<5.0	<0.002	<1.0	<0.20	<0.20
10-R-10	<5.0	<0.002	<1.0	<0.20	<0.20
10-BLANK	<5.0	<0.002	<1.0	<0.20	<0.20
10-M-10-DUP	<5.0	<0.002	1.0	<0.20	<0.20
13-L-0	<5.0	<0.002	<1.0	<0.20	<0.20
13-M-0	<5.0	<0.002	1.1	<0.20	<0.20
13-R-0	<5.0	<0.002	1.1	<0.20	<0.20
13-L-10	<5.0	<0.002	1.0	<0.20	<0.20

Table A.4-3, continued…

Sample ID	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Lead (µg/L)
13-M-10	<5.0	<0.002	1.0	<0.20	<0.20
13-R-10	<5.0	<0.002	1.0	<0.20	<0.20
13-R-10-DUP	<5.0	<0.002	1.1	<0.20	<0.20
14-R-10	<5.0	<0.002	1.1	<0.20	<0.20
14-R-0	<5.0	<0.002	1.1	<0.20	<0.20
14-L-0-DUP	<5.0	<0.002	1.2	<0.20	<0.20
14-L-10	<5.0	<0.002	1.1	<0.20	<0.20
14-L-0	<5.0	<0.002	1.1	<0.20	<0.20
14-M-10	<5.0	<0.002	1.1	<0.20	<0.20
14-M-0	5.0	<0.002	1.2	<0.20	<0.20

Table A.4-4. Laboratory results for total recoverable metals concentrations measured at each site transect, three locations along a transect (L ~ left, M ~ middle, and R ~ right), and at two depths (0 feet and 10 feet) (November 2007).

Sample ID	Total Arsenic (µg/L)	Total Cadmium (µg/L)	Total Lead (µg/L)	Total Zinc (µg/L)	Total Mercury (µg/L)
02-R-0	1.0	<0.20	0.23	<5.0	<0.002
02-L-10	1.1	<0.20	0.25	<5.0	
02-L-0-DUP	1.0	<0.20	<0.20	<5.0	
02-R-10	1.0	<0.20	<0.20	<5.0	
02-M-10	<1.0	<0.20	<0.20	<5.0	
02-L-0	1.2	<0.20	<0.20	<5.0	
02-M-0	1.1	<0.20	<0.20	<5.0	<0.002
02-BLANK	<1.0	<0.20	<0.20	<5.0	
05-R-10	1.1	<0.20	<0.20	<5.0	
05-M-0	1.1	<0.20	<0.20	<5.0	<0.002
05-L-0	1.1	<0.20	<0.20	<5.0	
05-R-0	1.1	<0.20	<0.20	<5.0	<0.002
05-M-0-DUP	1.3	<0.20	<0.20	6.0	
05-M-10	1.2	<0.20	<0.20	<5.0	
05-L-10	1.1	<0.20	<0.20	<5.0	
07-R-10	1.1	<0.20	<0.20	<5.0	
07-R-0	1.2	<0.20	<0.20	<5.0	
07-M-10	1.1	<0.20	<0.20	<5.0	
07-R-0-DUP	1.1	<0.20	<0.20	<5.0	
07-L-10	1.1	<0.20	0.54	<5.0	
07-L-0	1.1	<0.20	<0.20	<5.0	<0.002
07-M-0	1.1	<0.20	<0.20	<5.0	<0.002
8-L-0	1.0	<0.20	<0.20	<5.0	
8-L-10	1.1	<0.20	<0.20	<5.0	
8-M-0	1.1	<0.20	<0.20	<5.0	<0.002
8-M-10	1.0	<0.20	<0.20	<5.0	
8-R-0	1.2	<0.20	<0.20	<5.0	<0.002
8-R-10	1.1	<0.20	<0.20	6.0	
8-L-10-DUP	1.1	<0.20	<0.20	<5.0	
10-L-0	1.1	<0.20	<0.20	5.0	<0.002
10-L-10	1.1	<0.20	<0.20	<5.0	
10-M-0	1.0	<0.20	<0.20	<5.0	<0.002
10-M-10	1.2	<0.20	<0.20	<5.0	
10-R-0	1.2	<0.20	<0.20	<5.0	
10-R-10	1.2	<0.20	<0.20	<5.0	
10-BLANK	<1.0	<0.20	<0.20	<5.0	
10-M-10-DUP	1.1	<0.20	<0.20	<5.0	
13-L-0	1.1	<0.20	<0.20	5.0	
13-M-0	1.1	<0.20	<0.20	<5.0	<0.002
13-R-0	1.1	<0.20	<0.20	<5.0	<0.002
13-L-10	1.1	<0.20	<0.20	<5.0	
13-M-10	1.1	<0.20	<0.20	<5.0	

Table A.4-4, continued…

Sample ID	Total Arsenic (µg/L)	Total Cadmium (µg/L)	Total Lead (µg/L)	Total Zinc (µg/L)	Total Mercury (µg/L)
13-R-10	1.3	<0.20	<0.20	<5.0	
13-R-10-DUP	1.1	<0.20	<0.20	<5.0	
14-R-10	1.1	<0.20	<0.20	<5.0	
14-R-0	1.1	<0.20	<0.20	<5.0	<0.002
14-L-0-DUP	1.1	<0.20	<0.20	5.0	
14-L-10	1.1	<0.20	<0.20	<5.0	
14-L-0	1.0	<0.20	<0.20	<5.0	
14-M-10	1.1	<0.20	<0.20	<5.0	
14-M-0	1.1	<0.20	<0.20	6.0	<0.002

Appendix 5: Pore Water Data

Table A.5-1. General chemistry and dissolved metals results from pore water at sites in Boundary Reservoir (March 2008 sampling).

Sample ID	pH (units)	Dissolved Organic Carbon (DOC) (mg/L)	Soluble Reactive Phosphorus (SRP) (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Hardness (mg $CaCO_3$/L)
2-PW-2	7.50	3.97	0.030	23.3	5.53	81.0
2-PW-3	7.82	9.40	0.002	33.1	6.96	111
5-PW-1	7.63	1.90	0.012	24.7	6.72	89.3
5-PW-2	6.38	5.60	32.9	29.5	7.17	103
5-PW-3	7.78	1.49	0.013	22.8	6.61	84.1
7-PW-1	7.80	1.41	0.004	24.5	6.17	86.5
7-PW-2	7.80	1.60	0.003	23.3	6.50	85.0
7-PW-3	7.92	1.31	0.017	21.9	6.59	81.9
8-PW-1	7.34	5.64	2.82	32.4	11.6	129
8-PW-2	7.83	1.70	0.004	21.8	6.50	81.2
8-PW-3	7.86	1.90	0.005	23.9	6.97	88.5
10-PW-1	7.95	3.14	0.017	23.0	7.26	87.3
10-PW-2	7.61	3.43	17.1	34.5	8.29	120
10-PW-3	7.88	4.21	0.017	21.7	8.61	89.7
13-PW-1	7.57	16.0	0.528	31.5	8.48	114
13-PW-2	7.96	3.19	0.011	29.6	7.74	106
13-PW-3	7.90	2.32	0.001	25.1	6.55	89.7
14-PW-1	7.64	1.39	0.002	23.2	6.63	85.2
14-PW-2	7.90	1.40	0.001	21.2	6.25	78.6
14-PW-3	7.94	1.73	0.006	24.1	6.79	88.2

Note:
mg/L – milligram per liter

Table A.5-1, continued…

Sample ID	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Lead (µg/L)	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)
2-PW-2	1.5	<0.20	<0.20	10.0	0.00331
2-PW-3	1.8	<0.20	<0.20	11.0	0.00088
5-PW-1	<1.0	<0.20	0.29	26.0	0.00138
5-PW-2	1.9	0.27	3.98	279	0.0016
5-PW-3	<1.0	<0.20	0.35	44.0	0.00162
7-PW-1	<1.0	<0.20	0.30	17.0	0.00535
7-PW-2	<1.0	<0.20	<0.20	15.0	0.00874
7-PW-3	<1.0	<0.20	0.58	14.0	0.00976
8-PW-1	<1.0	0.22	1.57	566	0.0104
8-PW-2	<1.0	<0.20	1.45	56.0	0.00587
8-PW-3	<1.0	<0.20	1.06	73.0	0.00630
10-PW-1	<1.0	<0.20	0.39	15.0	0.00376
10-PW-2	<1.0	0.27	0.76	80.0	0.00499
10-PW-3	1.0	<0.20	0.46	8.0	0.00556
13-PW-1	<1.0	<0.20	0.31	13.0	0.00284
13-PW-2	1.0	<0.20	0.22	21.0	0.00156
13-PW-3	<1.0	<0.20	<0.20	12.0	0.00537
14-PW-1	<1.0	<0.20	0.22	22.0	0.00073
14-PW-2	<1.0	<0.20	<0.20	21.0	0.00407
14-PW-3	<1.0	<0.20	<0.20	14.0	0.0416

Notes:
µg/L – microgram per liter

Appendix 6: Water Column Profile Data

Table A.6-1. Field parameters measured at water column profile sites in Boundary Reservoir at surface, mid-, and bottom (March 2008 sampling).

Station #	Water Column Location	Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	pH (units)	Conductivity (umhos/cm)	Redox Potential mV
1	Surface	0	4.7	12.82	7.99	162.9	429
1	Mid	35.1	4.8	12.66	7.79	163.6	439
1	Bottom	55.7	4.74	10.66	7.58	164.1	169
2	Surface	0	4.69	12.71	7.87	161.3	390
2	Mid	29.5	4.73	12.55	7.75	161	399
2	Bottom	59.5	4.74	12.41	7.75	160.9	403
3	Surface	0.2	4.74	12.66	7.84	161.2	424
3	Mid	30.2	4.77	12.59	7.73	161.6	430
3	Bottom	60.2	4.76	12.42	7.7	161.6	433
4	Surface	0	4.85	12.76	7.69	160	419
4	Mid	2.1	4.87	12.77	7.68	160.1	427
4	Bottom	4.5	4.88	12.77	7.7	160.1	427
5	Surface	0.2	4.76	12.68	7.84	160.1	431
5	Mid	4.7	4.77	12.63	7.84	160.2	431
5	Bottom	10.2	4.77	12.56	7.83	160.6	432
6	Surface	0.2	4.74	12.62	7.81	159.8	443
6	Mid	5.4	4.75	12.66	7.87	159.8	441
6	Bottom	8.8	4.74	12.63	7.89	159.6	440
7	Surface	0.2	4.69	12.63	7.82	158.5	450
7	Mid	2.1	4.69	12.67	7.83	158.9	449
7	Bottom	4.9	4.69	12.69	7.88	158.5	447
8	Surface	0.1	4.77	12.64	7.89	159.5	465
8	Mid	0.7	4.77	12.67	7.9	159.8	464
8	Bottom	1.6	4.77	12.67	7.9	159.8	464
9	Surface	0	4.78	12.63	7.77	159.5	468
9	Mid	1	4.78	12.63	7.8	159.8	467
9	Bottom	1.4	4.77	12.7	7.82	159.8	467
10	Surface	0.2	4.85	12.7	7.86	160	467
10	Mid	3.5	4.85	12.73	7.89	159.5	465
10	Bottom	5.2	4.86	12.74	7.9	159.5	466
11	Surface	0.1	4.82	12.72	7.82	159.7	470
11	Mid	1.1	4.82	12.72	7.81	159.7	470
11	Bottom	1.2	4.82	12.75	7.84	159.9	468
12	Surface	0.3	4.92	12.59	7.83	160.1	467
12	Mid	1.1	4.92	12.7	7.86	160.5	465
12	Bottom	1.3	4.92	12.74	7.87	160.5	465
13	Surface	0.1	4.91	12.75	7.86	159.2	466
13	Mid	0.6	4.91	12.79	7.83	159.2	466
13	Bottom	0.8	4.91	12.03	7.86	159.3	464
14	Surface	0	4.88	12.83	7.95	159.2	468
14	Mid	0.4	4.88	12.82	7.82	159.6	468
14	Bottom	0.8	4.89	12.82	7.89	159.5	468

Table A.6-2. General chemistry results from water column profile sites in Boundary Reservoir (March 2008 sampling).

SAMPLE ID	Turbidity (NTUs)	Alkalinity (mg $CaCO_3$/L)	Hardness (mg $CaCO_3$/L)	Dissolved Organic Carbon (DOC) (mg/L)
1-BOT	0.76	82.0	81.1	1.18
1-MID	0.70	80.9	79.0	1.32
1-SURF	0.70	80.3	78.0	1.37
2-BOT	0.74	80.4	77.8	1.24
2-MID	0.73	81.0	77.6	1.40
2-SURF	0.78	80.4	77.8	1.50
3-BOT	0.74	80.5	77.8	1.27
3-MID	0.69	80.9	80.3	1.21
3-SURF	0.67	80.3	78.6	1.28
4-BOT	0.81	79.4	77.6	1.18
4-MID	0.84	79.9	77.0	1.38
4-SURF	0.81	79.9	76.4	1.25
5-BOT	0.83	79.5	77.2	1.44
5-MID	0.81	79.8	77.4	1.24
5-SURF	0.80	79.2	77.2	1.46
5-SURF-DUP	0.78	79.8	77.8	1.35
6-BOT	0.82	80.4	77.0	1.34
6-MID	0.83	78.5	77.4	1.21
6-SURF	0.74	78.4	77.4	1.23
7-BOT	0.77	79.3	76.8	1.32
7-MID	0.76	78.7	77.2	1.34
7-SURF	0.81	79.4	77.4	1.25
8-BOT	0.77	78.1	77.4	1.59
8-MID	0.80	80.3	78.2	1.42
8-SURF	0.79	79.0	78.6	1.34
9-BOT	0.79	78.2	77.0	1.55
9-MID	0.78	79.3	78.0	1.91
9-SURF	0.78	78.9	77.2	1.45
10-BOT	2.0	79.9	77.8	1.27
10-MID	0.89	80.3	77.0	1.50
10-SURF	0.78	79.5	76.2	1.51
11-BOT	4.9	78.7	78.4	1.30
11-MID	2.2	78.7	78.8	1.43
11-SURF	0.84	79.5	77.8	1.25
12-BOT	1.7	79.4	78.2	1.34
12-MID	0.98	78.9	76.2	1.27
12-SURF	0.94	78.2	77.4	1.33
12-SURF-DUP	0.95	78.9	77.6	1.85
13-BOT	1.8	78.3	77.8	1.45
13-MID	0.89	78.7	78.8	1.25
13-SURF	0.73	79.9	78.4	1.29
14-BOT	0.85	80.0	77.8	1.30
14-MID	0.81	78.6	77.2	1.27
14-SURF	0.73	78.4	76.8	1.31

Notes:
NTU – nephelometric turbidity unit mg/L – milligram per liter

Table A.6-3. Laboratory results for dissolved metals concentrations from water column profile sites in Boundary Reservoir (March 2008 sampling).

SAMPLE ID	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Lead (µg/L)	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)
1-BOT	<1.0	<0.20	<0.20	<5.0	<0.0002
1-MID	<1.0	<0.20	<0.20	<5.0	<0.0002
1-SURF	<1.0	<0.20	<0.20	<5.0	<0.0002
2-BOT	<1.0	<0.20	<0.20	<5.0	<0.0002
2-MID	<1.0	<0.20	<0.20	<5.0	<0.0002
2-SURF	<1.0	<0.20	<0.20	<5.0	<0.0002
3-BOT	<1.0	<0.20	<0.20	<5.0	<0.0002
3-MID	1.1	<0.20	<0.20	<5.0	<0.0002
3-SURF	<1.0	<0.20	<0.20	<5.0	<0.0002
4-BOT	<1.0	<0.20	<0.20	<5.0	0.002
4-MID	<1.0	<0.20	0.56	<5.0	<0.0002
4-SURF	<1.0	<0.20	0.34	<5.0	0.00020
5-BOT	<1.0	<0.20	<0.20	<5.0	0.00024
5-MID	<1.0	<0.20	<0.20	<5.0	<0.0002
5-SURF	<1.0	<0.20	<0.20	<5.0	0.00038
5-SURF-DUP	<1.0	<0.20	<0.20	<5.0	0.00054
6-BOT	<1.0	<0.20	<0.20	<5.0	<0.0002
6-MID	<1.0	<0.20	<0.20	<5.0	0.00023
6-SURF	<1.0	<0.20	<0.20	<5.0	<0.0002
7-BOT	<1.0	<0.20	<0.20	<5.0	0.00033
7-MID	<1.0	<0.20	<0.20	<5.0	0.00027
7-SURF	<1.0	<0.20	<0.20	<5.0	0.00027
8-BOT	<1.0	<0.20	<0.20	<5.0	<0.0002
8-MID	<1.0	<0.20	<0.20	<5.0	0.00167
8-SURF	<1.0	<0.20	<0.20	<5.0	0.00073
9-BOT	<1.0	<0.20	<0.20	<5.0	<0.0002
9-MID	<1.0	<0.20	<0.20	<5.0	0.00034
9-SURF	<1.0	<0.20	<0.20	<5.0	<0.0002
10-BOT	<1.0	<0.20	3.46	<5.0	0.00028
10-MID	<1.0	<0.20	0.29	<5.0	<0.0002
10-SURF	<1.0	<0.20	<0.20	<5.0	<0.0002
11-BOT	<1.0	<0.20	5.46	6.0	<0.0002
11-MID	<1.0	<0.20	4.15	<5.0	0.00026
11-SURF	<1.0	<0.20	<0.20	<5.0	0.00028
12-BOT	<1.0	<0.20	0.27	<5.0	0.00043
12-MID	<1.0	<0.20	0.28	<5.0	<0.0002
12-SURF	<1.0	<0.20	<0.20	<5.0	0.00025
12-SURF-DUP	<1.0	<0.20	<0.20	<5.0	<0.0002
13-BOT	<1.0	<0.20	0.47	<5.0	<0.0002
13-MID	<1.0	<0.20	0.66	<5.0	<0.0002
13-SURF	<1.0	<0.20	<0.20	<5.0	0.0002
14-BOT	<1.0	<0.20	0.70	<5.0	0.00023
14-MID	1.0	<0.20	0.29	<5.0	<0.0002
14-SURF	<1.0	<0.20	<0.20	<5.0	0.00065

Notes:
µg/L – microgram per liter

Table A.6-4. Laboratory results for total metals concentrations from water column profile sites in Boundary Reservoir (March 2008 sampling).

SAMPLE ID	Total Arsenic (µg/L)	Total Cadmium (µg/L)	Total Lead (µg/L)	Total Zinc (µg/L)
1-BOT	1.1	<0.20	<0.20	7.0
1-MID	<1.0	<0.20	<0.20	5.0
1-SURF	1.1	<0.20	<0.20	<5.0
2-BOT	<1.0	<0.20	<0.20	<5.0
2-MID	<1.0	<0.20	<0.20	5.0
2-SURF	<1.0	<0.20	<0.20	6.0
3-BOT	<1.0	<0.20	<0.20	5.0
3-MID	<1.0	<0.20	<0.20	5.0
3-SURF	<1.0	<0.20	<0.20	5.0
4-BOT	<1.0	<0.20	<0.20	6.0
4-MID	<1.0	<0.20	<0.20	5.0
4-SURF	<1.0	<0.20	<0.20	6.0
5-BOT	<1.0	<0.20	0.26	5.0
5-MID	<1.0	<0.20	<0.20	5.0
5-SURF	<1.0	<0.20	<0.20	6.0
5-SURF-DUP	<1.0	<0.20	<0.20	5.0
6-BOT	<1.0	<0.20	<0.20	<5.0
6-MID	<1.0	<0.20	<0.20	6.0
6-SURF	<1.0	<0.20	<0.20	6.0
7-BOT	<1.0	<0.20	0.26	7.0
7-MID	<1.0	<0.20	<0.20	7.0
7-SURF	<1.0	<0.20	<0.20	9.0
8-BOT	<1.0	<0.20	<0.20	7.0
8-MID	<1.0	<0.20	<0.20	6.0
8-SURF	<1.0	<0.20	<0.20	6.0
9-BOT	<1.0	<0.20	<0.20	6.0
9-MID	<1.0	<0.20	<0.20	5.0
9-SURF	1.0	<0.20	<0.20	<5.0
10-BOT	1.0	<0.20	12.50	14.0
10-MID	<1.0	<0.20	1.03	6.0
10-SURF	<1.0	<0.20	<0.20	6.0
11-BOT	<1.0	<0.20	17.30	17..0
11-MID	<1.0	<0.20	11.20	12.0
11-SURF	<1.0	<0.20	<0.20	<5.0
12-BOT	<1.0	<0.20	0.64	7.0
12-MID	<1.0	<0.20	0.21	6.0
12-SURF	1.0	<0.20	<0.20	7.0
12-SURF-DUP	1.0	<0.20	<0.20	6.0
13-BOT	<1.0	<0.20	0.61	6.0
13-MID	<1.0	<0.20	1.42	7.0
13-SURF	<1.0	<0.20	<0.20	<5.0
14-BOT	1.0	<0.20	1.40	6.0
14-MID	<1.0	<0.20	0.44	16.0
14-SURF	<1.0	<0.20	<0.20	<5.0

Note:
µg/L – microgram per liter