Continental Mine:
2003 Impact Assessment

Prepared for
Environmental Protection Division
Ministry of Environment
Kootenay Region

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EXECUTIVE SUMMARY

During 2003, the B.C. Ministry of Environment (MoE, formerly Water, Land and Air Protection), Environmental Protection Branch, in partnership with U.S. Department of Agriculture Forest Service, Region 1 collected data concerning surface water and sediment quality and macroinvertebrates from Boundary Creek. Integrated Ecological Research prepared this report for MoE in order to provide baseline data for long-term monitoring of the Continental Mine reclamation work

Water and sediment quality and macroinvertebrate data were collected from sites downstream of Continental Mine. Water and sediment quality data were compared to MoE guidelines. Benthic macroinvertebrate assemblages were evaluated upstream and downstream from impacts of the mine.

Surface Water Quality

Metal levels in the water of Boundary Creek decreased with increasing distance downstream from Blue Joe Creek indicating contamination from the Continental Mine.

Lead levels in water exceeded MoE guidelines for aquatic life at all sites downstream of impacts from the mine at least once during the study. In surface water, the MoE maximum (0.0139 mg/L) and 30-day average (0.004 mg/L) guidelines for lead were exceeded at sites closest to the potential downstream impacts from the mine (BC-1A, BC-1B, BC-2, BC-3 in June/July) on Boundary Creek in June/July and September 2003. Sites BC-3 (September), BC-4 (far-field sites) and the Wildlife refuge site (WR-1) were below maximum but above the 30-day average guidelines. At the control site, lead levels were below both guidelines in June/July and September monitoring sessions.

Lead levels in the Kootenay River water at the mouth of Boundary Creek were below MoE maximum guidelines of (0.082 mg/L) in June/July and September. Lead levels exceeded MoE 30-day average guidelines of 0.006 mg/L in June/July but were below these levels in September.

Total lead levels in Kootenay River at Environment Canada / MoE water quality monitoring station were generally below MoE guidelines for aquatic life. The 90^{th} percentiles calculated by decade from 1985-2005 were below (30-day average) guidelines of 4 μg/L (at hardness of 30 mg/L) and 7 μg/L (at hardness of 140 mg/L) for aquatic life and 10 μg/L for drinking water. Lead levels were significantly correlated with turbidity levels at this site.

Total zinc levels at site BC-1A were above the MoE maximum guideline (0.033 mg/L) in June/July and September monitoring periods. In September site BC-1B was below the MoE maximum guideline (0.033 mg/L) but above MoE 30-day guideline (0.0075 mg/L). Site KR-1 (September) was below the MoE maximum guideline (0.04 mg/L) but above the 30-day average guideline (0.015 mg/L MoE 30-day). Other sites were at or below detection (0.01 mg/L). However, the detection levels for total zinc were not low enough to assess whether these sites were below the MoE 30-day average guidelines.

Cadmium levels in surface water exceeded the MoE maximum guidelines (0.00001 mg/L) at all sites on Boundary Creek except at BC-1, where levels were below detection. The Boundary Creek Wildlife Refuge site, WR-1, also exceeded the MoE maximum guideline. On Kootenay River, cadmium levels at site KR-1A exceeded the MoE maximum guideline (0.00003 mg/L) in June/July but were below this guideline in September. Site KR-1 was below detection during both monitoring periods. The detection levels (0.0001 mg/L) were not low enough to assess MoE 30-day guidelines at KR-1 and BC-1.

Sediment Quality

Lead levels in sediment exceeded the Probable Effects Level (PEL) of the US National Oceanic and Atmospheric Administration (NOAA) of 91 μg/g and the MoE Interim Sediment Quality Guideline (ISQG) of 35 μg/g at all sites downstream of Blue Joe Creek. The only exceptions were KR-1 (below both guidelines) and KS-2 (exceeded MoE ISQG only). The control site, BC-1, also exceeded PEL during the June/July monitoring period but was below guidelines in September.

Zinc levels in depositional sediment exceeded PEL (315 μg/g) only at the floodplain site KS-1. However, zinc levels exceeded the lower MoE ISQG guideline of 123 μg/g at sites BC-1A (both sessions), BC-1B (September only), and sites, BC-3, KS-1 and KS-2, when monitored in June/July.

Concentrations of cadmium in sediment were below PEL of 3.5 μg/g at all sites in June/July and September monitoring periods. In addition, cadmium levels in June/July were below or at detection at all sites (2 μg/g). KS-1 was the only site that was above detection and the ISQG guideline of 0.6μg/g. Cadmium detection limits were lower in September sampling (0.02 μg/g) and allowed comparison with the MoE ISQG of 0.60 μg/g. Levels of cadmium exceeded this guideline at sites BC-1A and BC-1B.

Copper levels in sediment were below PEL of 197 µg/g at all sites. Copper levels exceeded the lower MoE ISQG of 36 µg/g at sites BC-1A and KS-1 in the June/July sampling period. Copper levels exceeded MoE ISQG at sites BC-1A, and BC-1B in September.

Mercury levels in sediment were below PEL of 0.846 µg/g at all sites, except BC-1A and KS-1 in June/July. Levels of mercury at BC-1A (September), BC-1B (September) and BC-3 (June/July) exceeded MoE ISQG but were below PEL. Other sites were below detection (0.2 µg/g), which was only slightly greater than MoE ISQG.

Cumulative toxic units

Cumulative toxic units (CTU) were used to assess potential impacts from the Continental Mine on the mortality of macroinvertebrates and community structure. Levels of CTU greater than one indicate potentially adverse effects to the biota.

For water samples, the upstream control site had a value of 0.4 CTU in both June/July and September. Sites BC-1A, BC-1B, BC-2 had CTU values ranging from 1-5.8 CTUs in June/July and September. Site 4 water samples had CTU values of 0.7 in both June/July and September.

Of the sediment samples, site BC-1A showed the highest CTUs (16.6 in June/July and 15.9 CTUs in September). Sites BC-1B, BC-2, BC-4 had CTU values ranging 1.8-8.7 CTUs in June/July and September. The control site (BC-1A) had a CTU value in sediment of 2.3 CTU in June/July and 0.25 in September.

Macroinvertebrates

General linear modelling (GLM) analysis showed that there was; (1) a significant decrease in density of metal sensitive mayflies when comparing the control site to treatment sites downstream of Blue Joe Creek, (2) an increase in density of metal sensitive mayflies with increasing distance from mine, and (3) a decrease in density of metal sensitive mayflies with increasing levels of CTU.

In addition, the density of EPT/Total was significant when testing the upstream/control site BC-1 against other treatment sites downstream of Blue Joe Creek. Significant increases in the EPT/Total density ratio downstream of the impacts of mining were likely due in part to increases in the metal tolerant species *baetis sp*. when compared with the upstream control.

Sites closest to the mine (BC-1A, BC-1B and BC-2) also had mean densities of metal sensitive mayflies at sites that were well below control sites in the Coeur d'Alene and St. Regis River basins.

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ACKNOWLEDGEMENTS

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Darcie Quamme of Integrated Ecological Research conducted project management, data analysis and reporting. John Boulanger of Integrated Ecological Research carried out statistical analyses and reporting of results. Kara Sundberg of Integrated Ecological Research helped with the data analysis and graphing.

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1 INTRODUCTION

The Continental Mine Impact Assessment was conducted for the British Columbia Ministry of Environment (MoE, formerly Water, Land and Air Protection), Environmental Protection Division to determine if the Continental Mine, a historic lead/silver mine located in northern Idaho, had adverse impacts on the aquatic ecosystems of Boundary Creek and the Kootenay River. The mine operated from 1890 until the 1940's and resulted in the deposition of tailings along the banks and directly into US-based Blue Joe Creek. Mining operations also lead to metal contamination of the water and sediments within Blue Joe Creek, Boundary Creek, and possibly, the Kootenay River. This project was carried out in collaboration with United States Department of Agriculture (USDA) Forest Service, Region 1.

1.1 Background

The Continental Mine is located on Blue Joe Creek in northwest Boundary County, Idaho (Figure 1). This mine was productive as a lead-silver mine mainly from 1890 until the 1940’s. Limited exploration and production continued until 1980. Initially, ore was removed by surface mining along the bulk of the mineralization. Later, it was removed by underground stoping methods.

Currently, the lead-silver mine is inactive. There is only one building structure left on-site and only outdoor enthusiasts and hunters currently use the lands, primarily for recreation.

The mine generated 70,000 cubic yards of jig and flotation tailings during production periods. These tailings were impounded behind a crib dam across Blue Joe Creek, which failed in the 1940s, causing much of this material to be distributed downstream to Boundary Creek and beyond.

In 1987, the Idaho National Guard channelled run-off across the tailings and into Blue Joe Creek. In addition, the coarser jig tailings were removed from Blue Joe Creek and placed on top of the flotation tailings. No additional remediation work was carried out until 2003.

In the past, contaminated soils from the mine-waste were not vegetated. As a result, the soils were subject to water and wind erosion. During run-off events in spring and early fall, erosion of the tailings into Blue Joe Creek and Boundary Creek was widespread. During dry weather, typical of summer and fall months, wind erosion further dispersed contaminants throughout the watershed.

Maxim (2002) conducted a study in 2002, which showed widespread lead contamination and deposition of overbank tailings along Blue Joe Creek. This study reported environmental impacts from tailings and mining activities on Blue

Joe Creek, which included: (1) high levels of dissolved lead, cadmium and zinc in surface water; (2) high levels of lead in sediment; (3) elimination of fish population in Blue Joe Creek; (4) reduced macroinvertebrate populations in the stream; and (5) elevated metals in road materials on FR 2546 because tailings were used to surface the road.

In 2003, the US Environmental Protection Agency (EPA) spent $2.5 million US dollars to clean up the Continental Mine Complex. During this five-month reclamation, 105,509 cubic meters of mine waste was consolidated under a protective barrier. In addition, the USDA Forest Service removed 27,210 metric tonnes of overbank deposits along 10.4 km of Blue Joe Creek from June-September 2003 (pers. com. Jim Nieman).

In the next phases of the remediation work (2005/2006) by the USDA Forest Service, overbank deposits will be removed from the remaining 500 meters of lower Blue Joe Creek. In addition, the streambed will be screened and contaminated fines will be stored in a protective repository.

1.2 Monitoring Objectives

In September 2003, the B.C. MoE conducted a coordinated environmental monitoring program with the USDA Forest Service. The environmental monitoring program corresponded with the first stages of remediation at the mine site and included the collection of water, sediment, and benthic invertebrate samples. These data were intended to provide initial "baseline" information that will be compared with samples collected following the completion of remedial work at the site and long-term recovery.

More specifically, the program aimed to promote an understanding and appreciation of the water quality and biological health of the Boundary Creek watershed and downstream waters.

General Objective:

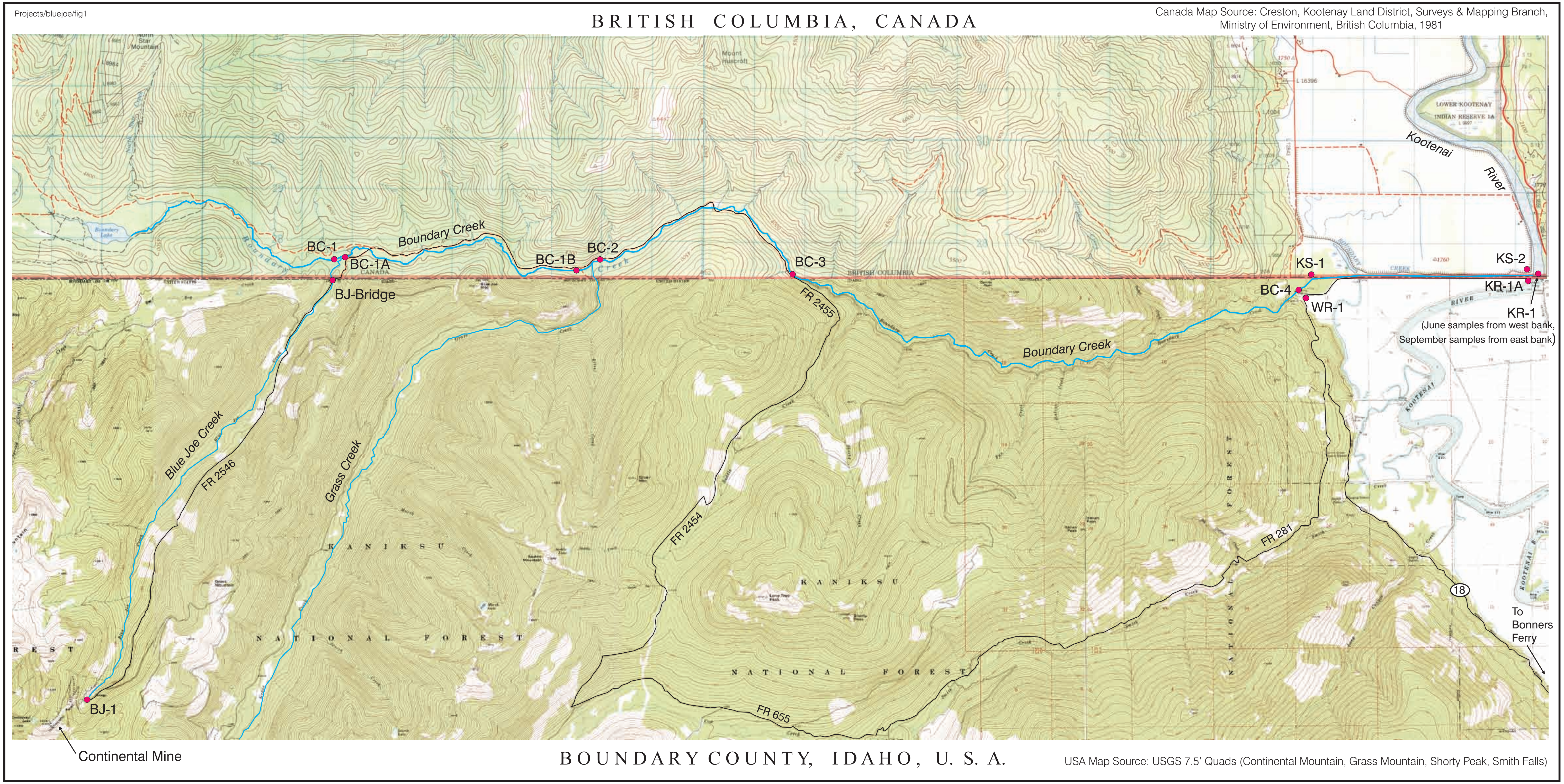
The objective of the monitoring program was to monitor the watershed condition, including water and sediment quality parameters and macroinvertebrate assemblages during the initial stages of the remediation of Continental Mine in order to track the long-term recovery of Boundary Creek and downstream waters.

The specific objectives of the initial program were to:

- Assess sediment quality in Boundary Creek at five sites collected in 2003 and compare to applicable B.C. and US guidelines and standards.
- Interpret water quality data from the federal/provincial monitoring station on the Kootenay River at Creston to assess if there are far-field downstream impacts to water quality.

- Evaluate macroinvertebrate assemblages collected at five locations in 2003 from Boundary Creek using appropriate metrics and statistics with respect to impacts from mining.
- Interpret the USDA Forest Service Baseline Monitoring Report by Maxim (2004) with respect to the above data.

The following report provides a compilation and interpretation of water quality and quantity data collected from Boundary Creek during 2003.



2003

BJ-1 • Sampling Station (approximate location)

(18) Boundary County Road (Idaho)

FR 655 Forest Route (USA)

NOTE: BJ-Bridge also referred to as BJ-Boundary Bridge

N

0 Feet 6600

MAXIM 2570264

Figure 1. Boundary Creek monitoring stations. Map from Maxim (2004).

2 METHODS

USDA Forest Service and MoE conducted environmental monitoring in the Boundary Creek drainage as a joint effort. Monitoring included two sampling periods on June 30/July 1, and September 23/24, 2003. Monitoring efforts included water quality and quantity, sediment quality, and macroinvertebrate communities. Details of monitoring are provided in Table 1.

Table 1. Summary of 2003 environmental monitoring to assess impacts from Continental Mine.

Parameters	Sampling periods	Responsible agency	Location of sampling sites
Water quality and physical parameters	June/July 2003 Sept. 2003	USDA Forest Service/Maxim	Blue Joe Creek, Boundary Creek, Kootenay River and Boundary Creek Wildlife Refuge (BCWR)
Sediment quality	June/July 2003	USDA Forest Service/Maxim	Blue Joe Creek, Boundary Creek, Kootenay River, BCWR, and Floodplain areas
	Sept. 2003	B.C. MoE	Boundary Creek
Macroinvertebrates	Sept. 2003	B.C. MoE	Boundary Creek

2.1 Site Locations

Boundary Creek drains Boundary Lake, which is upstream of the confluence of Blue Joe Creek and Boundary Creek. Boundary Creek in turn flows into the Kootenai/Kootenay River at the border between B.C. and Idaho (Figure 1). Stream characteristics are summarized in Table 2.

Table 2. Characteristics of Boundary Creek[1].

Measure	Boundary Ck.
Watershed code	340-491900
Stream Order	3rd
Stream Length	22.14 km
Number of Water Licences	2
Aspect	SE
Fish presence[1]	***Boundary Creek***- rainbow trout, brook trout, longnose sucker, westslope cutthroat trout, torrent sculpin, bull trout, burbot ***Tributary-Meadow Creek***- rainbow trout, brook trout, kokanee, westslope cutthroat trout ***Tributary-North Star Creek***- rainbow trout

[1] DFO and B.C. Fisheries Information Summary System (2005)

Several sites within Boundary Creek and the Kootenay River were monitored for water, sediment and/or macroinvertebrates. These sites are shown in Figure 1 and details for the Boundary Creek sites are provided in Table 3. Details for other sites locations are provided in Maxim (2004).

Site BC-1 was selected as an upstream/control and is located immediately upstream of the confluence of Blue Joe Creek and Boundary Creeks. Site BC-1A was located immediately downstream of the confluence of Blue Joe Creek and Boundary Creeks and was selected to reflect near-field conditions.

Other sites were selected further downstream in Boundary Creek to assess impacts at increasing distance from the mine site. BC-1B was located near a bridge, 200 m upstream of the confluence of Grass Creek and Boundary Creek. BC-2 was located approximately 250 m below confluence of Grass Creek and Boundary Creek. This site was located upstream of a clearcut to ensure impacts related to forestry did not confound those expected from Continental Mine. BC-4 is located approximately 250 m downstream of the bridge by the Boundary Creek gauging station. This site was also upstream of agricultural runoff and potential agricultural impacts on biota.

Table 3. Locations of Boundary Creek monitoring stations sampled June/July and September 2003.

	STATION				
	BC-1 (control)	**BC-1A**	**BC-1B**	**BC-2**	**BC-4**
B.C. Environmental Monitoring Station (EMS) #	E253490	E253491	E253492	E253493	E253494
GPS Coordinates	N49'00.197 W116'49.597	N49'00.191 W116'49.579	N49'00.086 W116'45.592	N49'00.186 W116'45.376	N48'59.799 W116'34.150
Distance from Mine (km)	10.1	10.1	10.4	17.4	33.8

2.2 *Water Quality and Quantity*

Maxim Technologies Inc. under contract to the USDA Forest Service collected all the water samples from Boundary Creek. Details of sample collection methods are provided in Maxim (2004).

In addition, water quality data from the Federal-Provincial trend site located on the Kootenay River at Creston (federal # BC08NH0005; B.C. # E206587) were used for this report. This trend station is operated by Environment Canada and MoE and is located approximately 15 km downstream of Boundary Creek and 5 km west of Creston, B.C.. Various parameters have been monitored at this site since 1979 and data for these variables were downloaded from the Environment Canada water quality website (Environment Canada 2005).

2.3 Sediment sampling

Sediment was collected within Boundary Creek and the Kootenay River in June/July and September.

Maxim Technologies Inc. collected sediment samples during the June/July collection period and sampling methods and quality assurance techniques are provided in Maxim (2004).

The September sediment sampling was done by MoE at the five Boundary Creek sites and included both riffle and depositional sediments. At each site, sediment was collected from riffle areas and submitted for analysis of grain size, moisture and organic carbon. Sediment was also collected from depositional areas and analysed for grain size, total metals including mercury, total organic carbon, and moisture.

MoE collected samples with a stainless steel spoon and were homogenized in a stainless steel bowl. Sampling equipment was decontaminated with liqinox soap and deionized water after collecting each sample. All samples were placed in a cooler with ice following collection and were submitted to PSC Analytical Services (Burnaby, B.C.) within recommended holding times for analysis. Laboratory analysis was conducted according to standard methodologies.

2.4 Benthic macroinvertebrates

Benthic invertebrates were collected on September 24 and 25 at five sites within Boundary Creek to identify possible changes in abundance or community structure related to mine discharges. A Hess sampler (mesh size 210 µm, area 0.642 m2) was used to collect invertebrates from riffle habitats at each sample site. Five replicates were collected per site in riffles with adequate flows and gravel/cobble substrates. Sampling always began at downstream locations and progressed upstream with each successive replicate.

The sampler was placed on the streambed and larger rocks were brushed and removed from the sampler first. Remaining gravels were then disturbed by hand to a depth of 0.05-0.10 m for a period of five minutes. All organisms were rinsed from the net into a sampling jar and were preserved in the field using formalin.

Samples were placed in a cooler and were submitted to Fraser Environmental Services in Vancouver for taxonomic identification. In the laboratory, macroinvertebrates were washed and decanted from sediments, detritus and preservative. Benthos was sorted using a dissecting microscope (10-40× magnification) and macroinvertebrates were removed from detritus and sediment.

Individuals were identified to the generic level wherever possible, and to broader levels (e.g., family, order) depending on the size and quality of the specimen. Identified taxa were preserved in 70% ethyl alcohol in glass vials. Vial lids were airtight fit and appropriately labelled. Quality assurance checks were done on 10% of the samples to ensure sorter accuracy. All individual organisms were counted and no sub-sampling was done.

2.5 Data Analysis

2.5.1 Water and sediment quality

Baseline water quality information was compared to maximum and 30-day average B.C. provincial guidelines (MoE 2001a, Appendix 8.1). These guidelines provide safe levels of substances for the protection of aquatic life.

The metals in stream sediment were compared to MoE working guidelines (adopted from other North American jurisdictions but currently under assessment, Appendix 8.3) including: the MoE Interim Sediment Quality Guideline (ISQG) developed by Environment Canada (ISQG 1995) and the Probable Effects Levels (PEL) for freshwater stream sediment developed by the US National Oceanic and Atmospheric Administration (NOAA 1999). These standards were adopted as a component of the B.C. provincial guidelines for stream sediment. Sediment chemical concentrations below the ISQG are not expected to cause adverse biological effects. Concentrations above the PEL may be frequently associated with adverse biological effects (ISQG 1995).

2.5.2 Biometrics

Macroinvertebrate data was initially screened using the US EPA's Rapid Bioassessment III (Plafkin et al. 1986). This screening process resulted in ratings of "non-impaired" to "slightly impaired" for all sites (Appendices 8.5-8.8).

As a result, a more detailed and specific assessment of the impact of upstream/downstream effects of metals from Blue Joe Creek, distance from mine site, and levels of cumulative toxic units (CTU) on various biometrics sensitive to impacts from mining was undertaken. These biometrics and their descriptions are provided in Table 4.

Metal sensitive mayfly taxa were defined as taxa that have very low tolerance to metal pollution. McGuire (2001) gives tolerance values for mayflies and other taxa. Mayflies with tolerance values less than two tend to drop out of macroinvertebrate community when metal pollution is present.

Table 4. Biometrics used in analyses of macroinvertebrate assemblages.

Biometric	Measure	Description
Total abundance/ density	Production	Indicator of stream health, production of food for other organisms such as fish
Density of EPT taxa	Biotic condition	Density of sensitive EPT taxa, including mayflies (E), stoneflies (P) and caddisflies (T), indicators of high water quality
Density of mayflies (Ephemeroptera)	Biotic condition	Density of sensitive taxa, indicators of high water quality
Density of metal sensitive (MS) mayflies	Tolerance to metal pollution	Low densities of mayflies with low tolerance to metals (Tolerance values <2) indicate impacts from heavy metal pollution
Total number of taxa[1]	Taxonomic richness	Indicates health of the community, reflects increasing water quality, habitat diversity and suitability
Number of EPT taxa	Taxonomic richness	Number of sensitive EPT taxa; indicators of good water quality
EPT/total taxa[1]	Taxonomic richness	Abundance ratio of sensitive EPT taxa to total number of taxa
Number of mayfly taxa	Taxonomic richness of mayflies	Number of sensitive mayfly taxa may indicate metal pollution
Number of MS mayfly taxa	Taxonomic richness of MS mayflies	Number of MS mayfly taxa indicate metal pollution

[1]from Plafkin *et al*. 1989

2.5.3 Evaluation of the toxicity of water and sediment

Cumulative toxicity units (CTUs) were used to describe the effects of metals on the aquatic community. CTU was selected because it best explains the additive effect of mixtures of metals resulting from mine waste. In contrast, water quality guidelines and criteria indicate the level at which individual metals may cause harm to aquatic biota. However, mixtures of metals show additive effects at chronic levels on aquatic organisms and CTUs incorporate this effect. A CTU value of one is a conservative estimate of the chronic criteria/guideline for metals of most concern on Boundary Creek (lead, zinc and cadmium).

Metal concentrations that are two to ten times criterion values (or 2-10 CTUs) are thought to influence community structure and cause mortality in sensitive species Above ten times criterion values (>10 CTUs) metal concentrations are considered significantly polluted (Clements et al. 2000).

Cumulative toxic units (CTU) were used to evaluate the additive effects of mixtures of toxic heavy metals on assemblages of macroinvertebrates. The cumulative toxic unit was calculated as:

$$CTU=\Sigma m_i/c_i$$

Where m_i is the dissolved metal concentration and c_i is the criterion value for the ith metal similar to Clements et al. (2000) and Maret et al. (2003).

Three metals were used in the calculations including lead, zinc and cadmium. These metals were selected because they were of highest concentrations and greatest ecological concern. US EPA acute water quality criteria for the protection of aquatic life were used as criteria in the calculations of CTU for water. The US National Oceanic and Atmospheric Administration (NOAA) screening values were used for CTU from sediment samples. US EPA- developed criteria were used in these calculations in order to compare the present study to a broader survey of the effect of hard-rock mining on macroinvertebrate assemblages in the Coeur d'Alene and St. Regis River basin in Idaho and Montana (Maret et al. 2003).

2.5.4 Statistics

Distance from mine site and CTU concentration were naturally confounded predictors. CTU and metals concentrations decreased with increasing distance downstream from mine site. Therefore, this precluded the joint modeling of these two predictors with one model. As a result, two models were used with the data. First, an analysis of covariance model was used to test for differences in the response of various biometrics between upstream and downstream sites while controlling for the position of sampling stations on the river (i.e., upstream or downstream from Blue Joe Creek) (Milliken and Johnson 2002).

$$\text{Biometric} = \beta_{\text{intercept}} + \beta_{\text{distance from mine site}} + \beta_{\text{upstream/downstream}} + \text{error}$$

Interactions between distance from mine site and upstream/downstream position of sites could not be tested, as there was only one control site upstream of Blue Joe Creek.

Second, a regression model that tested only the effect of CTU concentration on each macroinvertebrate biometric was used to test for an association between CTU and each biometrics.

$$\text{Biometric} = \beta_{\text{intercept}} + \beta_{\text{CTU}} + \text{error}$$

The statistical method used to analyze the data depended on the type of response variables. Standard least-squares based analysis of covariance was used when the response variables were densities or proportions. Densities were log-transformed to help meet the assumption of equal response variable variances (Zar 1996). Poisson regression was used for taxa count data. Poisson regression is ideally suited for count data in that it assumes that variance of counts is proportional to the mean (which is usually the case with count data). In addition, it is robust to non-normality of zero count data (McCullough and Nelder 1989). The analyses were carried out using the general linear modelling procedures (PROC GLM) and the generalized linear models (GENMOD) in SAS (Statistical Analysis Software Institute 2000). Significance of predictor variables was tested using type 3 F-tests (GLM) or type 3 likelihood ratio tests (GENMOD) tests which are robust to the ordering of variables in models (SAS Institute 2000). Biometrics were considered significant at α=0.05.

3 RESULTS AND DISCUSSION

3.1 Water Quality

Of the thirteen metals analyzed (data from Maxim 2004) cadmium, lead and zinc were the main parameters that consistently exceeded B.C. water quality guidelines to protect aquatic life. Dissolved metals in water generally followed comparable trends to total metals. Selected water quality parameters and flow for each site are given in Table 5.

Water samples collected in June/July and September 2003 showed that levels of cadmium lead and zinc were greatest immediately downstream of Blue Joe Creek and lowest in the upstream control (Figure 2-4). The levels in Boundary Creek attenuated with distance downstream from the creek indicating contamination from the Continental Mine.

Hardness dependent guidelines were calculated using 25 mg/L hardness values for Boundary Creek and the Boundary Creek Wildlife Reserve. Hardness dependent guidelines for the Kootenay River were calculated using 100 mg/L hardness values.

The MoE guideline for aquatic life for lead (maximum, 0.0139 mg/L) and (30-day average, 0.004 mg/L) were exceeded at sites BC-1A, BC-1B and BC-2 and site BC-3 (June/July only) (Figure 2).

In addition, sites BC-3 (September), BC-4 (June/July) and WR-1 (June/July) were below MoE maximum guidelines but above the MoE 30-day average guidelines. Lead levels at site BC-4 in September were below both the MoE maximum and 30-day average guidelines. At the control site, lead levels were below both MoE maximum and 30-day average guidelines during June/July and September monitoring sessions.

Lead levels in the Kootenay River water were below MoE maximum guidelines of (0.082 mg/L) in June/July and September. Lead levels exceeded MoE 30-day average guidelines (0.006 mg/L) in June/July but were below these levels in September.

Total zinc levels in water were below MoE maximum guidelines at all sites on Boundary Creek and the Wildlife Refuge except BC-1A. At this site, total zinc levels were above the MoE maximum guideline (0.033 mg/L) and MoE 30-day average guideline the (0.0075 mg/L) (Figure 3). In September site BC-1B was below the MoE maximum guideline but above MoE 30-day guideline. Site KR-1 (September) was below the MoE maximum guideline (0.04 mg/L) but above the 30-day average guideline (0.015 mg/L MoE 30-day).

Other sites including; BC-1, BC-2, BC-3, BC-4, WR-1, KR-1 (in June/July), and KR-1A were below or at detection (0.01 mg/L). As a result, it was not possible to assess whether levels were below 30-day average guidelines because the detection levels for total zinc were not low enough.

Cadmium levels in surface water of Boundary Creek (Figure 4) exceeded Moe guidelines at all sites downstream of Blue Joe Creek (0.00001 mg/L MoE working guideline). The levels of cadmium at the Wildlife refuge monitored only in June/July also exceeded this guideline. At the control site (BC-1A) cadmium levels were below detection (0.0001 mg/L), but the detection levels were not low enough to compare with the guideline.

Cadmium levels on the Kootenay River exceeded MoE guidelines at KR-1A in September (0.00003 mg/L). Levels of cadmium were below detection at KR-1A during June/July and KR-1 during both sampling periods. However, detection levels (0.0001 mg/L) were not low enough to compare with MoE guidelines.

Table 5. Selected characteristics of Boundary Creek, Kootenay River, and Boundary Creek wildlife refuge area monitoring sites[1].

		Boundary Creek						**Kootenay River**		**Wildlife Refuge**
Station	**Month sampled**	**BC-1**	**BC-1A**	**BC-1B**	**BC-2**	**BC-3**	**BC-4**	**KR-1**	**KR-1A**	**WR-1**
Flow (cfs)	*June/July*	15.11	43.96	NS	103.09	NS	149			1.34
	Sept.	3.28	8.05	5.4	12.79	18.1	31.53			NS
Specific Conductance (µs/cm)	*June/July*	46.3	6.8	NS	0.7	0.8	1.0	161.1	156.8	0.6
	Sept.	47.8	24.1	23.6	13	11.8	12.2	125.9	125.4	NS
Dissolved Oxygen (mg\l)	*June/July*	11.21	12.02	NS	11.23	11.2	11.7	11.1	11.3	11.24
	Sept.	11.4	11.7	10.85	11.1	10.75	11.76	9.8	10.30	NS
pH	*June/July*	7.36	7.16	NS	7.23	7.27	7.27	8.01	8.13	7.41
	Sept.	7.67	7.83	7.67	7.44	7.65	7.65	8.50	8.55	NS
Hardness	*June/July*	44	23	NS	12	12	8	45	105	8
	Sept.	60	35	35	26	21	23	102	102	NS

[1]Data from Maxim 2004; NS –not sampled; Boundary Creek (BC), Kootenay River (KR), and Boundary Creek wildlife refuge area (WR)

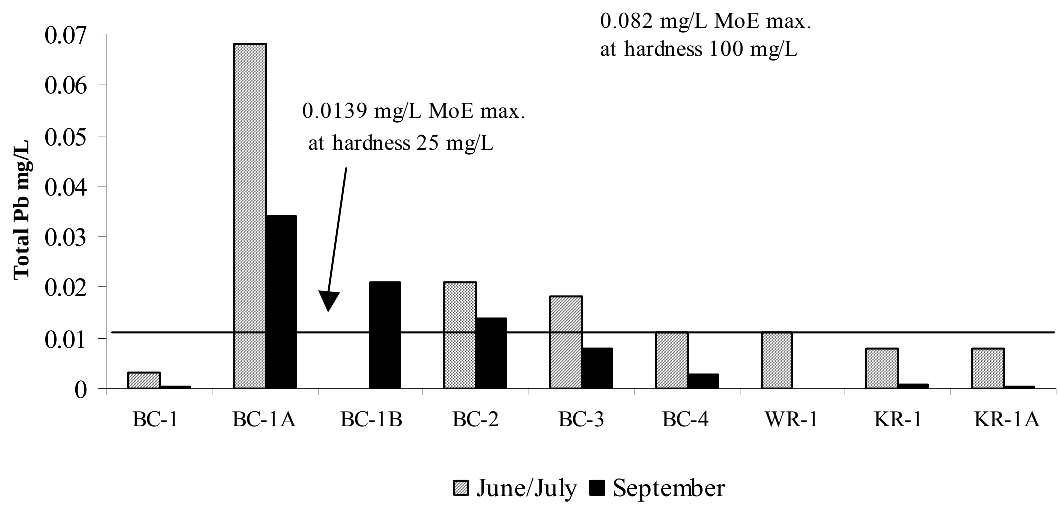


Figure 2. Lead concentration in Boundary Creek (BC), Boundary Creek Wildlife Refuge (WR) and the Kootenay River (KR). The solid line indicates B.C. MoE maximum guidelines for aquatic life (0.0139 mg/L) for Boundary Creek and the wildlife refuge (hardness 25 mg/L). B.C. MoE maximum guidelines for aquatic life (0.082 mg/L) for Kootenay River are not shown due to scale (hardness 100 mg/L).

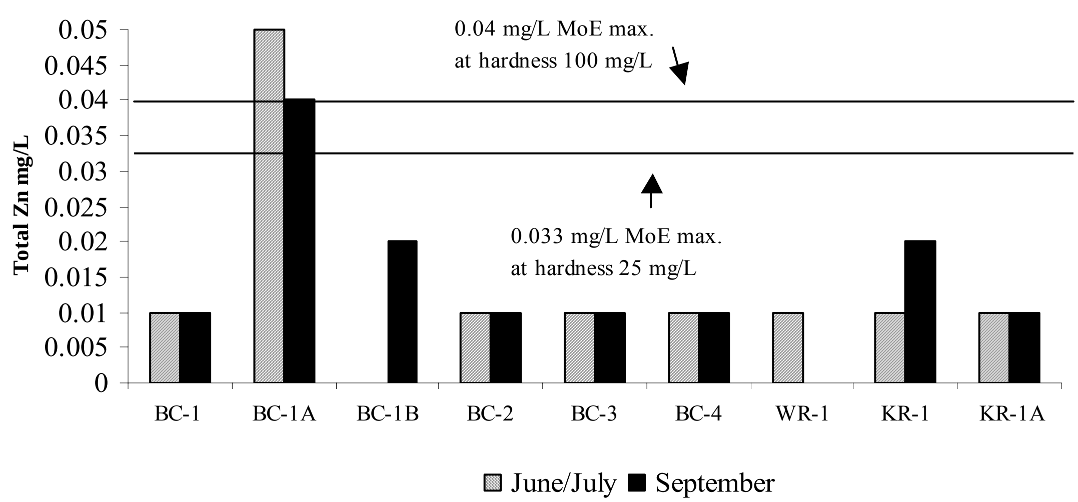


Figure 3. Zinc concentration in Boundary Creek (BC), Boundary Creek Wildlife Refuge (WR) and the Kootenay River (KR). The solid lines indicate MoE maximum guidelines for aquatic life (0.033 mg/L) for Boundary Creek and the wildlife refuge (hardness 25 mg/L) and maximum guidelines for aquatic life (0.04 mg/L) for Kootenay River (hardness 100 mg/L) .

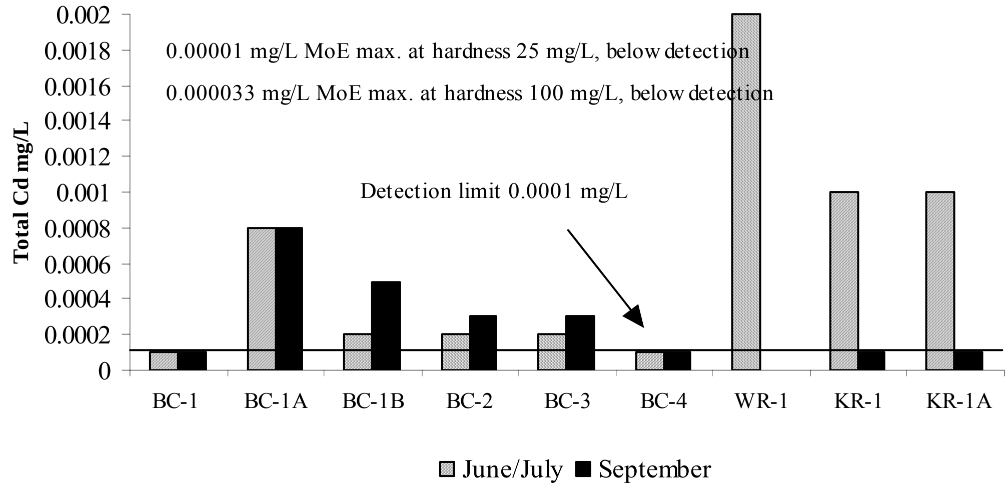


Figure 4. Cadmium concentration in Boundary Creek (BC), Boundary Creek Wildlife Refuge (WR) and the Kootenay River (KR). Guidelines are below the detection limit. The maximum guideline for aquatic life for Boundary Creek and the wildlife refuge (hardness 25 mg/L) is 0.00001 mg/L. The MoE maximum guideline for aquatic life for Kootenay River (hardness 100 mg/L) is 0.000033 mg/L.

3.1.1 Kootenay River Federal-Provincial Trend Station

Lead, zinc and cadmium concentrations were evaluated at the Kootenay River Federal-Provincial water quality trend station (Environment Canada 2005) near Creston to assess downstream impacts to water quality originating from the Continental Mine Complex.

Statistics for lead, cadmium and zinc were summarized by decade so as to compare recent years with past data. In addition, there was a large data gap in total metals levels monitored from 1986-1990 so the data from 1984-85 is summarized separately. Metals concentrations were compared to guidelines that are hardness dependent. Hardness values of 30 mg/L and 140 mg/L were used to bracket the range in hardness observed from 1984-2003 (Table 6).

The 90th percentiles of total lead levels for periods of 1984-85, 1991-1999, and 2000-2005 were well below (30-day average) guidelines of 4 µg/L (at hardness of 30 mg/L) and of 7 µg/L (at hardness of 140 mg/L) for aquatic life and 10 µg/L for drinking water (Table 7). During this time there were only fourteen dates in the entire data set (n=323) that exceeded the lowest MoE guideline of 4 µg/L. All of these dates occurred from February to July during freshet periods.

Table 6. Total hardness levels (mg/L) in Kootenay River from water samples collected at the Federal-Provincial trend station on the Kootenay River at Creston from 1984-2005.

	1984-85	1991-1999	2000-2005
Count	26	202	113
Median	106.5	102.5	107.8
90th percentile	115.5	122	120.8
Min	34	27	28
Max	122	139	127
Interquartile range (IQR)	18.4	27.4	32.1

IQR = 75th percentile minus 25th percentile

Table 7. Total lead levels (μg/L) in Kootenay River from water samples collected at the Federal-Provincial trend station on the Kootenay River at Creston from 1984-2005.

	1984-85	1991-1999	2000-2005
Count	24	198	101
Median	1.0	0.3	0.4
90th percentile	1.7	2.1	1.5
Max	4.0	42.8	8.4
Interquartile range (IQR)	0.0	0.8	0.5

IQR = 75th percentile minus 25th percentile

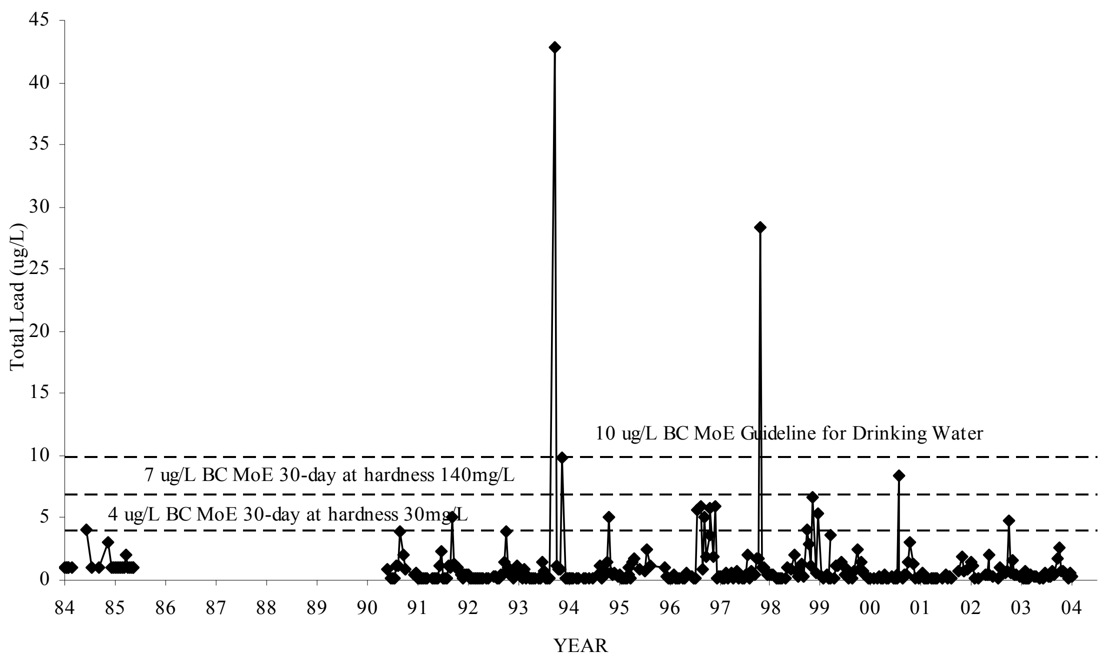


Figure 5. Total lead levels at the Federal-Provincial trend station on the Kootenay River at Creston from 1984 - 2004.

High levels of total lead in water are commonly associated with fine-grain materials of sediment (Figure 6). A significant linear relationship was observed between the logarithm of lead concentration and the logarithm of turbidity at the Federal-Provincial trend station at Creston ($p<0.001$, $r2=0.31$).

Sampling from the Kootenay River trend station suggests that total lead originating from the Continental Mine does not impact water quality on Kootenay River most of the time due to effects of dilution. In recent years only two samples out of ninety-nine days monitored from 2000-05 exceeded the lowest B.C. MoE guideline (30-day) of 4 μg/L. From 1990-99, eleven samples out of one hundred and eighty-seven exceeded the lowest B.C. MoE guideline (30-day) of 4 μg/L and from 1984-85 there were no exceedances. However, impacts on Kootenay River water quality from Boundary Creek will likely be highest during freshet conditions when turbidity is also high.

Contaminated fine-grains originating from Continental Mining activities may have settled in downstream habitats and feeding areas used by macroinvertebrates, fish, migratory birds and mammals of Boundary Creek, the Wildlife Refuge and the Kootenay River. Fine-grain materials can be mobilized great distances downstream over time. There has been little monitoring to date of depositional sediment or suspended sediment in the Kootenay River upstream and downstream of the confluence with Boundary Creek. This kind of data may provide further information on downstream cumulative impacts of the Continental Mine.

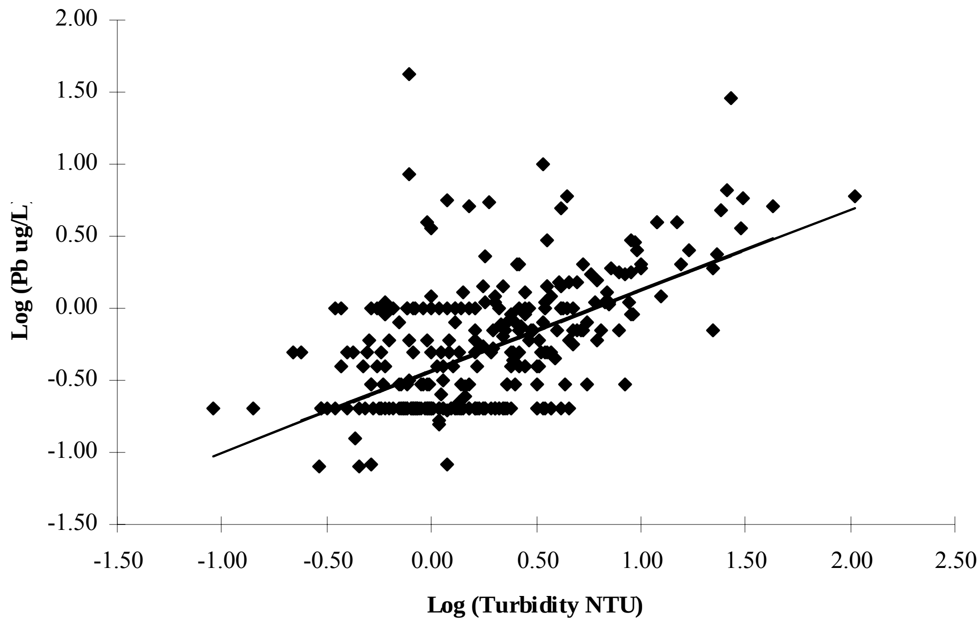


Figure 6. Log (Total lead µg/L) versus log (turbidity NTU) of water samples collected from 1984-2005 at the Federal-Provincial trend station on the Kootenay River at Creston ($y=0.56x-0.4357$, $r^2 = 0.31$, $p<0.001$).

For total zinc, the median of all three periods was well below MoE 30-day average guideline of 7.5 µg/L (at hardness of 30 mg/L) and 45 µg/L (at hardness of 140 mg/L) for aquatic life (Table 8). During the time period of 1984-1985, 84% (n=25) of the water samples were below 7.5 µg/L. Four samples during these years ranged from 7.5-45 µg/L. From 1991-1999, 98.5% (n=201) of the water samples were below 7.5 µg/L. Three samples during this period ranged from 7.5-45 µg/L. From 2000-2005, 99% (n=102) of the water samples were below 7.5 µg/L. Only one sample during this period, ranged from greater than 7.5-45 µg/L.

In addition, no significant positive correlation between log total zinc and log turbidity was observed.

Total zinc originating from the Continental Mine likely has a low impact water quality on Kootenay River during most of the year. In recent years only one sample out of one hundred and two monitored from 2000-05 exceeded the lowest B.C. MoE guideline (30-day) of 7.5 µg/L. From 1990-99, three out of two hundred and one samples exceeded the lowest B.C. MoE guideline (30-day) of

7.5 µg/L and from 1984-85 there were four out of twenty-five samples greater than 7.5 µg/L.

Table 8. Total zinc levels (µg/L) at the Federal-Provincial trend station on the Kootenay River at Creston from 1984-2005.

	1984-1985	1991-1999	2000-2005
Count	25	201	102
Median	6	1.2	0.8
90th percentile	10	3	2.2
Max	25	15.3	10.1
IQR	5	1.1	0.91

Cadmium levels at the Federal-Provincial trend station at Creston were monitored from 1984-2003. From 1984-1985, all values were at the detection limit of 1 µg/L. From 1991-2003, 97% of values were below the detection limit (0.1 µg/L). Eight other values during this period ranged from 0.2-0.5 µg/L over this period.

Note that the detection limits during 1984-2003 are above the MoE maximum guidelines of 0.01 µg/L (at hardness 30 mg/L) and 0.04 µg/L (at hardness 140 mg/L). Consequently, it was not possible to compare values below detection to MoE guidelines.

In March 2003, the detection limit was lowered again to 0.001 µg/L, which permitted comparison with the MoE guidelines. Between March and August 2003, twenty-one values out of thirty-seven exceeded the 0.01 µg/L (at hardness 30 mg/L) but did not exceed the MoE maximum guideline 0.04 µg/L (at hardness 140 mg/L). Only two values exceeded the MoE maximum guideline 0.04 µg/L (at hardness 140 mg/L) during this time. It is difficult to assess what contribution Boundary Creek makes to total cadmium load in the Kootenay River without further work on calculation of loading rates.

Also, the correlation between cadmium and turbidity levels could not be examined because so many of the values were below detection and because the detection limits changed drastically during the monitoring period.

Calculation of loading rates of metals from Boundary Creek to Kootenay River during freshet would allow better assessment of the impact of metals from Boundary Creek on Kootenay River. It would also allow an assessment of the proportion of the metals load in the Kootenay River attributable to Boundary Creek. However, seasonal water quality is lacking for Boundary Creek. Freshet is particularly important time to monitor water quality, as this is when levels of lead are highest and fine-grain sediments are mobilized.

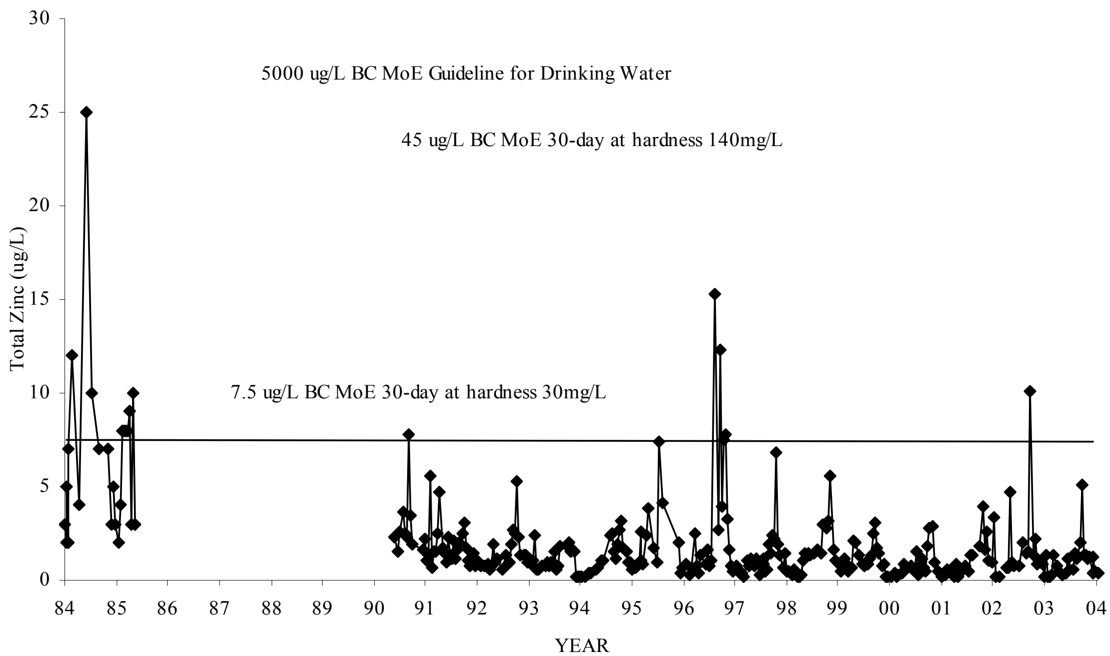
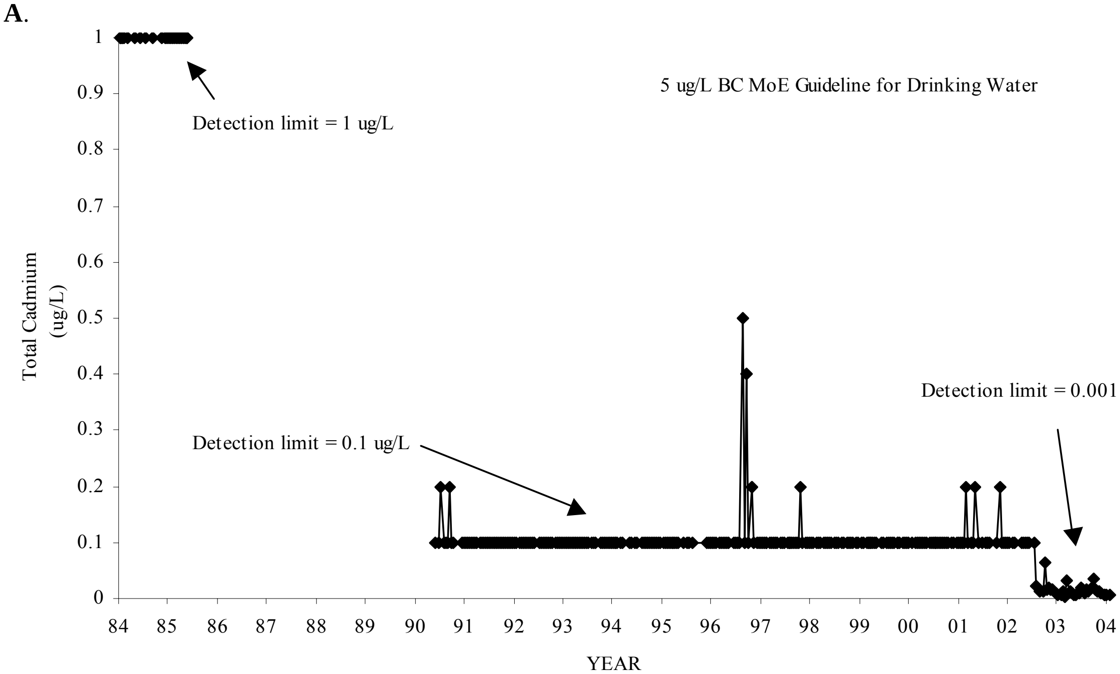


Figure 7. Total zinc levels at the Federal-Provincial trend station on the Kootenay River at Creston from 1984 - 2004.

A.



B.

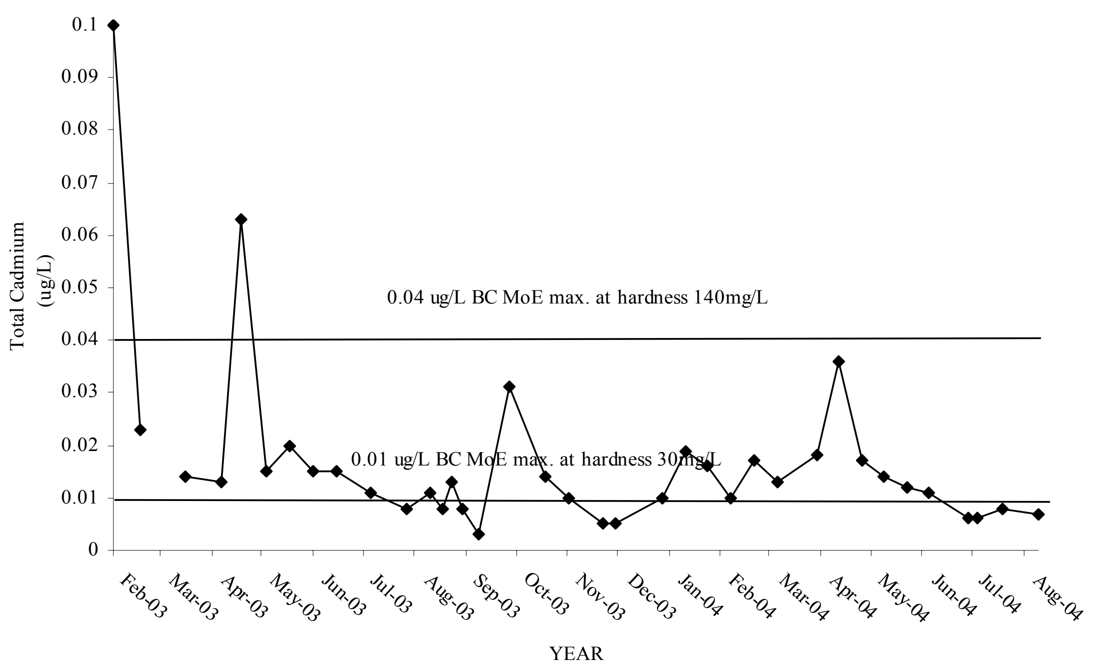


Figure 8. A. Total cadmium levels at the Federal-Provincial trend station on the Kootenay River at Creston from 1984 - 2004. **B**. Total cadmium levels from 2003 – 2004. B.C. MoE maximum guidelines shown because there are currently no 30-day guidelines for cadmium.

3.2 Sediment quality

3.2.1 Metals

The main metals in sediment that consistently exceeded guidelines were lead, zinc, and cadmium. However, mercury and copper were also high especially at sites just downstream of Blue Joe Creek in September. Levels of metals in Boundary Creek sediment decreased with distance from mine similar to the trend observed with water samples. However, the floodplain sites KS-1, KS-2 and WR-1 had elevated levels of metals possibly due to deposited tailings during high flow events. The raw sediment quality data is presented in Appendices 8.2.

In the June/July sampling period, lead levels in sediment exceeded PEL of the US NOAA of 91 μg/g and the MoE ISQG of 35 μg/g at all sites except KR-1 and KS-2. Site KS-2 exceeded the MoE ISQG but not the PEL. Maxim (2004) suggested that high levels of lead at the control site might have resulted from downstream movement of contaminated material displaced upstream during high waters associated with historical flood events. In September when only Boundary Creek sites were sampled, lead levels in sediment exceeded PEL and the MoE ISQG at all sites except the upstream control BC-1 (Figure 9).

In the June/July sampling period, zinc levels in depositional sediment exceeded PEL guidelines (315 μg/g) only at the floodplain site KS-1. At this time zinc levels exceeded MoE ISGQ guidelines of 123 μg/g at sites BC-1A, BC-3, KS-1 and KS-2. In September, zinc levels in depositional sediment did not exceed PEL (315 μg/g) at any of the sites. Zinc levels in September exceeded the MoE ISQG of 123 μg/g only at sites BC-1A and BC-1B (Figure 10).

Concentrations of cadmium in sediment monitored in June/July were at or below detection (2 μg/g) at all sites. However, the detection limits of cadmium were not low enough to compare with the MoE ISQG of 0.60 μg/g during this time period. Concentrations of cadmium in sediment during September monitoring periods were below PEL of 3.5 μg/g at all sites (Figure 11). Cadmium detection limits were lower (0.02 μg/g) in the September sampling session and allowed comparison with the MoE ISQG. In September, levels of cadmium exceeded this guideline at sites BC-1A and BC-1B.

Copper levels in sediment in June/July and September were below the PEL guidelines of 197 μg/g at all sites. Copper levels exceeded the MoE ISQG of 36 μg/g at site BC-1A in June/July and September. While site BC-1B exceeded the MoE ISGQ only in September. In addition, site KS-1 exceeded the MoE ISGQ when monitored in June/July (Figure 12).

Mercury levels in sediment exceeded PEL guidelines of 0.846 µg/g and MoE ISQG of 0.174 µg/g at sites BC-1A (June/July) and KS-1 (June/July). Levels of mercury at BC-1A (September), BC-1B (September) and BC-3 (June/July) exceeded MoE ISQG but were below PEL (Figure 13). All other sites were either below guidelines or below detection. Detection levels in June/July (0.2 µg/g) were only slightly greater than the ISQG guideline.

The floodplain sediment sample from site KS-1 had elevated levels of lead and elevated levels of zinc, mercury and copper. It is possible that tailings material or fine sediment have been deposited in the fan area of Boundary Creek during high flow events. In addition, water and sediment samples from Boundary Creek wildlife refuge WR-1 were high in lead. These two sites are just over one kilometer apart in distance. However, further sampling in this region is needed to better explain these high metal levels.

Levels of metals from the streambed of Kootenay River at the mouth of Boundary Creek (KR-1, sampled only September) were either below B.C. MoE guidelines or below detection (in cases where detection levels were above guidelines) (see Figures 9-13). Thus, impacts from Continental Mine on sediment quality at site KR-1 appear to be low. However as mentioned above, further investigations of metals levels in depositional sediment at additional sites on the Kootenay River, including upstream and downstream of the confluence with Boundary Creek, would provide key information on cumulative impacts of the Continental Mine.

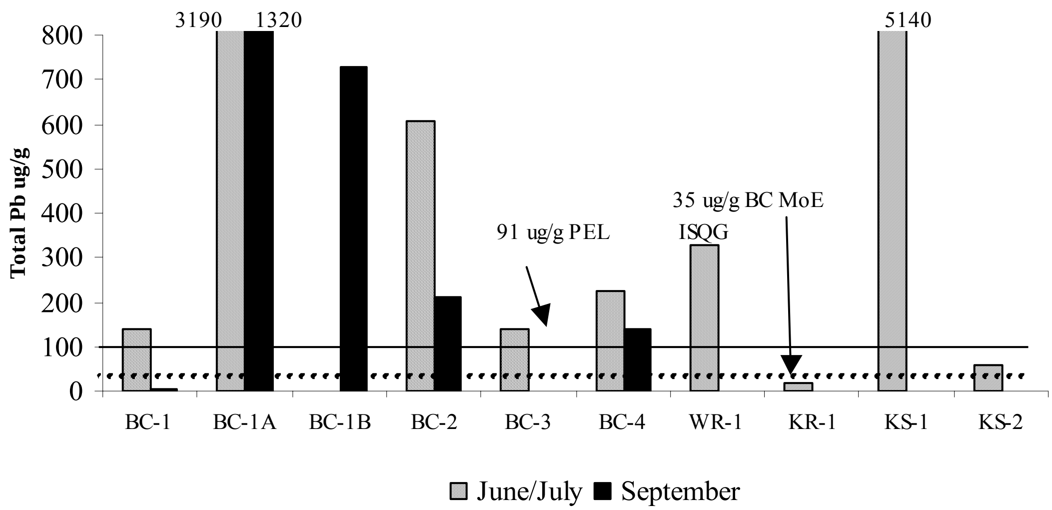


Figure 9. Levels of lead in sediment from Boundary Creek, Boundary Creek Wildlife Refuge and the Kootenay River and floodplain areas. Solid line indicates U.S. NOAA guidelines for PEL. Dotted line indicates MoE ISQG.

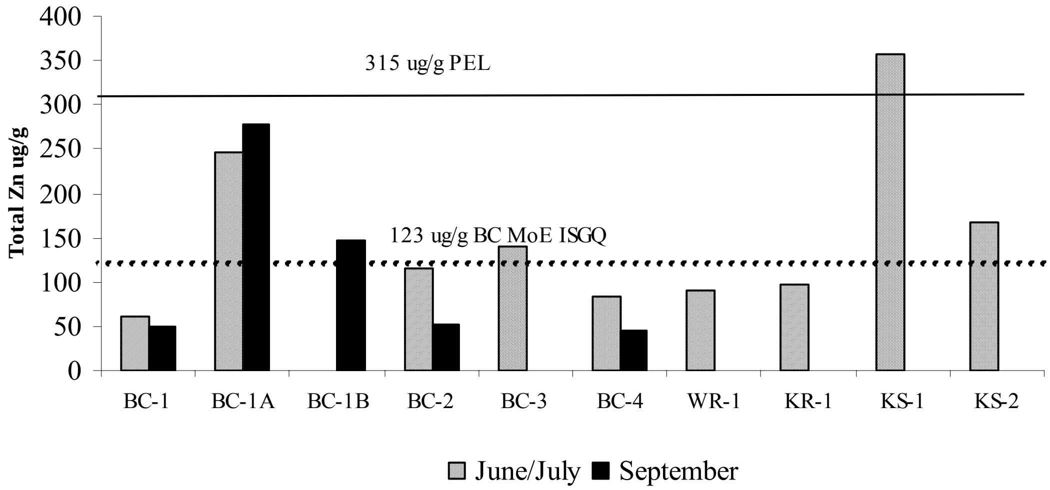


Figure 10. Levels of zinc in sediment from Boundary Creek, Boundary Creek Wildlife Refuge, Kootenay River and floodplain areas. Solid line indicates US NOAA PEL. Dotted line indicates MoE ISQG.

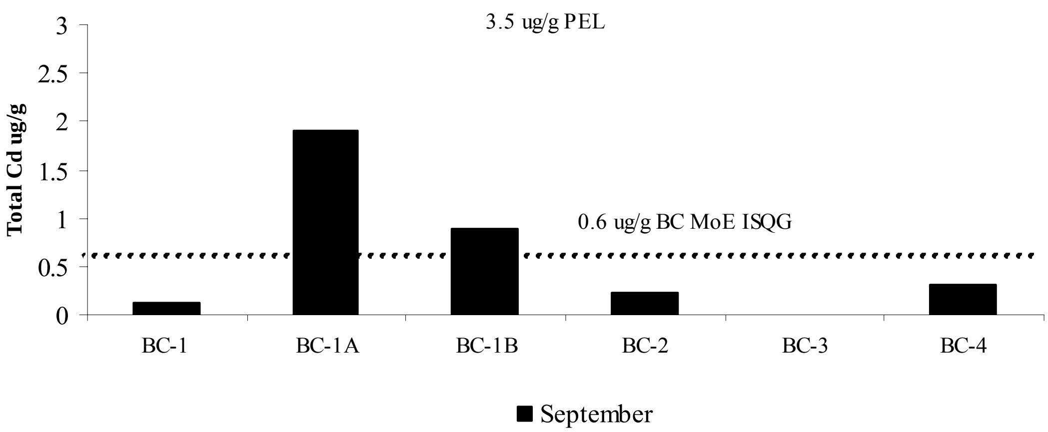


Figure 11. Levels of cadmium in sediment from Boundary Creek, Boundary Creek Wildlife Refuge, Kootenay River and floodplain areas. US NOAA PEL = 3.5 µg/g (not shown). Dotted line indicates MoE ISQG. June/July levels not shown because all samples were below the detection limit (2 µg/g) and below PEL. Detection levels in June/July were not low enough to compare with MoE ISQG. Detection levels in September were 0.05 µg/g.

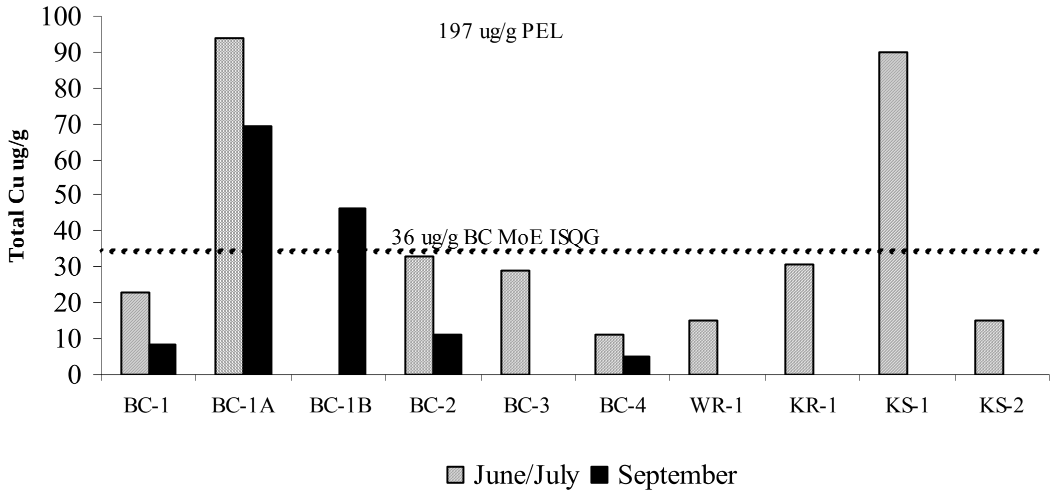


Figure 12. Levels of copper in sediment from Boundary Creek, Boundary Creek Wildlife Refuge, Kootenay River and floodplain areas. US NOAA PEL = 197 ųg/g (not shown). Dotted line indicates MoE ISQG.

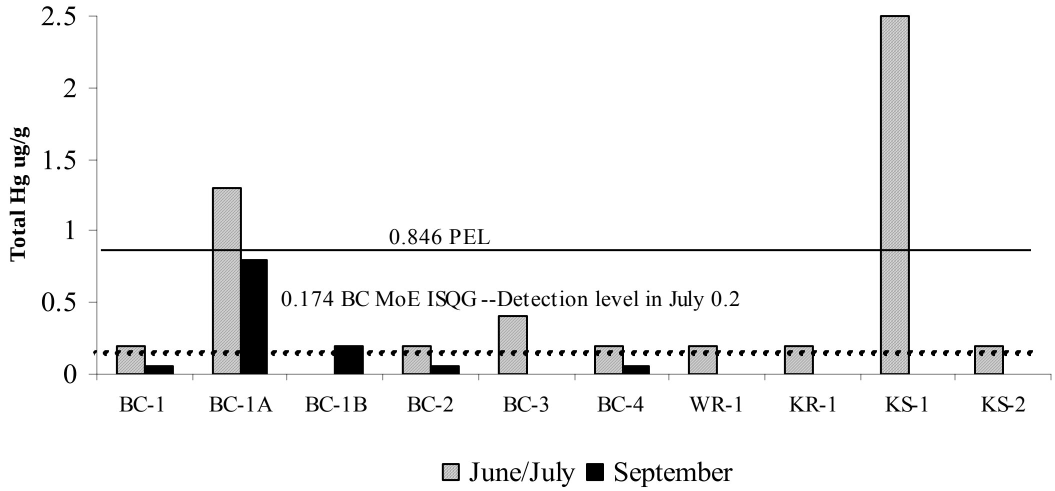


Figure 13. Levels of mercury in sediment from Boundary Creek, Boundary Creek Wildlife Refuge, Kootenay River and floodplain areas. Solid line indicates US NOAA PEL. Dotted line indicates MoE ISQG. Detection levels in June/July (0.20 µg/g) were slightly above the MoE ISQG while detection levels in September were 0.05 µg/g.

3.2.2 Other parameters

Depositional sediment sampled for metals varied in moisture from 17.1-27.6%. This corresponded with fairly low levels of total carbon (0.5-1%) at depositional sites. Total carbon was generally comprised primarily of organic carbon and inorganic carbon was below or just above detection. In addition, total phosphorus levels in depositional sediment declined with increasing distance downstream from the control site.

Sediment collected from macroinvertebrate sampling sites varied in moisture from 12.1-20.9%. This corresponded with fairly low levels of total carbon (0.2-0.4%) at macroinvertebrate sampling sites. Total carbon was generally comprised primarily of organic carbon (73-100%). Lower levels of total organic carbon are generally associated with higher levels of bioavailability and higher toxicity duBray (1989).

Table 9. Sediment parameters from depositional and riffle samples

Habitat	Parameter	BC-1	BC-1A	BC-1B	BC-2	BC-4
Depositional sediment sampled for metals	Moisture %(W/W)	27.6	35.5	16.8	17.1	20
	Carbon ug/g					
	Total inorganic	< 500	< 500	< 500	< 500	570
	Total Organic	11000	10000	6700	4500	9100
	Total	11000	10000	6700	4500	9700
	Phosphorus Total (P) (ug/g)	256	231	200	208	178
	% particle sizes <63 µm	10	7.8	2.8	0.8	1.4
Riffle Macroinvertebrate habitat	Moisture %(W/W)	20.9	12.1	14.9	12.4	12.7
	Carbon (ug/g)					
	Total inorganic	760	570	760	< 500	570
	Total Organic	2500	2700	3500	2500	1600
	Total	3300	3300	4300	2500	2200
	% particle sizes <63 µm	4.0	1.6	1.5	2.8	0.5

3.2.3 Particle size analysis

Particle sizes of the depositional sediment sample (whole sample) analyzed for metals were generally in the 63-2000 µm range at all sites (30-75%). Particle sizes of the <2000 µm fraction (sand and mud) of the same samples showed that the largest proportion of particles by weight was 63-2000 µm at all sites (92-98%). The proportion of the whole sample composed of mud (<63 µm) ranged from 1.4-10%.

Particle sizes of the whole riffle sediment (at macroinvertebrate sampling sites) were generally greater than 4000 µm at all sites (55-62%). Particle sizes of the less than 2000 µm fraction were primarily in the 63-2000 µm range at all sites (92-98%). The proportion of the whole sample composed of fine particulates (<63 µm) was 0.5-4%.

All sites had fairly low levels (0.5-10%) of fine particulates <63 µm. However, among depositional samples upper sites BC-1 and BC-1A had slightly higher levels of fine particulates (<63 µm) than lower sites BC-1B, BC-2 and BC-4 (Table 9). Among riffles samples upper site BC-1 had very slightly higher levels of mud than lower sites BC-1A, BC-1B, BC-2 and BC-4. The differences between sites could not be statistically analyzed because only one of each type (n=1) of sediment sample was collected from each site and within site variability was not quantified. It is well known, however, that higher levels of fine particulates (<63 µm) are associated with lower bioavailability of metals due to increased adsorption of dissolved metals on particulate surfaces. It is possible that variations in the percent fines could have slight effects on the bioavailability of metals at these sites (duBray 1989).

Raw data and graphs of particle sizes are presented in Appendices 8.4.1-8.4.5.

3.2.4 Quality Assurance/Quality Control (QA/QC)

The results of analyses of duplicate sediment samples collected in September 2003 showed that field sampling and laboratory analyses were generally accurate and repeatable for parameters that were fives times the detection limit (Table 10). Most parameters were within the acceptable limits of 35% for duplicates (Cavanaugh et al. 1997), with the exception of manganese (35.3%), which slightly exceeded this limit.

All five laboratory method blanks performed by PSC Analytical were below the method detection limit. All spiked samples (1 spike/ 20 samples) for total inorganic carbon, arsenic, cadmium, lead, selenium, thallium, mercury and acid volatile sulphides were within acceptable limits of 80-120% recovery. Laboratory duplicates for acid volatile sulphides were both below detection with 0% relative difference. Laboratory duplicates for moisture (20.9, 18.4 %w/w) had a relative difference of 12.72%, which was within acceptable limits. The laboratory QA/QC reports are given in Appendices 8.2.1-8.2.5.

Table 10. Results for duplicate sediment samples collected at BC-4 in September 2003. Analysis performed by PSC Analytical, Vancouver, B.C

Site	**BC-4 Regular**	**BC-4 Duplicate**	**Absolute % mean difference**
Moisture	20	19.8	1.0
Total Organic Carbon	9100	7200	23.3
Total Carbon	9700	7200	29.6
Phosphorus Total (P)	178	147	19.1
Aluminum	2670	2620	1.9
Barium	19.1	23.1	19.0
Cadmium	0.31	0.4	25.4
Chromium	1	1	0.0
Cobalt	2.3	2.7	16.0
Copper	5.3	4.6	14.1
Iron	7650	7650	0.0
Lead	140	126	10.5
Magnesium	1100	1210	9.5
Manganese	112	160	**35.3**
Potassium	782	840	7.2
Strontium	2.9	2.7	7.1
Titanium	148	167	2.1
Zinc	46	47	2.2

Bold values exceed acceptable limits for duplicates.

3.3 Boundary Creek Cumulative Toxicity Units (CTU)

As expected, CTU in sediment and water declined as a function of distance downstream from the Continental Mine complex and increasing dilution from surface runoff (Figure 14). Table 11 gives the CTU values for Boundary Creek sites.

The CTU value for water at the upstream control was 14.1 and 12.5 times lower than site BC-1A (closest downstream from the mine) in June/July and September 2003, respectively. At BC-4 (furthest from the mine), the CTU value of the upstream control was only 2.3 and 1.6 times lower in June/July and September 2003, respectively.

Table 11. CTU values for water and sediment of Boundary Creek

Date	Location	Distance from mine	Water		Sediment	
			CTU	Ratio of treatment to control	CTU	Ratio of treatment to control
June/July	1 (control)	10.2	0.4		***2.3**	
	1A	10.1	***5.8**	14.1	****16.6**	7.1
	2	17.4	**1.9**	4.6	***7.6**	3.3
	4	33.8	**1.0**	2.3	***3.3**	1.4
Sept.	1 (control)	10.1	0.4		0.3	
	1A	10.1	***5.1**	12.5	****15.9**	63.7
	1B	10.5	***2.3**	5.5	***8.7**	34.8
	2	17.4	**1.3**	3.1	***2.5**	10.1
	4	33.8	0.7	1.6	**1.8**	7.1

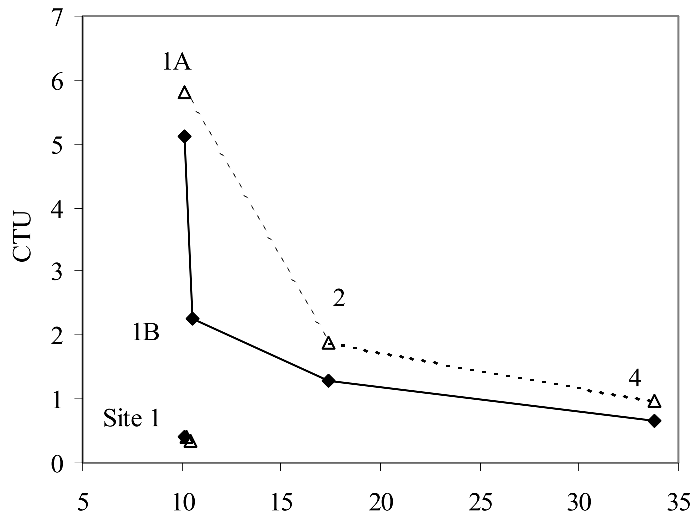
Bolded values are at least one times criterion values indicating potentially adverse effects to the biota; ***** indicates at least two times criterion values above which metals levels may influence benthic community structure and cause mortality in sensitive species; ****** indicates at least ten times criterion value and is considered significantly polluted (Clements et al. 2000).

Similarly, in the sediment samples the CTU values at the near-field site BC-1A were 7.1 and 63.7 times greater than the control in June/July and September 2003, respectively. The CTU values at the far-field site BC-4 were 1.4 and 7.1 times greater than the control in June/July and September 2003, respectively. The differences observed in the ratio of treatment to control between June/July and September is largely due to a high CTU value in June/July at the upstream control (Table 11).

The upstream control value of 2.3 CTU observed in June/July was higher than expected for a control. The CTU value was greater than two indicating cumulative toxicity at a site and potential impacts to the macroinvertebrate community. Maxim (2004) suggested that higher than expected metals values in sediment and water at the upstream control might be due to the effects of periodical historical flooding during freshet. There was only one sediment sample collected at each site per sampling time and as a result within-site variation and between-sites variation was not quantified. Thus, it is difficult to attribute differences observed between the sampling periods to a trend in time or due to within-site variation.

CTU values for depositional and stream water samples were primarily related to high levels of lead (Figure 15, Figure 16). Zinc and cadmium contributed less than one CTU or just over one CTU to the total value in both water and sediment samples.

A. Stream water



B. Sediment

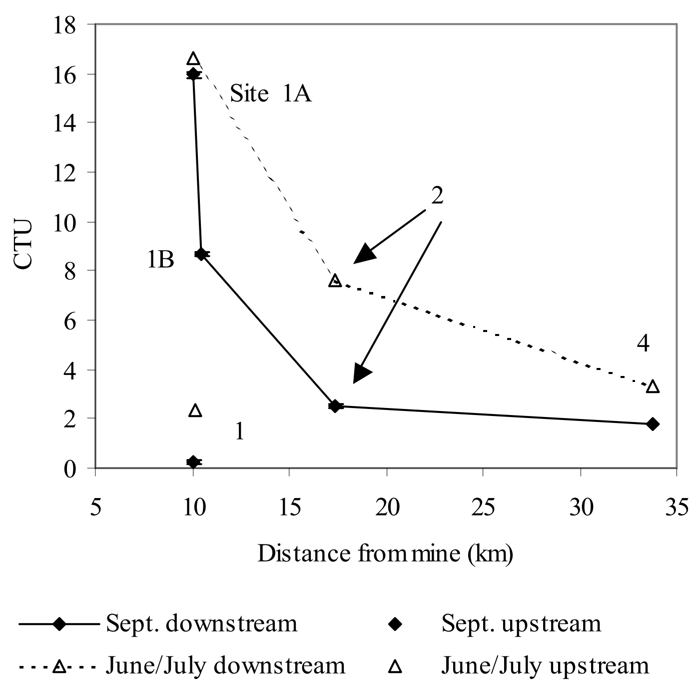


Figure 14. CTU of lead, zinc and cadmium in Boundary Creek in (A.) stream water and (B.) depositional sediment samples collected upstream (control) and downstream (treatment) of Blue Joe Creek.

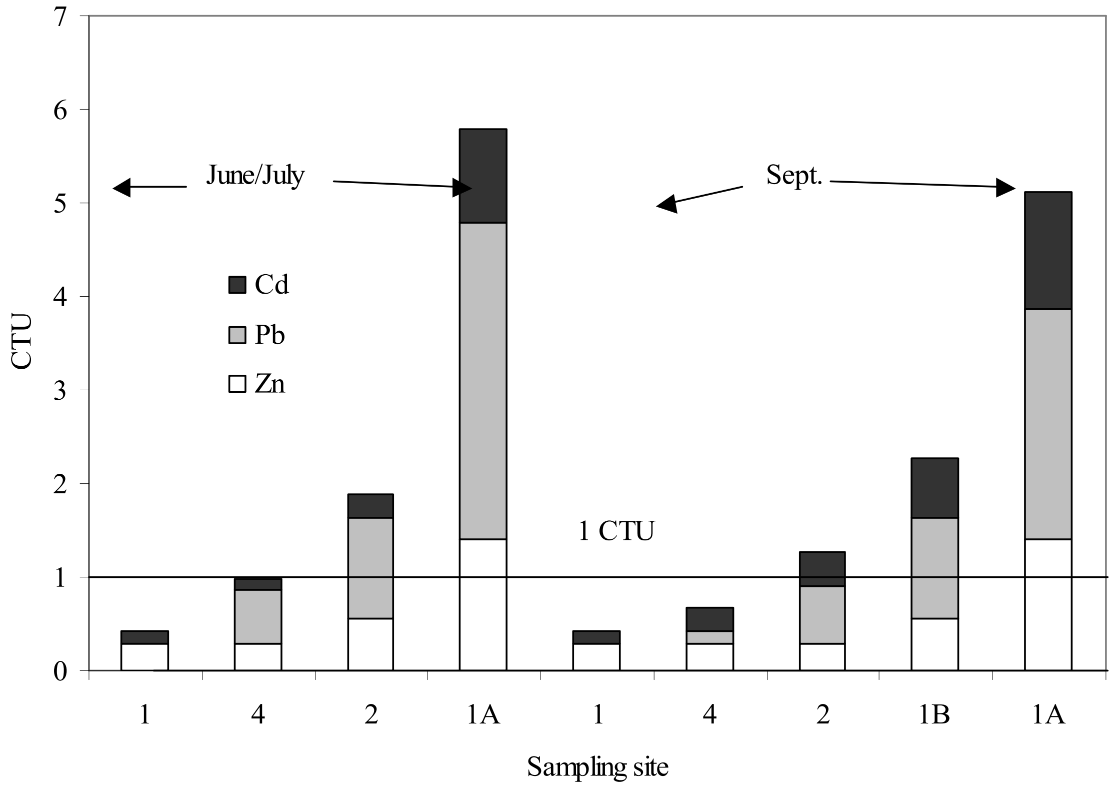


Figure 15. CTU of Boundary Creek surface water samples collected in June/July and September 2003. A CTU value greater than one indicates potential cumulative toxicity at a site. Macroinvertebrate sampling occurred in conjunction with the September collection of water samples.

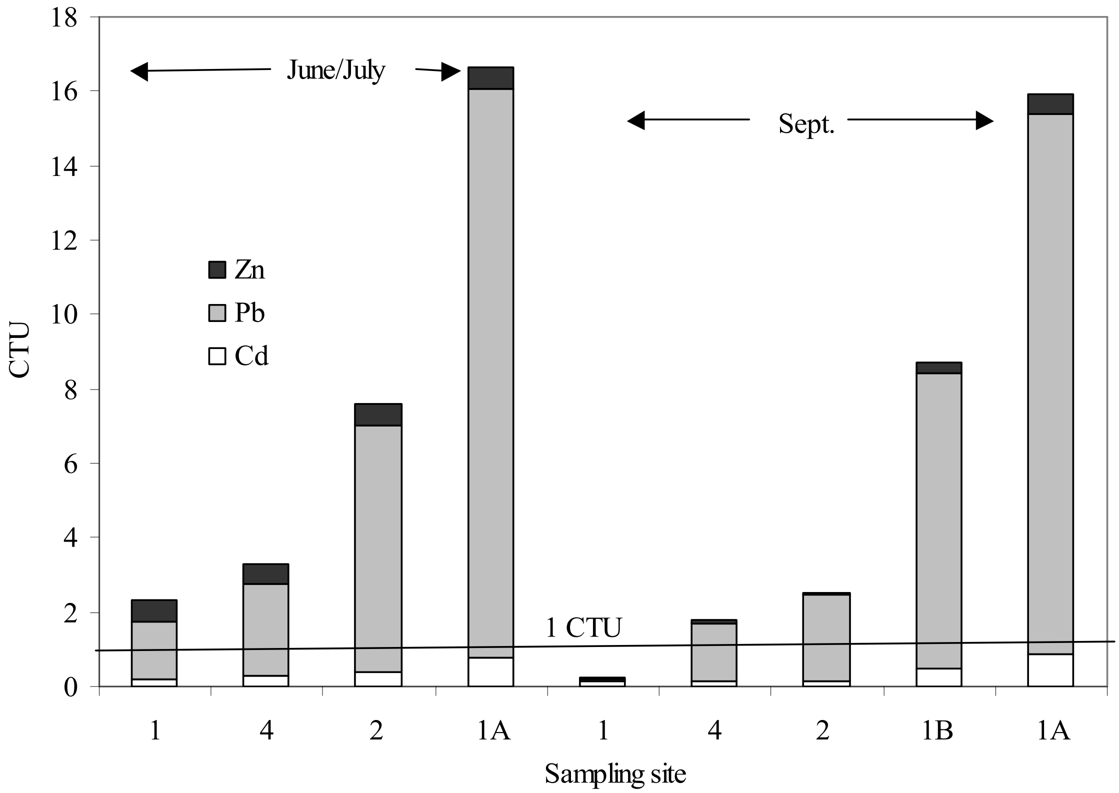


Figure 16. CTUs of Boundary Creek depositional sediment samples collected in June/July and September 2003. A CTU value greater than one indicates potential cumulative toxicity at a site. Macroinvertebrate sampling occurred in conjunction with the September collection of sediment samples.

The CTU values from water were used in the macroinvertebrate analyses and modelling effort. Plots of CTU from sediment and water suggest that the two variables are highly correlated and therefore the use of one of the variables is optimal (Figure 17). In addition, CTU values from September, which were closer to the time of macroinvertebrate sampling, were used. Inspection of plots revealed that these values are closely related to CTU values collected in June/July (Figure 18).

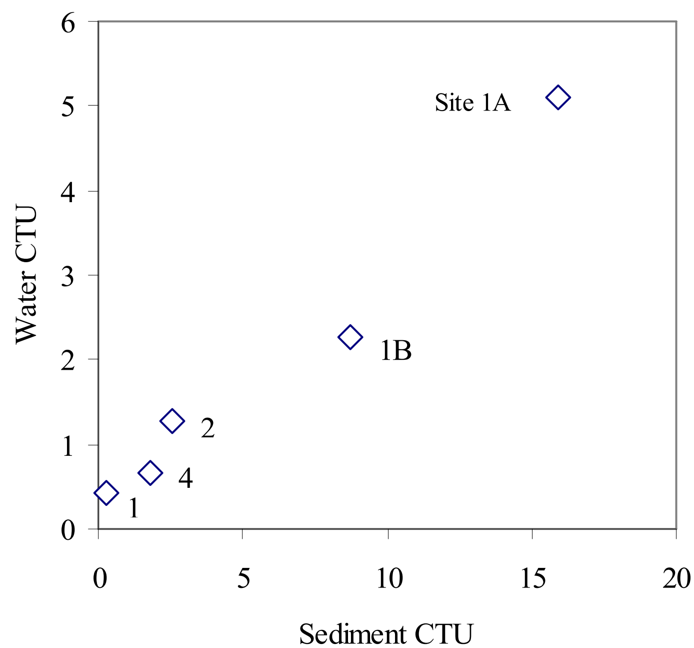


Figure 17. CTU of water versus sediment samples collected in September 2003.

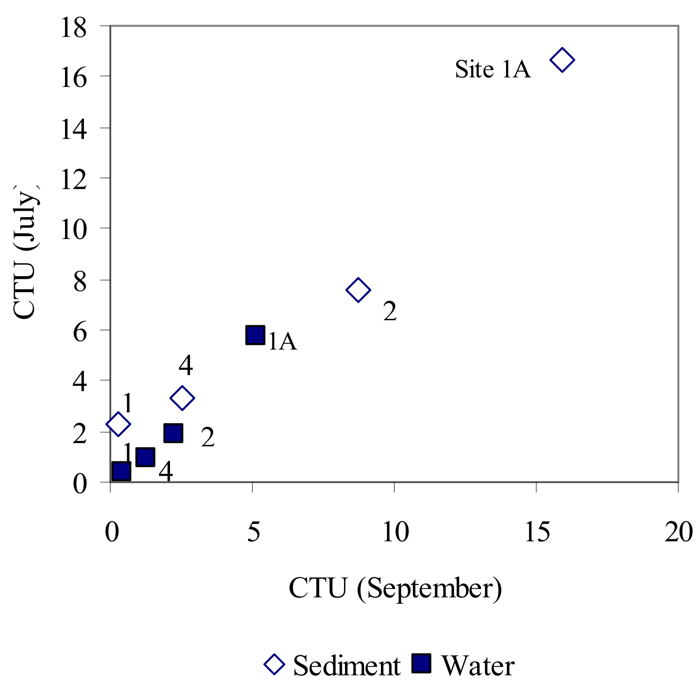


Figure 18. CTU of samples collected in June/July versus those collected in September 2003 for sediment and water.

3.4 Macroinvertebrates

Several biometrics were compared using GLM analysis to determine if there were statistically significant differences in response to sample site position, distance from mine, and CTU levels.

Significant relationships (Table 12, Figure 19, Figure 20) between the density of metal sensitive *Ephemeroptera* (mayflies) and all three parameters tested were found, including:

(1) A decrease in density of metal sensitive mayflies when comparing the control site to treatment sites downstream of Blue Joe Creek;

(2) An increase in density of metal sensitive mayflies with increasing distance from mine;

(3) A decrease in density of metal sensitive mayflies with increasing levels of CTU.

Clearly, decreases in densities of metal sensitive mayflies result from the effects of elevated metals levels originating from the Continental Mine site.

Other measures of invertebrate response were tested using GLM, including total density, density of EPT, total density of *Ephemeroptera*, and density of EPT/Total. The GLM analysis found no significant relationship for all of the parameters tested, with one exception. The density of EPT/Total was significant when testing the upstream/control site BC-1 against other treatment sites downstream of Blue Joe Creek (Figure 21, Table 12). However, there was no significant relationship between density of EPT/Total and distance from mine or levels of CTU.

Possion regression analyses showed that there were no significant relationships between indices of taxonomic richness (total number of taxa, number of ephemeropteran taxa, number of EPT taxa and number of metal sensitive taxa) and the independent parameters including; upstream/downstream location, distance from mine and level of CTU (Table 13).

Significant increases in the EPT/Total density ratio downstream of the impacts of mining and nonsignificant biometrics were likely due to increases in metal tolerant species, such as the *Baetis* sp., when compared with the upstream control. *Baetis sp*. is an emphemeropteran and included in the EPT counts. The ratio of density *Baetis sp*./Total densities was 0.6-1.9 fold higher at sites downstream of the impacts from the Continental Mine complex (Figure 22).

Clements et al. (2000) suggests that the EPT index may be a more useful indicator of heavy metal pollution at a large regional scale than in individual streams, largely due to a tendency of metal tolerant taxa to replace metal-sensitive taxa at moderate concentrations of metals such as those observed in Boundary Creek. Thus, metal sensitive mayflies are the most sensitive and applicable indicator of metal pollution on an individual stream.

Table 12. Results from GLM analysis of invertebrate response to sample site position, distance from mine site, and CTU levels.

Invertebrate Response	Parameter	DF	SS	F	P-value
Total Density	Upstream/Downstream	1,23	0.00	0.00	0.948
	Km from mine	1,23	0.18	0.66	0.424
	CTU	1,23	0.09	0.35	0.559
Density of EPT	Upstream/Downstream	1,23	0.17	0.66	0.424
	Km from mine	1,23	0.01	0.03	0.871
	CTU	1,23	0.13	0.52	0.477
Total density of *Ephemeroptera*	Upstream/Downstream	1,23	0.08	0.27	0.610
	Km from mine	1,23	0.65	2.05	0.166
	CTU	1,23	0.00	0.01	0.910
Density of metal sensitive *Ephemeroptera*	Upstream/Downstream	1,23	1.70	4.69	**0.041**
	Km from mine	1,23	6.00	16.54	**0.001**
	CTU	1,23	2.72	5.43	**0.029**
Density of EPT/Total	Upstream/Downstream	1,23	0.01	4.75	**0.040**
	Km from mine	1,23	0.00	0.00	0.981
	CTU	1,23	0.00	0.38	0.542

Bolded p-values are significant at less than 0.05

Table 13. Poisson regression analysis of counts of taxonomic richness in response to sample site position, distance from mine site, and CTU levels.

Invertebrate response	Predictor	DF	$\chi 2$	P-value
Total No. of Taxa	Upstream/Downstream	1	0.16	0.689
	Km from mine	1	1.47	0.225
	CTU	1	0.01	0.915
No. ephemeropteran taxa	Upstream/Downstream	1	0.23	0.635
	Km from mine	1	1.49	0.222
	CTU	1	0.72	0.397
No. EPT Taxa	Upstream/Downstream	1	0.21	0.646
	Km from mine	1	0.93	0.335
	CTU	1	0.12	0.728
No. metal sensitive ephemeropteran taxa	Upstream/Downstream	1	0.00	0.973
	Km from mine	1	0.01	0.921
	CTU	1	0.01	0.942

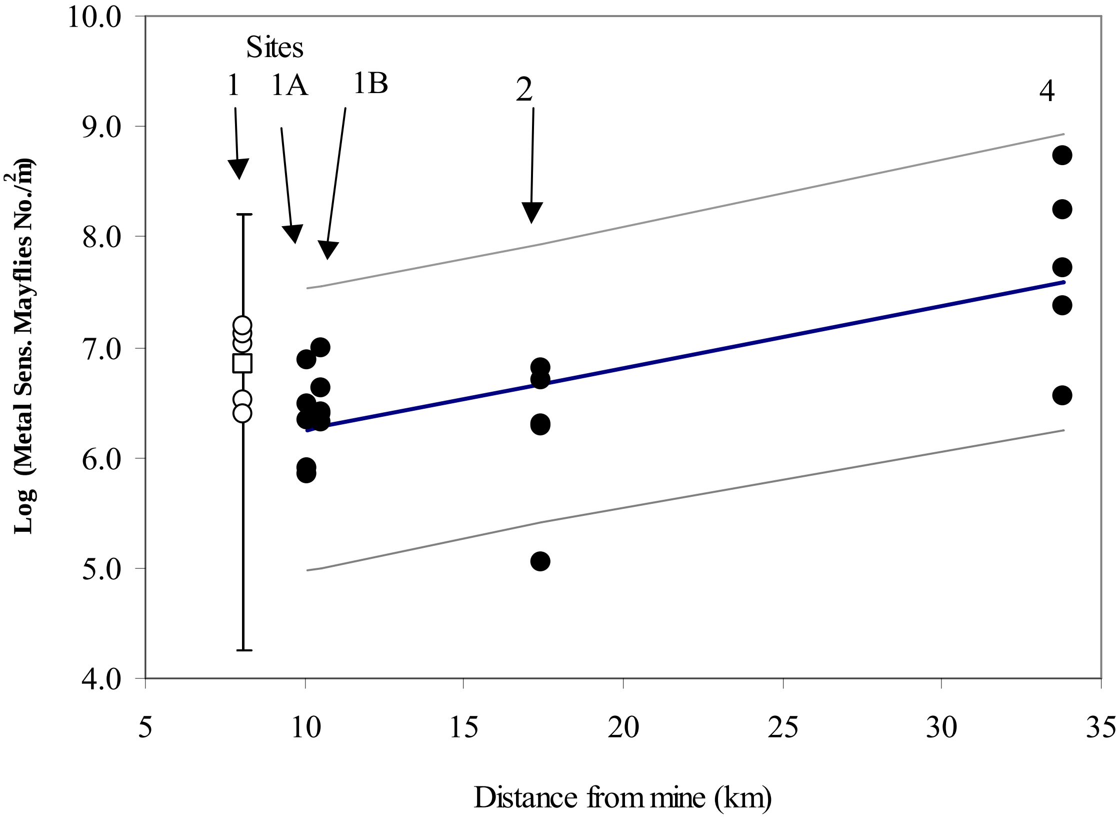


Figure 19. Relationship between density of metal sensitive *Ephemeroptera* as a function of distance from mine site and position (upstream/downstream) of sampling station. Predictions and confidence intervals are from GLM analysis (Table 12). Data points from upstream and downstream sites are given as empty and filled circles, respectively. Confidence limits on predictions for upstream sites (denoted by box) are shown as error bars. Confidence limits on predictions from downstream sites are shown as grey lines. Upstream site are staggered from corresponding downstream sites to ease interpretation.

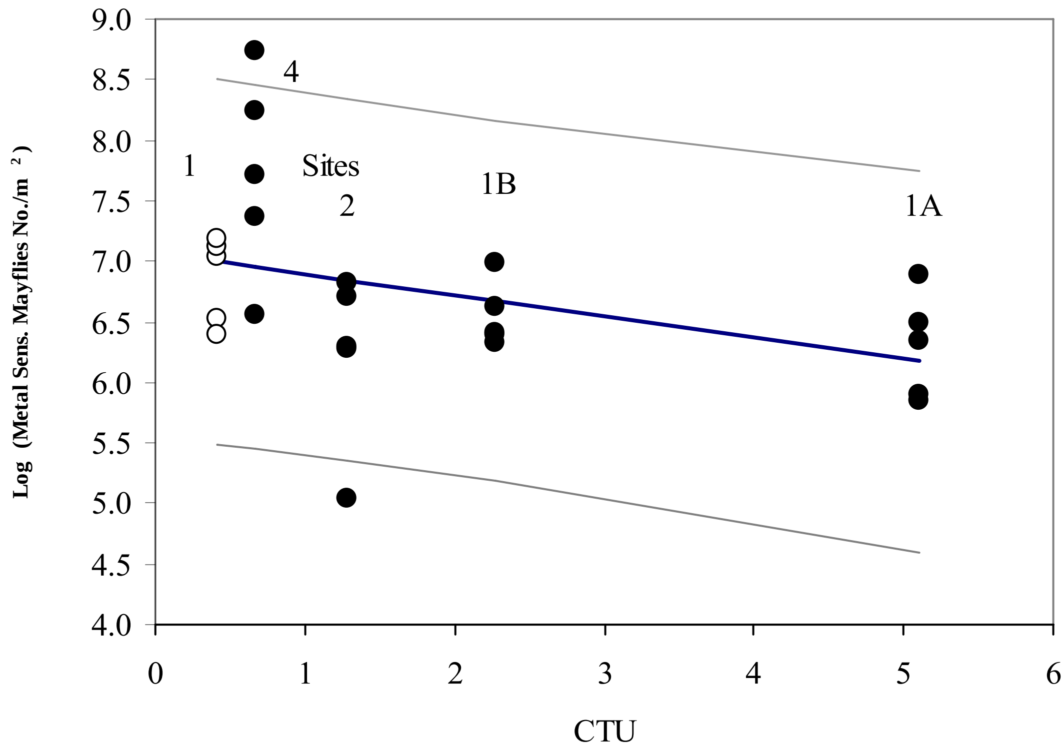


Figure 20. Relationship between densities of metal sensitive *Ephemeroptera* as a function of CTU levels (in water). Predicted line and confidence intervals are from GLM analysis (Table 12). Data points from upstream and downstream sites are given as empty and filled circles respectively.

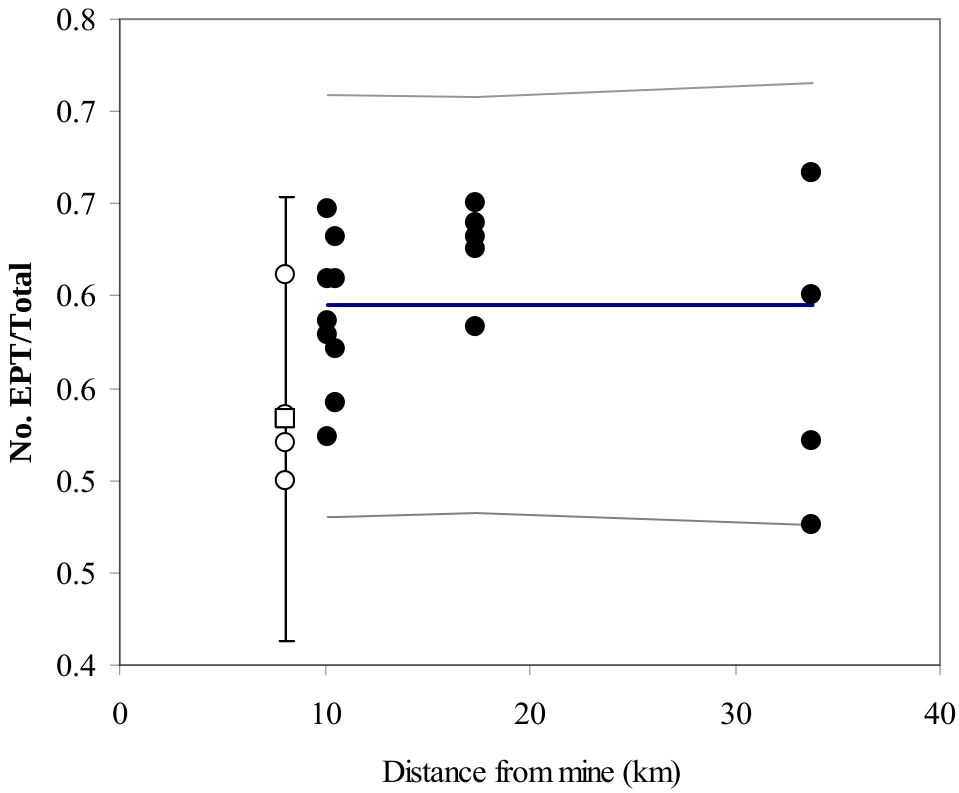


Figure 21. Relationship between EPT/total taxa as a function of distance from mine site and position upstream/downstream) of sampling station. Predictions and confidence intervals are from GLM analysis (Table 12). Data points from upstream and downstream sites are given as empty and filled circles, respectively. Confidence limits on predictions for upstream sites (denoted by box) are shown as error bars. Confidence limits on predictions from downstream sites are shown as grey lines. The upstream control site is staggered from corresponding downstream sites to ease interpretation.

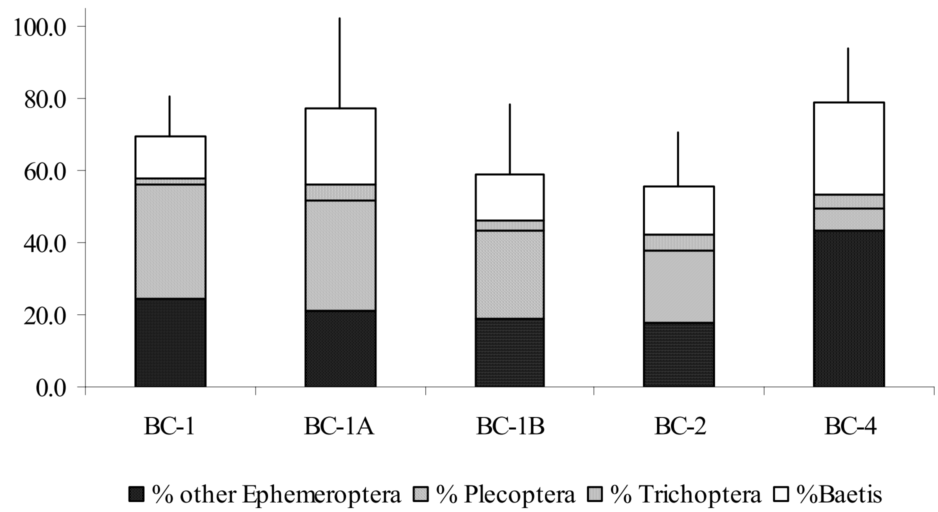


Figure 22. Percent composition of EPT groups at each macroinvertebrate sampling location.

3.4.1 Comparisons to other streams in Idaho and Montana

The present work on Boundary Creek was compared to the spatially extensive work on multiple streams carried out in 2000 by Maret et al. (2002) on the Coeur d'Alene and St. Regis River Basins located in northern Idaho and western Montana. Similar to Blue Joe and Boundary Creeks, levels of cadmium, zinc and lead resulting from lead, silver and zinc production mines were of most concern at the contaminated sites in these streams.

The evaluation was done in order to compare Boundary Creek sites to a larger synoptic study that incorporated: (1) greater range in the CTU units (2) a larger spatial area, (3) a balanced design and (4) a greater number of reference (n = 9) and contaminated sites (n = 9).

Sites BC-1A, BC-1B, BC-2 in the present study were most impacted by high levels of metals in sediment and water. These sites have depressed levels of metal sensitive mayflies when compared to the Boundary Creek control and the Coeur d'Alene and St. Regis River Basins reference stations. Mean densities of metal sensitive mayflies at sites BC-1A, BC-1B and BC-2 (closest to downstream effects of the Continental Mine) were well below the Coeur d'Alene and St. Regis River basin reference stations (Figure 23).

The density of metal sensitive mayflies as a function of CTU values in water was used so as to compare to the Maret et al. (2002) study. Sites BC-1A, BC-1B and

BC-2 had low to mid CTU values in water when compared to contaminated sites in the Maret et al. (2002) study. But despite a low to moderate range in CTUs in water, significant effects of metal pollution on sensitive mayfly taxa were detected in the present study.

CTU values in sediment were somewhat higher than CTU values in water and may be better indicators of significant effects on the macroinvertebrate community. For example in sediment, Site BC-1A indicated 16.5 and 15.9 times criterion values in June/July and September, respectively. These values for sediment are considered significantly polluted. While CTU values in water were only 5.8 and 5.1 times criterion values in June/July and September, respectively. At the criterion values found in water, metals levels may influence benthic community structure and cause mortality in sensitive species (Clements et al. 2000).

In addition, sites BC-1A, BC-1B and BC-2 on Boundary Creek had slightly lower mean densities of metal sensitive mayflies than Coeur d'Alene and St. Regis River basins sites with similar CTU values. Variation in location, time or habitat type related to differences in stream size could account for these differences. Discharge at sites BC-1A, BC-1B was 6-15 times greater than the mean discharge of treatment sites in the Maret et al. (2000) study.

The CTU value for the Boundary Creek control was higher than most of the reference stations in Idaho and Montana (Figure 23). As discussed above, it is possible that historic flooding may have deposited contaminated sediments at site BC-1, accounting for higher CTU value and low densities of metal sensitive mayflies. The mean densities of metal sensitive mayflies at the Boundary Creek control site were at the lower range of what was observed from the reference sites sampled in the Coeur d'Alene and St. Regis River basins (Maret et al. 2002). These factors may account for subtle differences in the macroinvertebrate biometrics observed at the treatment and the control sites on Boundary Creek.

Site BC-4 on Boundary Creek, furthest downstream from the mine complex, had higher mean densities of metal sensitive mayflies than all reference sites on the Coeur d'Alene and St. Regis River basins and the Boundary Creek control site. Thus, in comparison to these reference stations it appears that the densities of metal sensitive mayflies have recovered somewhat due to the effects of dilution.

Site BC-4 also had higher mean densities of metal sensitive mayflies than all contaminated sites with similar CTU values on the Coeur d'Alene and St. Regis River basins. This result could be due to differences in location, time or habitat related to stream size. There are quite large differences between the stream sizes at site BC-4 compared to the sites in the Maret et al. (2003) study. For instance, at BC-4 the mean discharge in June/July and September was thirty-eight times greater than the mean discharge of treated sites in the Maret et al. (2003) and ten times greater than BC-1 (control). These differences are considerable and habitat related differences could account for some of the variation observed.

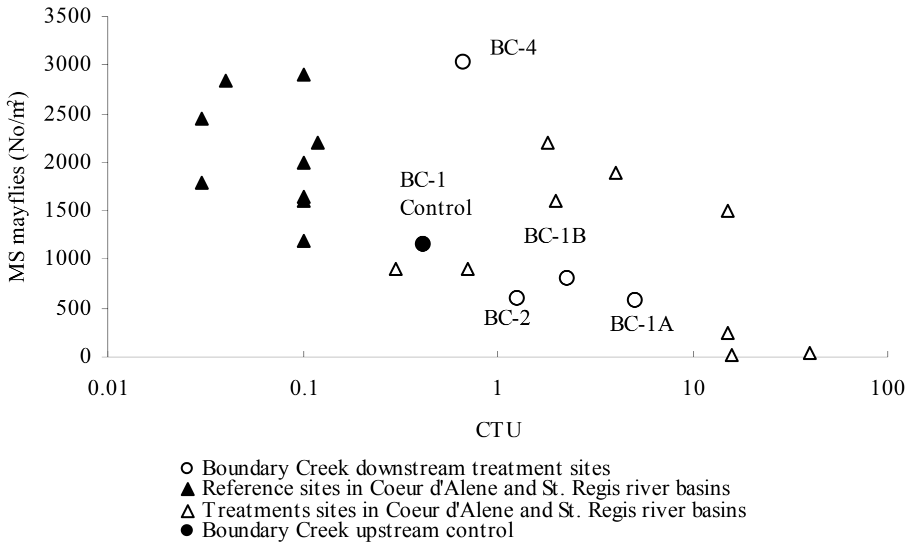


Figure 23. Mean density of metal sensitive (MS) mayflies in Boundary Creek and the Coeur d'Alene and St. Regis River basins as a function of CTU in water. Data from the Coeur d'Alene and St. Regis River basins approximated from Maret et al. 2002.

5 SUMMARY AND CONCLUSIONS

Levels of lead, zinc, and cadmium in water and sediment, and mercury and copper in sediment from Boundary Creek were greatest immediately downstream of Blue Joe Creek and lowest in the upstream control. These metal levels generally attenuated with distance downstream from the Blue Joe Creek indicating contamination from the Continental Mine. Levels of lead in the sediment and water of Boundary Creek are of greatest concern because they consistently exceeded B.C. MoE guidelines.

The floodplain sediment sample from site KS-1 had extremely high levels of lead and elevated levels of zinc and mercury in June/July sampling carried out by USDA Forest Service/Maxim Inc. In addition, water and sediment samples from Boundary Creek wildlife refuge WR-1 were high in lead.

Total lead levels in Kootenay River at the Federal-Provincial trend site located on the Kootenay River at Creston were typically below MoE 30-day average guidelines. However, a significant linear relationship was observed between the logarithm of lead concentration and the logarithm of turbidity at the Kootenay

River Monitoring Station at Creston. High lead levels generally occurred when turbidity levels were also high.

The CTU of Boundary Creek stream water and sediment declined as a function of distance from the Continental Mine complex at sites downstream from the confluence of Blue Joe and Boundary Creeks. CTU values of Boundary Creek depositional and stream water samples were primarily related to high levels of lead.

Results from the GLM analysis of the density of macroinvertebrate biometrics in response to sample site position, distance from mine and CTU levels demonstrate significant; declines in the density of metal sensitive mayflies when comparing the control site to treatment sites downstream of Blue Joe Creek, increases in density of metal sensitive mayflies with greater distance from mine, and decreases in the density of metal sensitive with higher levels of CTU.

In addition, the density of EPT/Total was significant when testing the upstream/control site BC-1 against other treatment sites downstream of Blue Joe Creek. However, there was no significant relationship between density of EPT/Total and distance from mine or levels of CTU. Significant increases in the EPT/Total density ratio downstream of the impacts of mining were likely due to increases in the metal tolerant species, *Baetis sp.*, when compared with the upstream control.

Mean densities of metal sensitive mayflies at sites up to 17.4 km downstream of the Continental Mine were also well below reference stations and contaminated sites of similar CTU values previously monitored in Idaho and Montana.

6 RECOMMENDATIONS

Further, long-term monitoring of surface water quality, sediment quality and benthos in Boundary Creek is recommended following final remediation work. Presently, B.C. MoE plans to sample surface water and sediment quality and macroinvertebrates again in Boundary Creek in 2007.

Additional control sites are suggested to balance the design (i.e. roughly similar number of treatments/controls). This would also allow testing of the effect of stream location on estimates. Jolene Raggett (pers. com. 2005) reports that there are not suitable upstream control sites for benthos due to limited comparable riffle habitat upstream of Blue Joe Creek. As a result, reference stations from alternative streams should be considered.

Inclusion of a sampling site on Blue Joe Creek (macroinvertebrate, water and sediment collection) just downstream from the mine site is recommended in order to capture possible effects at high levels of contamination. It would allow a greater range in both the CTU units and the potential effects on the macroinvertebrate biometrics used in the analysis.

Further sampling in the floodplain areas and the Boundary Creek wildlife refuge is required to better explain these high metal levels at these sites.

Future water quality monitoring for zinc and cadmium in Boundary Creek should incorporate detection levels low enough to assess MoE guidelines.

Calculation of loading rates of metals from Boundary Creek to Kootenay River during freshet would allow better assessment of the impact of metals from Boundary Creek on Kootenay River.

Monitoring of depositional sediment or suspended sediment in the Kootenay River downstream of the confluence with Boundary Creek is suggested. This information will provide further information on downstream impacts of the Continental Mine.

Additional collection of macroinvertebrate habitat parameters would be useful at each replicate sampling location within a site (percent fines, depth of stream, and velocity) to allow estimates of variance within a site. This would also allow statistical comparisons of habitat characteristics between sites.

Replicated sampling of sediment quality at each site would account for any spatial variability within a site and allow statistical comparison between sites and analyses of changes in sediment quality over time.

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