Lower Columbia River Water Quality Objectives Monitoring Program - Birchbank to the International Boundary 1997-2005

Data Summary and Interpretive Report

Final

February 2008

Prepared for:

Columbia River Integrated Environmental Monitoring Program
Ministry of Environment
Nelson, British Columbia

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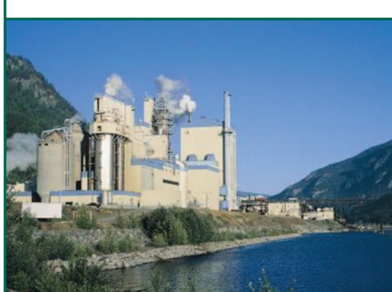


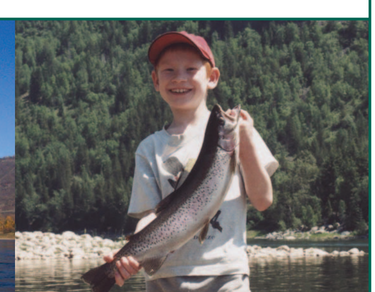

Hatfield CONSULTANTS

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LOWER COLUMBIA RIVER WATER QUALITY OBJECTIVES MONITORING PROGRAM, BIRCHBANK TO THE INTERNATIONAL BOUNDARY

1997 – 2005

DATA SUMMARY AND INTERPRETIVE REPORT

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Prepared for:

COLUMBIA RIVER INTEGRATED ENVIRONMENTAL MONITORING PROGRAM
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FEBRUARY 2008

LC1274.3

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LIST OF ACRONYMS

AVS	Acid volatile sulphides (chemical in sediments that can bind to metals)
AXYS	AXYS Analytical Ltd.
B.C. MOE	B.C. Ministry of the Environment
CFU	Colony Forming Units
COC	Contaminant of concern
CRIEMP	Columbia River Integrated Environmental Monitoring Program
DS or D/S	Downstream. For fish tissue it represents fish caught between Beaver Creek and the international border.
EVS	EVS Environment Consultants
EPA	Environmental Protection Agency
ICP	Inductively Coupled Plasma (analytical equipment for measuring metals)
ICPMS	Inductively coupled plasma with a mass spectroscopic detector (analytical equipment for measuring metals)
IDZ	Initial dilution zone
ISQG	Interim Sediment Quality Guideline
HNO_3	Nitric Acid
HLK	Hugh Keenleyside Dam
MDL	Method detection limit
MW	Mountain whitefish
ND	Not detected (i.e., not quantifiable)
NTU	Nephelometric turbidity units
OES	Optical emission spectroscopy (metals detector)
PCA	Principal component analysis
PCB	Polychlorinated biphenyl
PBDE	Polybrominated diphenyl ether
PESC	Pacific Environmental Sciences Centre
PSC	Phillips Scientific (now Maxxam Labs)

LIST OF ACRONYMS Cont'd.

QA/QC	Quality assurance/quality control
RBT	Rainbow trout
RL&L	RL&L Environmental Services Ltd.
RPD	Relative percent difference
SEM	Simultaneously extractable metals (metals extracted from sediments using a purge-and-trap method)
SQO	Sediment quality objective
STP	Sewage treatment plant
TEQ	Toxic equivalents quotient (numerical comparison to 2,3,7,8-tetrachlorodibenzo-para-dioxin [a dioxin])
TGP	Total Gas Pressure or Total Dissolved Gas Pressure
TOC	Total organic carbon
TRG	Tissue-residue guideline
TRO	Tissue-residue objective
UCLM	Upper confidence limit of the mean
W	Walleye
WQO	Water quality objective

ACKNOWLEDGEMENTS

Hatfield Consultants wishes to thank Jolene Raggett and Alison Stent at the B.C. Ministry of Environment, Nelson, for their assistance during this project.

We would also like to acknowledge:

- B.C. Ministry of Environment for the collection of water and sediment samples summarized in this report.
- B.C. Hydro and Golder Associates for collection of fish tissue samples (done as part of the annual fish indexing program) summarized in this report.
- Teck Cominco Metals Ltd. for financial assistance for sample collection and analysis.
- Zellstoff Celgar Ltd. for assistance with sample collection and analysis during their Environmental Effects Monitoring program in 2002 (Cycle Three).
- Columbia River Integrated Environmental Monitoring Program (CRIEMP) for review and comment of this report.
- Andrea Ryan, Environment Canada for running the Water Quality Index calculations.
- Bill Duncan, Teck Cominco for providing input.

EXECUTIVE SUMMARY

This data summary and interpretive report presents information on water quality, sediment quality, fish tissue chemistry, microbial indices, fish health and sediment toxicity collected for the Lower Columbia River water quality objectives (WQO) monitoring program between Birchbank and the international border from 1997 to 2005.

Data were reviewed and summarized, with concentrations of contaminants screened against applicable environmental objectives/criteria/guidelines, where available. Graphical and statistical techniques were used to assess trends over time and space, while correlation analysis was used to test for interrelationships between sediment toxicity testing results and sediment chemistry.

A searchable relational database created in Microsoft Access was developed for these data and is included with this report.

Results are summarized below.

WATER

All water sampling was done during the lowest flow periods during the year and therefore represent worst-case lowest dilution water quality conditions.

Metals

Highest metals concentrations generally were measured at either the Stoney Creek or New Bridge water sampling stations, followed by downstream stations, indicating that Teck Cominco and Stoney Creek are the source of most metals in the Lower Columbia River. Of the metals assessed, cadmium, chromium, copper, lead and zinc had one or more exceedance of the Lower Columbia WQOs. With the exception of chromium, all of these metals are associated with operation of the Teck Cominco smelter and related activities. Based on the number of WQO exceedances, cadmium and zinc were the metals of greatest ecological concern. Cadmium exceeded objectives most frequently and exhibited the largest single exceedance (i.e., 4.5 times the WQO) outside of the Teck Cominco initial dilution zone (IDZ). Maximum exceedances of all remaining metals of concern were only marginally larger than their respective WQOs.

Statistical comparison of water quality at Birchbank and Waneta indicated that arsenic, cadmium, copper, lead, thallium, and zinc were statistically higher at Waneta than at Birchbank. All of the metals are associated with operation of the Teck Cominco smelter and related activities.

There were no statistically significant trends over time for metals in the Lower Columbia River water from 1997 to 2005, which is expected given that most recent upgrades to the Teck Cominco operation were completed between 1995 and 1997, prior to the period covered in this investigation.

Nutrients

The nutrient status of the Lower Columbia River is largely influenced by the limnology and nutrient status of the Arrow Reservoir. However, additional nitrogen and phosphorus inputs to the study area may come from a variety of anthropogenic sources, including industry and wastewater discharges.

Of the nutrient variables measured, only ammonia, nitrite + nitrate, total nitrogen and total phosphorus were measurable. Nutrient concentrations were relatively similar at all locations in the Lower Columbia River, suggesting primary sources of nutrients were upstream of Birchbank. Significant upstream sources of nutrients may include STPs, run-off from agricultural lands, the Zellstoff Celgar mill, and B.C. Hydro fertilization of Arrow Lakes (to increase lake productivity). Nitrate, nitrite, total nitrogen, ammonia and total phosphorus concentrations were within their respective WQOs/guidelines; concentrations of nitrogen and phosphorus were consistent with oligotrophic fresh water bodies.

There were no statistically significant trends in nutrients over the study period (1997 to 2005); however, total phosphorus and ammonia have decreased in the current data set relative to the period of 1990 to 1996. Total nitrogen concentrations are similar to concentrations measured between 1990 and 1996. Statistical comparison of water quality at Birchbank and Waneta indicated that ammonia was statistically higher at Waneta than at Birchbank.

Field and Conventional Variables

River flows within the study area are controlled by upstream dams on both the Columbia and Kootenay Rivers, which are operated under the terms of the Columbia River Treaty. The treaty requires dams to operate in a manner to achieve optimum power and flood control benefits in Canada and the U.S.

Flows were measured during specific low flow periods targeted for the WQO monitoring program. Flows at Birchbank varied between 762 and 4,520 m^3/s. Water hardness was similar at all locations, ranging from 50 to 72 mg/L. Total hardness appeared to follow a seasonal trend, being lower at the beginning of the sampling period (October and November), than later in the sampling period (January to April). Turbidity was consistent among stations, but varied over time, with 30-day averages ranging from 0.15 to 0.8 NTUs. The similarity among stations suggested that turbidity was not affected by any point sources downstream of Birchbank. The pH was generally similar among stations and over time, ranging from 7.6 to 8.1 and was within the WQO of 6.5 to 8.5.

Dissolved oxygen (DO) was similar among stations and across time, with 30-day averages ranging from 8.7 mg/L to 14.3 mg/L. Many of the measured DO concentrations were below their applicable minimum 30-day WQO for November to April of 11.0 mg/L. Of all stations, Birchbank generally had the lowest DO concentrations in the period from 2002 to 2004.

Total Dissolved Gas Pressure (TGP) ranged from 100.4% to 112.4% (30-day averages) and appeared to decrease during the study period. Birchbank and Waneta had similar concentrations; however, Birchbank typically had slightly higher TGP, likely due to the closer proximity to two dams (Hugh Keenleyside and Brilliant). TGP only exceeded the 30-day WQO on two instances, October 1997 and April 1998.

Microbial indicators

Total fecal coliforms, *E. coli* and *Enterococcus* were assessed at Birchbank, D/S STP and Waneta from 1997 through 2005. Statistical comparison of water quality at Birchbank and Waneta indicated that fecal coliform and *E. coli* were statistically higher at Waneta than at Birchbank. Results indicate that the primary source of fecal bacteria to the Lower Columbia is the Trail STP, with additional inputs likely coming from the Fruitvale STP, which discharges to the Columbia River via Beaver Creek. The WQO for total fecal coliform and *E. coli* were only exceeded once, while the WQO for *Enterococcus* was exceeded on three occasions.

CCME's Water Quality Index (WQI)

Water quality data were used to calculate the Water Quality Index (WQI) for each water sampling station. The WQI is a standardized approach to quantify water quality of freshwater systems of Canada. Results suggested that water quality in the Lower Columbia River between Birchbank and the US Border generally provides good habitat for aquatic life. WQI values calculated for the New Bridge site tended to be the lowest, followed by the Stoney Creek site. However, New Bridge is located within the mixing zone downstream of the Teck Cominco discharge and therefore, the area of poor water quality would be localized within the discharge plume. Furthermore, the WQI values at New Bridge appear to be steadily improving with time. Improvements in water quality have also been observed within Stoney Creek due to remediation conducted by Teck Cominco on historical landfills.

SEDIMENTS

Chemistry

Conventionals

Grain size – The percentage of fine material (i.e., silt and clay) in sediments was generally low, ranging from 0.7 to 36%. The Beaver Creek station exhibited the greatest variability between 2002 and 2004, ranging from 1% to 36%. Differences between years for fines and TOC could be related to flow (higher flows flush fines, lower flows deposit fines), or variations in specific sampling location at each site.

TOC – Total organic carbon (TOC; measured as a percentage of dry weight) was also generally low, ranging from 0.02 to 1.80%. Similar to the fines content, the Beaver Creek station exhibited the greatest change of TOC between 2002 and 2004, changing from 0.23% to 1.8%.

SEM-AVS – In sediment samples from the Columbia River, the difference between SEM (simultaneously extractable metals) and AVS (acid-volatile sulphates) was always greater than zero, indicating that metals may be bioavailable. Results suggest that SEM-AVS is not likely a useful indication of metals bioavailability in the study area, given the well-oxygenated nature of the aquatic environment and the generally coarse nature of the sediments.

Metals

Metals concentrations in sediments were generally highest at Waneta, the furthest sampling station downstream. There were no apparent temporal trends; variability in measured concentrations, especially at Waneta likely was due to different sediment characteristics at each station. Deposition rates of slag within the river have resulted in some areas with much higher concentrations of metals than others, with large variability occurring within a small spatial scale. The relative concentrations of zinc, copper and lead appear to reflect a slag signature (slag generally consists of 2.5% zinc, 1.0% copper and 0.5% lead). A principle component analysis of metals concentrations in sediment indicated that the spatial distributions of arsenic, chromium, copper, lead and zinc are most similar and thus indicate a common source (i.e., Teck Cominco).

Metals that exceeded the Lower Columbia Sediment Quality Objectives (SQOs) one or more times included total arsenic, cadmium, chromium, copper, lead, mercury and zinc. Concentrations of cadmium, chromium and lead appear to have decreased in sediments at Waneta relative to concentrations measured in 1990/1991, indicating that capital improvements made at Teck Cominco during the early to mid 1990s have resulted in reduced metal concentrations in river sediments. However, copper and zinc concentrations were similar to those in 1990/1991 suggesting that slag in the river continues to influence some sediment chemistry measures.

Organics

Fatty acids – Total fatty acid concentrations were similar among stations during each sampling period. Highest total fatty acid concentrations occurred at Birchbank, while lowest concentrations occurred at Waneta, suggesting that Celgar was a likely source, although log-booming in the area and other, natural sources of organic material may also have contributed. The small number of observations (three) made it difficult to comment on time trends. However, relative to concentrations reported in 1992, total fatty acid concentrations were similar at Birchbank, but considerably lower at Waneta.

Resin acids – Concentrations of total resin acids were generally similar across stations and years, although concentrations at Birchbank appeared to be decreasing. Concentrations of resin acids observed in Arrow Lake appeared to be associated with higher TOC concentrations, suggesting that the deposition of natural forest-related organic matter above the Hugh Keenleyside Dam may have contributed to the resin acid concentrations. Relative to historical concentrations (1992), total resin acids concentrations are similar at Waneta, but were slightly higher at Birchbank.

Chlorinated Phenolics – Chlorinated phenolics were assessed only in 2001. Concentrations for all individual chlorinated phenolics were at or below the applicable detection limits.

Total PAHs – PAHs were assessed only in 2001. Concentrations of all individual PAHs were below applicable detection limits, with the exception of naphthalene and phenanthrene, which were quantified at or slightly above the detection limit. The highest total PAH concentration was 0.33 µg/g dw, which was below the B.C. MOE criteria for total PAHs of 4 µg/g dw (B.C. MOE 2006).

Dioxin/Furans – Dioxin/furan concentrations in sediment were measured in 2000, 2001 and 2002. Birchbank consistently had the highest 2,3,7,8-tetrachlorodibenzo-para-dioxin equivalence quotient (TEQ) concentrations, although concentrations generally decreased with time and concentrations at all stations were below the CCME interim sediment quality guideline (ISQG) of 0.85 pg/g TEQ. A comparison of results with historical values (1990/1991) indicated that dioxin and furan concentrations in sediments have decreased since the early 1990s (by three to 13 times). This followed a switch from elemental chlorine to chlorine-dioxide bleaching at the Celgar pulp mill, which resulted in a significant decrease in dioxins and furans in effluent.

Polychlorinated Biphenyls (PCBs) – PCB TEQs and total PCBs in sediments were measured in 2002 and 2004. Beaver Creek had the highest PCB TEQs, followed by D/S HLK (downstream of the Hugh Keenleyside Dam). Of the locations sampled, sediments collected from Waneta had the lowest concentrations. The maximum recorded sediment concentration was 5 to 6 times lower than the CCME sediment guideline (ISQG = 34,100 pg/g dw).

Polybrominated diphenyl ethers (PBDEs) – PBDEs in sediments were measured in 2002 and 2004. Concentrations in 2002 were similar among stations. However, in 2004 concentrations were much higher (up to 78 times higher at Beaver Creek) and more variable. In 2004, highest concentrations were measured at Beaver Creek (2,614 pg/g dw) and Bear Creek (2,346 pg/g dw). The high variability in 2004 may be partly attributable to differences in grain size and TOC content among stations. The DeBDE congener predominated, with concentrations over 10 times greater than the next most common congener. These results were similar to observations made by others. Four of the 12 sediment samples collected in 2002 and 2004 exceeded the maximum TOC-normalized concentration of 90.9 ng PBDE/g TOC observed within the Lower Columbia between 1992 and 2000 by Rayne et al. (2003).

Sediment Toxicity

No trend over time (1997 to 2004) was apparent in any of the toxicity tests.

Spearman correlation indicated significant negative correlations between metal concentrations and both survival and growth. There was also a significant negative correlation between TOC content and survival. *H. azteca* did not appear to be effected by grain size (i.e., fines content). The negative correlation between metals and toxicity indicates that the historical discharge of metals from Teck Cominco could be resulting in present-day impacts to sediment-dwelling organisms living downstream of the Teck Cominco site.

FISH

Condition

For all three species (whitefish, rainbow trout and walleye), mean condition (k) was similar between years, areas and sexes. No trends were apparent over time. Female mountain whitefish collected from the Waneta sampling area in 2002, 2003 and 2004 exhibited slightly higher condition factor than Birchbank females. However, there were no discernable trends in condition between areas, sexes or across time that might indicate an effect.

Chemistry

Metals – Metals that may accumulate in fish tissue were assessed in walleye (2000 to 2005), mountain whitefish (2001, 2003 and 2004) and rainbow trout (2000 and 2003), including arsenic, cadmium, chromium, lead and mercury. None of these metals differed significantly in concentration between Birchbank and Waneta sampling locations.

With the exception of mercury (as discussed below), it is unlikely that concentrations of any metals assessed posed health risks to humans or wildlife. Cadmium and lead concentrations in tissues were always below the detection limit (and were also much lower than applicable objectives or criteria).

Mercury – Walleye exhibited highest mean tissue mercury concentrations, followed by rainbow trout, and mountain whitefish. These results were expected, given that walleye have a long lifespan, were the largest fish caught and are at the top of the local aquatic food chain. There were no apparent differences in mercury concentration between fish caught in the Birchbank and Waneta sampling areas.

An analysis of mercury concentrations in fish muscle (i.e., edible portion of fish) did not indicate any changes between 2000 and 2005 for any of the three species assessed. Concentrations also were consistent with historical walleye data (1980 to 1988) and indicated that mercury concentrations in fish tissues collected from the Lower Columbia River are not changing over time.

Fish consumption advisories are published in the B.C. Freshwater Fishing Regulations Synopsis each year. Currently, there is no advisory for the consumption of game fish caught in the Lower Columbia River. However, based on B.C. provincial tissue-residue guidelines, the maximum consumption rate of walleye (given a mean concentration of 0.36 μg/g wet) should be limited to 260 g/week. Washington State currently has a consumption advisory for walleye in Lake Roosevelt, which is downstream of the Lower Columbia.

Concentrations in walleye exceed tissue-residue guidelines for the protection of fish eating wildlife (e.g., CCME and B.C. MOE), indicating possible risks to these species. Food chain modelling conducted for Teck Cominco, indicated that great blue heron in the area could be at risk by eating mercury-containing fish. Additional modeling refinements have been recommended and are pending.

Dioxin/Furans – Dioxin/furan concentrations in fish muscle were measured in mountain whitefish (2000, 2001, 2003 and 2004) and rainbow trout (2000).

Generally, dioxin and furan concentrations (total TCDD, total TCDF and dioxin/furan TEQs) in mountain whitefish were similar among sampling events and between Birchbank and Waneta. Relative to historical results, mean tissue concentrations have decreased by at least 30 times since 1990/1991. This decrease likely is attributable to the switch from chlorine to chlorine-dioxide bleaching at the Celgar pulp mill in 1993.

Calculated dioxin/furan TEQ concentrations for all mountain whitefish and rainbow trout were well below the Health Canada consumption guidelines of 15 pg/g wet weight in fish muscle (Health Canada 2005). The highest concentration observed (5.0 pg/g ww; in mountain whitefish), was three times lower than the Health Canada guideline.

However, the mean dioxin and furan TEQs for mountain whitefish in the Columbia River exceeded the guideline for fish-eating mammals (i.e., 0.79 pg TEQ/g ww) in 2000 and 2002, but did not exceed the guideline for fish-eating birds (i.e., 4.75 pg TEQ/g ww). The highest measured concentration in an individual fish (5.0 pg TEQ/g ww) exceeded the guidelines for fish-consuming mammal of fish by 6.5 times and bird consumers of fish by 1.05 times. The 95% upper confidence limit of the mean (95%UCLM; 0.95 pg TEQ/g ww) was approximately 1.2 times higher than the CCME guideline for mammals, but below the guideline for birds.

None of the rainbow trout tissue concentrations assessed in this study exceeded either of the CCME wildlife tissue-residue guidelines for mammals and birds that consume fish. Rainbow trout caught from the Birchbank sampling area appeared to have slightly higher concentrations of dioxins/furans than those from Waneta. Waneta is located further downstream from the Celgar pulp mill, which was historically the primary source of dioxins/furans to the river.

The TEQ results indicate that there are potential risks to mammalian wildlife species feeding on fish. The fact that rainbow trout concentrations are below the tissue-residue guideline is promising, as it indicates that if mammalian wildlife are consuming many different fish species, they may be exposed to lower dioxin/furan concentrations.

Mountain whitefish feed closer to the bottom than trout indicating that the primary pathway of exposure may be from sediments via benthic organisms.

PBDEs – PBDEs were assessed in mountain whitefish in 2002 and 2004 and rainbow trout in 2003. Many of the 43 congeners tested were not detectable. However, total PBDEs, total tribrominated diphenyl ethers (TriBDE), total tetrabrominated diphenyl ethers (TeBDE), total pentabrominated diphenyl ethers (PeBDE), total hexabrominated diphenyl ethers (HxBDE) and heptabrominated diphenyl ethers (HpBDE) could be calculated.

Tetra and pentabrominated diphenyl ethers accounted for the greatest proportion of PBDEs observed in fish tissue. Higher-molecular-weight PBDEs (i.e., DeBDE), although present in sediments in high concentrations, were found at very low concentrations in tissues. These observations are consistent with other studies, which indicated that intermediate-molecular-weight PBDEs tend to bioaccumulate more than the higher-molecular-weight congeners.

Generally, fish captured in the Birchbank sampling area (Genelle to Birchbank) had slightly higher PBDE concentrations. Mountain whitefish had much higher mean concentrations of TeBDE and PeBDE than rainbow trout, suggesting that the primary pathway of PBDE exposure is from sediments via benthic organisms (given mountain whitefish are more likely to be feeding off the bottom than trout).

No tissue-residue guideline currently exists for PBDEs. A proposed action level for posting a limited fish consumption advisory for humans (recommended by the North Carolina Department of Health and Human Services) is 5,000 ng/g ww in fish muscle for pentabromo diphenyl ether, based on a consumption rate of 0.91 kg/month. The highest measured PeBDE concentration in mountain whitefish muscle was 184 ng/g ww, which is approximately 27 times less than the proposed action level. Even if the assumed consumption rate is 1 kg/week, which is consistent with worst case approximations for the Lower Columbia, the highest PeBDE concentration measured in mountain whitefish is still 6.8 times less than this modified action level.

Therefore, the current PBDE concentrations do not appear to pose any immediate human health concerns. However, the estimates were based on a proposed action level and therefore, future regulatory developments associated with PBDE should be closely monitored. In addition, no tissue-residue guideline for wildlife exists.

Concentrations of PBDEs appear to be rapidly increasing in the Lower Columbia River. Between 1992 and 2000, concentrations had increased by up to 12 times. Data presented in this document (for 2002/2004) indicate that the concentration of total PBDEs at Birchbank and Waneta were approximately 20 times the concentrations measured in 1992. Continued monitoring of PBDEs in fish tissues in the future is strongly recommended.

Relative to PBDE concentrations in fish caught in Washington State, Lower Columbia Fish concentrations are on the high end of the range observed. However, large sport-fish species from several large water bodies had total PBDE concentrations within the range observed in the Lower Columbia.

1.0 INTRODUCTION

1.1 STUDY LOCATION AND CONTEXT

The Columbia River is considered by many to be the dominant river system in the Pacific Northwest. From its source between the continental divide and the Selkirk Mountain Range near Canal Flats, B.C., the Columbia flows more than 1,900 km to the Pacific Ocean, draining a total area of 669,500 km^2.

The study area, known in Canada as the Lower Columbia River, extends from the community of Birchbank to the international border with the United States, approximately 760 km downstream of its headwaters (Figure 1.1) and is a key aquatic resource for local communities. It supplies water for power, industry, recreation, irrigation and residential use (i.e., potable water), while receiving wastewater from industrial and municipal sources. The river also provides important habitat and resources for diverse communities of fish and wildlife.

Due to these conflicting resource needs, the Columbia River Integrated Environmental Monitoring Program (CRIEMP) was created in 1991 to monitor ecosystem integrity (e.g., river chemistry and fish health). CRIEMP is made up of key stakeholders from all levels of government, local industry, First Nations, and non-governmental organizations from Canada and the United States. The mission of CRIEMP is to assess the status of ecological health of the Canadian portion of the Columbia River between the Hugh Keenleyside Dam and the Canada-US border. The primary objective of CRIEMP is "to gather and share environmental information with the public, agencies, and industries in a coordinated and cost-effective manner" (CRIEMP 2005). The CRIEMP vision for the Lower Columbia River "embodies a productive ecosystem that enhances the natural aquatic and terrestrial environments and balances these values with human-based values (economic, traditional, cultural, recreational, social, aesthetic and health)" (CRIEMP 2005).

1.2 BACKGROUND

The B.C. Ministry of Environment (B.C. MOE) is a member of CRIEMP and routinely collects environmental data from the Lower Columbia River to assess impacts from local municipal and industrial inputs. The sampling program generally follows recommendations in the *Lower Columbia Water Quality Objectives* document (Macdonald 1997). Chemical and physical variables in various environmental media (water, sediments and fish tissue) are measured as part of the monitoring program and are compared to the site-specific water quality objectives (WQOs). These benchmark concentrations were designed to be protective of ecological organisms living in the Lower Columbia.

The WQOs and study design recommended in Macdonald (1997) were assembled with consideration of factors specific to the Lower Columbia. In this area, water quality is influenced by regulated point sources of contaminants, several dams, and non-point sources of contaminants (i.e., run off from roads, agricultural and urban lands, and log booming activities, amongst others). Major anthropogenic influences on the Lower Columbia River include:

- **STPs** – Several sewage treatment plants (STPs) discharge municipal wastewater to the Lower Columbia River upstream and within the study area. These include the Castlegar STP, the Trail STP and the Fruitvale STP, which discharges to the Lower Columbia via Beaver Creek. Sewage treatment plants can be a source of nutrients, oxygen-demanding substances, microbial pathogens and anthropogenic chemicals that can result in toxic effects.

- **Zellstoff Celgar** – The Celgar pulpmill does not fall within the study area, but is included because of historical effects to the water quality of the Lower Columbia River. Since being built in 1961, the mill has produced bleached softwood Kraft pulp. Environmental concerns associated with the mill have included increased biological oxygen demand (BOD) and discharges of chemicals to the Columbia River that can result in toxic effects (i.e., resin and fatty acids, chlorophenols, nutrients and dioxins/furans). Historical discharges also resulted in the formation of a fibremat in the river near the mill that smothered native habitat. In 1993, the mill underwent a modernization program (including improved effluent treatment), which resulted in improvements to downstream water quality (Hatfield 2007). The modernization also included a switch from elemental chlorine to chlorine dioxide in the bleaching process, which resulted in significant decreases in the discharge of dioxins/furans and other chlorinated substances to the Lower Columbia River.

- **Teck Cominco Metals Ltd.** – Teck Cominco operates an integrated smelting and refining complex in Trail. Since 1896, the facility has been processing ore concentrates to produce metals and a number of byproducts. Lead and zinc are the primary metals produced today; however, the facility also produces silver, gold, cadmium, bismuth, indium, germanium, germanium dioxide, copper sulphate, copper arsenate, sodium, antimonite (a form of antimony) and a variety of sulphur products and agricultural fertilizers (G3 2001).

  Environmental concerns associated with the facility include effluent releases to the Columbia River, groundwater discharges from soils containing smelter material and atmospheric discharges. Several outfalls discharge treated effluent to the Columbia River. In recent years, the smelter has undergone process upgrades to reduce potential ecological effects on to the river. Between 1980 and 1996, metals were removed from various effluent streams, effluent treatment was improved, and the phosphate fertilizer plant was closed. Reduced discharges of many metals and compounds, especially cadmium, mercury, lead, arsenic and phosphate, were achieved (G3 2001). Three recent upgrades anticipated to have beneficial results include: elimination of slag discharge; construction of a KIVCET lead smelter; and, the remediation of historical landfills in the Stoney Creek watershed. These are described below.

  - Slag is a glassy, metal-containing byproduct of smelting, which can impact aquatic organisms toxicologically (via exposure of metals contained in the slag) and physically (by causing abrasion to respiratory surfaces or gastrointestinal lining, or by smothering habitat). Prior to mid 1995, up to 145,000 tonnes of slag was discharged yearly to the Columbia River (G3 2001).

  - The KIVCET smelter became fully operational in 1999. Relative to the previous process, it reduced atmospheric emissions and improved effluent quality. Once it was brought online in 1997, there was a substantial decrease in the release of metals, particulates, and sulphur dioxide to air and water.

  - Remediation work was completed within the Stoney Creek watershed to reduce infiltration through historical landfills and divert seepage water from entering Stoney Creek and ultimately the Columbia River. Remediation activities included: (1) the capping of the Old Warfield Landfill in 2002; (2) the completion of the Duncan Dome Permanent Storage Facility in 2005; and (3) the building of a seepage collection system in 1997 (which has been subsequently expanded several times through to 2006). Improvements in water quality are expected and have been documented during monitoring studies in Stoney Creek (Duncan, *pers com,* 2008).

- **Dams** – There are several dams within the Columbia Basin with the potential to influence flows and water quality within the study area. On the Columbia River, there are three upstream dams, the closest being the Hugh Keenleyside dam, located approximately 30 km upstream of Birchbank. On the Kootenay River, there are six upstream dams within both Canada and the U.S., the closest being the Brilliant Dam. Near Waneta is the confluence of the Pend d'Oreille River, which is regulated by three dams, the closest of which is the Waneta Dam. Water flows in the study area are regulated by the Hugh Keenleyside and Brilliant dams.

  The primary water quality concern associated with dams is total dissolved gas pressure (TGP), which is a measure of the saturation of dissolved gases in water. Gas supersaturation occurs when water mixed with air is plunged into deep water below a dam spillway. The air dissolves into the water causing it to be supersaturated. Supersaturation can cause formation of gas bubbles within the tissues of resident aquatic organisms, which may lead to mortality. In order to minimize the impacts to fish, Fisheries and Oceans Canada (DFO) and B.C. Hydro have been working together to improve dam operations and minimize TGP in water downstream of dams on the Columbia.

- **Non-point sources** – These include contaminants or physical water quality changes that are not readily attributed to any one source. These may include run-off from roads, urban or agricultural areas, septic fields along the river, and aerial deposition. Some contaminants are more likely to originate from non-point sources. These may include polychlorinated biphenyls (PCBs), which can originate from industry, urban areas and dams, and polybrominated diphenyl ethers (PBDEs).

1.3 REPORT OVERVIEW AND OBJECTIVES

This report summarizes key findings from the annual Lower Columbia River WQO monitoring program conducted from 1997 to 2005. The findings will be used to assess the health of the Lower Columbia River, establish recommendations for future monitoring, and (if needed) update the WQOs. Water, sediment and fish tissue chemistry data, toxicity testing results, and fish size and age measurements for the Lower Columbia River from Birchbank to the international border were evaluated. An accompanying database was also created to allow easy access to historical data and to facilitate efficient upload of new data. Evaluated data included:

Water Chemistry and Bacteriology: Water chemistry and bacteriology data provide an instantaneous picture of contaminant concentrations within the Lower Columbia River. In addition to loadings from industry, sewage treatment plants (STPs) and numerous non-point sources, water quality is affected by the flow of water from the Hugh Keenleyside Dam, Kootenay River, and other tributaries. The concentrations of various contaminants in water provide an indication of direct exposure of aquatic organisms and humans to these substances.

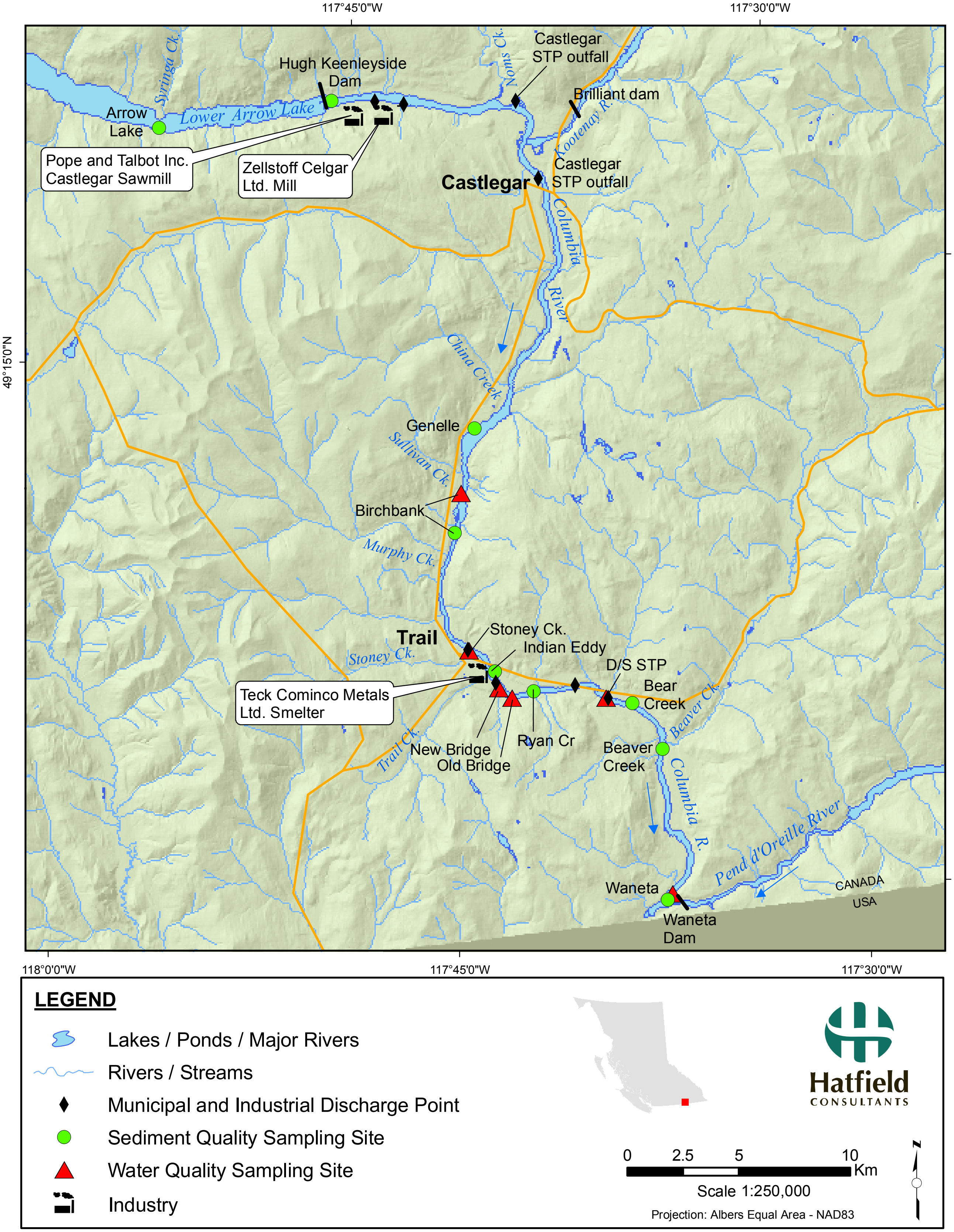
Sediment Chemistry: Sediments are a common repository of contaminants released to aquatic systems. Sediments also do not respond as quickly to contaminant loadings to an aquatic system as water. Consequently, sediment chemistry data provide an indication of water quality over a longer period of time (i.e., more of a "time-averaged" concentration than water). In addition, numerous aquatic organisms rely on sediments for habitat and as a source of food. Sediment concentrations of contaminants can be highly dependent on current velocity; higher velocities generally scour away fine sediments, leaving only gravel or cobble (these are called erosional areas); lower velocities do not remove fine sediments (sands, silts and even clays), which accumulate on the bottom (these are called depositional areas). Sediments assessed for the WQO program were collected in depositional areas. However, such areas are very limited in the Lower Columbia River.

Sediment Toxicity Testing: In addition to chemistry, toxicity testing using sediment-dwelling organisms can provide valuable insight into the health of river sediments. Sediment toxicity tests for the WQO program were performed with aquatic insects and crustaceans.

Fish Tissue: Fish accumulate various environmental contaminants (mercury, dioxins and furans, PBDEs) from water and dietary sources. Analysis of contaminant concentrations in fish tissues may provide an indication of impacts to higher organisms (for instance, wildlife and people) that consume fish in the Lower Columbia River.

Fish Health: Fish health can be assessed by investigating the relationships between age, length and weight. Fish under stress may be small for their age (i.e., size-at-age) and may have lower condition.

Figure 1.1 Study area and sampling locations for Water Quality Objectives Monitoring Program (1997 to 2005).



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2.0 METHODS

2.1 SAMPLE COLLECTION AND ANALYSIS

2.1.1 Water Quality

Water quality was sampled during low-flow periods throughout the year (from October to May) to provide an assessment when dilution was minimized. During each sampling period, water samples were collected on five days within a 30-day period. Water sampling was conducted following the protocols provided in the *B.C. Ministry of Environment Ambient Fresh Water and Effluent Sampling Manual* (RIC 1997).

Surface water samples were collected from six stations (Birchbank, D/S Stoney Creek, New Trail Bridge, Old Trail Bridge, D/S STP and Waneta) by directly immersing sampling bottles into the river (Table 2.1).

Sampling was conducted from a boat. Variables measured included:

- ***In-situ* water quality** (i.e., field measurements): Included dissolved oxygen (DO), pH, conductivity, temperature, flow and total gas pressure (TGP). In-situ water quality variables were measured in the field using either an Aquacheck or YSI multimeter. TGP was monitored at Birchbank and Waneta using a tensiometer. Flows were provided by B.C. Hydro at their Birchbank station.

- **Conventional variables**: Included hardness, turbidity, and non-filterable residue. Samples were analyzed by Environment Canada's Pacific Environmental Science Centre (PESC) laboratory (North Vancouver, B.C.) or Maxxam Analytical Services (Maxxam, formerly PSC Analytical Services) (Burnaby, B.C.).

- **Nutrients**: Included ammonia, total nitrogen and total dissolved phosphorus. Samples were analyzed by PESC or Maxxam.

- **Microbial indicators**: Included fecal coliform, *Enterococcus*, *Escherichia coli* and total coliform. Samples were analyzed by JR Laboratories Inc. or Cantest Ltd. (Burnaby, B.C.) using either the most probable number (MPN) method or the membrane filtration method (colonies or colony forming units [CFU] per unit volume). The method used was dependent upon factors such as turbidity, microbial levels, etc. Microbial indicators were measured to assess risks to human health from exposure to bacteria.

- **Metals**: Included total metals, dissolved metals and extractable metals. Samples were analyzed by PESC or Maxxam.

Additional samples were collected for quality assurance/quality control purposes. These samples provided a quantifiable assessment of precision and accuracy. Field QA/QC measures included the collection and analyses of field duplicates, trip blanks, and field blanks.

Table 2.1 Water quality monitoring stations used for WQO monitoring program, 1997 to 2005.

Columbia River Stations	#ID	Variables measured
Birchbank	0200003	*In-situ*, conventionals, nutrients, microbial indicators and metals
100 m D/S Stoney Creek	E223892	*In-situ*, conventionals, nutrients and metals
New Trail Bridge [1]	0200558	*In-situ*, conventionals, nutrients and metals
Old Trail Bridge	E216137	*In-situ*, conventionals, nutrients and metals
100 m D/S STP	E102817	*In-situ*, conventionals, nutrients, microbial indicators and metals
Waneta	0200559	*In-situ*, conventionals, nutrients, microbial indicators and metals

[1] Sampling station is within the initial dilution zone of Teck Cominco's outfall, therefore attainment of water quality objectives is not expected at this station.

2.1.2 Sediment Quality

Collecting sediments from the Lower Columbia River can be challenging because of variable flows and changing sediment dynamics in the river. Over time, depositional areas change and sediments are redistributed, which makes it difficult to collect sediments from a specific and consistent location each year. Generally, samples were collected from the same site each year. However, attempts were made to focus on areas within the site that would have the highest contaminant concentrations. These would generally consist of fine-grained depositional areas, which do not represent the typical erosional habitat (cobbles and boulders) that is predominantly found within the Lower Columbia River.

All sediment sampling was conducted by deploying a Ponar grab from a boat. Generally, multiple grabs were required to obtain sufficient sample volume for analyses. In some years, notably 2001, additional difficulty was experience recovering sufficient volume of sediments and numerous attempts were required to obtain sufficient sediments for analysis. Sediments were typically collected near the shore below two to three metres of water.

Samples were submitted to Elemental Research Inc (Trail, B.C.), PESC, Maxxam or ALS Laboratories (Vancouver, B.C.) for analysis of total metals (ICP or ICP-MS), mercury, resin and fatty acids, total organic carbon (TOC), simultaneously extractable metals (SEM), acid-volatile sulphides (AVS), and particle size. Polybrominated diphenyl ethers (PBDEs), polychlorinated biphenyls (PCBs), chlorophenols, PAHs, dioxins and furans were analyzed at AXYS Analytical Laboratories (Sydney, B.C.) or Pacific Rim Laboratories Inc. (Burnaby, B.C.).

Toxicity testing was performed either at PESC or EVS Environment Consultants (now Golder Associates Ltd, North Vancouver, B.C.). Sublethal toxicity tests varied among years. Two species were used: *Hyalella azteca* (a freshwater crustacean); and *Chironomid tentans* (a fly larvae). Tests were as follows:

- A 14-d H. azteca survival and growth test, conducted each year from 1999 to 2004;
- A 10-d C. tentans survival and growth test, conducted only in 1999; and
- The 28-day H. azteca survival and growth test, included from 2000 to 2004 to assess potential chronic effects not adequately quantified using the shorter 14-day test.

Sediment programs varied slightly from year to year. Differences included the number of sampling sites, variables measured, number of samples per site (Table 2.2), and small changes to sampling methodology.

Table 2.2 Summary of sediment analysis conducted for WQO program, 1999 to 2004.

Year	1999	2000	2001	2002	2004
# sites	3	2	6	6	7
# samples per site[1]	3	1	1	1	1
QA/QC samples	√	-	-	-	√
% Total Organic Carbon (TOC)	√	√	√	√	√
Simultaneously Extractable Metals (SEM)	-	-	√	-	√
Acid-Volatile Sulphides (AVS)	-	-	√	-	√
Dioxins and Furans	-	√	√	√	-
Metals	√	√	√	√	√
Wood Preservatives and Fatty Acids	-	√	√	√	-
Resin Acids	-	√	√	√	-
Polybrominated Diphenyl Ethers (PBDE)	-	-	-	√	√
Polychlorinated Biphenyls (PCB)	-	-	√	√	√
Chlorophenols	-	-	√	-	-
Polycyclic Aromatic Hydrocarbons (PAH)	-	-	√	-	-
Sediment Toxicity	√	√	√	√	√

[1] Each sample consisted of a composite of multiple grabs (3-8) depending on amount collected/grab, matrix, etc.

2.1.3 Fish Tissue

Fish tissue analysis focused on walleye (*Stizostedion vitreum*), mountain whitefish, (*Prosopium williamsoni*) and rainbow trout (*Oncorhynchus mykiss*).

All fish were captured by RL&L Consultants (now Golder Associates, Castlegar, B.C.) using boat electrofishing as part of B.C. Hydro’s fish indexing program. All fish were collected within two sections of the Columbia River:

- Between Genelle and Birchbank (”Birchbank”) located downstream of inputs from Zellstoff Celgar; and
- Between Beaver Creek and the US Border (”Waneta”) located downstream of inputs from the City of Trail and the Teck Cominco smelter.

The sampling program targeted larger fish, representative of what human consumers would be eating and also likely to contain the highest concentration of contaminants that accumulate in tissues.

Measurements

All fish were measured for fork length (± 1 mm) and total body weight (± 0.1 g) at time of capture. Mountain whitefish and rainbow trout were aged using scales from the left side of the fish above the lateral line, between the dorsal and adipose/caudal fins. The first two to three spines of the dorsal fin were used to age walleye. Aging of fish was conducted by RL&L Consultants.

Measurements of age, weight and length collected at the time of fish capture permit an assessment of overall fish health. Generally, fish having a greater weight and fork length for a given age may indicate a healthier system as these fish are feeding and converting food energy to biomass. Stressed fish generally weigh less at a given length and age. Relationships between weight, length and age can be analyzed graphically, assessed using calculated indices or analyzed using statistics.

Tissues

All fish dissections followed U.S. Environmental Protection Agency (USEPA) protocols for dissections (USEPA 2000). The 2000 survey also included a dissection following Environment Canada's protocol for comparison. For the chemical analysis of rainbow trout and mountain whitefish muscle, skin was left on. However, scales were removed from mountain whitefish. For walleye, skin was removed. Full fillets, including epaxial muscle and belly flap, were homogenized for the analysis.

Tissues were analyzed for metals, dioxins and furans, PCBs and PBDEs (Table 2.3).

Table 2.3 Fish tissue analysis conducted for WQO monitoring program, 2000 to 2005.

Year	# Sites	# Samples Analyzed	Fish Species	Metals	Dioxins & Furans	PBDE	PCB
2000	2	20	Walleye	√		-	-
	2	40	Mountain Whitefish	-	√	-	-
	2	32	Rainbow Trout	√	√	-	-
2001	2	10	Walleye	√	-	-	-
	2	10	Mountain Whitefish	√	√	-	-
2002	2	19	Walleye	√	-	-	-
	2	10	Mountain Whitefish	-	√	√	-
	2	10	Rainbow Trout	-	-	-	-
2003	2	20	Walleye	√	-	-	-
	2	20	Mountain Whitefish	√	√	-	-
	2	20	Rainbow Trout	√	-	√	-
2004	2	24	Walleye	√	-	-	-
	2	24	Mountain Whitefish	√	-	√	√
2005	2	24	Walleye	√	-	-	-

2.2 DATA SYNTHESIS

The WQO sampling program has resulted in a large amount of data between 1997 and 2005. Although all of these data will be contained in the accompanying database, it is not practical, nor useful, to include all of it in this data summary and interpretive report. Consequently, a rationale was developed for selecting key data. The approach was divided into two steps:

- Choice of specific monitoring variables (e.g., metals, organic compounds, nutrients, microbial indicators); and
- Choice of analysis group (e.g., for metals: use of dissolved, total or extractable fraction; use of ICP or ICP-MS analysis; and for dioxins/furans: use of total and TEQ concentrations).

2.2.1 Monitoring Variables

The following criteria were used to select monitoring variables to include in the data synthesis and analysis:

- Monitoring variables having known exceedances of Canadian criteria or guidelines;
- Monitoring variables that are good indicators of a particular type of industry or activity present within the study area and identified in the WQO technical assessment (Macdonald 1997) (e.g., dioxins and furans for historical pulpmill operation, metals for smelters);
- Monitoring variables that provide a good indication of ecosystem integrity (e.g., fish condition); and
- Chemicals that have been identified by the scientific community as chemicals potentially posing a future concern (and that were measured during field programs; i.e., PBDEs).

Variables retained for summary and synthesis were as follows:

Water

- ***In-situ measurements*** **–** DO, pH, conductivity, TGP, flow;
- ***Conventional variables*** **–** turbidity and hardness;
- ***Nutrients*** **–** Total nitrogen, ammonia and total dissolved phosphorus;
- ***Metals*** **–** Arsenic, cadmium, chromium, copper, lead, mercury, thallium and zinc;
- ***Organics*** **–** Resin acids and fatty acids; and
- **Microbial indicators –** Fecal coliform, *E. coli, Enterococcus.*

Sediment

- ***Physical Variables –*** Grain size and TOC;
- ***Metals Bioavailability –*** SEM-AVS;
- ***Metals –*** Arsenic, cadmium, chromium, copper, lead, mercury, cadmium, chromium, thallium and zinc;
- ***Halogenated Organics (i.e., containing either chlorine or bromine) –*** Total PCBs, and individual PCBs, dioxin and furans and PBDEs;
- ***Other Organics –*** Total resin acids, total fatty acids and total PAHs; and
- ***Sediment Toxicity –*** *H. azteca* and chironomid growth and survival.

Fish

- ***Fish Size and Age –*** Fish condition;
- ***Metals –*** Arsenic, cadmium, chromium, lead and mercury; and
- ***Halogenated Organics –*** PCBs, dioxins and furans and PBDEs (penta, octa, deca and total PBDEs).

2.2.2 Non-quantifiable Data

In all graphs, "not detected (ND)" indicates that the concentration of a chemical in an environmental sample was below the limits of analytical quantification. When sample means were calculated, the method detection limit (MDL) was used (i.e., ND = 1 x MDL). The only exception was the calculation of dioxin/furan or PCB toxic equivalents (TEQs), which assumed ND = ½ MDL (see Section 2.3.5).

2.2.3 Analysis Group

2.2.3.1 Total, Extractable and Dissolved Metals

Metals can be found in various forms in water. Each form varies in its ability to be absorbed by aquatic organisms and subsequently result in a possible toxic effect. Three types of metals analysis were conducted under the WQO program:

- ***Dissolved metals:*** Represent those metals that remain in the water after filtration through a 0.45-micron filter. Dissolved metals represent the fraction of metals in water that is most readily taken up by aquatic species. Many jurisdictions now consider the dissolved fraction as a more ecologically relevant measurement of water quality than the total fraction (USEPA 1996).

- ***Extractable metals:*** Includes metals in the dissolved form, plus the fraction that is easily extracted from particulate matter using a weak acid digestion. The extractable fraction represents metals that are more likely to be bioavailable. The analysis was done predominantly to achieve quantification at lower concentrations, which could not be achieved using the technique to derive total metals concentrations.

- ***Total metals:*** Represent the sum of dissolved and particulate-bound forms. Most guidelines for the protection of aquatic life are intended to be applied against total concentrations (e.g., B.C. MOE Approved and Working Criteria, CCME Water Quality Guidelines and the Lower Columbia WQOs).

Accordingly, retaining total metals for screening purposes was considered most appropriate for this assessment, and were reported herein. Dissolved and extractable metal concentrations appear in the database only.

2.2.3.2 ICP and ICP-MS Metals Data

Metals analyses in water were commonly measured by two types of analytical apparatus:

- Inductively coupled plasma – optical emission spectrometer (ICP); and

- Inductively coupled plasma – mass spectrometer (ICP-MS).

The optical emission spectrometer detector used with ICP is less sensitive than the more modern MS detector. ICP is generally only used either as a first analytical step to ensure that there are no concentration spikes that may damage a MS detector or when very low quantification limits are not required.

Accordingly, where both ICP and ICP-MS data were provided for a given sample, the ICP-MS data were selected.

2.3 DATA ANALYSIS

Qualitative and quantitative methods were used to assess the monitoring variables. Data were screened against applicable objectives/criteria/guidelines and graphs and statistics were used to investigate spatial and temporal trends. Where available, Lower Columbia Environmental Objectives were used for screening. In cases where no objective was available, screening was done against CCME or British Columbia Environmental Guidelines or Criteria (Appendix 2A). In those cases where there were no available Canadian objectives, criteria or guidelines, guidelines from other jurisdictions were used.

Water quality data collected from the New Bridge site were not included in data screening. The New Bridge site is within the initial dilution zone (IDZ) for discharges from Teck Cominco. Consequently, attainment of WQOs is not expected at this site.

Data were summarized using mean, median, standard deviation, minimum, maximum, 90th percentile and standard error. In addition, in certain circumstances (discussed further below), the 95% upper confidence interval of the mean was calculated. In most cases, samples that could not be quantified were given the full value of the reported detection limit to provide worst-case conditions. This approach introduced some variability into the data set, especially when detection limits varied for a given analysis.

As an additional analytical step, historical data (means) for Waneta taken from the WQO technical report (McDonald 1997) were compared with more recent data covered in this report. Waneta was selected for comparison, because it is the station furthest downstream and, therefore, would be reflective of all the potential upstream sources of contaminants to the Lower Columbia River. There are no significant tributaries in the study area that would result in notable chemical dilution in the main stem.

The specific date of collection was not provided for the historical data (McDonald 1997). In the current investigation (1997 to 2005), data were collected during known low-flow periods and low dilution capacity (i.e., "worst case" concentrations). Consequently, a decrease in mean concentrations in the current period relative to historical data would likely represent an improvement in water quality. On the other hand, an apparent increase in mean concentration may or may not represent a worsening of water quality.

When assessing sediment toxicity testing results, a 20% decrease in either growth or survival of individual test organisms relative to reference sediments was considered ecologically relevant. Reference sediments tested included sediments from Arrow Lake, sediments downstream of the Hugh Keenleyside Dam and sediments from Roberts Bank (which is not on the Columbia system, but was a standard reference sediment used by PESC).

For some variables, calculations were necessary to either provide an index (such as fish condition), to summarize and quantify a group of closely related chemicals (PCBs, dioxins and furans and PAHs), or to derive a reasonable estimate of exposure over time. Statistics and calculations used in this summary and data analysis report are as follows.

2.3.1 Water Quality Index

Water quality data were summarized using the CCME (Canadian Council of Ministers of the Environment) Water Quality Index (WQI) (CCME 2001). The WQI is a useful tool because it summarizes large amounts of information into simpler terms, providing a broad overview of environmental performance that is more easily understood by non-technical audiences.

For each site, the WQI was calculated using cadmium, copper, lead, thallium, zinc, and fecal coliform concentrations, where these data were available. The WQI was calculated by comparing these variables to their respective WQOs. The primary water use assessed was aquatic life, although the drinking-water objective for fecal coliforms was also included. The WQI assessed the number of variables exceeding objectives, the number of instances a given variable exceeded the objectives, and the magnitude of exceedances. It then provided a descriptive water quality ranking (excellent, good, fair, marginal, poor) in relation to that assessment. For example, an "excellent" site would have very few, if any, exceedences and would provide excellent habitat for aquatic life, while a "poor" site would have many exceedences, often of larger magnitude, and aquatic life would be threatened and possibly impaired.

The WQI provides information that is only as accurate as the data used to calculate it. This is important to note as some of the Lower Columbia water quality data were not much greater than the respective MDLs. As discussed earlier, reported measurements which are close to their respective MDLs generally have poor accuracy. Consequently, when these data are used to calculate the WQI, it can bias the resulting index value. The poor accuracy of these measurements becomes even more of an issue when the measured concentrations are either close to or exceed the respective WQOs. Cadmium measurements in water are subject to this concern. In addition, the WQIs for the more "ambient"-type sites, like Birchbank, are also more sensitive to this sort of bias. Unintentional contamination of samples (especially metals) in the dataset was also suspected in some instances. These erroneous results could result in a lower index value for a given sample.

The following information outlines how data quality issues were addressed by either correcting or eliminating suspect data.

- Chromium was not used since most of the measured concentrations were close to the MDL and therefore not considered accurate. Measured concentrations of chromium also did not tend to vary much between sites (i.e., no measurable effects of Teck Cominco on chromium concentrations in the river were observed at the MDL's used).

- Cadmium concentrations were also close to the MDL in some cases. However, these were included because cadmium is known to be associated with Teck Cominco operations The cadmium data displayed obvious differences between the sites.

- Zinc concentration measurements from December 2001 were not included in the WQI due to concerns with contamination or laboratory error.

- One copper measurement, collected at Waneta in 2001, was also excluded. This measurement was suspect because it was two to three orders of magnitude above upstream concentrations, and far higher than any historical recorded measurements in the routine monitoring data set from the site.

2.3.2 Statistics

Statistics were performed on sub-sets of the data set to answer the following specific questions:

1) **Was there an increasing or decreasing trend in the concentrations of contaminants in water over the study time period?** It was anticipated that upgrades at various industries should result in improvements in water quality during the study period. A statistical method that corrects for outside variability was sought.

To answer this question, multivariate linear regression was performed using the following equation:

$$C_{Waneta} = C_{Birchbank} + \text{Sampling date} + (C_{Birchbank} \times \text{Sampling date}) + \text{Constant}$$

Where C is the concentration of a given contaminant at either Waneta or Birchbank. The P value associated with the interaction term (i.e., $C_{Birchbank}$ x Sampling date) indicates whether there is a trend at Waneta relative to Birchbank. Consequently, the approach provides an indication of trends, while correcting for variability caused by factors upstream of Birchbank (i.e., reference variability). Analysis was done on 30-day mean concentrations, data was log transformed prior to statistical analysis, and sampling dates that yielded concentrations below the detection limit for both Birchbank and Waneta were removed from analysis. Residuals were plotted to assess test assumptions. In all cases, residual plots appeared to meet the assumptions of homogeneity of variance and normality. Chemical contaminants having outliers (i.e., individual sampling dates with residuals greater than 4 or less than -4) were tested first with outliers included and then with outliers removed.

2) **Were concentrations of contaminants in water significantly different at Birchbank and Waneta over the study time period?** If the answer to this question was yes, it indicated a significant source of a given contaminant over and above the concentration coming from upstream (or reference) sources.

To answer this question, a paired t-test was performed with Birchbank and Waneta data. The paired t-test determined if the mean of differences between Waneta and Birchbank was significantly different from zero. Therefore, the approach normalized for natural variability and/or changes that may have occurred within the river upstream of Birchbank. Similar to the regression analysis, the paired t-tests were done on 30-day mean concentrations, data was log transformed prior to statistical analysis, and sampling dates that yielded concentrations below the detection limit for both Birchbank and Waneta were removed from analysis. Furthermore, chemical contaminants having outliers were tested first with outliers included and then with outliers removed.

3) **Are the distributions of metals in sediments correlated? And is there a relationship between metal concentration and observed sub-lethal sediment toxicity testing results?** A multivariate data reduction technique called Principal Component Analysis (PCA) was used to reduce the data set from eight variables

(i.e., eight individual metals: arsenic, cadmium, chromium, copper, lead, mercury, thallium and zinc) to 2 variables, called principal components. The first principal component (Factor1) describes the majority of variability; the second principal component (Factor2) is perpendicular to the first principal component and describes the majority of the residual variability. Generally metals in sediments are highly intercorrelated and therefore, Factor1 provided a good surrogate (although a unit-less one) for the distribution of all metals in sediments. If some of the metals in the sediments were from a different source (or there was another reason for the metals to be distributed differently), this would appear in the loadings plot of the principal component. The loadings plot shows the correlation coefficient of each of the original metals to Factor1 and Factor2.

The Factor1 and Factor2 scores for each sampling event were then correlated against the results of the 14-day chironomid sub-lethal sediment toxicity test, to determine whether metals concentrations in the river sediments may have contributed to toxicity. The 14-day chironomid test was selected, given it spanned the greatest number of years and stations. Spearman correlation analysis, a non-parametric correlation technique, was used to assess potential correlation. Correlation coefficients were compared to a table of significance using sample size (n) and a two-sided alpha of 0.05.

Given the main intent of performing PCA was to have two metal variables (factors) to compare to toxicity testing results, PCA was only performed on sediment data having corresponding 14-day chironomid toxicity testing results.

2.3.3 Calculation of 95% Upper Confidence Interval of the Mean

Concentrations of various contaminants in fish tissue were measured in order to assess potential risks to human and wildlife consumers. As a first screen, the maximum measured concentrations in individual fish were screened against the criteria values. However, consumers of fish will not be affected by eating a single fish; rather, impacts associated with contaminants in fish occur due to eating fish over a period of time. The mean fish concentration caught each year would provide an estimate of time-weighted exposure over time; however, it doesn't account for uncertainty in the data set. Consequently, a conservative estimate of the mean, the 95% upper confidence interval (95% UCLM) of the mean, was chosen to screen against tissue criteria in order to assess potential impacts to humans and wildlife.

The 95% UCLM was calculated using ProUCL, software created and distributed by the USEPA (2003a). The program assesses each data distribution and selects the most appropriate method to calculate the 95%UCLM.

2.3.4 Calculation of Fish Condition

Condition (k) is defined by the relationship between body weight and body length, and essentially describes how "fat" fish are. The following formula was used to calculate Fulton-type condition:

$$Condition\ (k) = 100 \times (body\ weight / length^3)$$

Condition values were analyzed in various groups to test for spatial or temporal trends.

2.3.5 Calculation of Toxic Equivalents (TEQs)

Toxic equivalents (TEQs) were calculated for dioxins and furans and PCBs. These two groups of chemical pollutants have a similar toxicological mode of action and consist of many similar molecules, called congeners. Each congener is determined by the number of chlorine atoms on each molecule and the placement of the chlorine atoms. Each congener has a slightly different toxic potency, with 2,3,7,8-TCDD (a dioxin congener) having the greatest toxic potency.

To calculate TEQs, the toxic potency of each congener relative to 2,3,7,8-TCDD was determined and expressed as a fraction called the toxic equivalency factor (TEF). The measured concentration (pg/g in sediments or tissue) of each individual congener was then multiplied by its respective TEF, yielding a toxicity-normalized concentration of each congener. The 1998 World Health Organization TEFs (Van den Berg 1998) were used. When these toxicity-normalized concentrations were all added together, the result was a TEQ concentration for either total dioxins and furans or for total PCBs.

Concentrations of individual congeners that were below quantification limits (i.e., below the detection limit) can either be given a value of zero (the Environment Canada method) or one-half the reported detection limit (the B.C. MOE method). In this report, the B.C. MOE method was used because it results in a higher, more conservative estimate.

2.4 DATABASE

As part of the data summary, a database containing all water, sediment and fish tissue data was assembled in Microsoft Access. Assembly consisted of two main steps: a design step and a report generation step.

The design step included three main phases: conceptual design, logical design, and physical design. During the conceptual design, the data set was reviewed and a design was chosen that matched the data to the outputs needed. In the second stage (logical design), the data were placed within the framework of a relational model. This stage was used to identify redundant data. Macros were written in Microsoft Access to carry out all data comparisons and manipulations. The macros were also used as a QA/QC check to correct and standardize data naming structures. In the third stage (physical design), the data were transferred into the final database framework, and tools were created to import data from various file formats. Once the three design stages were completed, the report generation step was used to develop reports for standardized queries.

The completed database was provided to CRIEMP along with this report. The database has been provided in Microsoft Access in an attempt to provide broad access. Once the database has been installed on a computer, users can access data by following the simple drop down menu.

Data can also be uploaded to the database from a Microsoft Excel worksheet. A data input template in Excel has been provided to CRIEMP with this report.

2.5 QA/QC

2.5.1 Field QA/QC

In addition to following good field standard operating procedures for the collection of samples, a number of tests were performed on the collected data to assess data quality, as discussed below.

Collection of field duplicates – duplicate samples are additional water or sediment samples collected at the same site and time as an original sample. For sediments, a duplicate sample was generally collected from a stainless-steel bowl containing homogenized sediments after the original sample had been transferred to a sampling jar. Duplicates provide an indication of heterogeny (differences of concentration of an analyte within a sampling site), as well as measurement precision.

Field blanks – field blanks are water samples consisting of distilled water provided by an analytical laboratory. Generally the analytical lab provided distilled water in sampling bottles, which was treated in exactly the same manner as actual water collected in the field, including filtration (if required), preservation, storage and transportation. The purpose of the field blanks is to assess potential contamination from sampling bottles, preservative, filtration devices (if required), poor field procedures or laboratory error.

Trip blanks – trip blanks are water samples consisting of distilled water already in the individual sampling bottles and provided by the analytical laboratory. These samples are transported to the field and analytical laboratory with regular samples, but remain sealed for the duration of the sampling program. The purpose of trip blanks is to assess potential contamination of samples during transport.

Equipment swipes – clean filter paper is wiped over any surface that sediment samples may come into contact with before being transferred to sampling bottles. This would include the inside of the sampling grab, mixing bowls and spoons. Once all applicable surfaces have been wiped, the filter paper is placed into a jar and submitted to the lab where the filter paper, with any residual contaminants, is analyzed. The purpose of the equipment swipe is to assess cross contamination between samples. The results of equipment swipes must be interpreted with care as concentrations of the swipes and original sample are not comparable.

The following data acceptability criteria were used for assessing field duplicates:

- Duplicates must be greater than 5 times the detection limit for acceptability criteria to apply. Within 5 times the criteria, quantification is problematic and samples are subject to precision problems;

- Calculated relative percent differences (RPDs) for duplicates should be within 20 percent of each other. RPDs >20% indicate possible quantification problems; and

- Calculated RPDs >50% indicate a definite quantification problem, including possible contamination or lack of sample representativeness.

Blanks, including field blanks, trip blanks and equipment swipes, should be well below the values of quantified samples. Typically, individual analysis of blanks should be reported as below detection limits.

2.5.2 Data Analysis QA/QC

During data analysis, QA/QC checks were applied to capture possible transcription errors or errors in the original data set. QA/QC steps included the following:

- A 10% cross check for transcription errors – approximately 10% of the data in the final database were randomly cross-checked with the raw data provided on Excel spreadsheets. This technique was intended to capture possible transcription errors in reported units or values.

- The use of macros – macros were used during database construction to look for naming irregularities and redundancies in the original data. Macros were also used to provide summaries of data that were used as a back-check.

- A graphical analysis – graphs showing concentrations of various analytes over time were assessed for possible errors. Where data appeared to be an outlier (or otherwise did not appear correct), the data were investigated to ensure that a transcription error had not occurred.

3.0 RESULTS AND DISCUSSION

In the assessment provided below, spatial trends, magnitude (and number) of environmental objectives exceedances, and temporal trends are discussed.

In the graphical analysis, water quality data were presented as the mean of five samples collected over a 30-day period. Water sampling was done during the lowest flow periods during the year and therefore represents worst-case water quality conditions. Summary statistics of results are provided in Appendix A1, while applicable environmental objectives, guidelines and criteria are provided in Appendix A2.

3.1 WATER QUALITY

Water concentrations discussed in this report do not represent typical Lower Columbia River water quality conditions. Water sampling was done during the lowest annual flow periods and therefore represents worst-case water quality conditions.

3.1.1 Metals

Metals are natural elements found within the earth's crust and are generally only a concern where they have been concentrated (usually by human activities). Metals within the Lower Columbia River likely originate from a number of sources, including sewage outfalls, septic fields, historic mining activities and storm water run-off; however, the Teck Cominco outfalls and properties adjacent to Stoney Creek are the predominant source of metals within the study area. As discussed in Section 1.2, Teck Cominco has taken a number of steps to reduce metals loadings to the Lower Columbia. Most of these improvements were completed between 1995 and 1997.

One metal, mercury, has a high toxic potency and bioaccumulates to a greater extent than other metals. In addition to the possible sources of metals mentioned above, mercury can originate from the natural weathering of soils and from reservoirs due to flooding of lands.

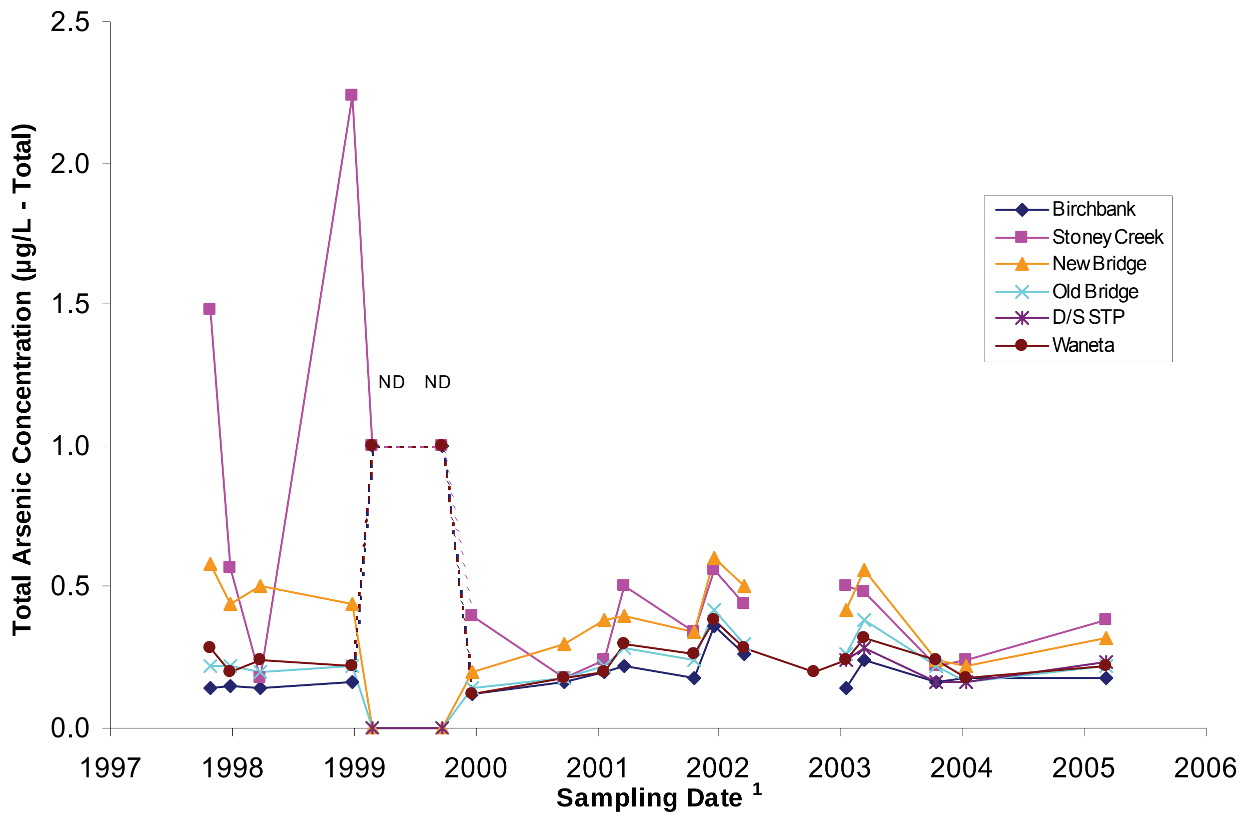
Arsenic

Arsenic concentrations were generally similar among stations (Figure 3.1). The 30-day average WQO for the Lower Columbia (5 µg/L) was not exceeded at any of the stations between 1997 and 2005.

The highest concentrations of arsenic occurred at D/S Stoney Creek and at New Bridge, suggesting that Teck Cominco property is the source. A possible major source of arsenic is the former Duncan Dome arsenic storage facility, located adjacent to Stoney Creek (G3 2001). The site has undergone extensive remediation; however, contaminants in ground water remain elevated and portions of arsenic-contaminated soils remain.

Concentrations of total arsenic at D/S Stoney Creek did not appear to follow the same pattern over time as other locations and were highly variable, particularly between 1997 and 2000, with individual measurements ranging from <0.1 to 5.6 µg/L. Concentrations appeared to decrease at this station during this period.

Figure 3.1 Total arsenic concentrations in the Lower Columbia River, 1997 to 2005 (30 day averages).



[1] Date presented represents January 1 of each year

[2] WQO (30-day average) = 5 µg/L

[3] ND = concentration is below the lowest quantification limit.

Cadmium

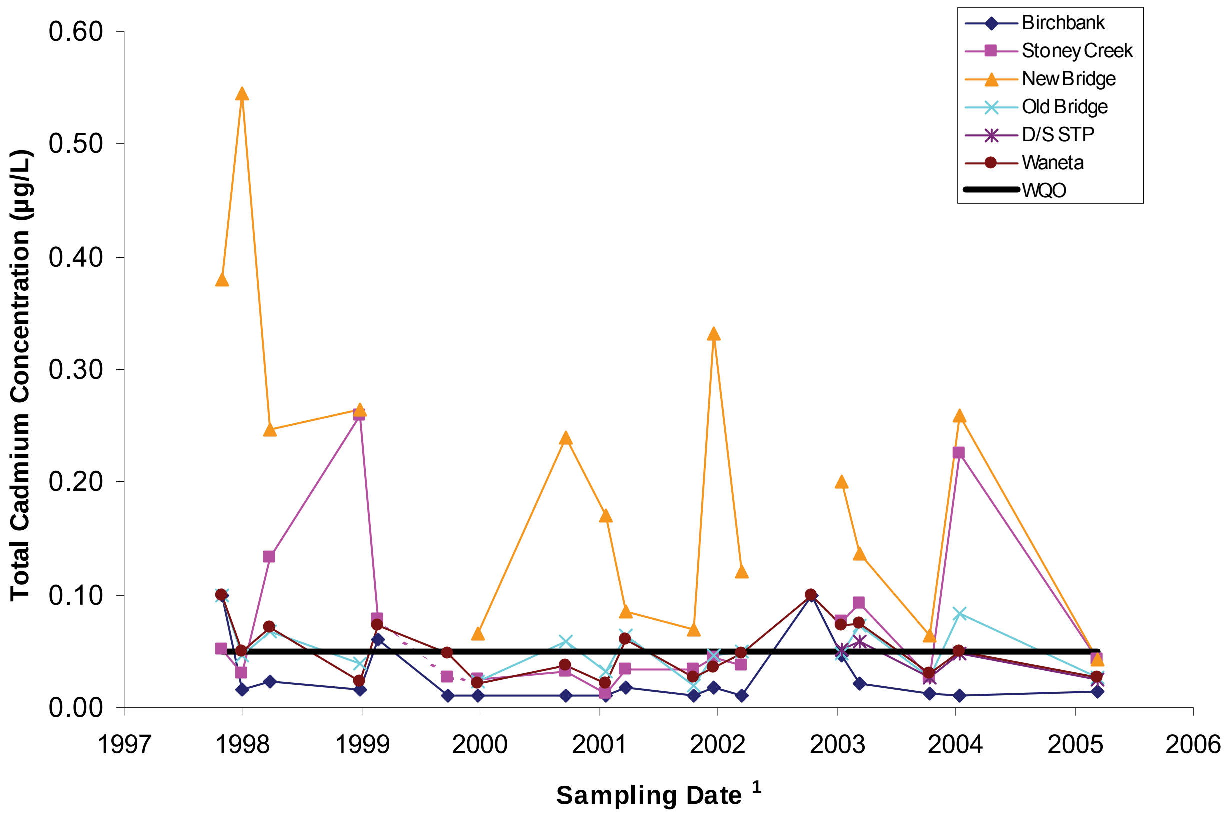
The WQO document provides both a 30-day average (0.03 µg/L) and a provisional WQO (0.05 µg/L). B.C. MOE generally uses the provisional WQO because the 30-day average WQO is within five times the MDL of 0.01 µg/L, which raises issues with analytical uncertainty for concentrations close to this value.

Cadmium had the greatest number of criteria exceedances (60% of sampling periods) and the largest single exceedance (12 times the provisional WQO). However, the highest concentrations of cadmium occurred at the New Bridge station, which is within the IDZ of Teck Cominco and is therefore not considered an attainment point (Figure 3.2). The concentrations of cadmium at D/S Stoney

Creek also exceeded the WQO by up to 4.5 times. The sequential decrease in cadmium concentration downstream of Teck Cominco indicates that Teck Cominco is the predominant source of cadmium to the Lower Columbia River.

Cadmium concentrations often exceeded the provisional WQO at stations below Birchbank and also at times exceeded at Birchbank; however, concentrations were generally within two times the WQO. Old Bridge, D/S STP and Waneta had very similar concentrations between 1997 and 2005. No temporal trends were evident between 1997 and 2005.

Figure 3.2 Total cadmium concentrations in the Lower Columbia River, 1997 to 2005 (30 day averages).



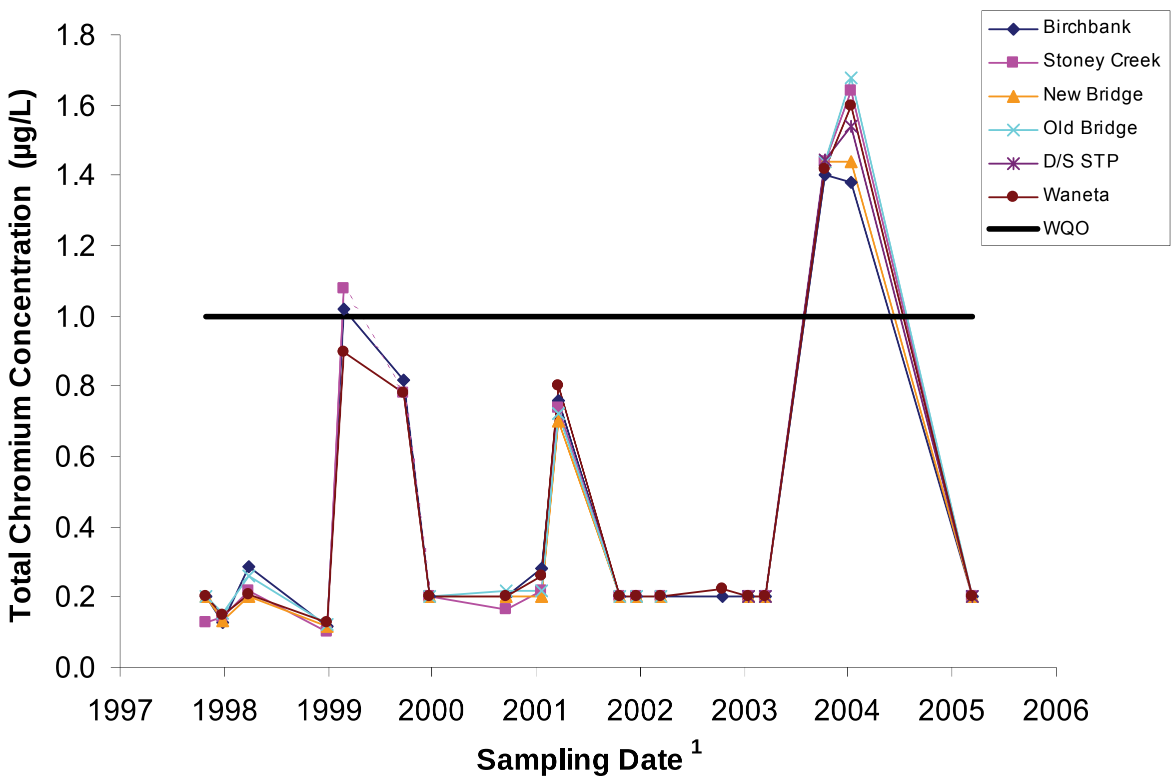
[1] Date presented represents January 1 of each year.

Chromium

Chromium concentrations in water were below the MDL (0.2 µg/L) for most periods; however, concentrations were quantifiable during periods in 1999, 2001, 2003 and 2004 (Figure 3.3). When chromium was quantified, concentrations were very similar among stations. This may indicate that the observed concentrations are primarily of natural sources or are from a source upstream of Birchbank. The fact that total chromium concentrations at Birchbank and Waneta were not significantly different (Table 3.2) appears to support this assertion. With the exception of samples collected in 2003 and 2004, measured concentrations were within five times the MDL, indicating that there may be issues of analytical uncertainty in most of the reported concentrations.

The 30-day average WQO, based on concentrations of chromium (VI) (1 µg/L), was exceeded at all stations during the winter 2003/2004 period. During this time, 30-day average concentrations were less than two times the WQO. These relatively high values did not coincide with periods of high flow or turbidity. The 2003/2004 data were compared to results from the federal-provincial trend stations at Birchbank and Waneta for the same time period. Total chromium concentrations measured at the federal-provincial station are at least an order of magnitude lower, which suggests there may be some issues with sample contamination. However, field QA/QC for 2003/2004 show duplicate samples were within acceptable RPDs and field and travel blanks had total chromium concentrations < MDL.

Figure 3.3 Total chromium concentrations in the Lower Columbia River, 1997 to 2005 (30 day averages).



[1] Date presented represents January 1 of each year.

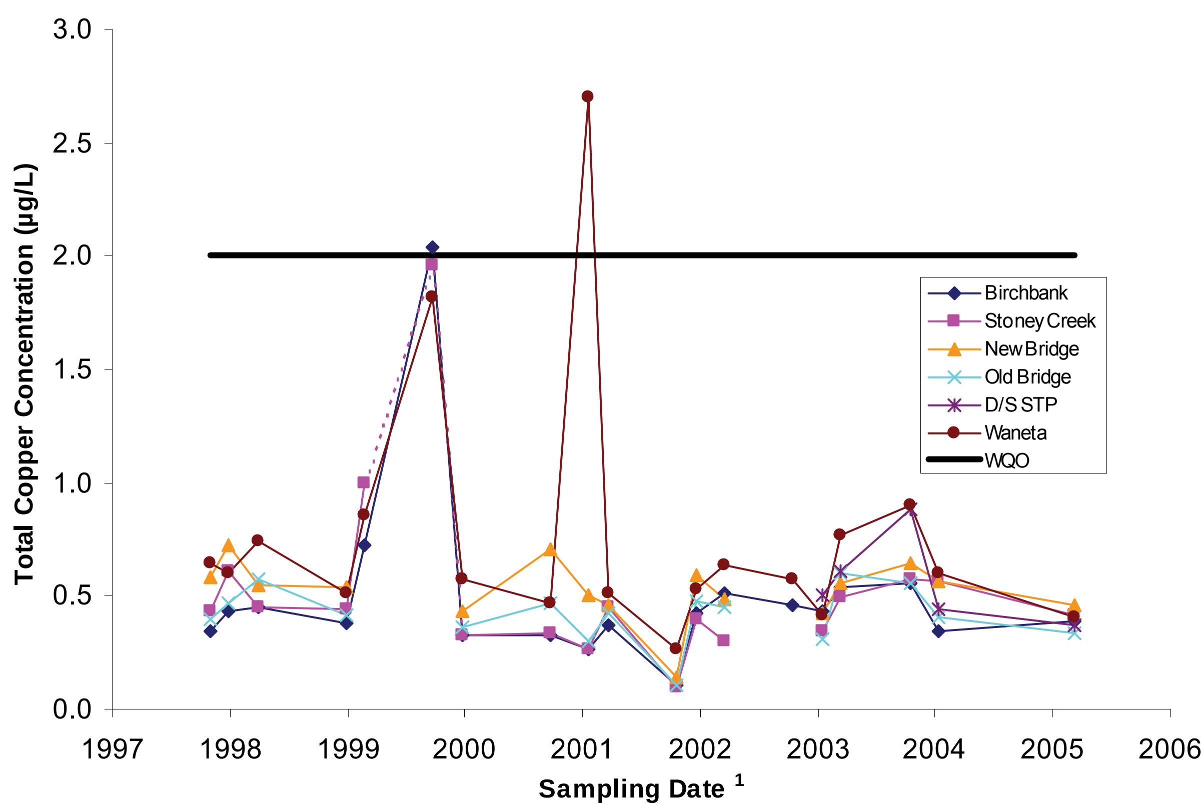
Copper

Concentrations of copper were generally similar among stations with the exception of Waneta in 2001 (Figure 3.4). This 30-day average is strongly biased by a single sample (an outlier) collected on February 22, 2001. Zinc concentrations also appeared unusually high in this sample. Flow and turbidity on February 22, 2001 were not notably different from other sampling events during the same 30-day period. It is possible that the high copper and zinc may be associated with re-suspension of particulates while sampling. Dissolved copper or zinc concentrations were not measured on this date, so a comparison to total concentrations could not be made (if dissolved concentrations are substantially smaller than total concentrations, re-suspension of particulates during sampling may be implicated).

The spatial variability appears to indicate that copper enters the river at a number of locations: one input upstream of New Bridge and another upstream of Waneta.

The 30-day average WQO for the Lower Columbia (2 µg/L) was exceeded at Birchbank in 1999 and at Waneta in 2001. The highest average concentration was 1.4 times higher than the WQO. All values were well below the instantaneous maximum WQO (7.2 µg/L).

Figure 3.4 Total copper concentrations in the Lower Columbia River, 1997 to 2005 (30 day averages).

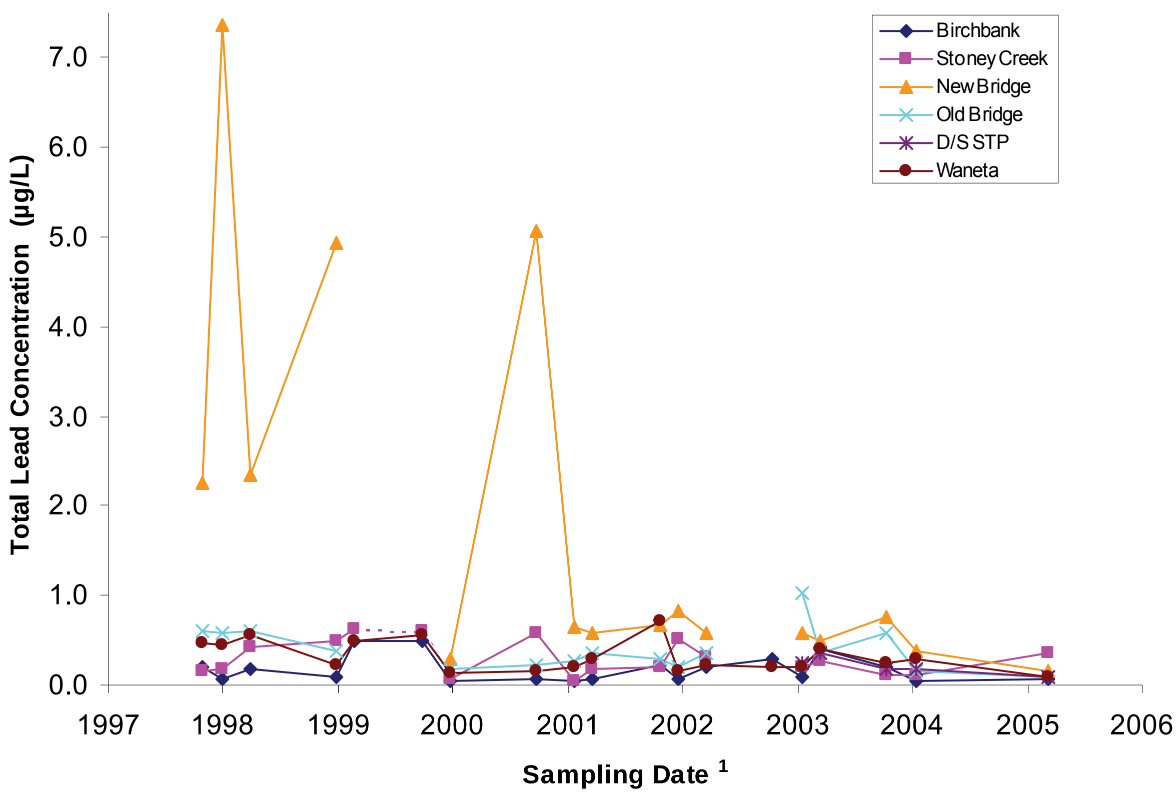


Lead

Lead concentrations were similar among sites and years, ranging from 0.034 to 5 µg/L (Figure 3.5). The highest lead concentrations were measured at the New Bridge site in 1997 (2.3 µg/L) and 2000 (5.1 µg/L). There was also a slight elevation of lead in water collected at D/S Stoney Creek in comparison with Birchbank suggesting that Teck Cominco was the source.

The 30-day average WQO (4.8 µg/L) was exceeded only at New Bridge in 2000; however, New Bridge is within the IDZ and therefore is not considered an attainment point. The concentrations of lead at all other stations were below both the 30-day average WQO and the maximum WQO (37.9 µg/L).

Figure 3.5 Total lead concentrations in the Lower Columbia River, 1997 to 2005 (30 day averages).

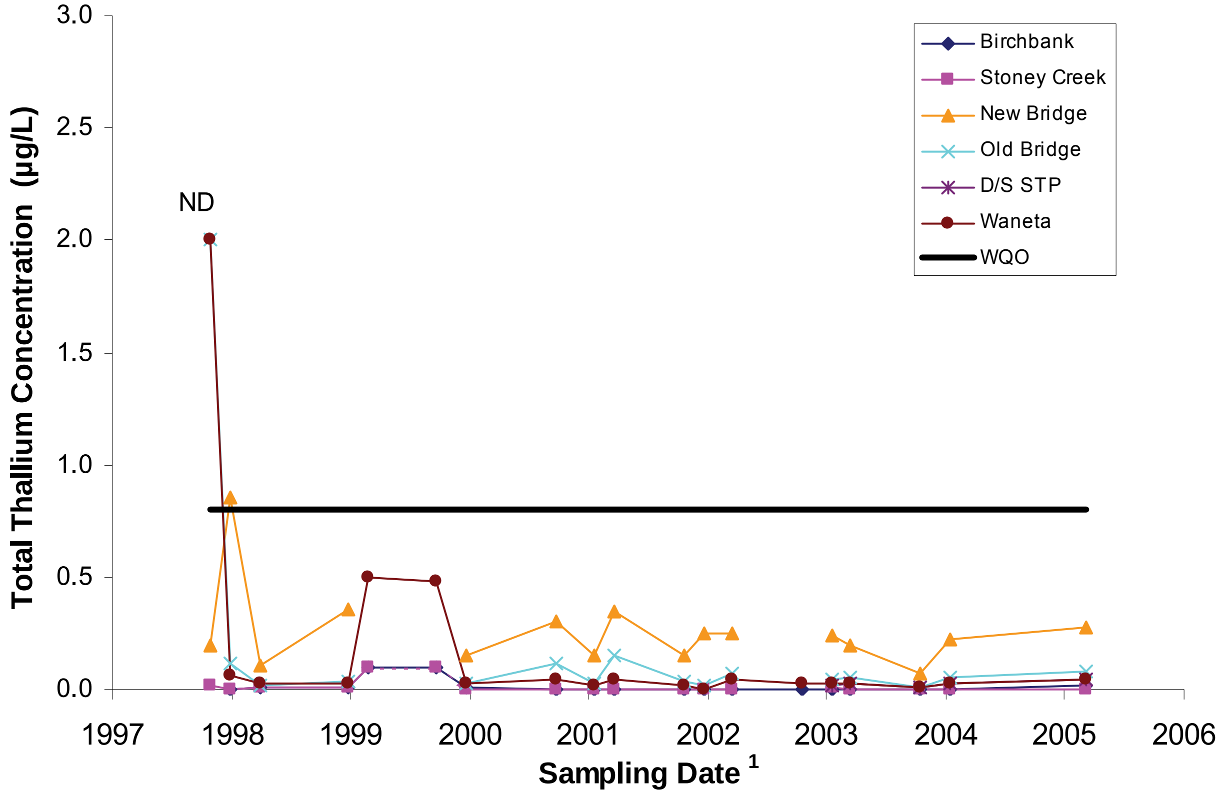


[1] Data presented represents January 1 of each year.
WQO (30-day average) = 4.8 µg/L.

Thallium

Thallium had no WQO exceedances (0.8 µg/L) during the sampling period from 1997 to 2005. Similar to cadmium, lead and zinc, the highest concentrations of thallium occurred at the New Bridge station, which is within the IDZ of Teck Cominco (Figure 3.6). Old Bridge had the next highest concentrations, followed by D/S STP and Waneta. The sequential decrease in thallium concentration downstream of Teck Cominco indicates that Teck Cominco is the predominant source of thallium to the Lower Columbia River.

Figure 3.6 Total thallium concentrations in the Lower Columbia River, 1997 to 2005 (30 day averages).



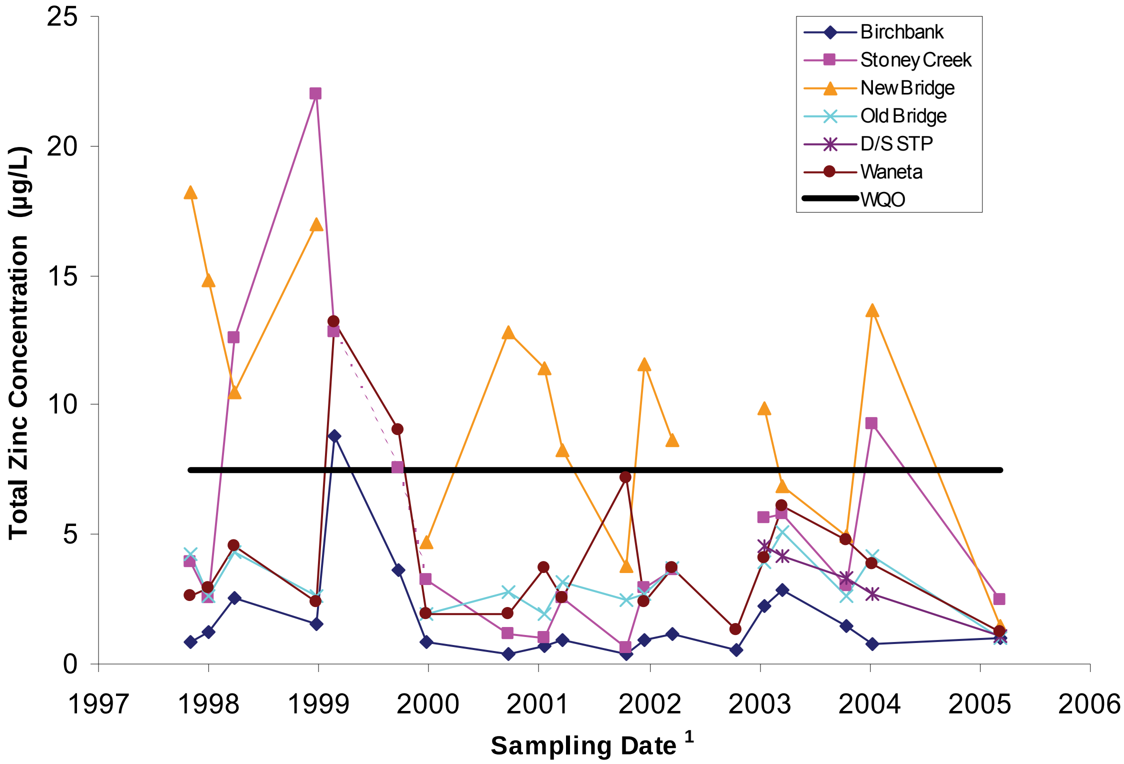
[1] Data presented represents January 1 of each year.

Zinc

Zinc concentrations appeared to be highly variable from 1997 to 2005 (Figure 3.7). The highest zinc concentrations were measured at the New Bridge site, suggesting that Teck Cominco was the source. There also appeared to be some incremental inputs of zinc above D/S Stoney Creek, D/S STP, and Waneta.

The 30-day average WQO (7.5 µg/L) was exceeded on several occasions at New Bridge; however, New Bridge is within the IDZ for Teck Cominco and attainment is not expected at this site. Concentrations measured at D/S Stoney Creek and Waneta exceeded this WQO on more than one instance, while concentrations measured at Birchbank exceeded the 30-day average WQO on one occasion. The highest measured 30-day average (excluding New Bridge results) was within 1.7 times the WQO. All values were well below the maximum WQO (33 µg/L).

Figure 3.7 Total zinc concentrations in the Lower Columbia River, 1997 to 2005 (30 day averages).



[1] Data presented represents January 1 of each year.

Data Trends

A number of trends were observed in the metals data set. Where total and extractable metals concentrations were reported for a given sample, the concentrations typically were very comparable. Also, where total, extractable and dissolved metals concentrations were measured concurrently, concentrations were similar, indicating that there was little suspended particulate matter in the river and that most metals were present in the dissolved form or associated with particles small enough to pass through a 0.45 µm filter.

Temporally, there were no statistically significant increasing or decreasing trends in waterborne metals at Waneta relative to Birchbank from 1997 to 2005 (Table 3.1).

Table 3.1 Results of trend analysis of contaminant concentrations in water at Waneta relative to Birchbank between 1997 and 2005.

Chemical	n	T -statistic	P	Is there a trend over time?	Comment
Arsenic	16	-0.014	0.99	No	
Cadmium	17	-0.056	0.96	No	
Chromium	10	0.94	0.39	No	10 non-detected
Chromium (outliers removed)	9	2.03	0.095	No	
Copper	19	0.004	1.0	No	
Copper (outliers removed)	18	0.24	0.82	No	
Lead	18	-0.52	0.61	No	
Thallium	17	-1.5	1.6	No	
Thallium (outliers removed)	13	1.2	0.25	No	
Zinc	19	-0.53	0.60	No	
Zinc (outliers removed)	18	0.11	0.91	No	

[1] Sampling events which yielded non-detected values for both Birchbank and Waneta were removed.

[2] Analysis performed on log-transformed data set.

[3] $P < 0.05$ used for testing significance.

Spatially, the highest metals concentrations generally were measured at either the Stoney Creek or New Bridge water sampling stations, followed by downstream stations. This indicates that Teck Cominco and Stoney Creek are the source of most metals in the Lower Columbia River. Of the metals assessed, cadmium, chromium, copper, lead and zinc had one or more exceedance of the Lower Columbia WQOs. With the exception of chromium, all of these metals are associated with operation of the Teck Cominco smelter and related activities. Based on the number and magnitude of WQO exceedances, cadmium and zinc were the metals of greatest ecological concern. Cadmium and zinc concentrations exceeded their respective criteria in greater than twenty percent of monitoring periods at one or more station (including the New Bridge station).

Statistical testing of concentrations of contaminants in water collected at Birchbank and Waneta also indicated that arsenic, cadmium, copper, lead, thallium and zinc were statistically higher at Waneta than at Birchbank (Table 3.2).

Table 3.2 Results of paired t-test, comparing contaminant concentrations in water at Waneta and Birchbank between 1997 and 2005.

Chemical	n	T -statistic	P	Are concentrations measured at the two sites significantly different?
Arsenic	16	-4.9	<0.001	Yes
Cadmium	17	-9.4	<0.001	Yes
Chromium	10	-0.087	0.93	No
Copper	19	-3.7	0.002	Yes
Copper (outlier removed)	18	-5.7	<0.001	Yes
Lead	18	-5.5	<0.001	Yes
Thallium	18	-10.3	<0.001	Yes
Thallium (outliers removed)	13	-8.6	<0.001	Yes
Zinc	19	-7.4	<0.001	Yes
Zinc (outliers removed)	18	-9.2	<0.001	Yes

P < 0.05 used for testing significance.

Comparison to historical data

Compared to water concentration data collected between 1990 and 1996 (Appendix A4), concentrations of total metals in water have decreased for all metals of concern (Table 3.3). Cadmium decreased the most (12x), followed by lead (6x), arsenic (5.3x) and copper (4.3x). As discussed in Section 1.2, recent improvements and upgrades at Teck Cominco are likely largely responsible for the observed decrease in metals concentrations downstream of Stoney Creek and the smelter.

Table 3.3 Comparison of current (1997 to 2005) and historical (1990 to 1996) concentrations[1] of total metals and nutrients in water at the Waneta sampling station, Lower Columbia River.

	Current (1997 to 2005) Mean (90th percentile)	Historical (1990 to 1996)[2] Mean (90th percentile)
Arsenic (µg/L)	0.32 (0.84)	1.7 (5.0)
Cadmium (µg/L)	0.051 (0.10)	0.62 (1.9)
Chromium (µg/L)	0.50 (1.2)	0.96 (2.0)
Copper (µg/L)	0.80 (0.93)	3.4 (5.0)
Lead (µg/L)	0.302 (0.5)	1.8 (3.2)
Zinc (µg/L)	4.2 (9.7)	7.5 (11.4)

[1] Mean and 90th percentile calculated from testing period means.

[2] Historical data as per McDonald (1997); Table 10.4.

3.1.2 *In-Situ* and Conventional Variables

Flow

River flows within the study area are controlled by upstream dams on both the Columbia and Kootenay Rivers, which are operated under the terms of the Columbia River Treaty. The treaty requires dams to operate in a manner to achieve optimum power and flood control benefits in Canada and the U.S.

Average daily flows in the Lower Columbia River at B.C. Hydro's Birchbank station ranged from 762 to 4520 m^3/s between the fall of 1997 and 2005. Highest flows occurred during summer months.

During the low flow periods assessed for the WQO monitoring, flows varied between 962 and 3339 m^3/s (Figure 3.8). During the sampling period the highest relative flows each year generally occurred between November and January. Lower flows occurred in October, and between February and April of each year.

Hardness

Water hardness was similar at all locations, ranging from 50 to 72 mg/L (Figure 3.9). Total hardness appeared to follow a seasonal trend, being lower at the beginning of the sampling period (October and November), than later in the sampling period (January to April). A spearman correlation between hardness and flow at Birchbank and Waneta indicated no significant relationship (Rs = -0.406 and -4.59 respectively, n=17).

The hardness of water plays an important role in determining the toxicity of several metal contaminants (B.C. MOE 1999, CCME 2005). Dissolved calcium and magnesium (measured as hardness) tend to compete for binding sites with metal ions on the respiratory surfaces of aquatic organisms. An increase in this type of competition tends to decrease toxicity to aquatic organisms (USEPA 2003b). Therefore, an increase in hardness tends to decrease the observed toxicity of many metals. Many of the CCME guidelines, B.C. MOE criteria and WQOs utilize hardness concentrations to calculate site-specific guidelines/criteria.

Turbidity

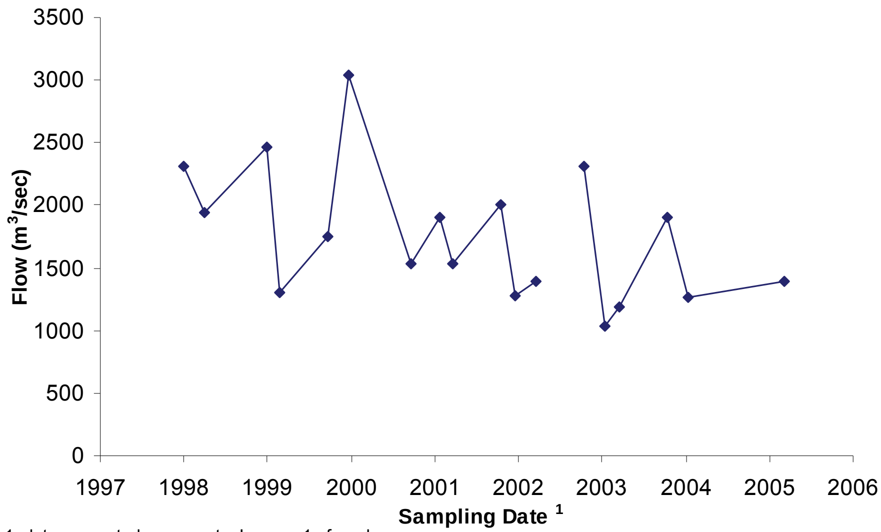
Turbidity was low and consistent among stations, with 30-day averages ranging from 0.15 to 0.8 NTUs (Figure 3.10). The similarity among stations, suggests no major incremental inputs of turbidity anywhere in the study area. April tends to have the highest measured turbidity each year; however, no other pattern was apparent. A Spearman correlation between turbidity and flow at Birchbank and Waneta indicated no significant relationship (R_s = 0.10 and 0.038 respectively, n=17).

pH

The pH was generally similar among stations and over time, ranging from 7.6 to 8.1 (Figure 3.11) and was within the WQO (6.5 to 8.5). However, on two occasions the reported mean pH was as low as 7.0. The absence of variability in the 1999 data suggests instrument error.

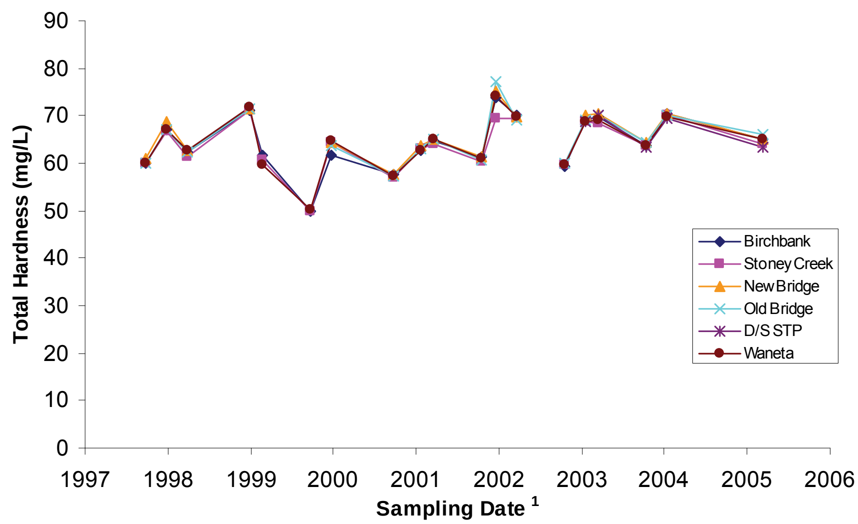
Like hardness, the pH of water plays an important role in determining the toxicity of numerous chemical contaminants (B.C. MOE 1999, CCME 2005). Many chemicals assume several distinct forms (both ionic and non-ionic; called species) in water and each of these has a specific bioavailability and toxic potency. Generally speaking, the toxicity of metals increases at lower pHs, while the toxicity of ammonia increases with increasing pH. Many of the CCME guidelines and B.C. MOE criteria utilize pH to calculate site-specific guidelines/criteria.

Figure 3.8 Flows at Birchbank during WQO monitoring periods (30-day averages; Lower Columbia River, 1997 to 2005).



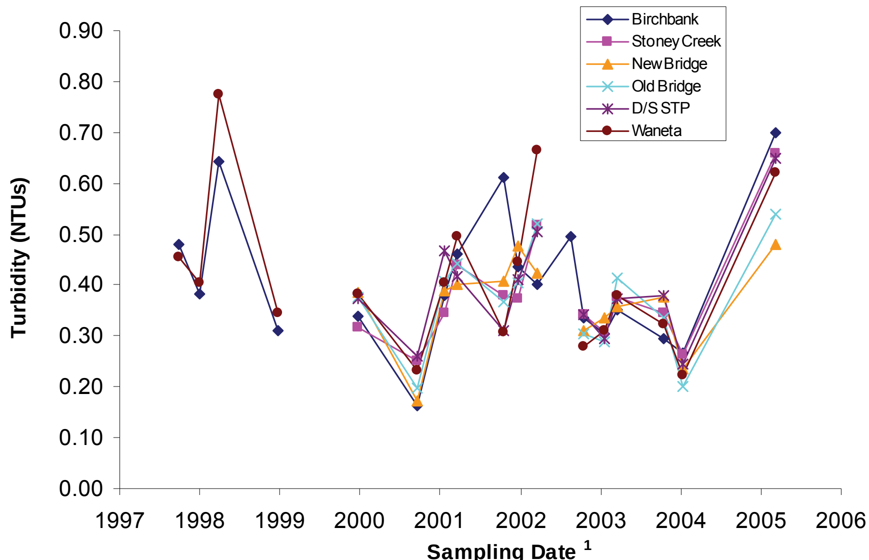
1. date presented represents January 1 of each year

Figure 3.9 Total water hardness (30-day averages; Lower Columbia River, 1997 to 2005).



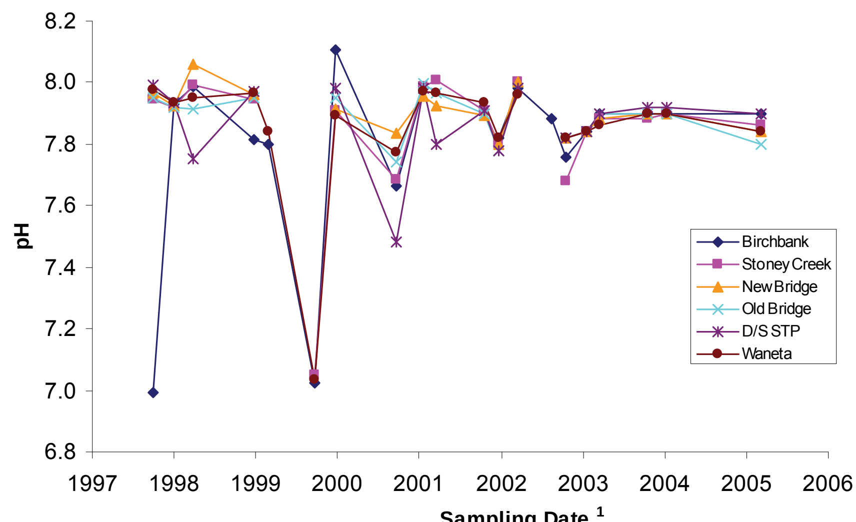
1. date presented represents January 1 of each year

Figure 3.10 Turbidity (NTUs) of water (30-day averages; Lower Columbia River, 1997 to 2005).



1. date presented represents January 1 of each year

Figure 3.11 Water pH (30 – d average; Lower Columbia River, 1997 to 2005).



1. date presented represents January 1 of each year

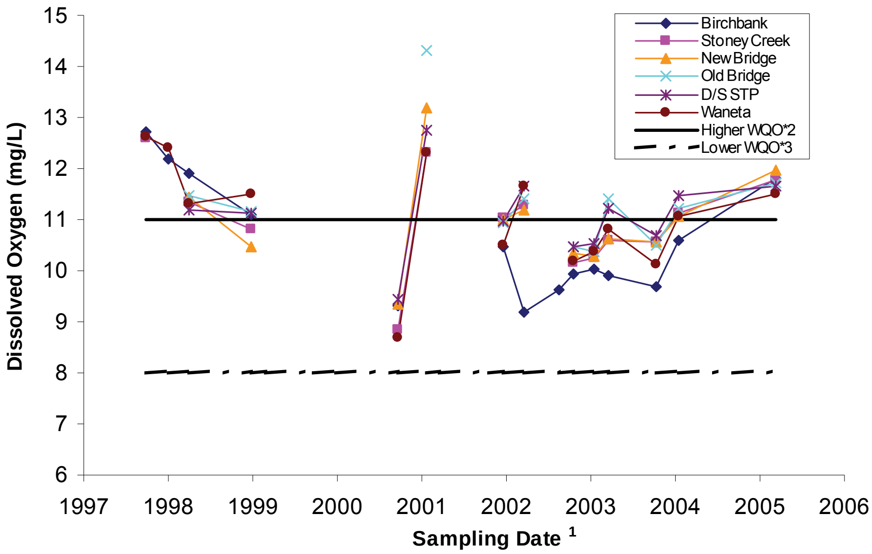
Dissolved Oxygen (DO)

The DO concentration was similar among stations and across time, with 30-day averages ranging from 8.7 mg/L to 14.3 mg/L. The WQO for May to October is 5 mg/L (instantaneous minimum), with a 30-day average of ≥ 8 mg/L. Between November and April, the instantaneous minimum WQO is 9 mg/L and 30-day average is ≥ 11 mg/L. The higher (more conservative) WQO is intended to protect freshly hatched fish that are living amongst the rocky bottom substrate (B.C. MOE 2006).

Many of the DO concentrations measured between November and April were below their applicable 30-day average WQO. The lowest measured DO (October 2000) was above the applicable 30-day average WQO for that period, 8.0 mg/L. Of all stations, Birchbank generally had the lowest DO concentrations in the period from 2002 to 2004 (Figure 3.12).

Similar to terrestrial organisms, aquatic organisms need oxygen for respiration. In a normally well-oxygenated system, low DO can occur as a result of microbial metabolism when large amounts of organic material are discharged into the aquatic receiving environment.

Figure 3.12 Dissolved oxygen of water (30-day averages; Lower Columbia River, 1997 to 2005).



[1] Date presented represents January 1 of each year.

[2] WQO for period November to April. (minimum 30-day average).

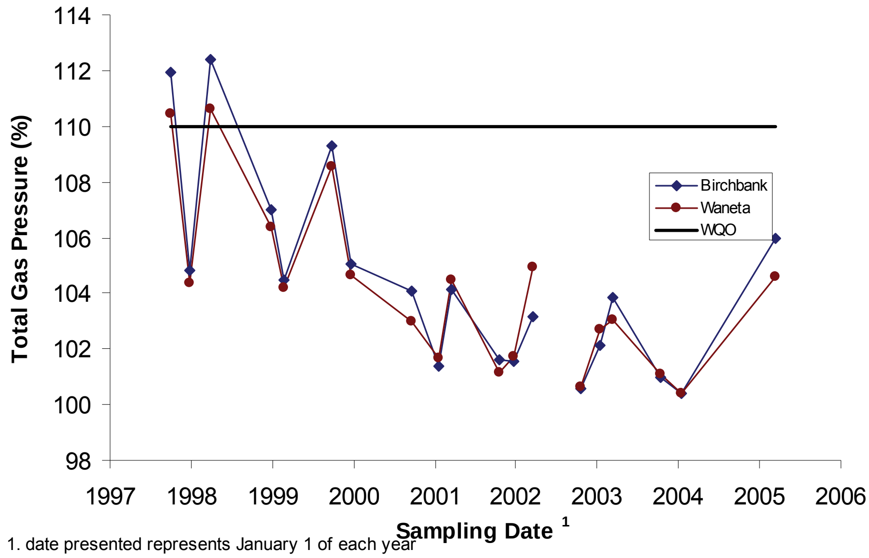
[3] WQO for period May to October (minimum 30-day average).

Total Gas Pressure (TGP)

TGP ranged from 100.4% to 112.4% (30-day averages) and appeared to decrease during the study period, possibly related to construction and operation of the Arrow Lakes Generating Station (ALGS) located downstream of the Hugh Keenleyside dam. Birchbank and Waneta had similar levels; however, Birchbank typically had slightly higher TGP, likely due to the closer proximity to two dams (Hugh Keenleyside and Brilliant). TGP only exceeded the 30-day WQO on two instances, October 1997 and April 1998 (Figure 3.13).

High TGPs can cause gas bubbles to form within the tissues of aquatic organisms, resulting in stress and/or death.

Figure 3.13 TGP at Birchbank and Waneta (30-day averages; Lower Columbia River, 1997 to 2005).



3.1.3 Nutrients

The nutrient status of the Lower Columbia River is largely influenced by the limnology and nutrient status of the Arrow Reservoir (Butcher 1992). However, additional nitrogen and phosphorus inputs to the study area may come from a variety of anthropogenic sources, including industry and wastewater discharges. As a group, nutrients are necessary for the normal ecological functioning of rivers. Nutrients are generally only a concern when concentrations of nutrients become elevated.

Nitrogen

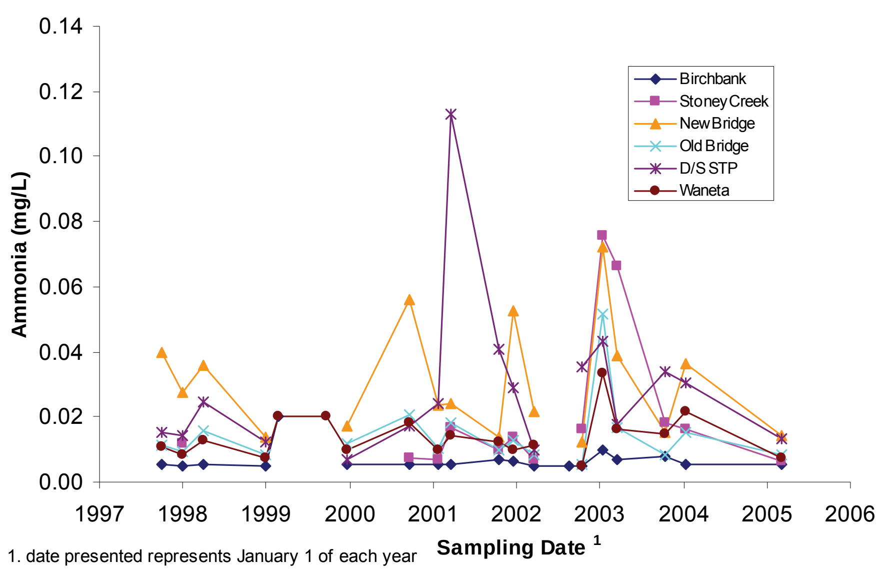
Nitrogen can occur in aquatic systems in a variety of forms; however, ammonia, nitrite and nitrate are the dissolved forms generally considered to have the greatest environmental relevance. Ammonia and nitrite are the most toxic forms of nitrogen. Ammonia is typically a waste product of natural metabolic processes; for instance, most aquatic organisms eliminate unwanted nitrogen as ammonia. Ammonia's toxicity increases with increasing temperature and pH. Nitrite is commonly formed by bacterial metabolism of ammonia. Nitrate, the most common form of nitrogen in water, is generally formed by bacterial metabolism of nitrite and ammonia and tends to be the least toxic form of dissolved nitrogen. High nitrogen (along with phosphorus) is often responsible for nutrient enrichment of aquatic systems. Total nitrogen is the sum of nitrate, nitrite, ammonia and organic nitrogen. Ammonia and nitrate tend to be the forms most readily absorbed by aquatic plants.

The WQO program measured various forms of nitrogen, including ammonia, dissolved nitrite, nitrate, and total nitrogen. Nitrite (not assessed in this document) was consistently below detection limits (<0.002 mg/L) at all water quality monitoring stations. Total nitrogen was used as a surrogate for nitrate, as nitrate was often the predominant component of total nitrogen in the Lower Columbia River and because total nitrogen was measured at a larger number of stations and at greater frequency.

The ammonia WQO is a function of both pH and temperature; if the highest measured temperature (20 °C) and pH (8.2) are assumed, a conservative 30-day average WQO (0.491 mg/L) is derived. Ammonia concentrations were similar among stations and sampling events and were below the WQO (Figure 3.14). However, two samples collected at Birchbank on November 2 and 8, 1999 were notably higher and caused the 30-day average at this site (3.81 mg/L) to exceed the conservative WQO. However, these results are highly questionable and are not included in Figure 3.14; no spills were reported and no fish kills were observed during this period and there is no ammonia source upstream of Birchbank that would result in a significant increase in ammonia (Jolene Raggett, B.C. MOE, *pers. comm.*). Furthermore, the total dissolved nitrogen at Birchbank on November 2, 1999 (from the federal/provincial monitoring program) was 0.22 mg/L. Ammonia is a constituent of total nitrogen, so it is not possible for ammonia to have a concentration higher than 0.22 mg/L. In rivers, most of the nitrogen is in the form of nitrate, with ammonia comprising a very small proportion.

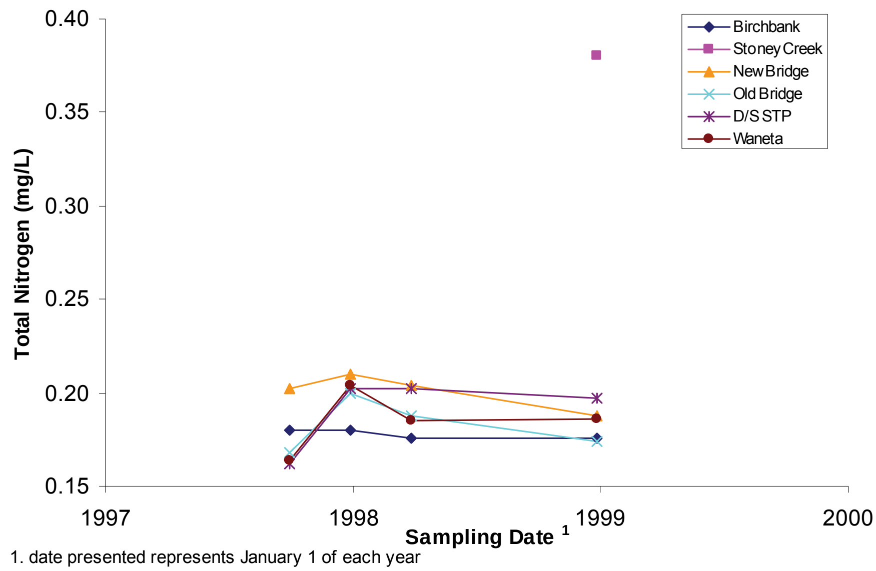
Concentrations of ammonia appear to indicate that there are sources upstream of New Bridge, D/S Stoney Creek and D/S STP. Water collected at Birchbank exhibited the lowest ammonia concentrations.

Figure 3.14 Ammonia concentrations (30-day averages; Lower Columbia River, 1997 to 2005).



Total nitrogen is not a requirement of the WQO and was not measured consistently over time (Figure 3.12). Total nitrogen was only measured during four sampling periods between 1997 and 1999, making it difficult to assess any temporal trends. Total nitrogen concentrations were similar among stations from 1997 and 1999, with the exception of Stoney Creek in 1999. This site had a 30-day average concentration almost two-fold higher than other stations. However, this value was 26 times lower compared than the lowest B.C. approved criterion for nitrate (10 mg/L for drinking water or recreation and aesthetics). This elevated concentration of total nitrogen may be related to a legacy landfill on the south side of Stoney Creek. However this would be unexpected because in 1997 Tech Cominco capped impacted soils and installed a leachate collection system. Comparison of total nitrogen (which included ammonia and nitrate) to the criterion for nitrate is a conservative approach. Similar to ammonia, the total nitrogen concentrations indicate that there are sources of total nitrogen upstream of New Bridge and D/S STP, and possibly D/S Stoney Creek.

Figure 3.15 Total nitrogen concentrations (30-day averages; Lower Columbia River, 1997 to 1999).



Phosphorus

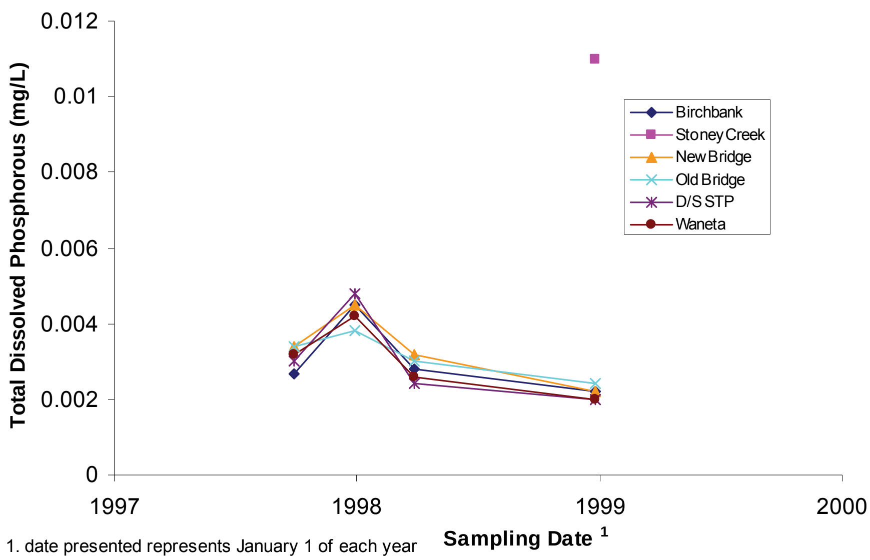
Like nitrogen, phosphorus also occurs in the aquatic environment in a variety of forms, and can lead to nutrient enrichment of aquatic systems. Phosphorus can originate from the natural weathering of minerals, but is also released from human activities within the Lower Columbia River (e.g., Celgar pulp mill, septic leachate, and municipal sewage discharges). Dissolved ortho-phosphorus, also called soluble reactive phosphorus, is generally the form most available to aquatic plants.

The WQO program measured various forms of phosphorus, including dissolved ortho-phosphorus, total dissolved phosphorus and total phosphorus. Total dissolved ortho-phosphorus, was not detected (<0.001 mg/L) at most stations and therefore, it is not included in this analysis. Total phosphorus was only measured in 2002 at Birchbank and results were similar to total dissolved phosphorus; therefore, total phosphorus was not included in this analysis.

Total dissolved phosphorus was not measured consistently over time (Figure 3.16), making it difficult to assess any temporal trends. Analysis of phosphorus is not a requirement of the WQO program; however, it is necessary for assessing overall nutrient loadings and for the calculation of trophic status.

Most quantified concentrations were between 0.002 and 0.0048 mg/L. These concentrations are within five times the MDL (0.001 mg/L) and must be interpreted with caution. An exception was a single sample collected at Stoney Creek in 1999, which had a total dissolved phosphorus concentration of 0.011 mg/L. It is possible that this relatively higher concentration was associated with the historical fertilizer plant; however, concentrations were similar both upstream and downstream of Stoney Creek, suggesting that concentrations within Stoney Creek do not influence main stem phosphorus concentrations. In addition, the similarity of concentrations among all stations suggests that phosphorus is originating from natural and anthropogenic sources upstream of Birchbank.

Figure 3.16 Total dissolved phosphorus concentrations in the Lower Columbia River, 1997 to 2005 (30 day averages).



Data Trends

Temporally, there were no statistically significant increasing or decreasing trends in waterborne ammonia at Waneta relative to Birchbank from 1997 to 2005 (Table 3.4).

Table 3.4 Results of trend analysis of Ammonia concentrations in water at Waneta relative to Birchbank between 1997 and 2005.

Chemical	n	T -statistic	P	Trend?
Ammonia	16	-0.33	0.75	No

[1] Sampling events which yielded non-detected values for both Birchbank and Waneta were removed.

[2] Analysis performed on log-transformed data set.

Statistical testing of concentrations of contaminants in water collected at Birchbank and Waneta indicated that ammonia, was statistically higher at Waneta than at Birchbank, but total nitrogen and total dissolved phosphorus were not (Table 3.5).

Table 3.5 Results of paired t-test, comparing nutrient concentrations in water at Waneta and Birchbank between 1997 and 2005 (P <0.05).

Chemical	n	T -statistic	P	Sig?
Ammonia	16	-9.4	<0.001	Yes
Total nitrogen	4	-0.75	0.51	No
Total dissolved phosphorus	4	0.21	0.85	No

Comparison to Trophic-State Criteria

The total nitrogen and phosphorus concentrations were compared to criteria describing freshwater trophic state. The range of nitrogen and phosphorus concentrations observed in the Lower Columbia River are consistent with an oligotrophic waterbody (Florida Department of Fisheries and Aquatic Sciences 2007, Alberta Lake Management Society 2004), indicating low biological productivity. The oligotrophic status is related to the upstream impoundments, which trap sediments and nutrients within the reservoirs.

Nutrient Historical Context

Total phosphorus and ammonia appear to have decreased in the current data set relative to the period of 1990 to 1996; however, total nitrogen concentrations were similar to historical ranges (Table 3.3).

Table 3.6 Comparison of current (1997 to 2005) and historical (1990 to 1996) concentrations[1] of nutrients in water at the Waneta sampling station, Lower Columbia River.

	Current (1997 to 2005) Mean (90th percentile)	Historical (1990 to 1996)[2] Mean (90th percentile)
Ammonia (µg/L)	13.9 (22.1)	25.6 (100)
Total Nitrogen (µg/L)	185 (212)	210 (237)
Total Dissolved Phosphorus (µg/L)	7.62 (6.0)	16.2 (28.7)

[1] Mean and 90th percentile calculated from list of testing period means.

[2] Historical data as per McDonald (1997); Table 10.4.

3.1.4 Microbial Indicators

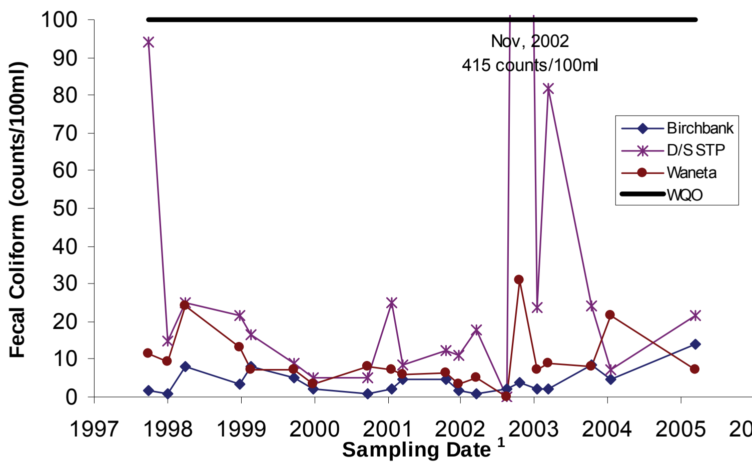
Total fecal coliforms, *E. coli*, and *Enterococcus* are indicators of the microbiological quality of water. Indicator bacteria are generally not those that make people sick, but their concentrations provide an indication of the quantity of bacteria, viruses, and parasites present, which do cause human disease (NOAA 2006).

The concentration of fecal coliforms, particularly *E. coli*, indicates the presence of mammal or bird feces in the water. *Enterococcus* bacteria are also an indicator of feces from warm-blooded animals in the water. *Enterococci* have a greater correlation with swimming-associated gastrointestinal illness in both marine and fresh waters than other bacterial indicator organisms (NOAA 2006). Elevated microbial indicators may be associated with sewage treatment plant outfalls (i.e., the Trail, Castlegar, and Fruitvale STPs) and septic fields.

Total fecal coliforms, *E. coli* and *Enterococcus* were only measured at Birchbank, D/S STP and Waneta from 1997 through 2005 (Figure 3.17 to Figure 3.19). Results indicate that there is one or more sources of sewage upstream of D/S STP, but downstream of Birchbank. Given the proximity of the Trail sewage treatment plant outfall (i.e., 100 m), it is the obvious source of most microbial indicators measured at this station. In addition, given that Waneta sometimes has higher concentrations of all microbial indicators, there appears to be an additional input of sewage between the Trail sewage outfall and Waneta, likely sewage discharges from Fruitvale, which enter the Columbia River via Beaver Creek. The only other major source of sewage is the Castlegar STP, which is upstream of Birchbank. According to the plots (Figure 3.17 to Figure 3.19), effluent from the Castlegar STP appears to be well assimilated before reaching Birchbank.

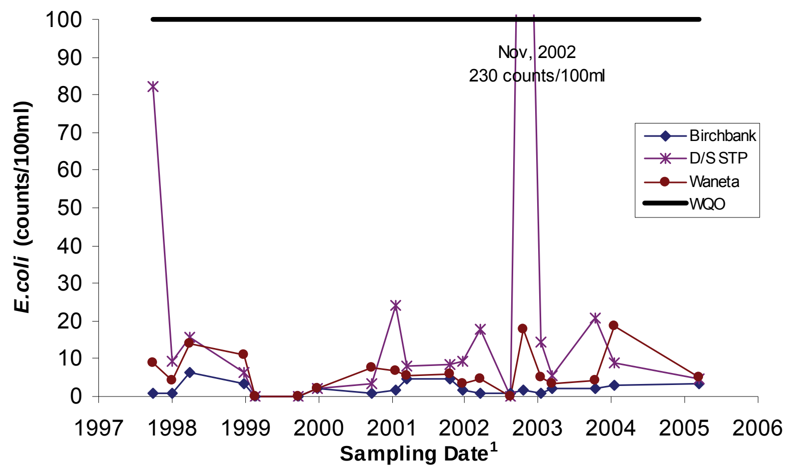
The WQO for total fecal coliform (100 CFU/100 mL) and *E. coli* (100 CFU/100 mL) were only exceeded once. The WQO for *Enterococcus* (25 CFU/100 mL) was exceeded on three occasions. The maximum exceedances for total fecal coliform, *E. coli* and *Enterococcus* occurred in November 2002 at D/S STP and exceeded the WQO by 4.2, 2.3 and 5.1 times, respectively.

Figure 3.17 Total fecal coliform concentrations in the Lower Columbia River, 1997 to 2005 (90th percentiles).



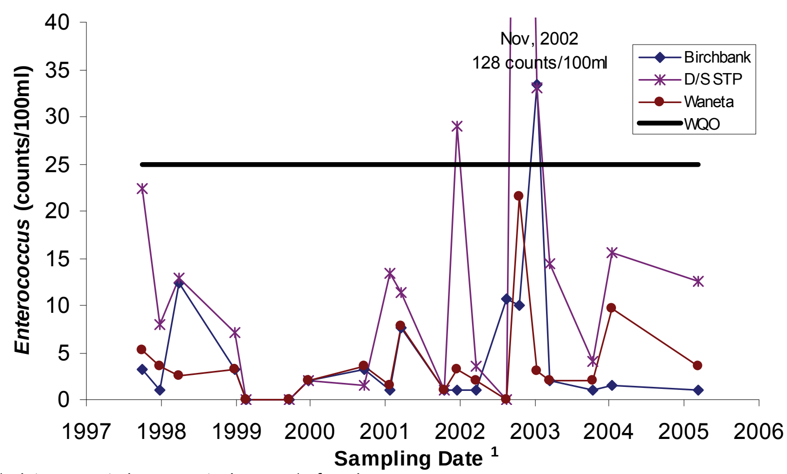
1. date presented represents January 1 of each year

Figure 3.18 *E. coli* concentrations in the Lower Columbia River, 1997 to 2005 (90th percentiles).



1. date presented represents January 1 of each year

Figure 3.19 *Enterococcus* concentrations in the Lower Columbia River, 1997 to 2005 (90th percentiles).



1. date presented represents January 1 of each year

Temporally, there were no statistically significant increasing or decreasing trends in waterborne microbial indicators at Waneta relative to Birchbank from 1997 to 2005 (Table 3.7).

Table 3.7 Results of trend analysis of microbial indicators in water at Waneta relative to Birchbank between 1997 and 2005.

Chemical	n	T -statistic	P	Trend?
Fecal Coliform	19	-0.082	0.94	No
E. coli	17	-0.35	0.73	No
Enterococcus	17	-0.35	0.73	No

[1] Sampling events which yielded non-detected values for both Birchbank and Waneta were removed.

[2] Analysis performed on log-transformed data set.

However, statistical testing of concentrations of contaminants in water collected at Birchbank and Waneta indicated that fecal coliform and *E. coli* were statistically higher at Waneta than at Birchbank (Table 3.8).

Table 3.8 Results of paired t-test, comparing microbial indicator concentrations in water at Waneta and Birchbank between 1997 and 2005 ($p < 0.05$).

Chemical	n	T -statistic	P	Sig?
Fecal Coliform	19	-5.3	<0.001	Yes
E. coli	17	-6.3	<0.001	Yes
Enterococcus	17	-1.1	0.27	No

3.1.5 Water Quality Index

The WQI was calculated using cadmium, copper, lead, thallium, zinc, and fecal coliform concentrations, where these data were available. Figure 3.20 illustrates the average WQI for each station over the 9-year period assessed.

Water quality at Birchbank was assessed as being “good” to “excellent” every year except for 1999, when WQI values were “fair”, due to several observed zinc concentrations that exceeded the water quality objective (this may have been due to detection limit issues)(Figure 3.21).

Below Stoney Creek, seepage from historic Teck Cominco landfills resulted in a number of metals exceedences, primarily cadmium and zinc. The resulting calculated WQI was “fair” to “good” for most years, but was highly variable. The results at this site are more reflective of the quality of Stoney Creek water rather than the Columbia River as a whole, due to the sampling site location, which is within the Stoney Creek mixing zone.. Sources of metals to Stoney Creek have undergone extensive remediation work, which was completed in 2006.

The New Bridge sampling site, below Teck Cominco’s effluent outfalls, is not a WQO attainment point, but has been included in this WQI analysis simply to illustrate trends in the river over time. Not surprisingly, water quality at this site was ranked poorest overall, with a WQI that was usually “poor” to “marginal” due numerous objective exceedences for cadmium and zinc. Cadmium exceedences were at times greater than ten times the WQO, also resulting in a lower WQI. Copper, lead and thallium also exceeded objectives on occasion. In more recent years (2003, 2005), the WQI at the New Bridge station rose to “fair”, indicating that water quality is improving at this site over time.. It should be also be noted that the New Bridge site is located within the mixing zone of Teck Cominco effluent and therefore not truly representative of water quality in this section of the Lower Columbia.

At the Old Bridge site, the WQI improved considerably relative to New Bridge. The improved WQI is likely associated with additional mixing of effluent, although in some years a minimal number of samples were collected, which also tends to result in a higher index.

The water quality monitoring site downstream of the Trail STP (D/S STP) only had sufficient metals data to calculate the index between 2003 and 2005. The site was rated as "good", with only minor cadmium exceedences. It is worth noting that the fecal coliform objective was not exceeded at D/S STP during this time period. However the coliform objective was exceeded several times in previous years, indicating a possible concern for human health if the water was being used as a drinking water source.

At the Waneta site, the downstream improving WQI trend continued, although there were two years (1999 and 2003) when the site was ranked as "marginal" and "fair", respectively. The poor WQI values calculated during these years was due to several zinc exceedences (and copper and thallium exceedances in 1999).

Figure 3.20 Comparison of WQI (9-year average) at Lower Columbia Water Quality Sampling Sites.

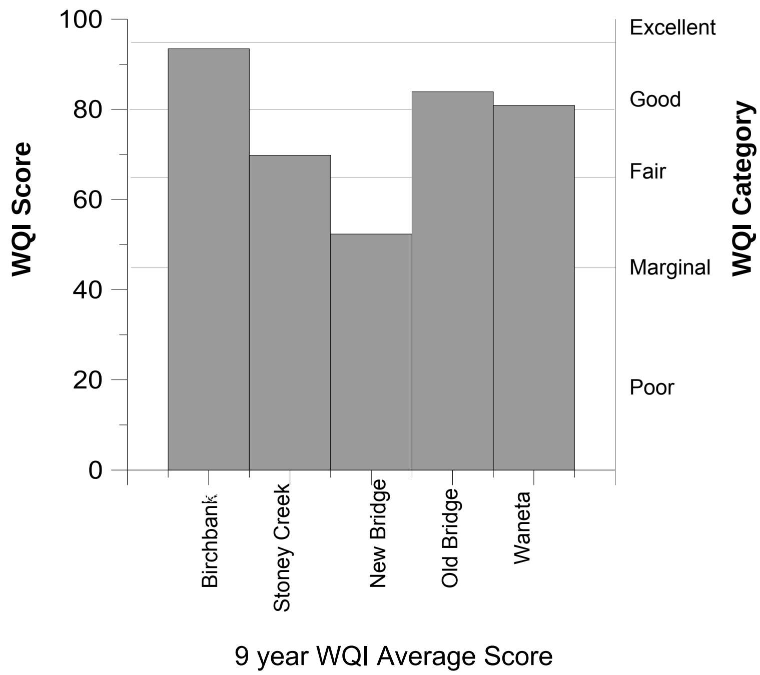
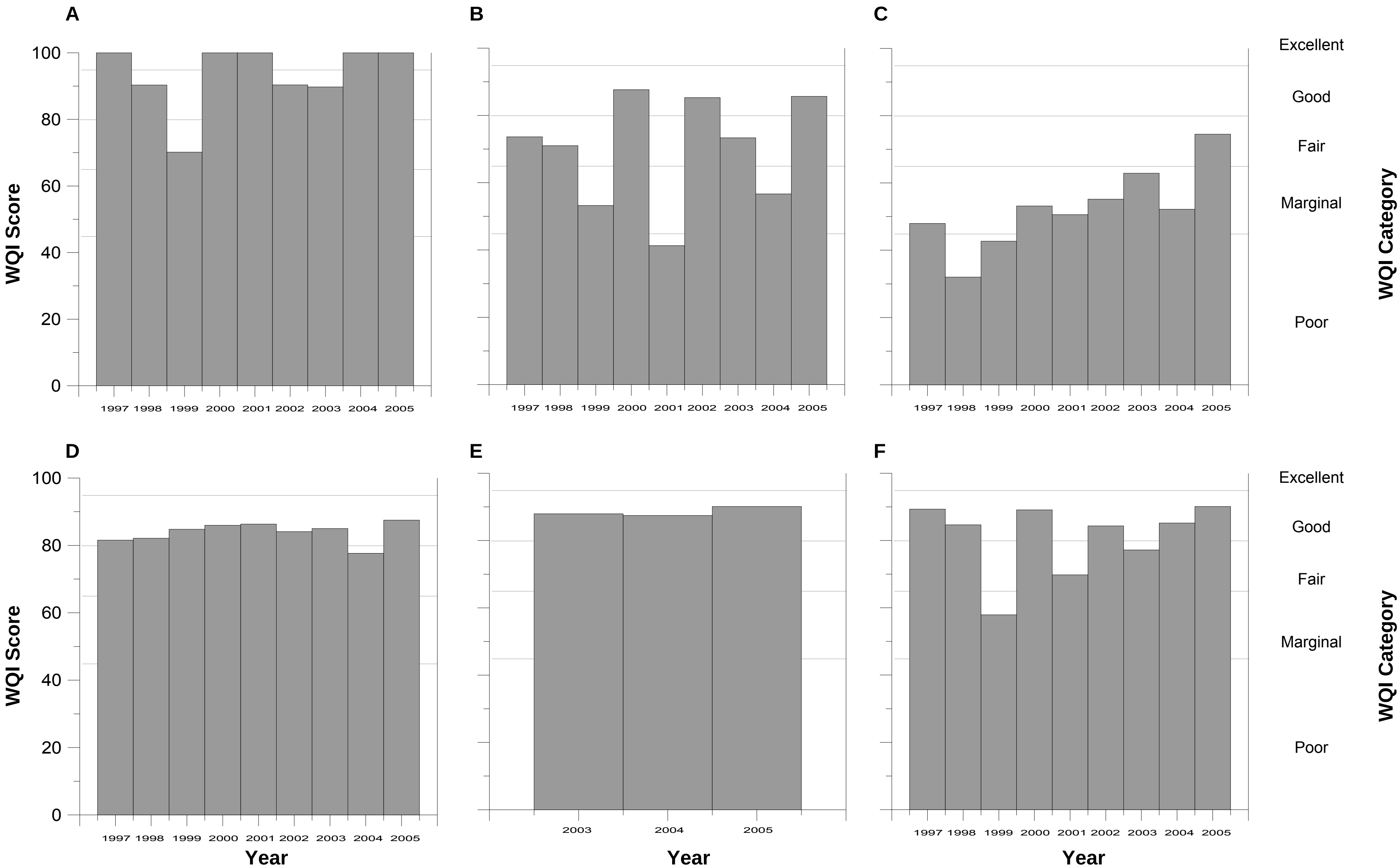


Figure 3.21 **Annual WQI Scores at Lower Columbia Water Quality Sampling Sites, 1997-2005. (A – Columbia River at Birchbank, B – Columbia River at Stoney Creek, C – Columbia River at New Bridge, D – Columbia River at Old Bridge, E – Columbia River ds STP, and F – Columbia River at Waneta.)**



3.2 SEDIMENT QUALITY

3.2.1 Sediment Chemistry

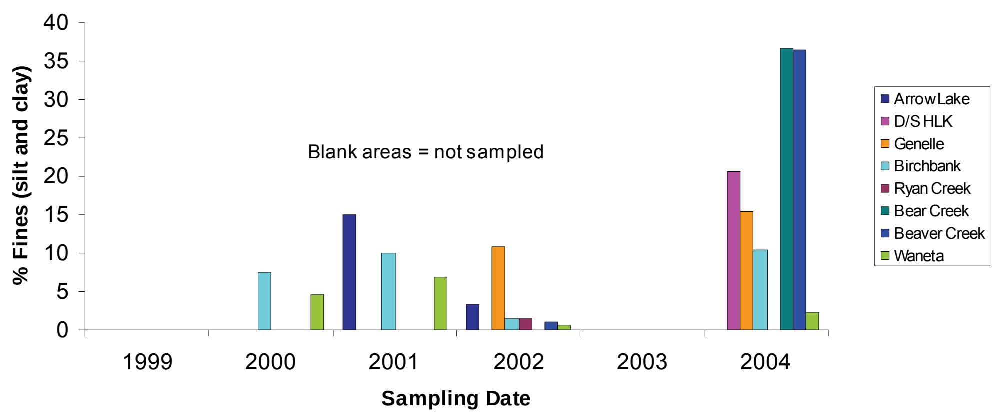
3.2.1.1 Conventional Variables

Contaminant concentrations are often related to conventional sediment variables. The relationship between the two can provide information about contaminant transport processes and distribution. In addition, grain size and TOC often provide clues regarding the bioavailability of contaminants in sediments and therefore may indicate a contaminant's ability to biomagnify and/or cause toxic effects.

Percent Fines (clay and silt)

Grain size composition of sediments was measured once in 2000, 2001, 2002 and 2004 (Figure 3.22). The percentage of fine material was generally low, ranging from 0.7 to 36%. The Beaver Creek station exhibited the greatest change between 2002 and 2004, increasing from 1% to 36%. The difference between years for fines and TOC could be related to flow: higher flows remove fines; lower flows deposit fines. However, differences also may reflect minor variations between sampling locations.

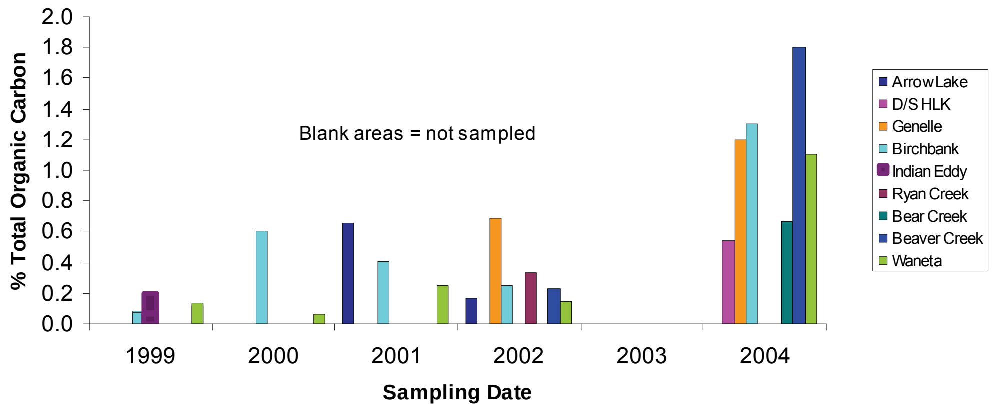
Figure 3.22 Percentage of fine material (silt and clay % dry weight) in sediment, Lower Columbia River, 2000 to 2004.



Total organic carbon (TOC)

Total organic carbon measured as a percentage of dry weight was generally low, ranging from 0.02 to 1.8% (Figure 3.23). Similar to percent fines, the Beaver Creek station exhibited the greatest change of TOC between 2002 and 2004, changing from 0.23% to 1.8%.

Figure 3.23 Total organic carbon content of sediments (% w/w dry weight), Lower Columbia River, 1999 to 2004.

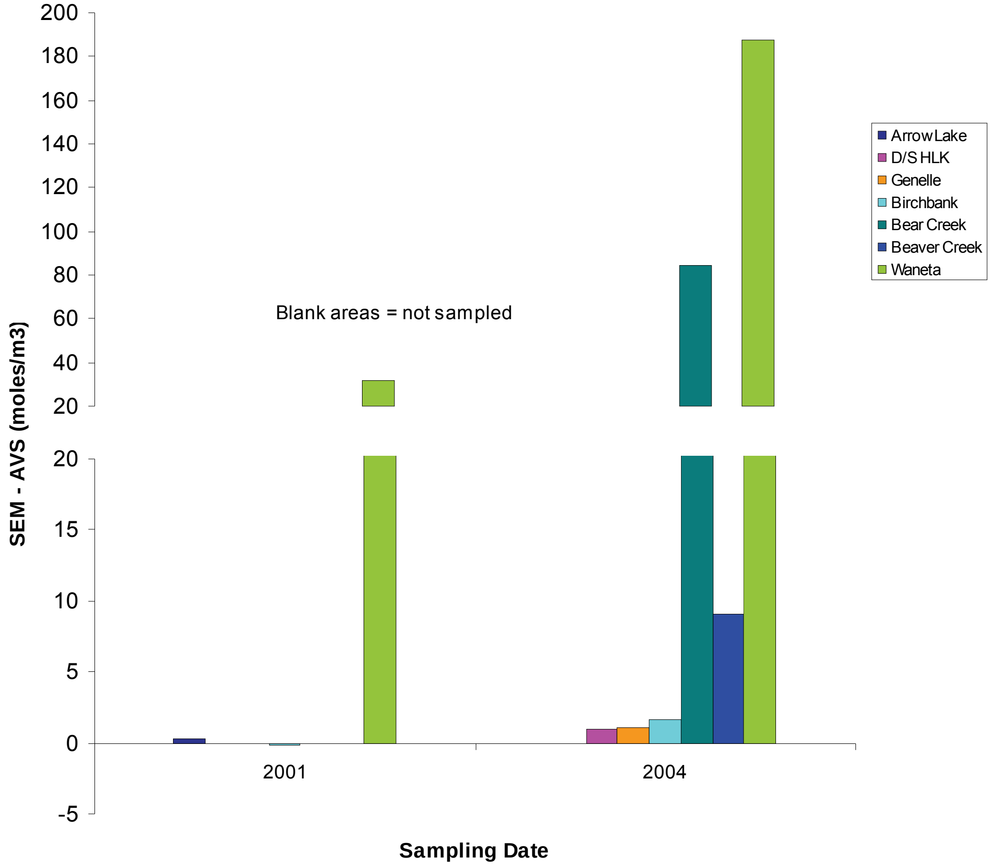


Metals Bioavailability (SEM – AVS)

Metals bioavailability in sediments is often assessed by looking at the difference between SEM (simultaneously extractable metals) and AVS (acid-volatile sulphates) (Hansen *et al*. 1996) (Figure 3.24). AVS is a naturally occurring organic molecule containing sulphur that is usually associated with anoxic sediments. In sediments, AVS binds to metals, thus reducing metals bioavailability. If the difference between SEM and AVS (i.e., SEM-AVS) is negative (i.e., there is more AVS than SEM), then metals would be primarily bound to AVS and are likely not very bioavailable. In such cases, sediments can have high concentrations of metals, but exert no effect on biota because they are bound at the sediment-water interface.

SEM-AVS was only measured in 2001 and 2004 in sediment samples from the Columbia River. In these samples, the difference between SEM and AVS was generally greater than zero, indicating that metals may be bioavailable. However, SEM-AVS is not likely a useful indication of metals bioavailability in the study area, given the well-oxygenated nature of the aquatic environment, and the generally coarse nature of the sediments. AVS generally form in anoxic environments, such as stable marine sediments containing a large percentage of decaying organic matter. The only area where AVS could to be found is the deepest portion of Waneta Eddy (J. Raggett, B.C. MOE, *pers comm*.). Even at this site, metals concentrations were much higher than AVS on a molar basis; therefore, AVS moderation of metals bioavailability was unlikely. In well-oxygenated environments, organic matter and oxyhydroxides of iron and manganese are generally the most important determinants of metals bioavailability (Eriksson-Wiklund and Sundelin 2002).

Figure 3.24 Difference between simultaneously extractable metals and acid volatile sulphides (SEM-AVS) in sediments (moles/m^3 dry weight; Lower Columbia River, 2001 and 2004).



3.2.1.2 Metals

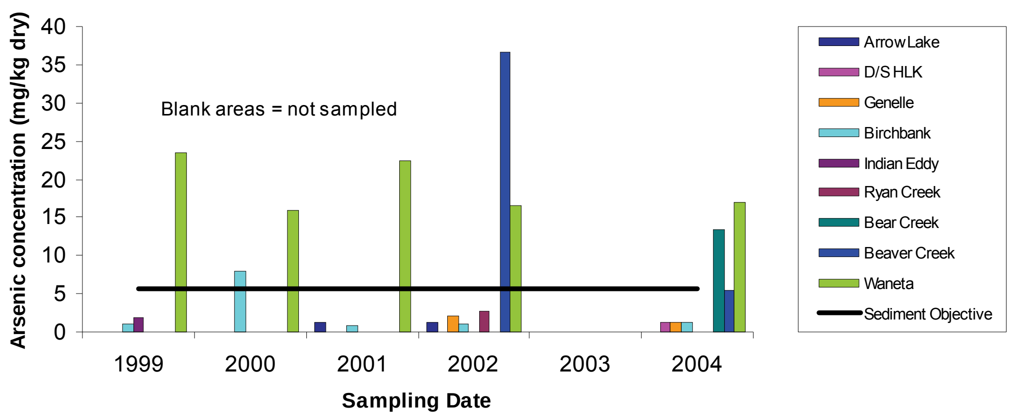
Generally, metals concentrations in sediments were highest at Waneta, the sampling station furthest downstream. There were no apparent temporal trends; variability in measured concentrations (especially at Waneta) likely was due to heterogeneity of metals concentrations within sediments. Variable deposition rates of slag within the river have resulted in some areas with much higher concentrations of metals than others; this appears to have happened even within a small spatial scale.

Variability aside, measured concentrations are not necessarily supposed to be representative of a given reach of the river. Historically, B.C. MOE has been more interested in worst-case sediments For instance, during the 2004 sediment sampling program, the Waneta sampling location was moved slightly (based on results of a bottom survey at Waneta) to include sediments with a higher composition of slag material (Jolene Raggett, B.C. MOE, *pers. comm.*).

Arsenic

Arsenic concentrations were below the Lower Columbia Sediment-quality objectives (SQO) except at Birchbank in 2000, Bear Creek, Beaver Creek and Waneta (Figure 3.25). Sediments collected at Ryan Creek (approximately 4 km upstream of Bear Creek) and upstream locations were very similar. Concentrations measured at Bear Creek, Beaver Creek and Waneta exceeded the SQO for arsenic (5.7 mg/kg dry) by up to seven times. No trends over time were evident. All measurements shown were above the method detection limit, with the exception of Birchbank in 2000, which was assessed only with ICP and therefore had a higher detection limit (8.0mg/kg dry).

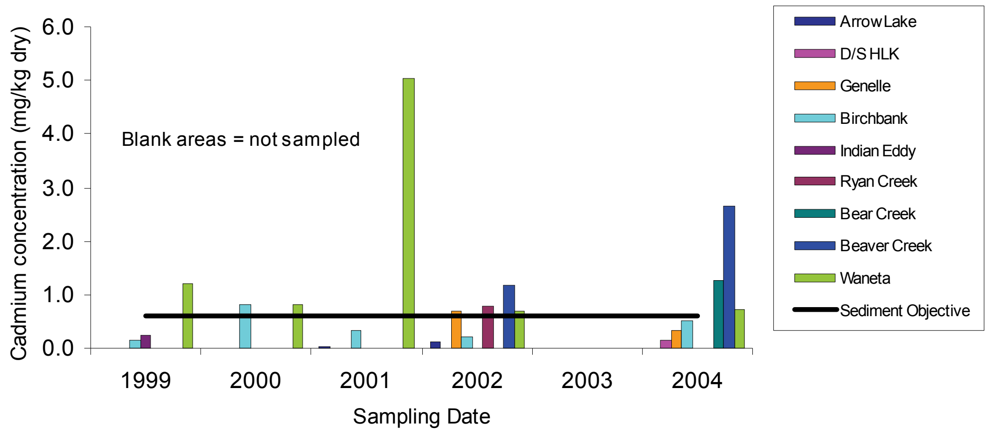
Figure 3.25 Total arsenic in Lower Columbia River sediments, 1999 to 2004.



Cadmium

Cadmium concentrations were below the SQO except at Birchbank in 2000, Bear Creek, Beaver Creek and Waneta. Highest cadmium concentrations occurred at and downstream of Bear Creek (Figure 3.26). The highest measured concentration occurred at Waneta in 2001, and exceeded the SQO for cadmium (0.6 mg/kg dry) by 8.3 times. This elevated concentration did not appear to be associated with higher TOC or %fines. This sample did not exhibit higher concentrations of other metals that are typically associated with slag (i.e., copper and zinc). No trends over time were evident.

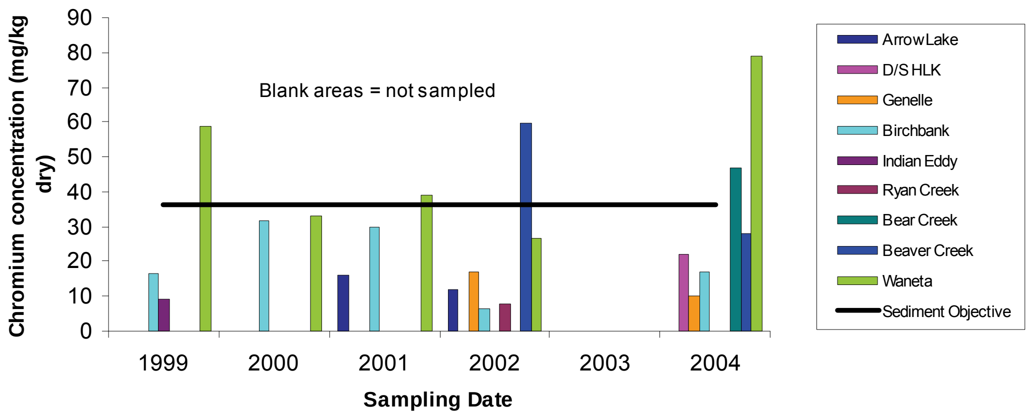
Figure 3.26 Total cadmium in Lower Columbia River sediments, 1999 to 2004.



Chromium

Chromium concentrations were below the SQO except at Bear Creek, Beaver Creek and Waneta. Highest chromium concentrations in sediment occurred at and downstream of Bear Creek. The highest measured concentration occurred at Waneta in 2004 and was just over two times the SQO (36.4 mg/kg dry). No trends over time were evident (Figure 3.27); variability in concentration could not be explained by either the distribution of TOC or %fines.

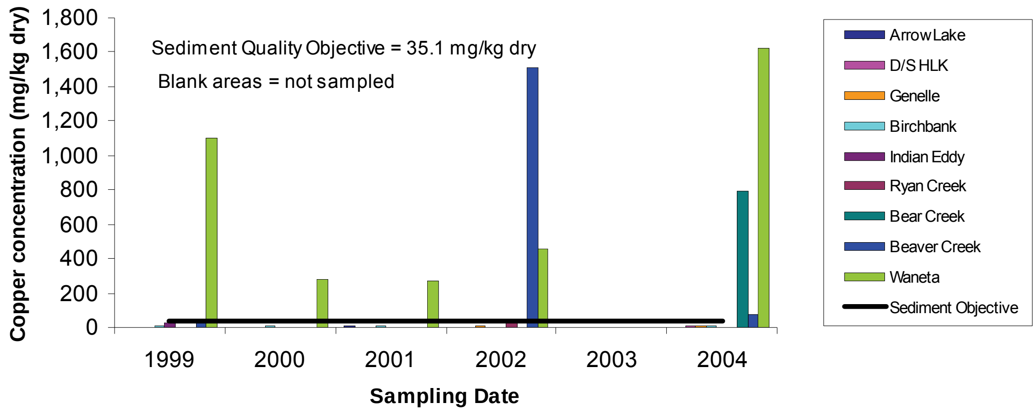
Figure 3.27 Total chromium in Lower Columbia River sediments, 1999 to 2004.



Copper

Copper concentrations were below the SQO except at Bear Creek, Beaver Creek and Waneta (Figure 3.28). The highest measured concentration occurred at Waneta in 2004, which exceeded the SQO by 40 times (35.1 mg/kg dry).

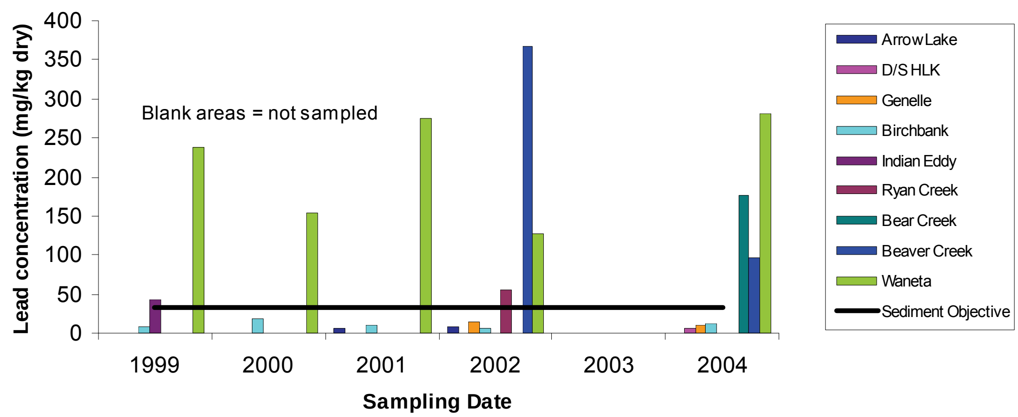
Figure 3.28 Total copper in Lower Columbia River sediments, 1999 to 2004.



Lead

Lead concentrations were below the SQO except at Indian Eddy, Ryan Creek, Bear Creek, Beaver Creek and Waneta (Figure 3.29). Highest lead concentrations in sediment occurred at and downstream of Bear Creek. The highest measured concentration occurred at Beaver Creek in 2002, which exceeded the SQO by just over eleven times (33.4 mg/kg dry).

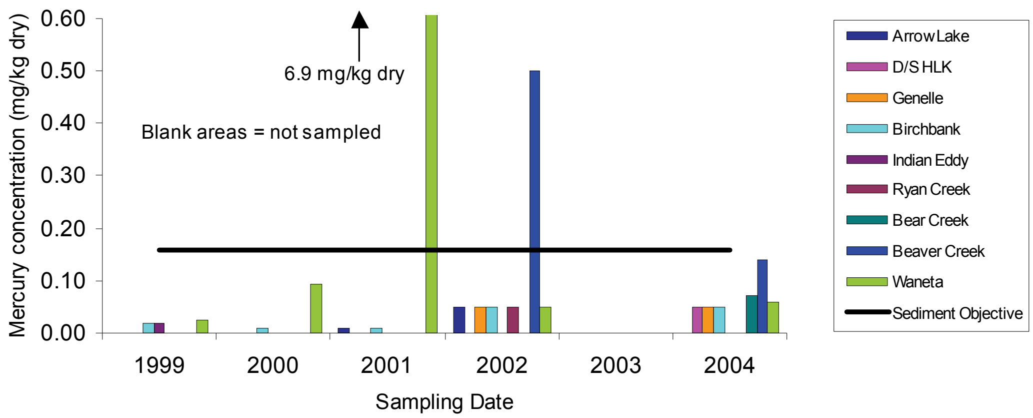
Figure 3.29 Total lead in Lower Columbia River sediments, 1999 to 2004.



Mercury

Mercury concentrations were similar at all stations and sampling events, falling below the SQOs, except for Waneta in 2001 and Beaver Creek in 2002 (Figure 3.30). The highest measured concentration occurred at Waneta, which exceeded the SQO by 44 times (0.16 mg/kg dry). The next highest concentration (Beaver Creek in 2002) was 3.1 times the SQO. Neither concentration appears to be associated with higher TOC or %fines content.

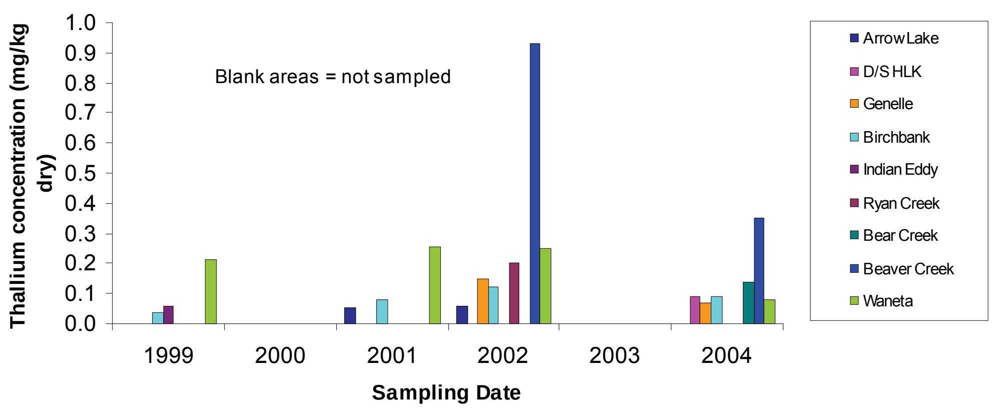
Figure 3.30 Total mercury in sediments (Lower Columbia River, 1999 to 2004).



Thallium

Thallium concentrations appeared to be similar across time, with the exception of a possible decrease between 2002 and 2004; however, this observation is only based on two years of data. Concentrations were highest at Beaver Creek followed by Waneta (Figure 3.31). There were no criteria available for thallium in sediments.

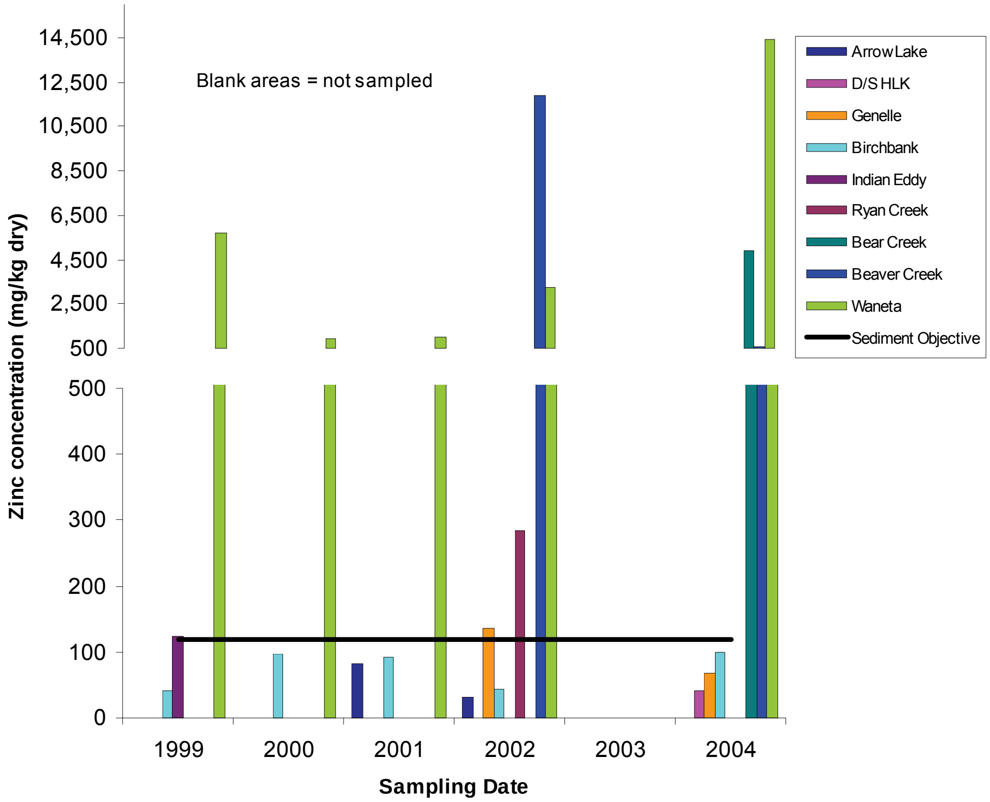
Figure 3.31 Total thallium in Lower Columbia River sediments, 1999 to 2004.



Zinc

Zinc concentrations appear to follow a similar pattern to copper; concentrations were below the SQO except at Ryan Creek, Bear Creek, Beaver Creek and Waneta (Figure 3.32). Concentrations at Waneta appear to have been increasing since 2000. The highest measured concentration occurred at Waneta in 2004, which exceeded the SQO (120 mg/kg dry) by over a hundred times. This elevated concentration is likely related to the slight adjustment in sampling location in 2004, which targeted areas in Waneta containing a high proportion of slag.

Figure 3.32 Total zinc in Lower Columbia River sediments, 1999 to 2004.



Metals Summary

Metals concentrations were generally highest at the furthest downstream stations, Waneta and Beaver Creek. There were no apparent temporal trends; variability across time was likely due to spatial variability in the substrates being sampled. The percent composition of clay and silt (i.e., %fines) was variable between years (Figure 3.22), supporting the assertion that sediment sampling areas had sediment which were quite heterogenic. The small sampling frequency (one sample per area per year) made it very difficult to detect trends over time. Furthermore, some minor modifications were made each year to target depositional sediments. The dynamic nature of the river causes sediments to be re-distributed from year to year, making it more difficult to collect a single sample representative of a sampling area. In 2004, the sampling location at Waneta specifically targeted areas containing slag as shown by Golder during a sturgeon habitat survey using a remote vehicle (J. Raggett, B.C. MOE, *pers. comm.*, October 12, 2006). As would be expected of a sample containing a high proportion of slag, this sample contained some of the highest concentrations of cadmium, copper, lead and zinc.

Attempts were made to normalize metal concentrations to grain size (% fines) and %TOC. However, neither appeared to improve the observed variability substantially. Even with normalization, samples collected at Waneta, Beaver Creek and sometimes Bear Creek were much higher than other samples. It is likely that these samples contain a high proportion of slag material from Teck Cominco. The relative concentrations of zinc, copper and lead appear to reflect a slag signature (Table 3.9); slag from Teck Cominco generally consists of 2.5% zinc, 1.0% copper and 0.5% lead (Duncan *pers. comm.*, 2007). In section 5.0, some recommendations are made to reduce (or at least account for) the apparent variability of metals concentrations in sediment data.

Metals concentrations generally only exceeded the SQOs at Beaver Creek, Bear Creek and Waneta. Metals having one or more exceedance of the SQOs included total arsenic, cadmium, chromium, copper, lead, mercury and zinc. Despite the SQO exceedances, concentrations of cadmium, chromium and lead appear to have decreased in sediments at Waneta since 1990/1991 (Table 3.9). Copper and zinc concentrations were similar to 1990/1991 concentrations (possibly suggesting that slag in the river is fairly immobile within the depositional zones and continues to influence sediment chemistry measurements. Teck Cominco stopped discharging slag to the Lower Columbia in 1995. However, the lower portions of the study area are characterized by lower flows. Therefore, results may indicate that seasonal scouring in this area of the river is minimal and that deposition of clean sediments (i.e., capping) also does not occur at a significant rate (McDonald 1997).

Mean mercury concentrations between 1997 to 2004 were elevated at Waneta due to a single high concentration in 2001 (6.9 µg/g dw). Without that data point, concentrations of mercury (mean = 0.56 µg/g dw) are similar between historical and current time periods (Figure 3.30). A QA/QC check on the sample indicated that other metals in the same sample also were elevated and therefore the concentration does not appear to be an error.

Table 3.9 Comparison of current (1997 to 2004) and historical (1990/1991) concentrations of metals in sediment collected at Waneta (µg/g dw).

	Current (1997 – 2004) Mean (n = 5)	Historical (1991/1992) Mean (n = 6)
Arsenic	19.1	16
Cadmium	1.69	5
Chromium	47.3	77
Copper	747	939
Lead	215	359
Mercury	1.43	0.62
Zinc	5,044	4,939

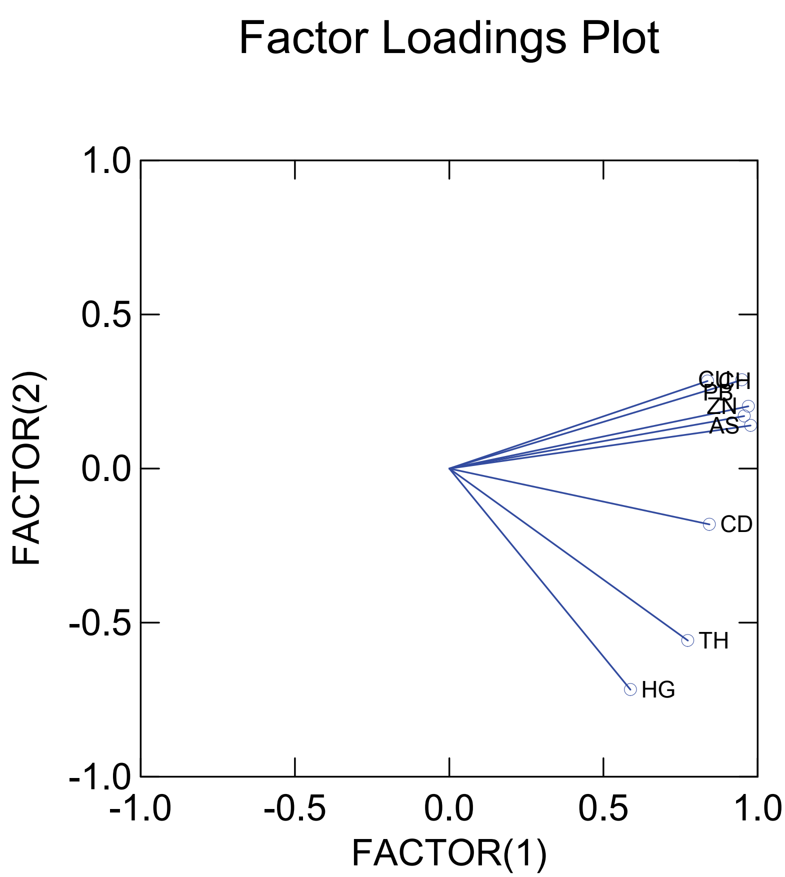
Historical data from Tuominen et al. (1994) as per McDonald (1997); Table 11.3.

A multivariate data reduction approach was used to explore spatial trends within the metals data set. Principal component analysis (PCA), was used to reduce the number of variables representing the metals data from eight (i.e., eight different metals) to two, (called Factor1 and Factor2). Individual metals are often highly correlated spatially and therefore data reduction techniques, such as PCA can be effective at describing (and simplifying) the metals data set as a whole. Factor1 and Factor2 are unit-less; however, the relative position of individual stations/sampling events within Factor1 and Factor2 provide spatial inferences.

Together Factor1 and Factor2 accounted for 90% of variability seen in the metals data set; individually Factor1 accounted for a much larger portion of the variability (76%) than Factor2 (14%).

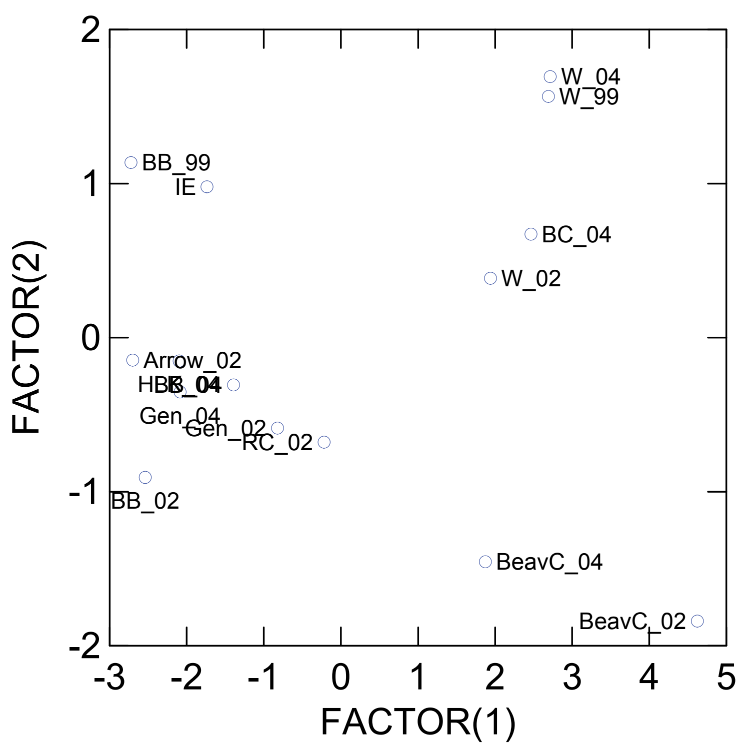
The PCA loading graph (Figure 3.33) shows that most metals are highly correlated with Factor1, which indicates (along with the fact that Factor1 accounts for 90% of data variability) that most metals distribute similarly in river sediments. Arsenic, chromium, copper, lead and zinc cluster together on Factor2,

Figure 3.33 Factor loading plot of metals concentrations in Lower Columbia Sediment Samples.



indicating that these metals distribute more similarly with each other than the other metals: cadmium, mercury and thallium. The cluster of arsenic, chromium, copper, lead and zinc is likely representative of slag from the Teck Cominco smelter. The principal component plot shows how stations/sampling events plot onto Factor1 and Factor2 (Figure 3.34). The results show that stations upstream of Teck Cominco have very low Factor1 values, whereas stations downstream of Teck Cominco had high Factor1 values; indicating that Teck Cominco is the source of the metals assessed. Beaver Creek sediment samples have the lowest Factor2 values, which appears to be related to the high concentrations of mercury and thallium observed at these stations. The high Factor2 scores of Waneta 1999 and 2004 appears to the related to the high concentrations of copper, chromium, zinc and lead measured at these stations (these metals plot weekly and positively on Factor2). Factor1 and Factor2 scores of each station/sampling event will be used in the assessment of sediment toxicity (Section 3.2.2) to assess whether metals concentrations play an important role in determining the observed toxicity.

Figure 3.34 Principal Component Plot of metals concentrations in sediments.



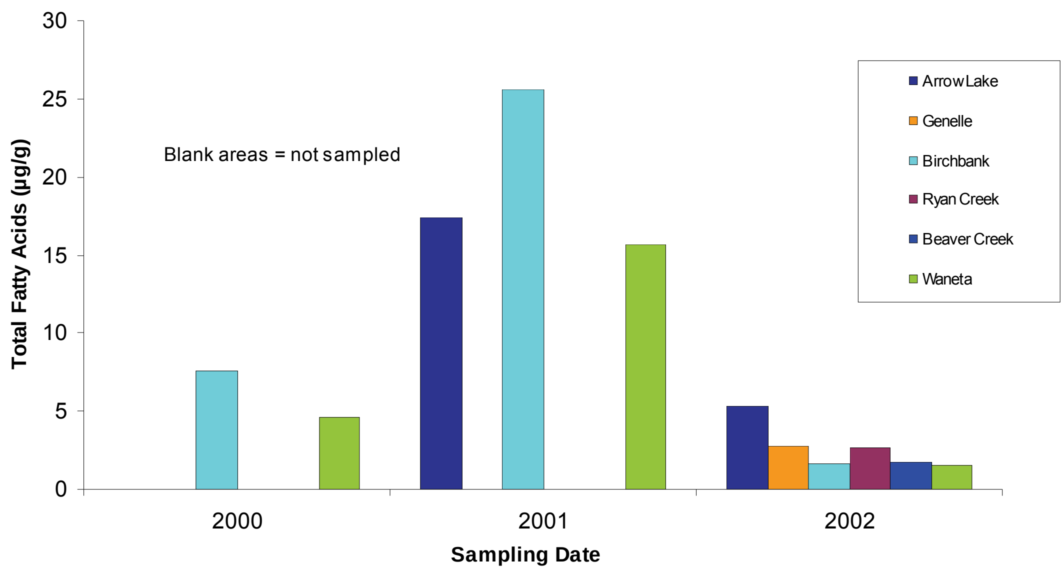
3.2.1.3 Organic Compounds

Fatty Acids and Resin Acids

Resin acids and fatty acids are a group of similar chemicals usually derived from the degradation of plant material. They can be from natural sources, but are monitored in the study area because of the presence of the Celgar pulp mill. Other possible sources of fatty and resin acids are the Pope and Talbot sawmill, logging in the Columbia River watershed, and log-booming activities above and below the Hugh Keenleyside Dam. At higher concentrations, resin and fatty acids have been known to result in ecological impacts.

Total fatty acid concentrations were similar between stations during each sampling period. The highest total fatty acid concentrations occurred at the Birchbank station, while the lowest occurred at Waneta. There are no SQOs for fatty acids. Variance in the data set between years was greater than the difference between stations. The small number of observations (three) makes it difficult to comment on trends over time. Results indicate that Celgar and/or log-booming activities upstream of Birchbank are likely the source. The pattern seen between 2000 and 2002 appears to be related to the grain size of collected sediments; therefore, observed concentrations may be determined predominantly by sediment dispersion processes and the characteristics of sediments collected each year. A comparison of the recent concentrations to historical concentrations (1992) indicate that total fatty acids are similar at Birchbank, but are at Waneta (Table 3.10), although only one sample was collected in 1992.

Figure 3.35 Total fatty acids in Lower Columbia River sediments, 2000 to 2004.



Concentrations of total resin acids were generally similar across stations and years, ranging from 0.4 µg/g dry to 2.5 µg/g dry (Figure 3.36). The small number of samples collected makes it difficult to comment on trends; however, concentrations at Birchbank over the three years appear to be decreasing. It is interesting to note that concentrations at the reference station (Arrow Lake) are similar to Ryan Creek, Beaver Creek and Waneta in 2002, despite the presence of an obvious anthropogenic source. Concentrations of resin acids within Arrow Lake may be attributable to higher sedimentation rates in the reservoir than in the Lower Columbia River. A comparison of the recent concentrations to historical concentrations (1992) indicate that total resin acids were similar at Waneta, but have increased at Birchbank (Table 3.10).

Figure 3.36 Total resin acids in Lower Columbia River sediments, 1999 to 2004.

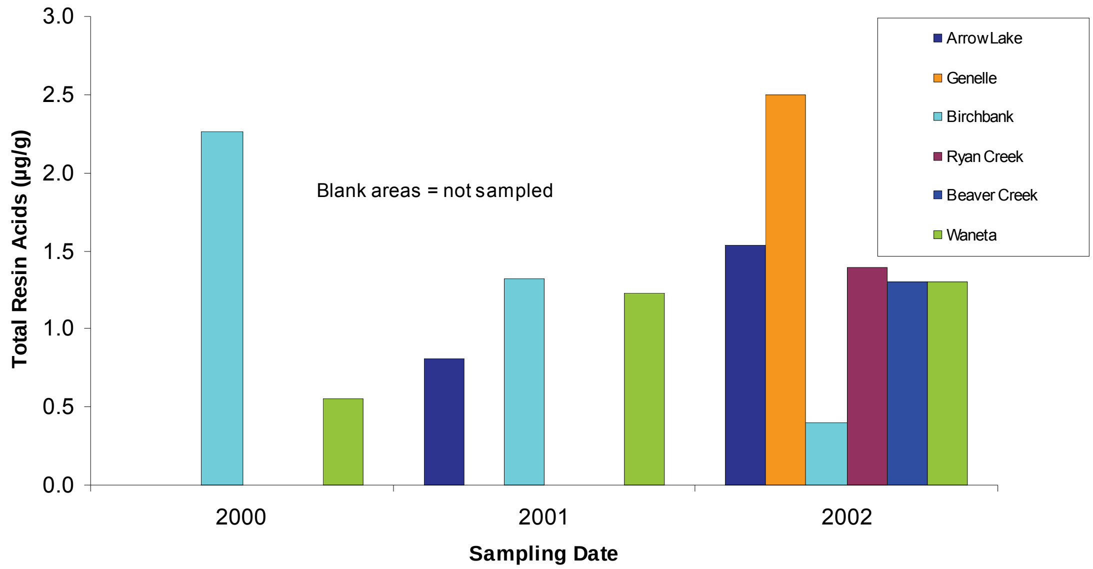


Table 3.10 Comparison of current (2000 to 2002) and historical (1992) concentrations of fatty acids and resin acids in sediment collected at Birchbank and Waneta (µg/g dw), Lower Columbia River.

		Current Mean (n=3)	Historical (n=1)
Total Fatty Acids	Birchbank	11.6	16.5
	Waneta	7.3	261
Total Resin Acids	Birchbank	1.33	0.114
	Waneta	1.03	1.03

Historical data from NECL (1993) as per McDonald (1997); Table 11.8.

Chlorinated Phenolic Compounds

Chlorinated phenols are present in bleached Kraft pulp mill effluent and were detected in water and sediment samples downstream of Celgar in 1989 and 1990, prior to facility upgrades and modernization. A significant decrease in effluent concentration of these compounds (i.e., 90%) was expected following modernization (Butcher 1992).

Chlorinated phenolics were only assessed in 2001. Concentrations for all individual chlorinated phenolic compounds were at or below the applicable detection limits: 0.0005 µg/g for 2,3,4,5-tetrachlorophenol and 2,3,4,6-tetrachlorophenol, and 0.0002 µg/g for pentachlorophenol.

No readily available sediment quality guideline for chlorophenols was found. However all reported concentrations (detection limits) were below a provisional objective derived for the Fraser River (0.01 µg/g; B.C.MOE 1998).

Total PAHs

Concentrations for all individual PAHs were below the applicable detection limits (0.02 µg/g), with the exception of naphthalene and phenanthrene, which were quantified at or slightly above the detection limit. Total PAH concentrations ranged between <0.32 and <0.33 µg/g, and are below the B.C. MOE criterion for total PAHs of 4 µg/g dw (B.C. MOE 2006). PAHs were only assessed in 2001 at three stations.

Dioxin/Furans

Dioxins and furans are a group of similar chemicals that are produced as a byproduct of manufacturing processes using elemental chlorine, and have also been linked to combustion, especially exhaust from incinerators. Up to and including the early 1990s, dioxins and furans were released by Kraft pulp mills, such as Celgar, that used elemental chlorine in their bleaching process. Dioxins and furans are similar to polychlorinated biphenyls (PCBs) in that they bioaccumulate within food chains, are persistent in the environment, are not readily metabolized by biological organisms, and can result in ecological impacts at low concentrations. Dioxin/furans share the same mode of toxicity as PCBs, but generally have greater toxic potency. 2,3,7,8-TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) is recognized as the most toxic of the dioxins and furans.

Dioxin/furan concentrations were measured in 2000, 2001 and 2002, and were generally similar among stations. Concentrations are presented as dioxin/furan TEQs (Figure 3.37). Concentrations provided as TEQs provide an indication of the relative toxicity of a dioxin/furan mixture.

Birchbank consistently had the highest TEQ concentration across the three years. Concentrations appeared to be generally decreasing with time (e.g., from 0.84 pg TEQ/g to 0.3 pg TEQ/g at Birchbank). All concentrations were below the CCME interim sediment quality guideline (ISQG = 0.85 pg TEQ/g; CCME 2006).

A comparison of the current results to historical values (1990/1991) indicated that dioxin and furan concentrations in sediments have decreased since the early 1990s (Table 3.11). This is likely a direct result of modernization at Celgar and a switch to using elemental chlorine in the bleaching process in 1993.

Figure 3.37 Dioxin/furan Toxic Equivalents (pg TEQ/g dry weight); in Lower Columbia River sediments, 2000 to 2002.

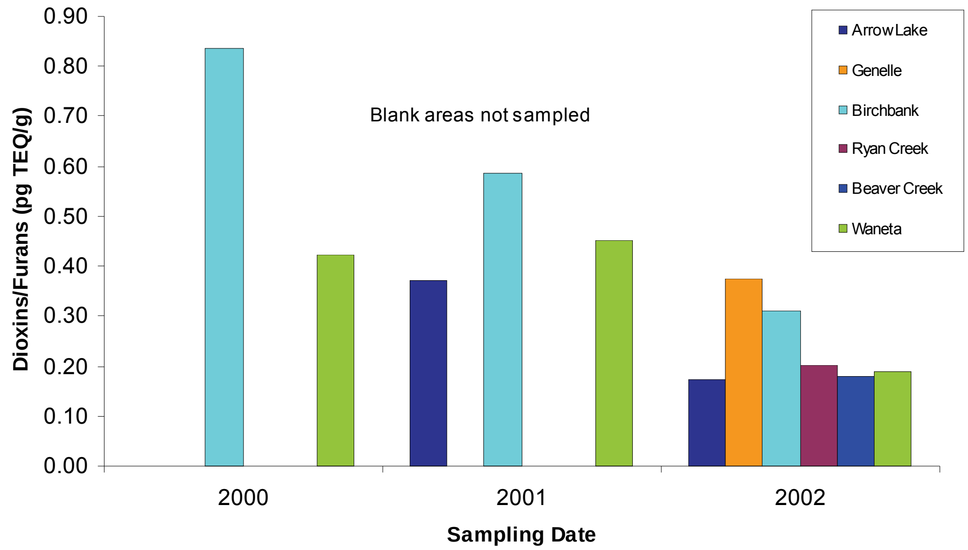


Table 3.11 Comparison of current (1997 to 2005) and historical (1990/1991) concentrations of dioxins and furans in sediment collected at Birchbank and Waneta (pg TEQ/g dw).

	Current	Historical		
	1997 – 2005	1990	March 1991	June 1991
Birchbank	0.58	2.15[1]	7.79[1]	6.5[1]
Waneta	0.35	< MDL[2]	1.1	4.36

Historical data as per McDonald (1997); Table 10.4.

[1] Sediment sample collected near Celgar.

[2] Shown as “0” in McDonald, 1997.

Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are a group of similar chemicals that were used primarily to stabilize oils under high heat conditions (e.g., electrical transformers at hydroelectric facilities such as Brilliant and Hugh Keenleyside dams), but were found in a number of other products including carbon-less copy papers. In the late 1970s, manufacture and export of PCBs was banned in North America when it was found that PCBs bioaccumulate within food chains, are highly persistent in the environment, are not metabolized by biological organisms, and can cause ecological impacts at low concentrations.

Similar to dioxins and furans, concentrations of PCBs are presented as PCB TEQs (Figure 3.38) and total PCBs (Figure 3.39). Genelle had the highest PCB TEQs in 2002, while Beaver Creek and D/S HLK had the highest PCB TEQs in 2004 (Figure 3.38).

Total PCBs in sediments were quantified in 2002 and 2004. Concentrations were similar among stations, with the exception of Genelle in 2002 and D/S HLK in 2004, which were notably higher (Figure 3.39). Of the locations sampled, sediments collected from Waneta had the lowest concentrations. The maximum recorded sediment concentration in 2002 and 2004 was 5 to 6 times less than the CCME sediment criteria (ISQG = 34,100 pg/g dw).

Figure 3.38 PCBs in Lower Columbia River sediments, expressed as Toxic Equivalents (pg TEQ/g dry weight) 2002 and 2004.

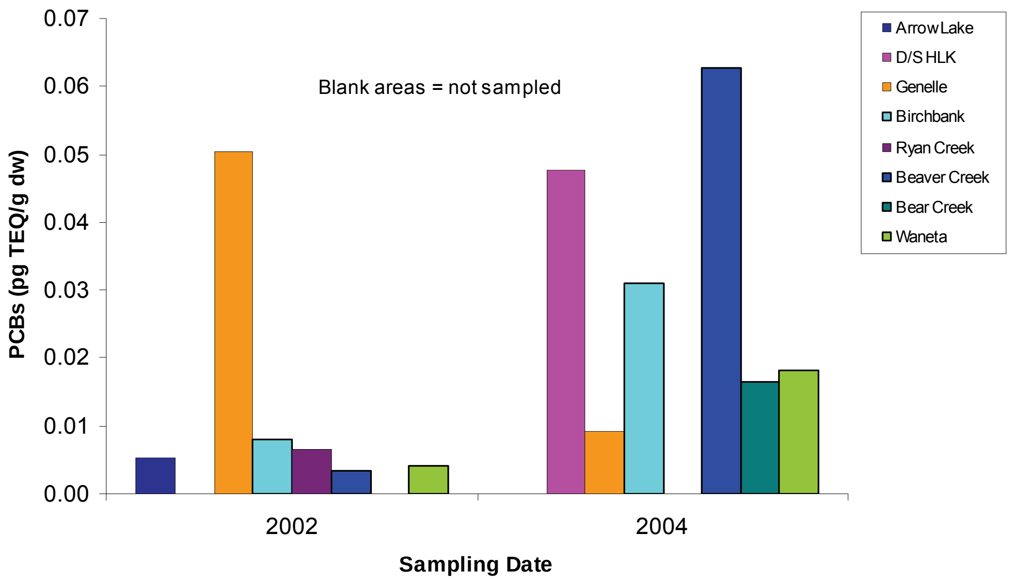
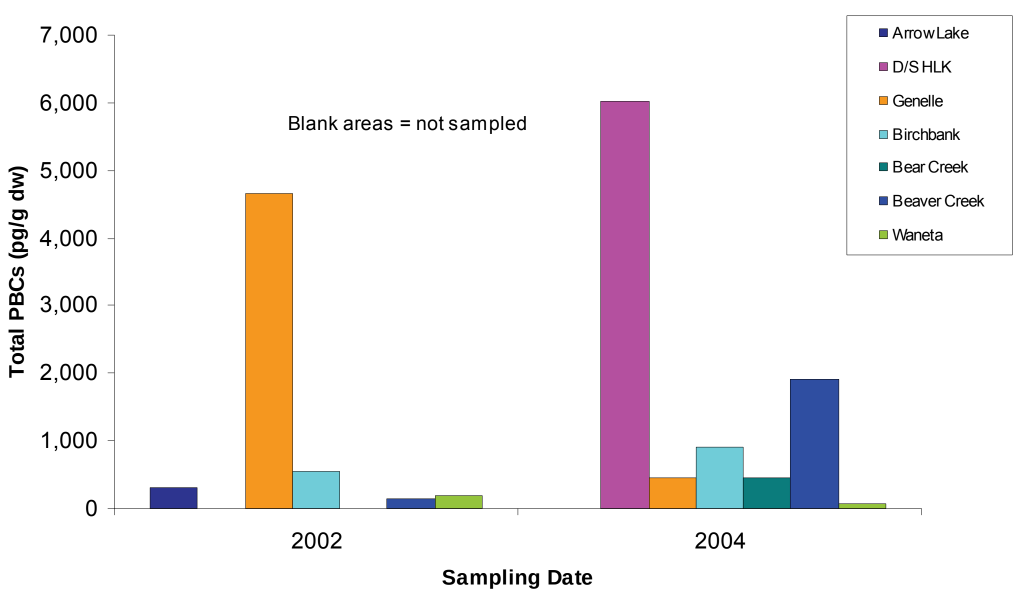


Figure 3.39 Total PCBs in Lower Columbia River sediments (2002 to 2004).

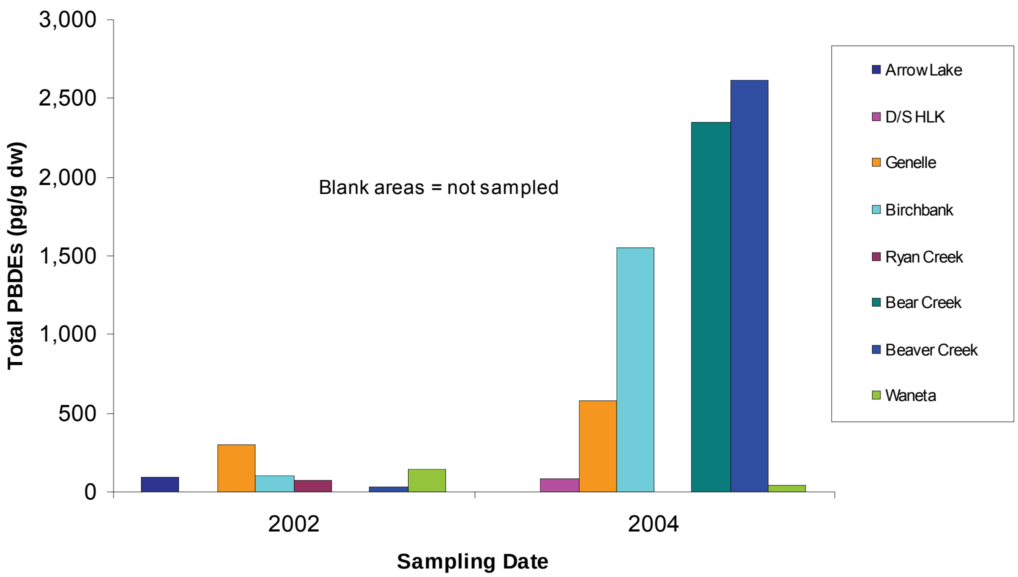


Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers (PBDEs) are a group of similar chemicals added to consumer products as fire retardants. Similar to PCBs, they bioaccumulate within food chains, are highly persistent in the environment, are not metabolized by biological organisms, and may cause ecological impacts at low concentrations. Unlike PCBs, PBDEs are in use today and their concentrations in sediments and fish tissues appear to increasing with time in the Lower Columbia River (Rayne *et al.* ,2003).

PBDEs in sediments were measured in 2002 and 2004. Concentrations in 2002 were similar among stations; however, in 2004 concentrations were higher and more variable, with the highest concentrations at Beaver Creek (2,614 pg/g dw) and Bear Creek (2,346 pg/g dw). The high variability among years can be explained partly on the basis of differences in grain size and TOC content. Sediment samples collected in 2002 generally had much lower fines and TOC content than the 2004 samples (Figure 3.22, Figure 3.23). The sediment sample collected from Waneta in 2004 also had much lower fines content than either the Bear or Beaver Creek stations.

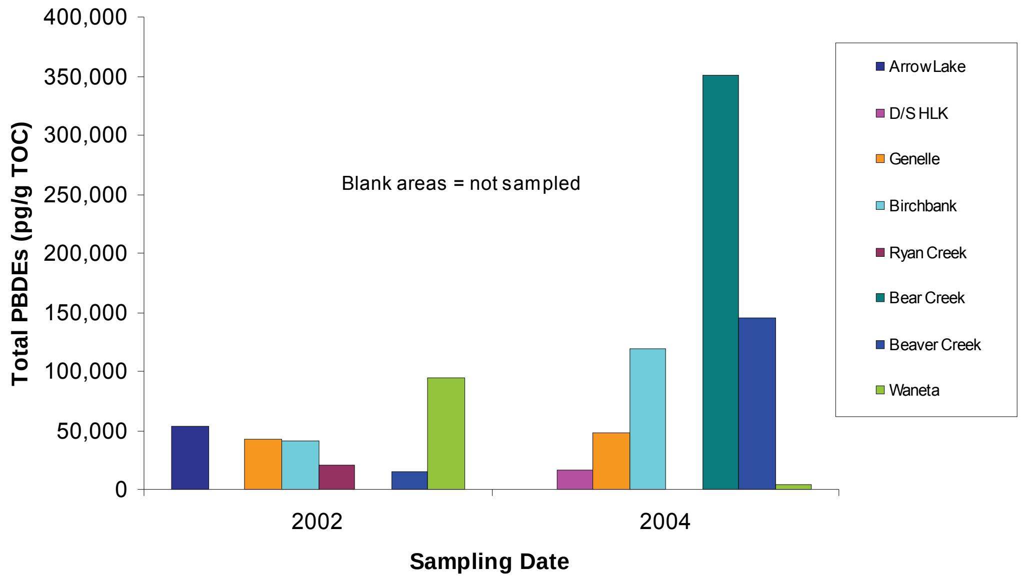
Figure 3.40 Total PBDEs in Lower Columbia River sediments (2002 and 2004).



However, when total PBDE concentrations are normalized for fines or TOC, there is still an increase in total PBDE concentration between 2002 and 2004 at most locations. This observation is consistent with observations by Rayne *et al.* (2003), who documented significant increases of PBDE concentrations in whitefish living in the Lower Columbia from 1992 to 2000.

In addition, four of the 12 TOC-normalized total PBDEs concentrations measured in sediments were greater than the highest carbon-normalized sediment concentration reported by Rayne *et al.* (2003) of 90.9 ng/g TOC (90,900 pg/g TOC). There is no criterion value available for PBDEs in sediments.

Figure 3.41 Total PBDEs (TOC normalized) in Lower Columbia River sediments (2002 and 2004).



Rayne *et al*. (2003) suggested that although PBDEs may enter the Columbia River by numerous pathways (e.g., sewage outfalls, urban run off, landfills), septic fields are likely the primary source. For the last several decades, PBDEs have been used in numerous consumer products to decrease their flammability. Recommendations for future study are provided in section 5.0.

3.2.2 Sediment Toxicity

A decrease of 20% in survival or growth relative to a reference sediment results (Arrow Lake Station, D/S Hugh Keenleyside Dam or Roberts Bank sediments) was considered ecologically significant for this assessment.

H. azteca test – toxicity appeared to be similar from Arrow Lake down to Birchbank for both the 14 and 28-day tests (Figure 3.42). In this section of the Columbia, responses were generally within 20% of the reference station. In a few test periods, effects were observed starting at Genelle, but in most instances a 20% decrease in growth (i.e., an increase in toxicity), occurred at Beaver Creek and Waneta only. Beaver Creek typically exhibited the greatest mortality and lowest relative growth relative to other stations for each year.

Chironomid test – similar to the *H. azteca* results, toxicity to chironomids was greatest in the furthest downstream site, Waneta. Indian Eddy, which is located immediately across the river from Teck Cominco, had a similar toxic response as Birchbank samples, and therefore did not appear to be influenced by Teck Cominco.

The results appear to be consistent with concentrations of contaminants of concern in sediments. Beaver Creek and Waneta generally had the highest concentrations of metals and some organic contaminants (i.e., PCBs and PBDEs). However, Beaver Creek (in one out of two samples) and Waneta also had coarser sediments (Figure 3.22) and lower organic carbon (Figure 3.23) than other stations, which may have negatively influenced sediment toxicity tests. Physical attributes of sediments can influence the outcome of toxicity results (Lacy 1999). Test organism health is generally optimal within a limited range of grainsize and TOC that best approximates the conditions of their natural habitat. Generally, no trend over time (1997 to 2004) was apparent in any of the tests.

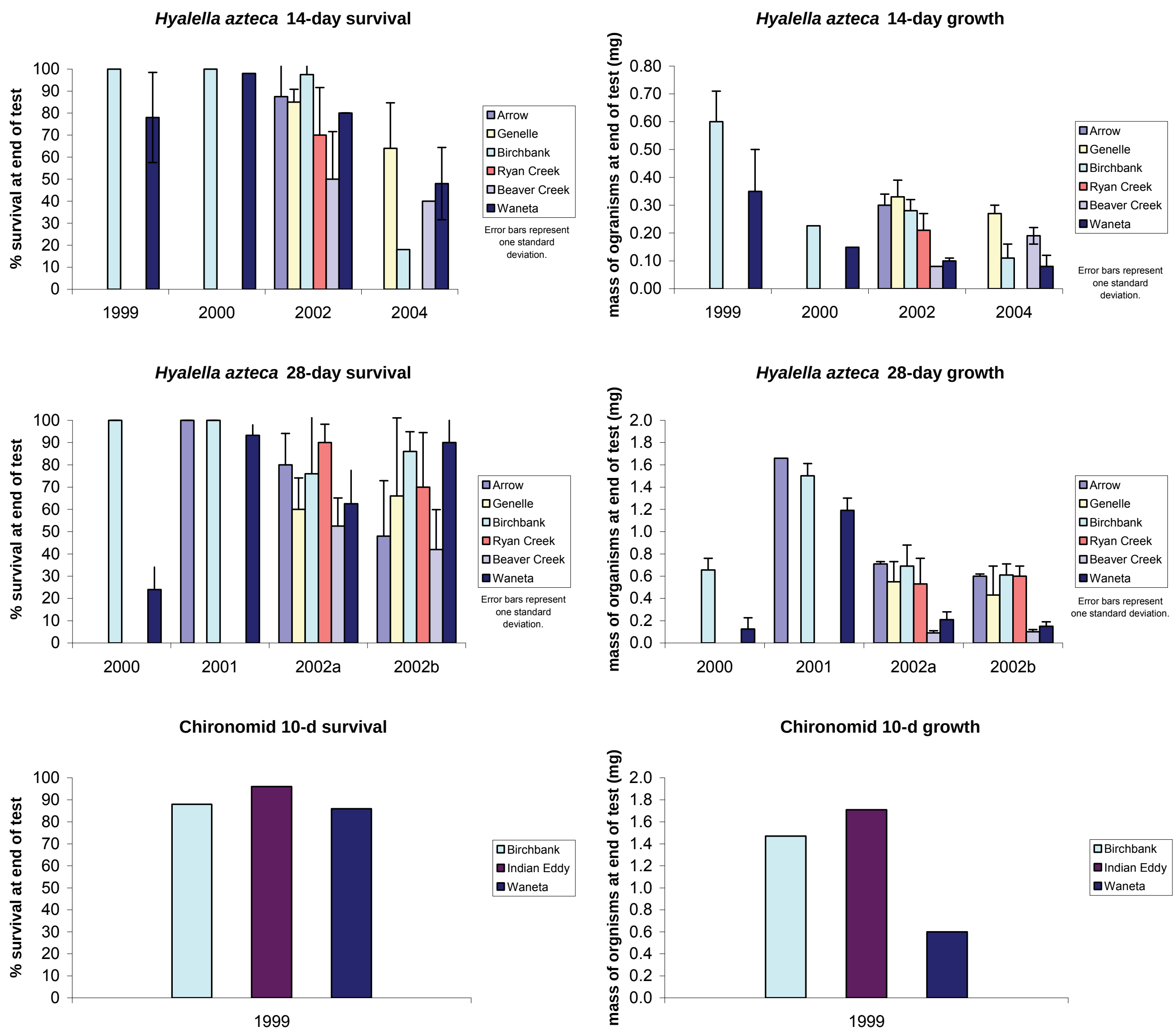
The distribution of metals concentration (Section 3.2.1.2) in the Columbia River (specifically the heterogeneity of concentrations between sites and between years), suggests that spatially limited deposits of slag material might be influencing both the observed metals concentrations and sediment toxicity. Recommendations are presented in Section 5.0, which should limit some of the natural variance in future sediment assessments.

Results of the 14-day *H. azteca* growth and survival test were compared to sediment quality variables to determine if the chemistry (metals PCA Factor 1 and Factor 2) or physical properties (percent fine material and percent total organic carbon) of sediment were contributing to the observed toxicity.

Spearman correlation analysis results indicated significant negative correlations between metals (i.e., the PCA Factor1) and both survival and growth (Table 3.12). There was also a significant negative correlation between percentage TOC and survival.

H. azteca did not appear to be effected by the fines content. The negative correlation with metals (Factor 1) suggests that the historical discharge of metals from Teck Cominco could be resulting in present day impacts to sediment dwelling organisms living downstream of the Teck Cominco site. The negative correlation between survival and TOC is somewhat unexpected, as the relatively low TOC content of Lower Columbia sediments would not be expected to result in toxicity. However, TOC is often correlated to sediment contaminant concentrations and therefore the apparent negative correlation with toxicity might be attributable to sediment distribution patterns in the Lower Columbia and a contaminant other than metals. The percentage fines and percentage TOC do not appear to be correlated to metals concentrations in the Lower Columbia.

Figure 3.42 Results of sediment toxicity testing. Tests included a 14-day *Hyalella azteca* test, a 28-day *Hyalella azteca* test and a 10-day *Chironomid* test; survival and growth were measured.



[1] "2002b" is a retest of "2002a" due to poor organism survival in the negative control group. However, the "2002b" group also did not meet minimum survival in the negative control group. Therefore 2002a and 2002b results should be interpreted with caution.

Table 3.12 Results of Spearman correlations between sediment toxicity (*H. azteca* 14-day growth test) and sediment quality.

	Survival	Growth
Metals Factor 1 [1]	**-0.68**	**-0.66**
Metals Factor 2 [1]	0.21	0.25
% Fines [2]	-0.13	0.27
TOC [2]	**-0.61**	-0.028

[1] Rs=0.52 (n=15, alpha[2]=0.05)
[2] Rs=0.59 (n=12, alpha[2]=0.05)

	% Fines	TOC
Factor 1	-0.17	0.063
Factor 2	0.14	-0.07

Rs=0.59 (n=12, alpha[2]=0.05)

3.3 FISH

Adult sport fish were collected from two locations on the Lower Columbia River:

- Between Genelle and Birchbank ("Birchbank"); and
- Between Beaver Creek and the US Border ("Waneta").

Fish analyzed were captured during a B.C. Hydro fish-indexing project. No attempts are made to target sex and/or age classes. However, the largest fish were collected, thus representing the sizes of fish legally retained and consumed by humans. Assessing the largest fish also provides a worst-case picture of contaminants that that bioaccumulate in tissues (e.g., mercury, dioxins/furans and PBDEs). The three fish chosen are common, popular sport fish in the study area. Walleye represent a top-level aquatic predator and therefore were anticipated to have high concentrations of bioaccumulative substances. Mountain whitefish tend to feed nearer to the bottom and therefore would tend to attain a higher proportion of their contaminant body burdens from sediments via benthic organisms.

3.3.1 Condition

The condition factor (k) was investigated for individual fish of each species collected between 2000 and 2005. The condition factor is essentially a length normalized measure of weight and indicates whether a fish is storing energy (i.e., how "fat" the fish is). Generally, fish that are storing energy are more likely to be healthy and finding adequate quantities of food.

Because fish were not sampled randomly, it was not possible to assess differences in other fish whole body variables, such as age, and weight and fork length independently.

For all three species, mean condition (k) was similar between years, areas and sexes, and no trends were apparent. However, female mountain whitefish collected from the Waneta sampling area in 2002, 2003 and 2004 appear to have a slightly higher condition factor than Birchbank females. In general, there were no discernable trends between areas, sexes or across time that might indicate an effect (Figure 3.43).

3.3.2 Fish Tissue Quality

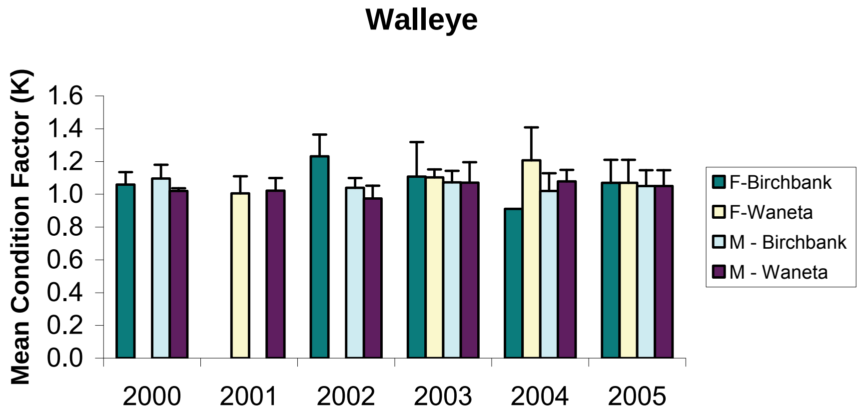
Muscle tissue from each captured fish was assessed for concentrations of metals, PCBs, dioxins/furans and PBDEs.

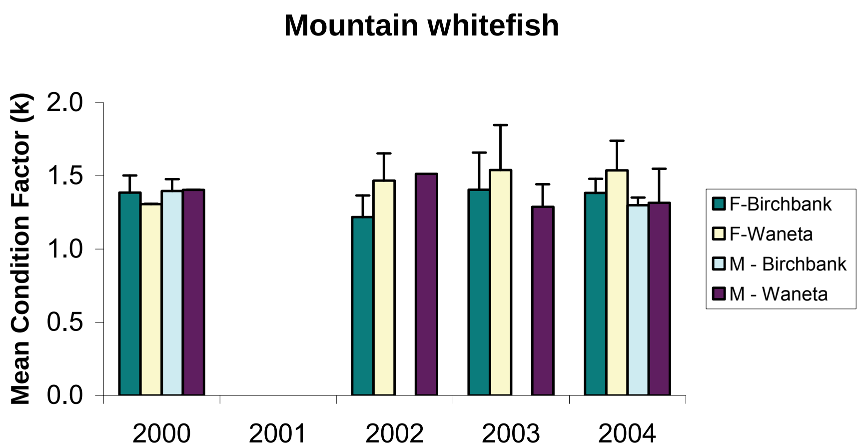
3.3.2.1 Metals

Metals that have the ability to accumulate in aquatic organisms were assessed, including arsenic, cadmium, chromium, lead and mercury. Concentrations were compared to tissue residue objectives (TRO) for the protection of human health and wildlife consumers (Table 3.8).

Concentrations of metals in 2000 and 2001 were based on dry weights (dw) of tissue, not wet weights (ww) like the remainder of years. Consequently, concentrations in 2000 and 2001 were converted to wet weights before means were calculated. In some cases, metals that were consistently below detection limit in 2000 and 2001 showed apparent variability. This variability was due to the dry tissue to wet tissue weight concentration conversion. Once these values were converted, the calculated concentrations were sometimes less than the provided MDL. In the remaining years, variability in detection limits between years appeared to be largely a function of changing analytical laboratories.

Figure 3.43 Fish Condition (k; Lower Columbia River, 2000 to 2005).





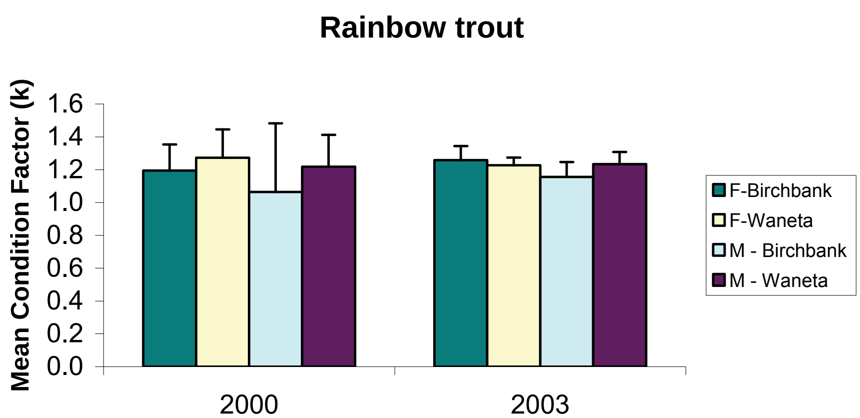


Table 3.13 Tissue-residue objectives (TROs) and guidelines for arsenic, cadmium, chromium, lead and mercury.

	Arsenic	Cadmium	Chromium	Lead	Mercury
Human Health	3.5 µg /g ww (Health Canada)	NA	NA	0.5 µg /g ww (Health Canada)	0.5 µg /g ww (Health Canada), 0.1 µg/g ww (TRO, see text)
Wildlife	0.47 µg /g ww (TRO)	0.90 µg /g ww (TRO)	0.94 µg /g ww (TRO)	0.16 µg /g ww (TRO)	0.33 µg /g ww (TRO)

TRO = Lower Columbia River tissue-residue objectives. Protective of wildlife consumers of fish (McDonald 1997).

NA = not available.

Arsenic

Arsenic concentrations were below the detection limit (<0.2 to <1.2 µg/g ww) in all fish muscle samples, except in 2004 when concentrations in walleye and mountain whitefish (0.58 µg/g ww) were above the detection limit (Figure 3.41). On this occasion, arsenic exceeded the TRO (0.471 µg/g ww) in both species; however, the quantified values were very close to the MDL. In 2000 and 2001, the detection limit (up to <1.2 µg/g ww; rainbow trout in 2000) was above the Columbia River TRO (0.471 µg/g ww). As a result, even though concentrations were below the detection limit, a number of apparent exceedances were observed.

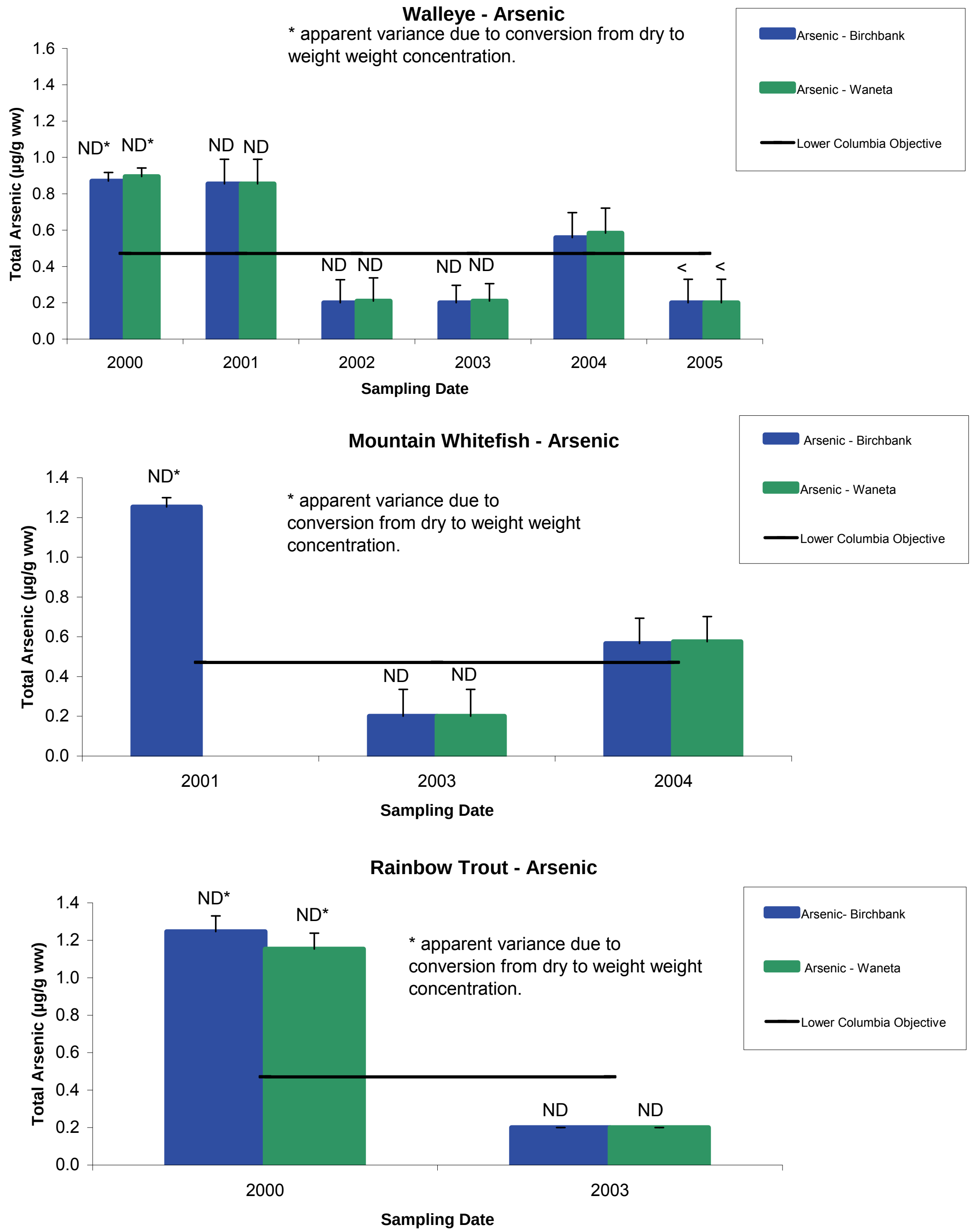
It appears that mean concentrations between fish species were similar, and concentrations were also similar in Birchbank and Waneta fish. No trends with time were detectable.

It is unlikely that arsenic poses a health risk to humans or wildlife consumers of fish. Arsenic concentrations were measurable and were above their respective TROs on at least one sampling date; however, the quantified values were very close to the method detection limit. It is likely that future sampling will indicate that fish tissue concentrations of arsenic are below their respective objectives/criteria. The mean tissue concentration was marginally above the TRO for arsenic (0.47 µg/g ww); however, the mean concentration represents the average of measurable and non-detectable concentrations (i.e., "< values"). Consequently the means likely over estimate the true mean of arsenic in Lower Columbia River fish. The Lor2 study (Cantox 2003), indicated minimal risk to fish eating wildlife. Given that wildlife tend to be more sensitive receptors than humans (Table 3.13) additional investigation may not warranted.

Cadmium

Cadmium concentrations were consistently below the reported detection limit (0.05 to 0.12 µg/g ww) and also well below the TRO (0.9 µg/g ww) for all species assessed (data not shown). Therefore, it is unlikely that cadmium concentrations in fish tissue poses health risk concerns to humans or wildlife consumers of fish.

Figure 3.44 Arsenic concentrations in muscle of Columbia River walleye, mountain whitefish and rainbow trout (µg/g wet), 2000 to 2005.



“<” = mean concentrations represent an average of measurable and non-detectable concentrations.

Error bars represent 1 SD.

Chromium

Mean chromium concentrations were non-detectable (detection limits ranged from 0.2 to 1.0 µg/g ww) in most samples, except for walleye and rainbow trout samples collected in 2000, mountain whitefish samples collected in 2003 and Birchbank samples of each species in 2004 (Figure 3.42). Concentrations of chromium were highest in walleye, followed by mountain whitefish and rainbow trout, which had similar concentrations. The maximum mean concentration in tissue was within two times the TRO (0.94 µg/g ww); however, all means consisted of one or more samples below the MDL. Therefore, true sample means are likely lower than shown. Chromium concentrations were similar in fish collected from the Birchbank and Waneta sites. No trend over time was apparent.

It is unlikely that chromium poses health risk concerns to humans or wildlife consumers of fish. Like arsenic, chromium concentrations were measurable and were above their respective TROs on at least one sampling date; however, the quantified values were very close to the method detection limit. It is likely that future sampling will indicate that fish tissue concentrations of chromium are below their respective objectives/criteria. The mean tissue concentration was marginally above the TRO for chromium (0.94 µg/g ww); however, the mean concentration represents the average of measurable and non-detectable concentrations (i.e., "< values"). Consequently (similar to arsenic) the mean likely over estimates the true mean of chromium in Lower Columbia River fish. The Lor2 study (Cantox 2003), indicated minimal risk to fish eating wildlife. Given that wildlife tend to be more sensitive receptors than humans (Table 3.13) additional investigation is not warranted.

Lead

Lead concentrations were consistently below the reported detection limits (0.1 to 1.4 µg/g ww) in all species and years. Detection limits used in 2000 and 2001 were greater than the TRO (0.16 µg/g ww). As a result, it is not possible to conclude that there were no exceedances in 2000 and 2001. However, the fact that there were no exceedances during years where the detection limit was below the TRO, suggests that there would not have been exceedances in 2000 and 2001. The highest mean detection limit occurred in 2000 (1.3 µg/g ww; for mountain whitefish) and exceeded the TRO by approximately eight times. There were no apparent differences between the Birchbank and Waneta sampling areas, and no apparent trend with time.

Given that lead concentrations in tissues were never quantifiable (i.e., were less than the detection limit) and the reported detection limits were much lower than the applicable objectives or criteria, is unlikely that measured lead concentrations in fish tissue poses health risk concerns to humans or wildlife consumers of fish.

Mercury

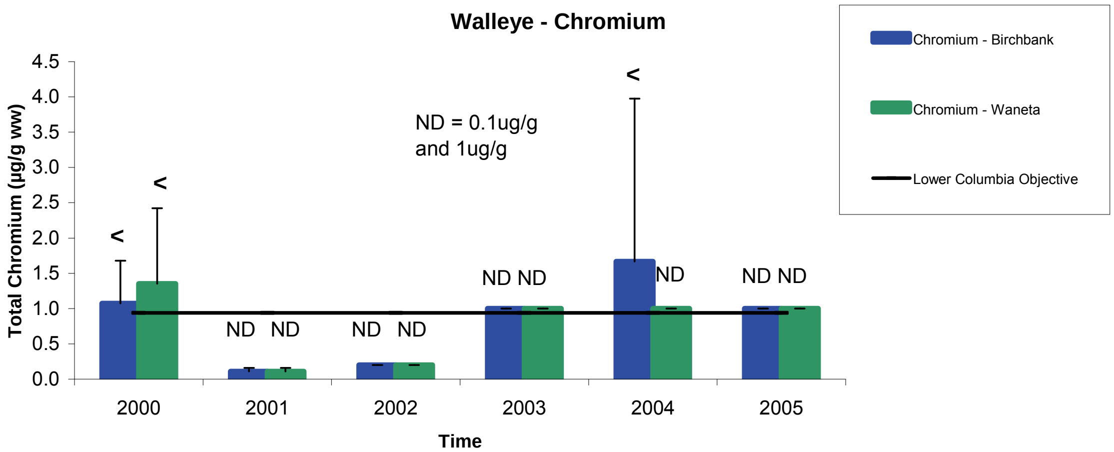
Mercury concentrations in fish muscle have been measured in walleye (2000 to 2005), mountain whitefish (2001, 2003 and 2004) and rainbow trout (2000 and 2003).

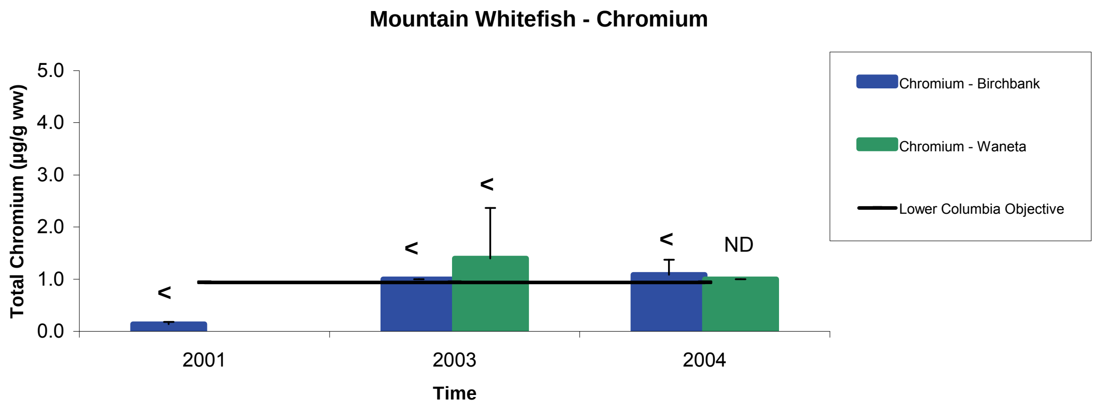
Walleye had the highest mean tissue concentrations (0.08 to 0.65 µg/g ww), followed by rainbow trout (0.04 to 0.21 µg/g ww) and then mountain whitefish (0.05 to 0.17 µg/g ww) (Figure 3.46). These results were expected given that walleye were the largest fish caught and are at the top of the local aquatic food chain.

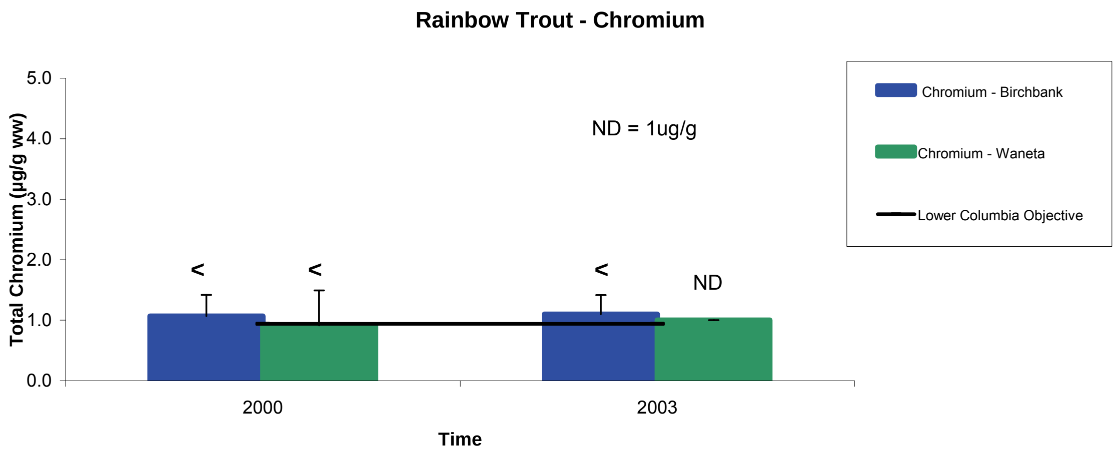
There were no apparent differences in mercury concentration between fish caught in the Birchbank and Waneta sampling areas. As discussed earlier, this may be due to the fact that these large-bodied fish likely migrate between the two sampling locations. There were also no apparent changes in mercury between 2000 and 2005 for any of the three species assessed. Concentrations were also consistent with historical walleye data (1980 to 1988, Table 3.14).

Compared to the other fish species, mercury concentrations in walleye displayed the strongest visual relationship with fish length (Figure 3.47). Mercury concentrations in mountain whitefish and rainbow trout also appeared to increase with fish size; however, the relationship was less distinct.

Figure 3.45 Chromium concentrations in Lower Columbia fish muscle (µg/g wet), 2000 to 2005.



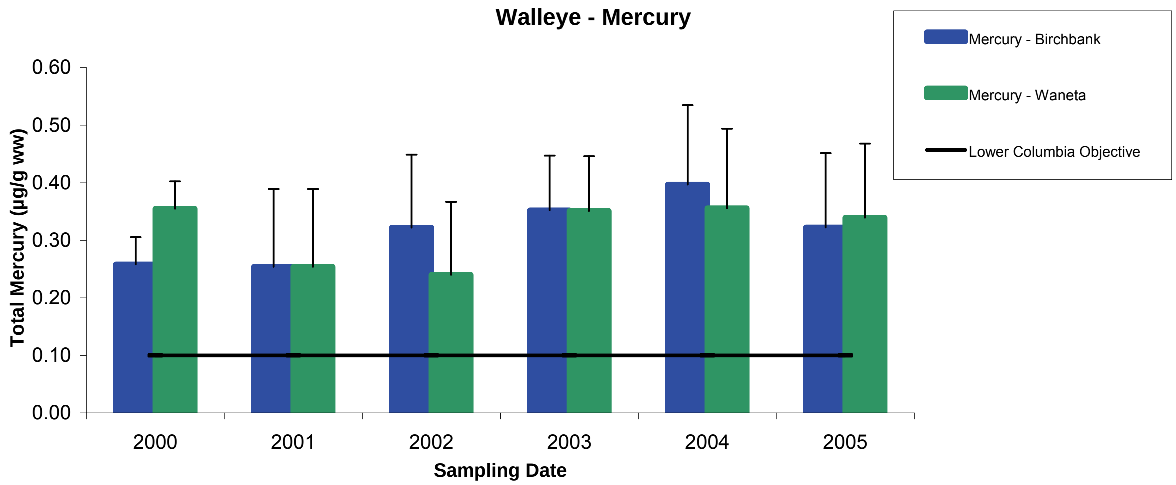


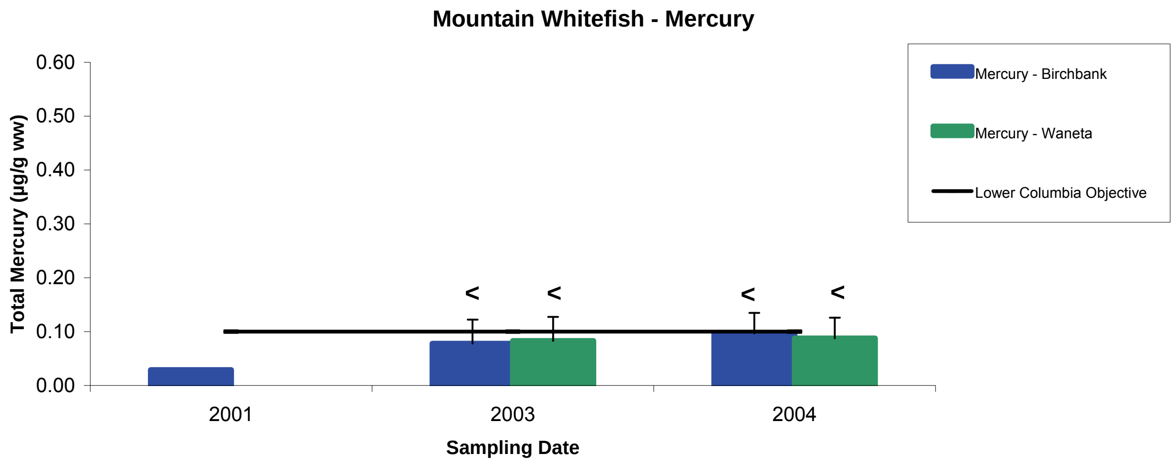


"<" = mean concentrations represent an average of measurable and non-detectable concentrations.

Error bars represent 1 SD.

Figure 3.46 Mercury concentrations in Lower Columbia fish muscle (µg/g wet), 2000 to 2005.





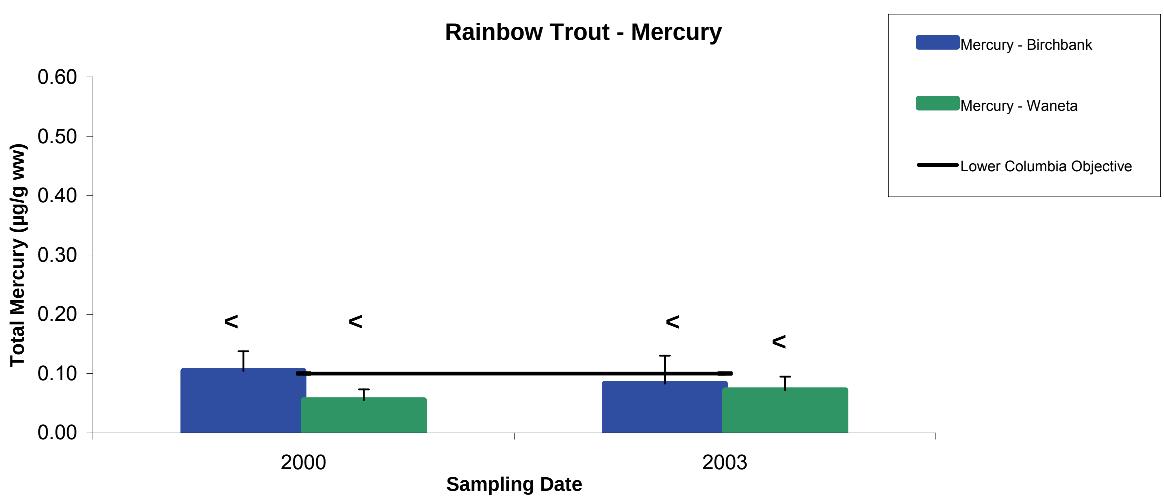
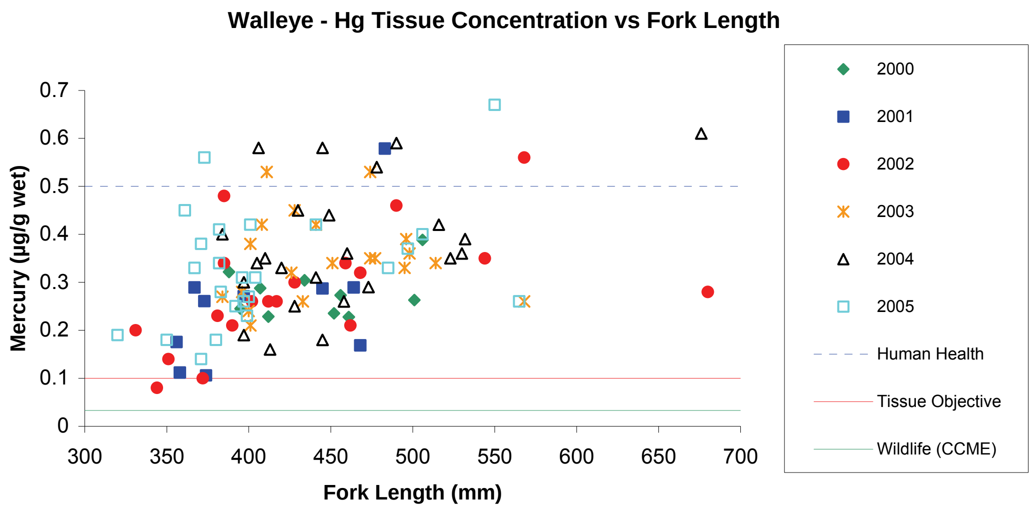
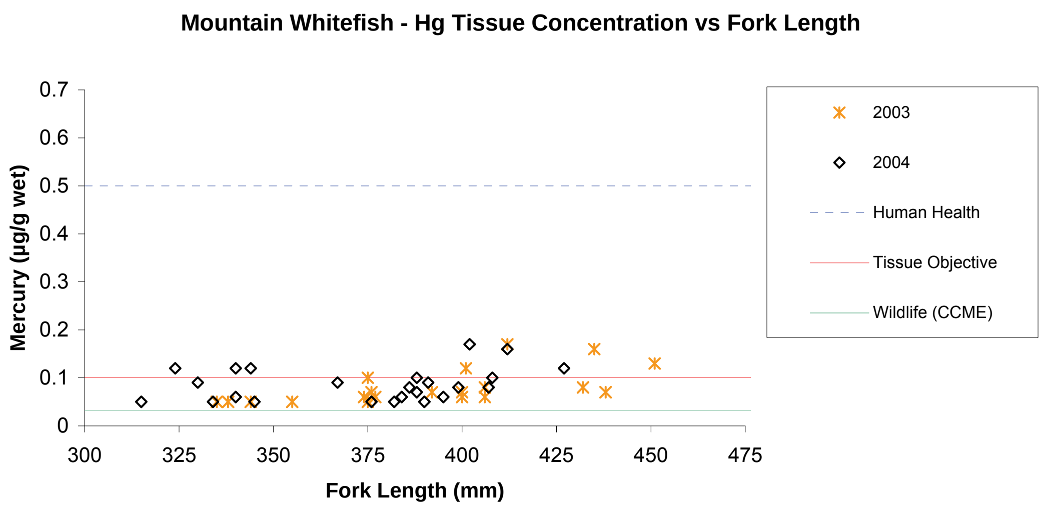


Figure 3.47 Mercury concentrations in Lower Columbia muscle as a function of fish size (µg/g wet), 2000 to 2005.





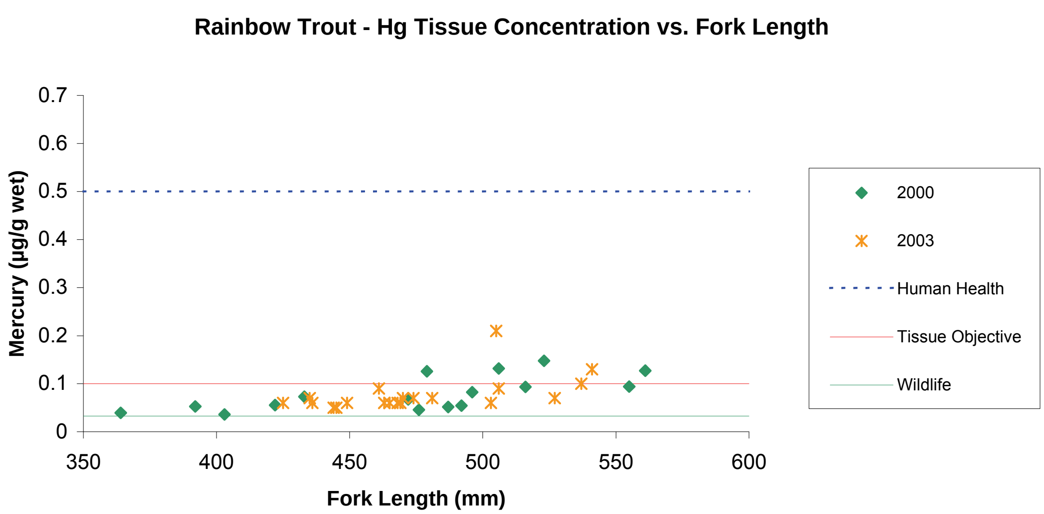


Table 3.14 Comparison of current (2000 to 2005) and historical (1980-88) mean concentrations of mercury in walleye muscle (µg/g ww), Lower Columbia River.

Current 2000 – 2005	Historical 1980 –1988
N = 107 (11 means)	N = 88 (7 means)
0.24 – 0.40	0.21 – 0.40

Historical data as per McDonald (1997); Table 12.9.

There are a few different tissue guidelines for mercury in Canada. The Health Canada consumption guideline for general consumers is 0.5 µg/g wet weight. However, Health Canada's regulatory responsibilities are for market fish consumption (Health Canada 2002) and therefore, the 0.5 µg/g wet weight guideline may not be sufficiently protective in cases where game fish are being consumed. It is assumed that people who eat game fish tend to eat fish more frequently than those who eat market fish.

Approximately 10% of individual walleye tissue concentrations were slightly above the proposed Health Canada consumption guideline of 0.5 µg/g ww; however, the highest measured tissue concentration was only 1.34 times larger than this guideline. Considering that people eating walleye would be consuming fish over the range of observed mercury concentrations, the mean concentration would provides a better indication of actual exposure over time. Both the mean (0.32 µg/g wet) and 95% upper confidence limit of the mean (UCLMs; 0.35 µg/g wet) for walleye were below the Health Canada consumption guideline. The concentrations of mountain whitefish and rainbow trout were lower than walleye; therefore, their means and 95% UCLMs were also below the Health Canada consumption guideline.

The B.C. water quality guidelines (B.C. MOE 2006) present a graduated fish tissue criterion based on the weekly consumption of fish by an individual (Table 3.15). The Lower Columbia River TRO for mercury was based on this criterion, which ranges from 0.1 to 0.5 µg/g ww, depending on the average weekly consumption of fish. The lowest, most conservative concentration (0.1 µg/g ww) was chosen to provide a high level of protection for human consumers and a moderate level of protection for fish eating wildlife species (MacDonald 1997). Most walleye and approximately 30% of mountain whitefish and rainbow trout had tissue concentrations that exceeded this TRO. Both the mean (0.32 µg/g wet) and 95% upper confidence limit of the mean (UCLMs; 0.35 µg/g wet) for walleye were above the Lower Columbia TRO. Following the B.C. tissue-residue criteria, the maximum consumption rate of walleye (given a mean concentration of 0.32 µg/g wet) would be limited to 260 g/week. The concentrations of mountain whitefish and rainbow trout were lower than walleye; and their mean and 95% UCLM concentrations were below the Lower Columbia TRO (Table 3.16).

Table 3.15 B.C. Guidelines for mercury in fish/shellfish when human diet is based primarily on fish (B.C.MOE 2006).

Concentration of total Hg in the edible portion of fish and shellfish (µg Hg/g wet weight fish)	Safe quantity for weekly consumption on a regular basis (g fish wet weight)
0.5 µg/g	210 g
0.4 µg/g	260 g
0.3 µg/g	350 g
0.2 µg/g	525 g
0.1 µg/g	1050 g

Table 3.16 Mean and 95% Upper Confidence Limits of the Mean of Mercury concentrations in fish tissue.

	Walleye (µg/g wet)	Mountain Whitefish (µg/g wet)	Rainbow Trout (µg/g wet)
Mean	0.32	0.085	0.079
95% UCLM	0.34	0.093	0.088

Game fish advisories are a provincial and territorial responsibility in Canada. In B.C., fish consumption advisories are published in the Freshwater Fishing Regulations Synopsis each year. Currently, there is no advisory for the consumption of game fish caught in the Lower Columbia game fish; an advisory on walleye consumption was removed in 1996 (B.C. MOE 2007).

Washington State has a consumption advisory for walleye for Lake Roosevelt, which is downstream of the Lower Columbia. Based on a mean measured concentration of mercury in walleye of 0.3 µg/g wet, which is similar to concentrations found in the study area, recommended weekly consumption rates are 454 g/week for adults, 113 g/week for pregnant women and 38 g/week for children under six years of age.

In addition to TROs (or criterion) designed to protect humans, the CCME (and B.C. MOE) have published a tissue-residue guideline designed to be protective wildlife that eat fish (CCME 2006, B.C. MOE 2006). Compared to humans, wildlife are known to rely to a much greater degree on a smaller range of food items. The CCME guideline for methyl mercury is 0.033 µg/g ww for wildlife. It should be noted that this guideline is for methyl mercury, not elemental mercury (which was measured as part of the WQO program). However, approximately 95% of mercury in fish tissue will be in the methylated state (Watras and Bloom 1992, *cited in* Morel *et al.* 1998), and therefore, the application of a guideline for methyl mercury to total mercury concentrations is reasonable. When the fish tissue data from the Lower Columbia River is screened against the CCME guideline, it appears that all fish of each species (walleye, mountain white fish and rainbow trout) exceed the guideline.

Food chain modelling conducted by Cantox (2005) for Teck Cominco indicated that great blue heron in the area could be at risk by eating mercury containing fish. The Cantox document recommended additional model refinement (or other analysis) to investigate possible risks to great blue heron from mercury exposure. These results are still pending.

Based on the findings of this report, mercury concentrations in fish tissues collected from the Lower Columbia River are not changing over time. Mercury in the Lower Columbia has been associated with historic Teck Cominco discharges (MacDonald 1997); apatite, a phosphate-containing rock used in the phosphate fertilizer production at Teck Cominco contained significant amounts of mercury. However, due to the large number of dams in the Columbia watershed, it is possible that some of the measured mercury concentrations could be associated with natural weathering and flooded reservoirs.

3.3.2.2 Dioxin and Furans

Both dioxins and furans consist of numerous related chemicals (called congeners) that have similar physical chemical properties and mechanisms of toxicity. The congeners differ on the basis of the number of chlorine atoms attached to the dioxin or furan molecule and the location of the chlorine on the molecule. Some congeners, for instance, have a much greater toxicity relative to other congeners. The toxicity of 2,3,78-TCDD (the most toxic of the dioxin/furan congeners), is also used as a standard by which other congeners are compared. All congeners of dioxin and furans have been given a toxicity equivalence factor (TEF). By multiplying all a congeners with its respective TEFs, a toxicity equivalent (TEQ) to 2,3,7,8 TCDD is derived. This value is the concentration of 2,3,7,8 TCDD that would result in the same toxicity. If the individual TEQs are added up for each sample, individual samples can be compared on the basis of 2,3,7,8 TCDD equivalents. For fish tissue samples, the units are generally expressed as pg/g ww TEQs.

In many cases, individual dioxin and furan congeners were non-detectable; however, three surrogate measures of dioxins and furans could be calculated for all samples (Figure 3.44).

1. Total TCDD – Total TCDD is a sum of all dioxin congeners having four chlorine molecules. Total TCDD includes 2,3,7,8-TCDD, which is the most toxic of the dioxin and furan congeners.

2. Total TCDF – Total TCDF is a sum of all furan congeners having four chlorine molecules. Total TCDF includes 2,3,7,8-TCDF, which is the most toxic of the furan congeners.

3. Dioxin and furan TEQs – Dioxin and furan TEQs is the sum of all dioxin and furan congeners that have been normalized to the toxicity of 2,3,7,8-TCDD. Dioxin/furan concentrations expressed as TEQs provide a better indication of absolute toxic potency and therefore regulatory criteria have been derived which are expressed in term of TEQs. In this data summary

report, the CCME tissue-residue guideline has been selected over the Columbia River TRO, as it based on more current scientific literature (J. Raggett, B.C. MOE, *pers comm*.).

Total TCDD and total TCDF provide a better indication of how dioxin/furan concentrations are varying over time than TEQs alone; therefore, all three surrogates were used in this report.

Calculated dioxin/furan TEQ concentrations for all mountain whitefish and rainbow trout were well below the Health Canada consumption guidelines for fish (15 pg/g wet weight in fish muscle; Health Canada 2005). The highest concentration observed (5.0 pg/g ww TEQ; in mountain whitefish), was three times lower than the Health Canada guideline.

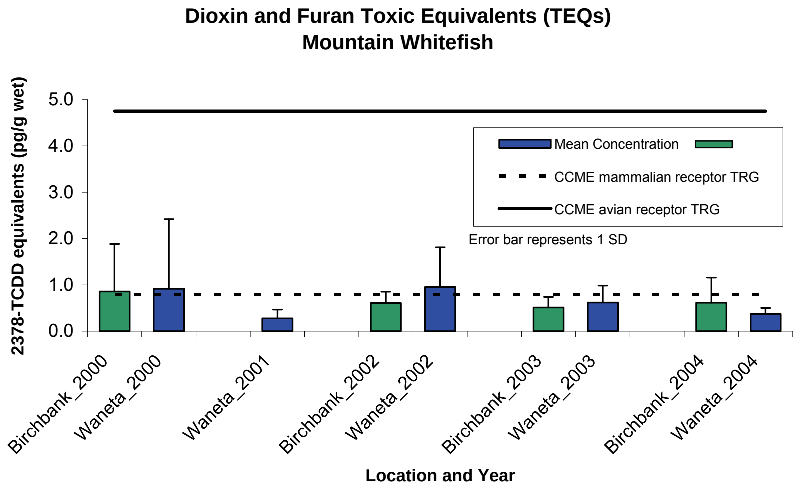
Calculated dioxin/furan TEQ concentrations were also screened against the CCME tissue-residue guidelines for the protection of wildlife that consume fish. The mean dioxin/furan TEQs for mountain whitefish in the Columbia River exceeded the guideline for mammals that consume fish (0.79 pg TEQ/g ww) in 2000 (both Birchbank and Waneta) and 2002 (Waneta only). None of the mean TEQ concentrations exceeded the guideline for birds that consume fish (4.75 pg TEQ/g ww; Figure 3.45). The highest measured concentration (5.0 pg TEQ/g ww) exceeded the guidelines for mammal consumers of fish by 6.5 times and bird consumers of fish by 1.05 times. The 95% upper confidence limit of the mean (95%UCLM; 0.95 pg TEQ/g ww) was approximately 1.2 times higher than the CCME guideline for mammals, but below the guideline for birds. The 95%UCLM is a calculated value that provides a conservative estimate of time-weighted average exposure.

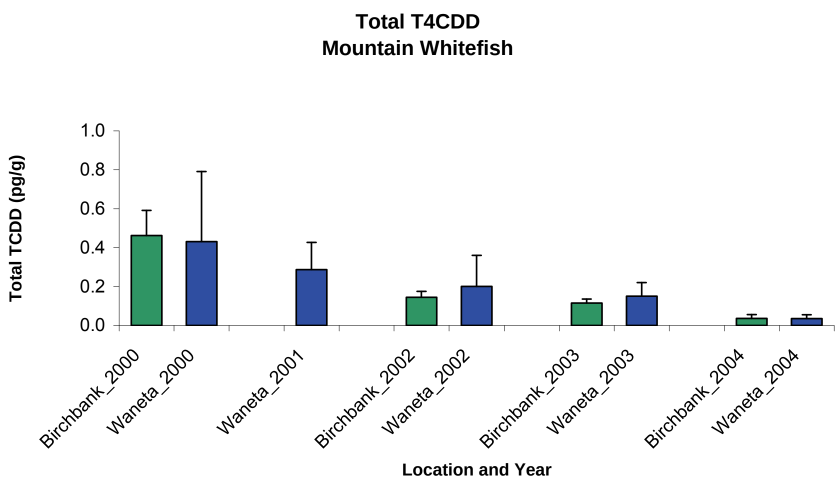
None of the mean rainbow trout tissue concentrations assessed in this study exceeded either of the CCME wildlife tissue-residue guidelines for mammals and birds that consume fish (Figure 3.46).

In general, dioxin/furan concentrations were similar between the Birchbank and Waneta sampling areas. Rainbow trout caught from the Birchbank sampling area appear to have higher concentrations of dioxins and furans (Figure 3.46), while there is no apparent Birchbank vs. Waneta trend in the mountain whitefish data (Figure 3.48).

Dioxins and furans concentrations in mountain whitefish were similar between sampling events. Total TCDD in mountain whitefish appeared to decrease slightly from a mean value of 0.40 pg/g ww in 2000 to a mean value of less than 0.20 pg/g ww in 2004. Total TCDF in mountain whitefish did not indicate any trends either over time or between the Birchbank and Waneta sampling areas. Dioxin/furan TEQs in mountain whitefish also did not indicate any trends over time (Figure 3.45). Fish collected in 2000 and 2001 had the highest mean age, which might account for the fact that the total T4CDD concentrations in tissue were the highest during this period.

Figure 3.48 Mean dioxin/furan concentrations in mountain whitefish muscle (µg/g wet), Lower Columbia River, 2000 to 2004.





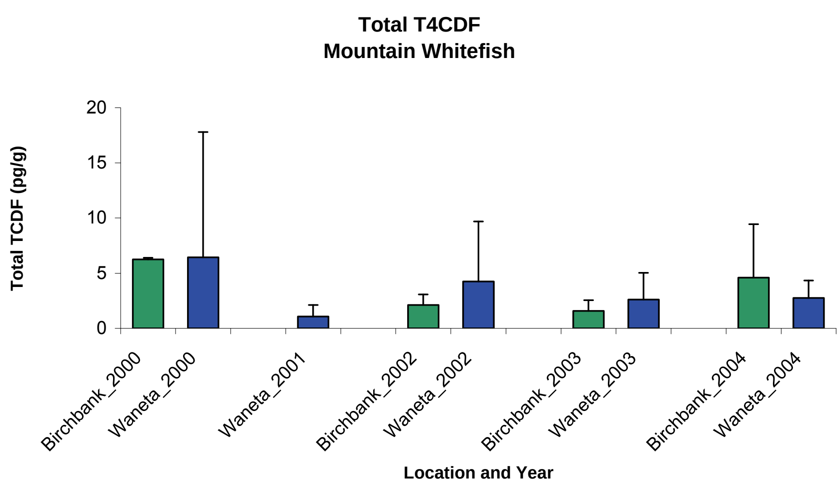
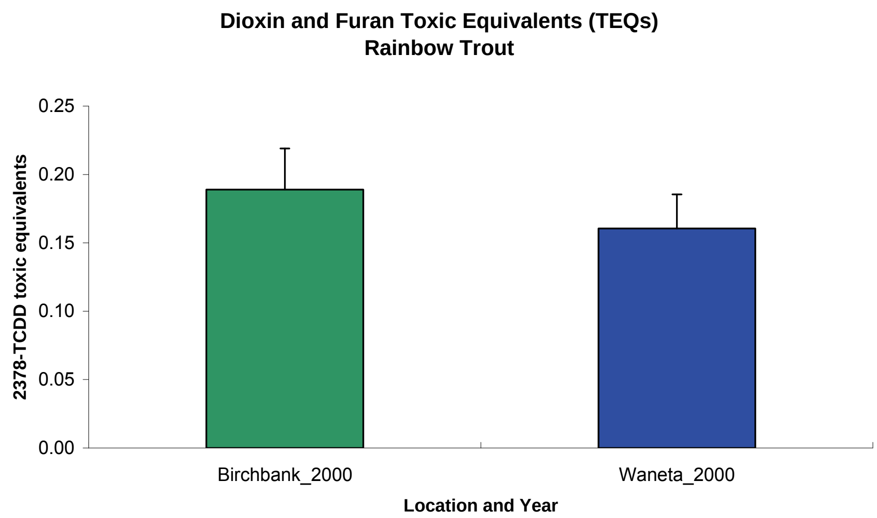
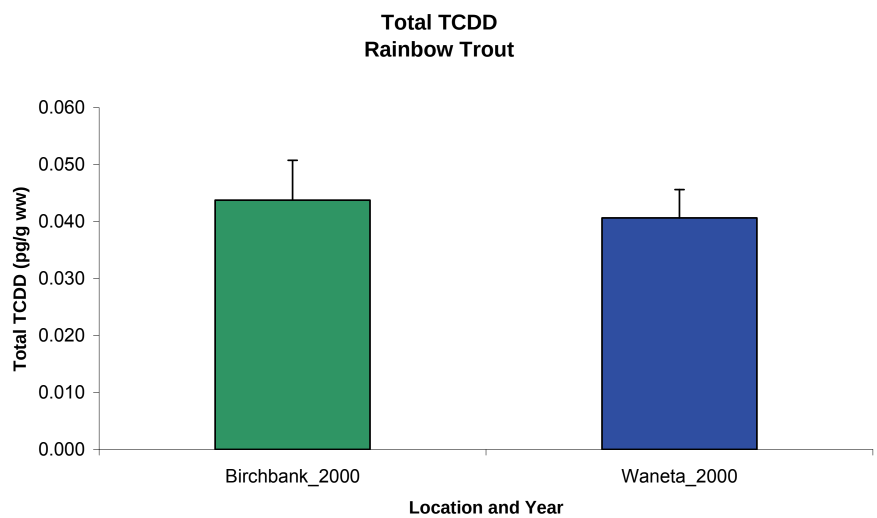
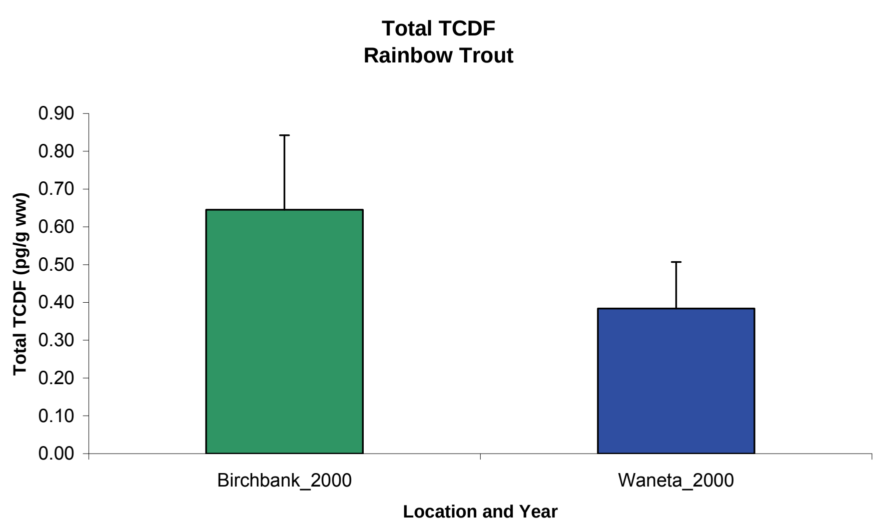


Figure 3.49 Dioxin/furan concentrations in rainbow trout muscle (μg/g wet), Lower Columbia River, 2000.







Mean tissue concentrations of 2,3,7,8 TCDD TEQs appear to have decreased since 1990/1991 (Table 3.17). This apparent decrease is likely attributable to the switch from chlorine to chlorine dioxide bleaching at the Celgar pulpmill in 1993. In 1990/1991, mean mountain whitefish concentrations were reported as 26.1 pg TEQ/g wet for the Birchbank sampling area and 34.3 pg TEQ/g wet for Waneta sampling area (Table 12.4, Appendix A4).

Table 3.17 Comparison of current (2000 to 2004) and historical (1990/1991) concentrations of dioxin/furans in mountain whitefish muscle tissues collected at Birchbank and Waneta (pg TEQ/g ww).

	Current 2000 to 2004	Historical 1990/1991
Birchbank	0.61 – 3.14	26.1
Waneta	0.28 - 0.95	34.3

Historical data as per McDonald (1997); Table 10.4.

3.3.2.3 PCBs

Similar to dioxin and furans, PCBs consists of numerous related chemicals (called congeners) that have similar physical chemical properties and mechanisms of toxicity. The congeners differ on the basis of the number of chlorine atoms attached to a central biphenyl molecule and the location of the chlorine on the molecule. PCBs share the same mode of toxicity as dioxins/furans. Consequently, similar to dioxins/furans, the potential for a PCB mixture to result in an impact can determined by expressing the PCB concentrations as a 2,3,7,8-TCDD (the most toxic of the dioxin congeners) toxic equivalence concentration (or TEQ). The TEQ concentration is the concentration 2,3,7,8-TCDD that would result in the same level of toxicity as the concentration of PCBs measured in the tissue sample. The TEQs for PCBs were calculated using the 1997 World Health Organization toxicity equivalence factors as provided by USEPA (2007). The estimated total TEQ of the PCBs in tissue were then compared to a PCB TEQ tissue residue guideline (TRG).

PCBs were measured only in mountain whitefish and only in 2004. The calculated PCB TEQs were well below the lowest TRG (0.79 pg TEQ/g ww; for mammals that consume fish). The highest PCB TEQ concentration was 0.038 pg TEQ/g ww.

3.3.2.4 PBDEs

PBDEs are widely used as flame retardant in polymer resins and plastics and are found in consumer products such as mattresses, furniture, electrical appliances, computers and carpets (Rahman *et al.* 2001). PBDEs enter aquatic environments through atmospheric deposition, through surface water runoff, and via discharges from landfills and sewage treatment plants (WSDE 2006). Like many other halogenated organic compounds, PBDEs are persistent and are known to biomagnify within food chains. PBDEs also are believed to pose a risk to the endocrine system and therefore can affect normal development, reproductive health and the immune system. The highest PBDE concentrations have generally been observed in North America, where concentrations are 10 or more times greater than in Japan or Europe (Hites 2004).

Two toxic, lighter forms of PBDEs, penta and octa, were voluntarily withdrawn from the Canadian and U.S. marketplaces in 2005. Environment Canada is currently evaluating a third type, deca PBDE, as it has been shown to break down into smaller congeners which biomagnify.

Unlike other halogenated hydrocarbons which biomagnify (e.g., DDT, PCBs, and dioxin), PBDE concentrations have been increasing in the environment. Increasing PBDE concentrations have been observed in aquatic sediments, fish, bird eggs, seal blubber, and human tissues (Norén and Mieronyté 2000; She *et al.* 2002; Luross *et al.* 2000 *as cited in* WSDE 2006).

Approximately 43 distinct congeners of PBDEs were assessed in mountain whitefish in 2002 and 2004, and in rainbow trout in 2003. Many congeners were not detectable; however, total PBDEs, total tribrominated diphenyl ethers (TriBDE), total tetrabrominated diphenyl ethers (TeBDE), total pentabrominated diphenyl ethers (PeBDE), total hexabrominated diphenyl ethers (HxBDE) and heptabrominated diphenyl ethers (HpBDE) could be calculated.

Tetra and pentabrominated diphenyl ethers accounted for the greatest proportion of PBDEs observed in fish tissue. Higher molecular weight PBDEs (i.e., DeBDE), although present in sediments in high concentrations, were at very low concentrations in tissues. These observations are consistent with other studies (Rahman *et al.* 2001), which indicated that intermediate molecular weight PBDEs tend to bioaccumulate to a greater extent than the higher molecular weight congeners.

Generally, fish captured in the Birchbank sampling area (Genelle to Birchbank) had similar PBDE concentrations (Figure 3.50 and 3.48). Mountain whitefish had much higher mean concentrations of TeBDE (32 to 46 ng/g ww) and PeBDE (41 to 71 ng/g ww) than rainbow trout (7.1 to 9.0 and 7.8 to 8.5 ng/g ww, respectively), likely reflecting differences in feeding behavior. Mountain whitefish generally reside near the bottom feeding primarily on nymphs and pupae (McPhail and Troffe 1998). Trout are more likely to make foraging movement to the water’s surface and thus are more likely to feed upon terrestrial dietary items and flying insects. Consequently, mountain whitefish are more reflective of in-river conditions. Another possible explanation is age, given that mountain whitefish is a long-lived fish species (McPhail and Troffe 1998). The longer a fish lives, the greater potential it has to accumulate PBDE; however, ages of mountain whitefish and trout collected were similar.

Figure 3.50 PBDEs in mountain whitefish muscle, 2002 and 2004.

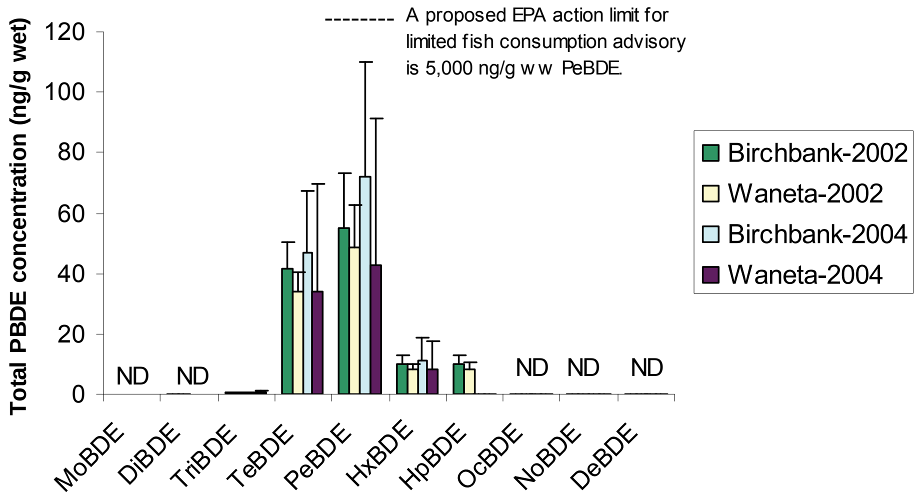
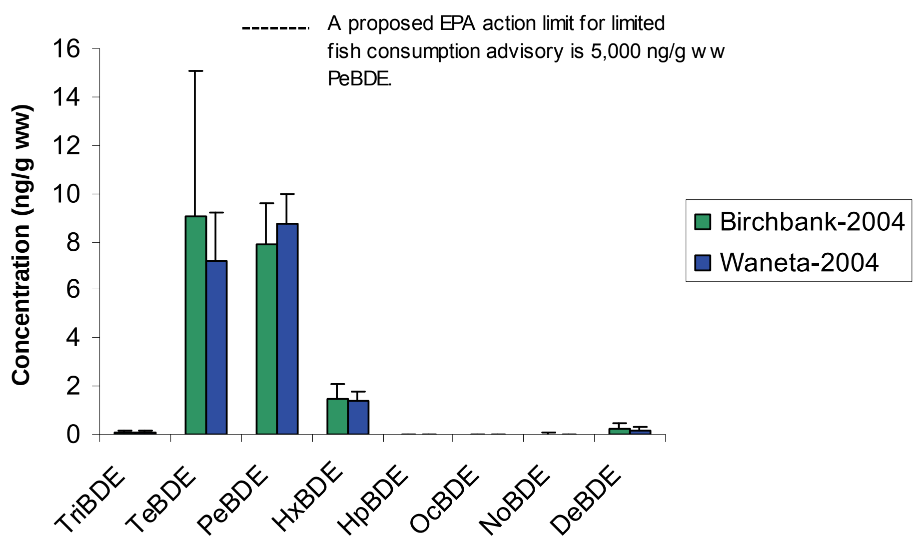


Figure 3.51 PBDEs in rainbow trout muscle tissue, Lower Columbia River, 2004.



No tissue-residue guideline currently exists for PBDEs. Proposed human reference doses for penta, octa and deca bromo diphenyl ethers have been recommended by North Carolina Department of Health and Human Services (Williams 2006) for non-cancer endpoints. A proposed action level for posting a limited fish consumption advisory for humans is 5,000 ng/g ww in fish muscle for PeBDE. The highest measured PeBDE concentration in Lower Columbia mountain whitefish muscle was 184 ng/g ww. This is approximately 27 times less than the proposed USEPA action level.

It should be noted that the approach used to calculate the action level assumed a fish consumption of 0.908 kg per month. The fish consumption rate assumed in the Lower Columbia River environmental objectives technical report (for the mercury objective) assumed a conservative fish consumption rate of 1 kg/week (McDonald 1997). This higher assumed fish consumption rate is more than four times the ingestion rate assumed by USEPA. A modified action level using the higher consumption rate would be 1,250 ng/g ww. The highest PeBDE concentration measured in mountain whitefish is still 6.8 times less than this modified action level.

Therefore, the current PBDE concentrations do not appear to pose any immediate human health concerns. However, the results are based solely on a proposed action level. It is recommended that regulatory developments associated with PBDE be closely monitored. It should also be noted that no tissue-residue guideline for wildlife exists.

Concentrations of PBDEs appear to be rapidly increasing in the Lower Columbia River. The paper by Rayne *et al.* (2003) demonstrated that concentrations had increased substantially since 1992 and the data presented in this document for 2002/2004 indicate that the concentration of PBDEs have continued to increase (Table 3.18). Total PBDE concentrations in mountain whitefish at both Birchbank and Waneta in 2002/2004 are approximately 20 times the concentrations measured in 1992. Monitoring of PBDEs in fish tissues in the future is highly recommended.

Table 3.18 Mean (+/- SD) concentrations of total PBDEs in Columbia River mountain whitefish in 1992, 1994, 1995, 2002 and 2004.

	Total PBDE (ng/g ww)	
	Birchbank (Genelle)[1]	**Waneta (Beaver Creek)[1]**
1992[1]	6.1 +/- 4.6	4.5 +/- 1.8
1994/1995[1]	19.1 +/- 5.3	ND
2000[1]	71.8 +/- 19.0	29.2 +/- 15.4
2002	107 +/- 25	90.8 +/- 19
2004	130 +/- 35	85.5 +/- 93

[1] 1992 to 2000 data taken from Rayne et al (2003).

ND = no data.

Relative to PBDE concentrations in fish caught in Washington State, Lower Columbia fish concentrations are on the high end of the range (WSDE 2006). In most Washington rivers and lakes, total PBDE concentrations in fish fillets were less than 10 ng/g wet weight. However, certain fish species from several large water bodies (Columbia River, Cowlitz River Lake, Washington, Palouse River, Snake River and Snohomish River) had total PBDE concentrations between 10 and 200 ng/g range. High PBDE levels in fish fillets were found throughout the Spokane River , exceeding 1,000 ng/g in some cases (WSDE 2006). However, total PBDEs in fish from watersheds with minimal human disturbance were at or below the limit of detection.

3.4 QA/QC

This section presents the results of the field QA/QC programs, including the results of field duplicates, field blanks, trip blanks and equipment swipes. A field QA/QC program was done to determine whether or not there were any sample contamination concerns, to quantify sample heterogeny (difference of concentration of an analyte within a sampling site) and to quantify measurement precision. Raw field QA/QC data are provided in Appendix A3. Key findings are summarized below. Detection limits (for comparison) are provided in Appendix A5.

3.4.1 Water

QAQC replicate samples were collected at Birchbank, D/S STP and Waneta (Table 3.19). The difference between replicates was calculated as a relative percent difference (RPD). RPDs calculated from the 2000 and February 2003 duplicates were generally all below 20%. Many of those exceeding an RPD of 20% were within 5X the method detection limit and therefore poor precision was expected. Of the water quality variables discussed in this report, the following had RPDs greater than 20% and had reported concentrations greater than 5X their respective detection limits (Appendix A3.3):

- Birchbank (February 2003): lead = 59%, and copper = 37%
- D/S STP (February 2003): ammonia = 82%
- D/S STP (April 2005): lead = 40%
- Waneta (February 2003): arsenic = 40%, cadmium = 50%, copper = 28%, lead = 40%
- Waneta (March 2003): arsenic = 40%, chromium = 164%

In blanks, most analyte concentrations were either not detected, within 5X the detection limit or well below quantified measurements of water quality from the Lower Columbia River. The exception was copper in a preservative blank collected at D/S STP in December 2003 (1.31 µg/L) and field blank collected at D/S STP in April 2005 (0.49 µg/L).

3.4.2 Sediments

Replicates were collected in 1999 (Waneta) and 2004 (Beaver Creek), and an equipment swipe was analyzed in 2004. The RPD between duplicate samples in 1999 and 2004 was generally below 20%. Notable exceptions were cadmium (25%), silver (37%) and mercury (40%) in 1999 and AVS (32%), cadmium (21%), mercury (40%), tin (22%), total PCBs (21%), and PBDEs: HxBDE (25%), OcBDE (68%) and NoBDE (66%) in 2004. The mercury concentrations were within five times the detection limit, so the RPD criteria do not apply. In the 2004 duplicate sample, percent gravel had an RPD of 46%. However, gravel in the duplicate sample constituted a very small portion of the sample (< 1% w/w) and therefore, the high RPD is a reflection of being close to the quantification limit. SEM cadmium was within five times the applicable detection limit; therefore, the RPD criterion does not apply.

There were some RPD exceedances for individual PCBs; however, only total PCB was used in this analysis, and the RPD for total PCB was acceptable. For the PBDEs, only PeBDE was used in the data compilation/analysis and the RPD was acceptable.

An equipment swipe in 2004 (equivalent of a blank for sediment samples), indicated that sample contamination was not an issue. Antimony, cobalt, manganese and potassium were the only metals that were found at detectible concentrations in the swipe. However, none of these metals were of concern in the study areas, nor did they exceed the SQOs (or other guidelines).

Some individual PCBs and PBDEs were detected in the swipe, indicating that there may be some cross contamination between samples; however, it is highly unlikely because the concentrations of these parameters within river sediments do not vary more than an order of magnitude between stations, and samples collected from the ponar grab sampler were always taken from the inside of the sample, away from the inside surfaces of the grab. With the small difference, the surface of the sampling equipment that would directly contact the collected sample (i.e., bowl and spoon) would provide an insignificant mass of contaminants relative to the amount in the subsequent sample.

Table 3.19 Availability of QA/QC data for water quality analysis.

Location	Date	Type	Field measurements	Hardness	Metals – ICP (selected metals)	Metals - ICP-MS	Ammonia	Microbial Indicators
Birchbank	19-Oct-97	Replicate	√			E		
	25-Oct-97	Replicate				E		
	31-Oct-97	Replicate				E		
	6-Nov-97	Replicate				E		
	12-Nov-97	Replicate				E		
	15-Nov-00	Pres Blank				T		
	15-Nov-00	Field Blank				T		
	15-Nov-00	Replicate			T/E	T		
	16-Dec-02	Replicate		√	T		√	
	17-Feb-03	Replicate	√	√		T		
	13-May-03	Replicate	√	√		T		
D/S STP	17-Feb-03	Replicate	√	√		T	√	√
	17-Feb-03	Blank						√
	13-May-03	Replicate	√					√
	13-May-03	Blank			T	T		
	4-Dec-03	Replicate	√	√	T	T	√	√
	4-Dec-03	Field Blank		√	T	T		
	4-Dec-03	Pres Blank		√	T	T		
	18-Feb-04	Replicate				T	√	√
	18-Feb-04	Blank						√
	18-Feb-04	Blank						√
	27-Apr-05	Replicate	√	√	T	T	√	√
	27-Apr-05	Field Blank	√	√	T	T	√	√
	27-Apr-05	Lab Blank	√	√	T	T	√	√
Waneta	16-Dec-02	Replicate			T		√	√
	17-Feb-03	Replicate	√	√	T	T		√
	13-May-03	Replicate	√	√	T	T	√	√
	4-Dec-03	Replicate						√
	18-Feb-04	Replicate	√	√	T	T	√	√
	27-Apr-05	Replicate	√	√	T	T	√	√

√ = QAQC data present

T = QAQC data present, Total Metals

E = QAQC data present Extractable Metals

4.0 SYNOPSIS

This data summary and interpretive report includes water, sediment and fish tissue chemistry, microbial indices, fish health and sediment toxicity data for the Lower Columbia River between Birchbank and the international border collected between 1997 to 2005. Key findings are provided below.

- Arsenic, cadmium, copper, lead, thallium, zinc and ammonia concentrations, and fecal coliform and *E. coli* densities were significantly higher in water collected at Waneta (the furthest downstream station) than Birchbank (the furthest upstream station), indicating a net input of these contaminants to the Lower Columbia between these sites during the period of this study. However, the concentrations of potential contaminants measured in water would unlikely be associated with ecological impacts.

- Contaminant concentrations in sediments were highly variable during the study period and sediment samples consisted of individual composite samples (i.e., n=1), making interpretation difficult.

- Water, sediment and tissue residue data were screened against environmental quality objectives for the Lower Columbia River, or other relevant Canadian guidelines/criteria. Based on this screening, concentrations of arsenic, cadmium, chromium, copper, lead, mercury, zinc and dioxins/furans may pose potential environmental risks and should be investigated further. Terrestrial and aquatic risk assessments being conducted at this time by Teck Cominco should provide additional perspective to risk.

- Water quality data was also used to calculate the CCME Water Quality Index (WQI). In general terms, the WQI results suggest that water quality in the Lower Columbia between Birchbank and the US Border provides good habitat for aquatic life. WQI values calculated for the New Bridge site tended to be the lowest, followed by the Stoney Creek site. However, New Bridge is located within the mixing zone downstream of the Teck Cominco discharge and therefore, the area of poor water quality would be localized within the discharge plume. Furthermore, the WQI values at New Bridge appear to be steadily improving with time. Improvements in water quality have also been observed within Stoney Creek due to remediation conducted by Teck Cominco on historical landfills.

- Concentrations of most contaminants did not change significantly in water, sediments or fish tissue during the period covered in this report (1997 to 2005). The exceptions were dioxin, which appeared to be decreasing in sediments and fish tissue, and PBDEs, which exhibited greater concentrations in sediments in 2004 relative to 2002.

- Relative to historical studies from the 1970s to the early 1990s, concentrations of many contaminants in the Lower Columbia River decreased during the period covered in this report (1997 to 2005). However, some contaminants remained the same (i.e., mercury in fish tissue) or increased (i.e., PBDEs in fish tissue) relative to historical studies.

- Relative to a proposed human health benchmark, PBDEs in game fish currently do not appear to pose immediate health concerns to humans. However, the state of knowledge on PBDEs is evolving, and concentrations in game fish tissue appear to be increasing over time. Therefore, future monitoring work should investigate PBDEs further.

- Sediment toxicity testing results were significantly correlated to metals concentrations indicating a possible causative relationship with metals.

Key findings from the assessment of chemical and microbial data are also summarized in a "measles plot" provided in Table 4.1 and Table 4.2. Table 4.1 provides criteria for ranking potential effects based on water, sediment and fish tissue chemistry. Table 4.2 summarizes possible effects, apparent primary sources of contaminants of concern, and apparent trends, from 1997 to 2005.

Table 4.1 Criteria for assessing the relative ecological importance of each analyte.

Component	Score	Level of Concern	Criteria[1]
Water Chemistry[2]			
	○	**Negligible – Low**	30-day average concentration of the analyte does not exceed 5x the WQO (or CCME guidelines or B.C. MoE water quality criteria) at any time.
	◉	**Moderate**	30-day average concentration of the analyte exceeds 5x the WQO in two or fewer instances.
	●	**High**	30-day average concentration of the analyte exceeds 5x the WQO in greater than two instances.
Sediment Chemistry			
	○	**Negligible – Low**	Concentration of the analyte does not exceed 5x the criteria/guidelines or objectives.
	◉	**Moderate**	Concentration of the analyte exceeds 5x the criteria/guidelines in two or fewer instances.
	●	**High**	Concentration of the analyte exceeds 5x the criteria/guidelines in greater than two instances.
Fish Tissue Chemistry			
	○	**Negligible – Low**	95% UCLM[3] concentration does not exceed criteria/guidelines or objectives.
	◉	**Moderate**	95% UCLM[3] concentration exceeds criteria/guidelines or objectives by 1 to 5 times.
	●	**High**	95% UCLM[3] concentration exceeds criteria/guidelines or objectives by over 5 times.

[1] Criteria developed for assessing Level of Concern uses 5x the applicable guidelines/criteria or objective as a threshold for potential effects. Guidelines/criteria or objectives typically have a 10 fold safety factor incorporated into the derived number and therefore using the Guidelines/criteria or objectives as potential thresholds for effect is overly conservative.

[2] Water quality samples collected at New Bridge have not been included in the assessment, because the New Bridge site is within the mixing zone down-stream of Tech Cominco and therefore not truly representative of Columbia River water quality.

[3] 95% UCLM (95% upper confidence interval of the mean) was used as a conservative (upper bound) estimate of the population mean.

Table 4.2 Summary of chemistry and bacteriology for the Lower Columbia River, 1997 to 2005.

Analyte	Possible effects				Apparent primary source[3] is:	Apparent trend 1997 to 2005		
	Water[1]	Sediment	Tissue[2]			Water	Sediments	Tissue
Arsenic	○	○	NA	◉[4]	Teck Cominco (WQ)	None apparent	None apparent	None apparent
Cadmium	○	◉	NA	○	Teck Cominco (WQ)	None apparent	None apparent	None apparent
Chromium	○	○	NA	◉[4]	Upstream source? (WQ)	None apparent	None apparent	None apparent
Copper	○	●	NA	NA	Not clear	None apparent	None apparent	—
Lead	○	●	○	○	Teck Cominco (WQ)	None apparent	None apparent	None apparent
Mercury	—	◉	○[5]	●	Not Clear[6] (SQ)	—	None apparent	None apparent
Thallium	○	NA			Teck Cominco (WQ)	None apparent		
Zinc	○	●	NA	NA	Teck Cominco (WQ)	None apparent	—	—
Ammonia	○	—	—	—	Teck Cominco and Trail STP for ammonia, possibly upstream sources for total nitrogen and dissolved phosphorus. (WQ)	None apparent	—	—
Total nitrogen	NA	—	—	—		None apparent	—	—
Total dissolved phosphorus	NA	—	—	—		None apparent	—	—
Fecal Coliform	○	—	—	—		None apparent	—	—
E. Coli	○	—	—	—	Trail STP and Beaver Creek (WQ)	None apparent	—	—
Enterococcus	○	—	—	—		None apparent	—	—
Fatty Acids	—	NA	—	—	Zellstoff Celgar[7] (SQ)	—	None apparent	—
Resin Acids	—	NA	—	—	Zellstoff Celgar[7] (SQ)	—	None apparent	—
Dioxin/Furans	—	○	○	◉[8]	Zellstoff Celgar[9] (SQ)	—	Decreasing[10]	Decreasing[11]
PAHs - total	—	○	NA	NA	Not clear	—	None apparent	—
PCBs	—	○	○	○	Not clear	—	None apparent[12]	None apparent
PBDEs	—	NA	○[13]	NA	Not clear [14]	—	Increasing[15]	Increasing[16]

"—" indicates that analytical variable was not measured.

"NA" no applicable guideline, criteria or objective.

[1] Water sampling was done during the lowest flow periods during the year and therefore represent worst-case water quality conditions. Concentrations do not represent typical Lower Columbia River water quality conditions.

[2] First column represents risks to humans from eating fish; second represents risks to wildlife.

[3] Primary source of observed contamination, if "WQ", represents inferences based on water quality data, if "SQ", represents inferences based on sediment quality data.

[4] Concentrations of arsenic and chromium are generally close to the quantification limit and apparent exceedances of the Lower Columbia TROs are small (<2x for mean values). It is likely that additional monitoring, if done using lower quantification limits, will result in no exceedances. In addition, the LOR2 terrestrial risk assessment performed for Teck Cominco (Cantox 2003) indicated no risk to terrestrial organisms due to these chemicals.

[5] Based on screening against Health Canada consumption guideline (0.5 mg/kg wet weight).

[6] Based on sediment data. Higher mercury concentrations are likely due to sampling in a depositional area.

[7] Insufficient number of samples to assess spatial trends.

[8] 95% UCLM concentration in mountain whitefish exceeds CCME guidelines for the protection of fish eating mammals.

[9] Based on dioxin/furan sediment TEQs.

[10] Only three stations monitored for more than one year. Concentrations presented as pg TEQ /g dw appear to be decreasing over time in sediments, but no discernable trend observed in the total dioxin/furan concentration (pg/g dw).

[11] Concentrations of total TCDD in whitefish muscle decreased between 2000 and 2003 (Figure 3.48).

[12] Only one sample collected (2004). However, a comparison to data from period 1990 to 1995 indicated decreasing concentrations.

[13] Based on a screening against a proposed USEPA fish advisory action level.

[14] Not clear in this study; however, Rayne et al (2003) hypothesized that septic leachate might be the source PBDEs.

[15] Based on only two data points. However, a comparison to data from 1992 and 1994/1995 indicated increasing concentrations; Table 3.18.

[16] Concentrations of TeBDE, PeBDE and HxBDE in mountain whitefish captured in the Birchbank sampling area increased between 2002 and 2004 (Figure 3.50). A comparison to data from 1992 to 2000 also found increasing concentrations.

5.0 RECOMMENDATIONS

Water

- Continue monitoring water quality during low flow periods (one or two periods per year). Consistent with current practice, each period should be approximately a month long and should consist of five separate water sampling events.

- Analysis should continue to include in-situ water quality, conventional variables, nutrients, microbial indicators and metals.

- Where possible, ensure the analytical laboratory uses MDLs at least five to ten times lower than expected concentrations and WQOs. Detection limits for chromium and cadmium in water were often within five times the WQOs.

Sediment

- Continue monitoring sediment, but reduce monitoring frequency to every three years. The cost savings could be used towards increasing the number of replicates in each area.

- Analysis should continue to include physical variables (grain-size and TOC), metals, halogenated organics (PBDEs, PCBs and dioxins/furans), non-halogenated organics (resin and fatty acids) and sediment toxicity.

- Sediment toxicity tests should continue using the 14-d *Hyalella* test. The addition of a second test species (Chrionomid 10-d growth) would improve assessment. If cost is a factor, either frequency or the number of sites assessed could be reduced for the second test species.

- A single reference site should be chosen for the sediment toxicity tests. In future this site should be consistently sampled both for chemistry and toxicity testing.

- Conduct additional sediment sampling at Beaver Creek and Bear Creek stations, specifically for metals. These stations have some of the highest concentrations of contaminants of concern, yet they are poorly characterized over time.

- Normalize sediment concentrations to slag content of sediments. Much of the variability of metals concentrations in sediments collected from Bear Creek, Beaver Creek and Waneta likely is due to the presence of slag in sediments. If it were possible to normalize to the slag content, it may be possible to explain spatial trends in sediments more effectively.

- Where possible, ensure the analytical laboratory uses MDLs at least five to ten times lower than expected concentrations and WQOs.

- Specific sampling stations should be selected and consistently sampled over time for both sediment chemistry and toxicity testing. While chemistry samples should be represented by a minimum of three individual replicates in each area, sediments for toxicity can be represented by a single composite sample. At a minimum, replicates should be collected at Birchbank and Waneta.

Fish

- Continue monitoring fish tissue, however frequency can be reduced to every three years, and fish capture could coincide with sediment sampling.
- Consider catching only walleye and mountain whitefish, as adults of these species tend to accumulate higher concentrations of contaminants than rainbow trout. However it may be prudent to continue catching rainbow trout due to the popularity of this sport fish.
- Monitoring should include metals (specifically arsenic, cadmium, chromium, lead and mercury), dioxins/furans and PBDE.)
- Conduct an assessment of the potential exposure of wildlife to fish in the Lower Columbia River. Concentrations of dioxins and furans in fish may pose a risk to fish-eating mammals, while concentrations of mercury in fish may pose a risk to both fish-eating mammals and birds. A detailed risk assessment that is planned for the Lower Columbia should provide this information.
- Attempt to better quantify human consumption of fish from the Lower Columbia River. The assessment included in this report indicates that humans may be at risk from ingesting mercury associated with fish tissue if Lower Columbia walleye make up a large proportion of their diet. Currently there is no information on the amount of fish that may be ingested by people in the area. Such a study, if done, should be carried out in cooperation with the regional health officer.
- If possible, use lower detection limits for arsenic and chromium analyses in fish tissue, to allow effective comparisons with relevant objectives.
- Focus greater attention on PBDEs in the Lower Columbia River given that concentrations in sediments and fish muscle appear to be rapidly rising. It also may be prudent to do a literature-based toxicity assessment for PBDEs.
- Consider conducting an EEM style fish-population study that includes analysis of age-class structure to better assess the health of fish populations in the Lower Columbia River.
- Where possible, ensure the analytical laboratory uses MDLs at least five to ten times lower than expected concentrations and WQOs.

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7.0 CLOSURE

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APPENDICES

Appendix A1

Data Summary Tables

Table A1.1 Summary of water quality data for the Lower Columbia River, Birchbank to the international border (1997 to 2005).

Analyte	Location	Mean	Median	Standard Deviation	Minimum	Maximum	90th Percentile	Standard Error	n
Arsenic	Birchbank 020003	0.276	0.200	0.269	0.100	1.000	1.000	0.028	91
µg/L	Stoney Creek E223892	0.608	0.300	0.878	0.000	5.600	1.000	0.092	91
	New Bridge 0200558	0.403	0.400	0.183	0.100	1.000	0.600	0.020	80
	Old Bridge E216137	0.243	0.200	0.108	0.100	0.600	0.400	0.012	80
	downstream STP E223893	0.215	0.200	0.073	0.100	0.300	0.300	0.014	26
	Waneta 0200559	0.319	0.200	0.252	0.100	1.000	0.840	0.026	95
Cadium	Birchbank 020003	0.029	0.010	0.040	0.010	0.240	0.100	0.004	81
µg/L	Stoney Creek E223892	0.062	0.040	0.094	0.010	0.630	0.100	0.012	64
	New Bridge 0200558	0.170	0.110	0.174	0.010	0.820	0.338	0.022	63
	Old Bridge E216137	0.050	0.050	0.034	0.010	0.160	0.100	0.004	64
	downstream STP E223893	0.041	0.030	0.026	0.010	0.110	0.075	0.005	26
	Waneta 0200559	0.051	0.040	0.040	0.010	0.250	0.100	0.005	78
Chromium	Birchbank 020003	0.474	0.200	0.518	0.100	2.80	1.20	0.058	81
µg/L	Stoney Creek E223892	0.441	0.200	0.580	0.020	2.90	1.25	0.071	66
	New Bridge 0200558	0.429	0.200	0.562	0.200	2.90	1.12	0.070	65
	Old Bridge E216137	0.452	0.200	0.589	0.200	2.80	1.32	0.073	65
	downstream STP E223893	0.697	0.200	0.832	0.020	2.80	1.95	0.163	26
	Waneta 0200559	0.497	0.200	0.570	0.200	3.10	1.20	0.065	77
Copper	Birchbank 020003	0.508	0.400	0.730	0.050	6.60	0.700	0.081	81
µg/L	Stoney Creek E223892	0.399	0.360	0.214	0.050	1.50	0.610	0.026	66
	New Bridge 0200558	0.509	0.460	0.253	0.050	1.76	0.777	0.032	64
	Old Bridge E216137	0.399	0.380	0.166	0.050	0.84	0.616	0.021	65
	downstream STP E223893	0.554	0.505	0.255	0.270	1.48	0.810	0.050	26
	Waneta 0200559	0.801	0.580	1.419	0.050	12.00	0.925	0.161	78
Lead	Birchbank 020003	0.185	0.090	0.226	0.010	1.37	0.500	0.025	81
µg/L	Stoney Creek E223892	0.245	0.115	0.413	0.000	2.67	0.560	0.051	66
	New Bridge 0200558	1.024	0.470	2.695	0.020	21.63	1.68	0.334	65
	Old Bridge E216137	0.361	0.190	0.582	0.020	4.30	0.750	0.072	65
	downstream STP E223893	0.207	0.175	0.130	0.020	0.55	0.415	0.026	26
	Waneta 0200559	0.302	0.200	0.359	0.030	3.03	0.500	0.040	79
Zinc	Birchbank 020003	1.76	0.95	2.36	0.1	15	4.3	0.267	78
µg/L	Stoney Creek E223892	4.56	3.3	4.34	0.1	20	8.92	0.508	73
	New Bridge 0200558	9.19	7.6	7.38	0.5	39.9	17.65	0.938	62
	Old Bridge E216137	3.09	2.7	1.62	0.3	7.5	5.86	0.205	62
	downstream STP E223893	3.1	2.75	1.63	0.3	6.4	5.5	0.319	26
	Waneta 0200559	4.2072	2.9	3.75	0.4	17	9.732	0.433	75

Table A1.1 (Cont'd.)

Analyte	Location	Mean	Median	Standard Deviation	Minimum	Maximum	90th Percentile	Standard Error	n
Dissolved Oxygen	Birchbank 020003	10.7	10.7	1.75	1.50	13.4	12.5	0.221	63
mg/L	Stoney Creek E223892	11.0	11.2	1.24	6.60	13.4	12.5	0.168	55
	New Bridge 0200558	10.9	10.9	1.24	6.70	14.8	12.0	0.174	51
	Old Bridge E216137	11.2	11.2	1.13	9.30	16.5	12.1	0.163	48
	downstream STP E223893	11.1	11.1	1.03	8.30	13.1	12.4	0.141	53
	Waneta 0200559	11.2	11.2	1.08	8.70	13.2	12.7	0.141	58
Turbidity	Birchbank 020003	406	355	212	80	1330	606	22.6	88
µg/L	Stoney Creek E223892	380	360	159	50	900	600	20.1	63
	New Bridge 0200558	366	360	133	70	700	550	16.5	65
	Old Bridge E216137	369	340	146	60	810	578	18.1	65
	downstream STP E223893	396	375	191	17	1050	691	24.3	62
	Waneta 0200559	415	355	209	16	1390	661	22.8	84
Ammonia	Birchbank 020003	198.8	5.0	1346.1	5.0	10200.0	20.0	135.3	99
µg/L	Stoney Creek E223892	24.4	11.0	48.4	5.0	273.0	37.0	6.2	62
	New Bridge 0200558	30.3	25.0	22.0	5.0	102.0	61.1	2.4	84
	Old Bridge E216137	14.2	11.0	18.9	3.0	174.0	22.0	2.0	85
	downstream STP E223893	27.7	17.0	56.8	3.4	500.0	40.0	6.3	81
	Waneta 0200559	13.9	12.0	8.8	5.0	44.0	22.1	0.9	94
Total Dissolved Phosphorus	Birchbank 020003	2.8	2	1.30	1	7	4	0.27	23
µg/L	Stoney Creek E223892	11.0	11	0.000	11	11	11	0.00	1
	New Bridge 0200558	3.3	3	1.56	2	7	6	0.36	19
	Old Bridge E216137	3.2	3	1.50	2	7	5.1	0.33	20
	downstream STP E223893	3.1	2	1.82	2	8	5.4	0.42	19
	Waneta 0200559	7.6	2	21.2	2	100	6	4.64	21
Total Nitrogen	Birchbank 020003	188	170	51	120	340	210	11	21
µg/L	Stoney Creek E223892	380	380	0	380	380	380	0	1
	New Bridge 0200558	201	200	29	150	250	242	7	19
	Old Bridge E216137	183	180	29	140	260	211	6	20
	downstream STP E223893	191	190	25	140	230	222	6	19
	Waneta 0200559	185	190	28	130	240	212	6	19
Fecal Coliform	Birchbank 020003	2.5	2.0	2.7	1.0	16.0	5.0	0.3	100
CFU/100 mL	downstream STP E223893	20.5	7.0	61.8	1.0	520.0	26.8	6.4	92
	Waneta 0200559	5.4	4.0	6.6	1.0	36.0	9.7	0.7	94
E. Coli	Birchbank 020003	1.6	1.0	1.2	1.0	7.0	2.1	0.1	90
CFU/100 mL	downstream STP E223893	12.9	4.0	36.8	1.0	270.0	16.7	4.0	84
	Waneta 0200559	3.8	2.0	4.7	1.0	29.0	8.0	0.5	85
Enterococcus	Birchbank 020003	2.7	1.0	6.3	1.0	55.0	4.0	0.7	90
CFU/100 mL	downstream STP E223893	9.4	3.0	20.7	1.0	170.0	18.0	2.3	84
	Waneta 0200559	2.7	2.0	3.7	1.0	32.0	4.0	0.4	85

Table A1.2 Summary of sediment quality data for the Lower Columbia River, Arrow Lake to the international border (1999 to 2004).

Analyte	Location	Mean	Median	Geomean	Standard Deviation	Minimum	Maximum	90th Percentile	Standard Error	n
% Fines (silt and clay w/w)	Arrow Lake 200524	9.17	9.17	7.12	8.15	3.40	14.93	13.78	5.77	2
	downstream HLK E249077	20.55	20.55	20.55	NA	20.55	20.55	20.55	NA	1
	Genelle E249088	13.11	13.11	12.90	3.27	10.80	15.42	14.96	2.31	2
	Birchbank	7.35	8.76	5.76	4.16	1.40	10.46	10.32	2.08	4
	Indian Eddy	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ryan Creek E249089	1.40	1.40	1.40	NA	1.40	1.40	1.40	NA	1
	Bear Creek E257539	36.64	36.64	36.64	NA	36.64	36.64	36.64	NA	1
	Beaver Creek E249090	18.73	18.73	6.04	25.07	1.00	36.45	32.91	17.73	2
	Waneta	3.66	3.50	2.69	2.73	0.70	6.95	6.27	1.37	4
% TOC (w/w)	Arrow Lake 200524	0.28	0.17		0.34	0.00	0.66	0.56	0.20	3
	downstream HLK E249077	0.54	0.54	0.54	NA	0.54	0.54	0.54	NA	1
	Genelle E249088	0.95	0.95	0.91	0.36	0.69	1.20	1.15	0.26	2
	Birchbank	0.39	0.25	0.19	0.45	0.02	1.30	0.88	0.17	7
	Indian Eddy	0.08	0.07		0.08	0.00	0.20	0.16	0.04	4
	Ryan Creek E249089	0.17	0.17		0.23	0.00	0.33	0.30	0.17	2
	Bear Creek E257539	0.67	0.67	0.67	NA	0.67	0.67	0.67	NA	1
	Beaver Creek E249090	1.02	1.02	0.64	1.11	0.23	1.80	1.64	0.79	2
	Waneta	0.28	0.14	0.17	0.37	0.06	1.10	0.59	0.14	7
SEM-AVS	Arrow Lake 200524	0.29	0.29	0.29	NA	0.29	0.29	0.29	NA	1
	downstream HLK E249077	0.96	0.96	0.96	NA	0.96	0.96	0.96	NA	1
	Genelle E249088	1.05	1.05	1.05	NA	1.05	1.05	1.05	NA	1
	Birchbank	1.05	1.05	0.89	0.79	0.49	1.61	1.50	0.56	2
	Bear Creek E257539	84.60	84.60	84.60	NA	84.60	84.60	84.60	NA	1
	Beaver Creek E249090	9.09	9.09	9.09	NA	9.09	9.09	9.09	NA	1
	Waneta	109.79	109.79	77.22	110.39	31.74	187.85	172.24	78.06	2
Arsenic (mg/kg dw)	Arrow Lake 200524	1.2	1.2	1.2	0	1.2	1.2	1.2	0	2
	downstream HLK E249077	1.3	1.3	1.3	NA	1.3	1.3	1.3	NA	1
	Genelle E249088	1.65	1.65	1.6	0.6	1.2	2.1	2.01	0.45	2
	Birchbank	2.42	1	1.5	3.1	0.8	8	5.32	1.4	5
	Indian Eddy	1.8	1.8	1.8	NA	1.8	1.8	1.8	NA	1
	Ryan Creek E249089	2.8	2.8	2.8	NA	2.8	2.8	2.8	NA	1
	Bear Creek E257539	13.5	13.5	13.5	NA	13.5	13.5	13.5	NA	1
	Beaver Creek E249090	21	21	14.1	22.1	5.4	36.6	33.48	15.6	2
	Waneta	19.1	16.9	18.8	3.6	16	23.5	23.1	1.6	5

Table A1.2 (Cont'd.)

Analyte	Location	Mean	Median	Geomean	Standard Deviation	Minimum	Maximum	90th Percentile	Standard Error	n
Cadium (mg/kg dw)	Arrow Lake 200524	0.08	0.08	0.07	0.06	0.04	0.12	0.11	0.04	2
	downstream HLK E249077	0.14	0.14	0.14	NA	0.14	0.14	0.14	NA	1
	Genelle E249088	0.51	0.51	0.47	0.25	0.33	0.68	0.65	0.18	2
	Birchbank	0.40	0.33	0.33	0.27	0.15	0.80	0.68	0.12	5
	Indian Eddy	0.23	0.23	0.23	NA	0.23	0.23	0.23	NA	1
	Ryan Creek E249089	0.79	0.79	0.79	NA	0.79	0.79	0.79	NA	1
	Bear Creek E257539	1.27	1.27	1.27	NA	1.27	1.27	1.27	NA	1
	Beaver Creek E249090	1.92	1.92	1.78	1.03	1.19	2.65	2.50	0.73	2
	Waneta	1.69	0.80	1.20	1.88	0.70	5.03	3.49	0.84	5
Chromium (mg/kg dw)	Arrow Lake 200524	14.0	14.0	13.8	2.97	11.9	16.1	15.7	2.1	2
	downstream HLK E249077	22.0	22.0	22.0	NA	22.0	22.0	22.0	NA	1
	Genelle E249088	13.5	13.5	13.0	4.95	10.0	17.0	16.3	3.5	2
	Birchbank	20.3	17.0	17.6	10.5	6.4	31.8	31.0	4.7	5
	Indian Eddy	9.00	9.00	9.00	NA	9.00	9.00	9.00	NA	1
	Ryan Creek E249089	7.60	7.60	7.60	NA	7.60	7.60	7.60	NA	1
	Bear Creek E257539	47.0	47.0	47.0	NA	47.0	47.0	47.0	NA	1
	Beaver Creek E249090	44.0	44.0	41.0	22.6	28.0	59.9	56.7	16.0	2
	Waneta	47.3	39.0	43.7	21.4	26.6	79.0	70.9	9.6	5
Copper (mg/kg dw)	Arrow Lake 200524	8.36	8.36	7.42	5.46	4.50	12.22	11.45	3.86	2
	downstream HLK E249077	7.50	7.50	7.50	NA	7.50	7.50	7.50	NA	1
	Genelle E249088	8.25	8.25	8.06	2.47	6.50	10.00	9.65	1.75	2
	Birchbank	9.36	9.70	8.76	3.31	4.20	13.17	12.26	1.48	5
	Indian Eddy	26.7	26.7	26.7	NA	26.7	26.7	26.7	NA	1
	Ryan Creek E249089	39.8	39.8	39.8	NA	39.8	39.8	39.8	NA	1
	Bear Creek E257539	792	792	792	NA	792	792	792	NA	1
	Beaver Creek E249090	537	73	143	843	27	1,510	1,223	487	3
	Waneta	747	460	574	595	272	1,620	1,413	266	5
Lead (mg/kg dw)	Arrow Lake 200524	6.81	6.81	6.79	0.69	6.32	7.30	7.20	0.49	2
	downstream HLK E249077	6.40	6.40	6.40	NA	6.40	6.40	6.40	NA	1
	Genelle E249088	12.15	12.15	11.83	3.89	9.40	14.90	14.35	2.75	2
	Birchbank	11.07	9.74	10.36	4.79	6.70	19.00	16.04	2.14	5
	Indian Eddy	43.37	43.37	43.37	NA	43.37	43.37	43.37	NA	1
	Ryan Creek E249089	56.20	56.20	56.20	NA	56.20	56.20	56.20	NA	1
	Bear Creek E257539	177.00	177.00	177.00	NA	177.00	177.00	177.00	NA	1
	Beaver Creek E249090	232.10	232.10	188.15	192.19	96.20	368.00	340.82	135.90	2
	Waneta	214.87	237.00	204.61	70.61	127.00	281.00	278.74	31.58	5

Table A1.2 (Cont'd.)

Analyte	Location	Mean	Median	Geomean	Standard Deviation	Minimum	Maximum	90th Percentile	Standard Error	n
Zinc (mg/kg dw)	Arrow Lake 200524	57.25	57.25	51.13	36.42	31.50	83.00	77.85	25.75	2
	downstream HLK E249077	42.00	42.00	42.00	NA	42.00	42.00	42.00	NA	1
	Genelle E249088	103.00	103.00	97.23	48.08	69.00	137.00	130.20	34.00	2
	Birchbank	74.98	93.00	69.50	29.84	40.30	100.00	98.80	13.34	5
	Indian Eddy	124.67	124.67	124.67	NA	124.67	124.67	124.67	NA	1
	Ryan Creek E249089	284.00	284.00	284.00	NA	284.00	284.00	284.00	NA	1
	Bear Creek E257539	4,930.00	4,930.00	4,930.00	NA	4,930.00	4,930.00	4,930.00	NA	1
	Beaver Creek E249090	6,250.00	6,250.00	2,672.08	7,990.31	600.00	11,900.00	10,770.00	5,650.00	2
	Waneta	5,043.60	3,220.00	3,005.35	5,578.13	900.00	14,400.00	10,904.00	2,494.61	5
Thallium (mg/kg dw)	Arrow Lake 200524	0.06	0.06	0.06	0.00	0.06	0.06	0.06	0.00	2
	downstream HLK E249077	0.09	0.09	0.09	NA	0.09	0.09	0.09	NA	1
	Genelle E249088	0.11	0.11	0.10	0.06	0.07	0.15	0.14	0.04	2
	Birchbank	0.08	0.08	0.08	0.03	0.04	0.12	0.11	0.02	4
	Indian Eddy	0.06	0.06	0.06	NA	0.06	0.06	0.06	NA	1
	Ryan Creek E249089	0.20	0.20	0.20	NA	0.20	0.20	0.20	NA	1
	Bear Creek E257539	0.14	0.14	0.14	NA	0.14	0.14	0.14	NA	1
	Beaver Creek E249090	0.64	0.64	0.57	0.41	0.35	0.93	0.87	0.29	2
	Waneta	0.20	0.23	0.18	0.08	0.08	0.26	0.25	0.04	4
Mercury (mg/kg dw)	Arrow Lake 200524	0.03	0.03	0.02	0.03	0.01	0.05	0.05	0.02	2
	downstream HLK E249077	0.05	0.05	0.05	NA	0.05	0.05	0.05	NA	1
	Genelle E249088	0.05	0.05	0.05	0.00	0.05	0.05	0.05	0.00	2
	Birchbank	0.03	0.02	0.02	0.02	0.01	0.05	0.05	0.01	5
	Indian Eddy	0.02	0.02	0.02	NA	0.02	0.02	0.02	NA	1
	Ryan Creek E249089	0.05	0.05	0.05	NA	0.05	0.05	0.05	NA	1
	Bear Creek E257539	0.07	0.07	0.07	NA	0.07	0.07	0.07	NA	1
	Beaver Creek E249090	0.32	0.32	0.26	0.25	0.14	0.50	0.46	0.18	2
	Waneta	1.43	0.06	0.13	3.06	0.02	6.90	4.18	1.37	5
Fatty Acids, Total (µg/g dw)	Arrow Lake 200524	11.37	11.37	9.62	8.55	5.32	17.41	16.20	6.05	2
	Birchbank	11.61	7.54	6.83	12.50	1.65	25.63	22.01	7.21	3
	Genelle E249088	2.75	2.75	2.75	NA	2.75	2.75	2.75	NA	1
	Ryan Creek E249089	2.71	2.71	2.71	NA	2.71	2.71	2.71	NA	1
	Beaver Creek E249090	1.69	1.69	1.69	NA	1.69	1.69	1.69	NA	1
	Waneta	7.27	4.56	4.80	7.45	1.55	15.69	13.46	4.30	3
Resin Acids (µg/g dw)	Arrow Lake 200524	1.18	1.18	1.12	0.52	0.81	1.54	1.47	0.37	2
	Birchbank	1.33	1.32	1.06	0.93	0.40	2.26	2.07	0.54	3
	Genelle E249088	2.50	2.50	2.50	NA	2.50	2.50	2.50	NA	1
	Ryan Creek E249089	1.39	1.39	1.39	NA	1.39	1.39	1.39	NA	1
	Beaver Creek E249090	1.30	1.30	1.30	NA	1.30	1.30	1.30	NA	1
	Waneta	1.03	1.23	0.96	0.41	0.55	1.30	1.29	0.24	3

Table A1.2 (Cont'd.)

Analyte	Location	Mean	Median	Geomean	Standard Deviation	Minimum	Maximum	90th Percentile	Standard Error	n
Dioxins & Furans, TEQs (pg TEQ/g dw)	Arrow Lake 200524	0.27	0.27	0.25	0.14	0.17	0.37	0.35	0.10	2
	Birchbank	0.58	0.59	0.54	0.26	0.31	0.84	0.79	0.15	3
	Genelle E249088	0.38	0.38	0.38	NA	0.38	0.38	0.38	NA	1
	Ryan Creek E249089	0.20	0.20	0.20	NA	0.20	0.20	0.20	NA	1
	Beaver Creek E249090	0.18	0.18	0.18	NA	0.18	0.18	0.18	NA	1
	Waneta	0.35	0.42	0.33	0.14	0.19	0.45	0.44	0.08	3
PCBs, Total (pg/g dw)	Arrow Lake 200524	308	308	308	NA	308	308	308	NA	1
	downstream HLK E249077	6,020	6,020	6,020	NA	6,020	6,020	6,020	NA	1
	Birchbank	727	727	706	246	553	901	866	174	2
	Genelle E249088	2,557	2,557	1,467	2,961	463	4,650	4,231	2,094	2
	Indian Eddy	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Ryan Creek E249089	222	222	222	NA	222	222	222	NA	1
	Bear Creek E257539	453	453	453	NA	453	453	453	NA	1
	Beaver Creek E249090	1,016	1,016	501	1,250	132	1,900	1,723	884	2
	Waneta	129	129	114	87	68	191	179	62	2
PBDEs, Total (pg/g dw)	Arrow Lake 200524	92	92	92	NA	92	92	92	NA	1
	downstream HLK E249077	87	87	87	NA	87	87	87	NA	1
	Birchbank	827	827	401	1,023	104	1,550	1,405	723	2
	Genelle E249088	437	437	414	200	296	579	550	141	2
	Ryan Creek E249089	68	68	68	NA	68	68	68	NA	1
	Bear Creek E257539	2,346	2,346	2,346	NA	2,346	2,346	2,346	NA	1
	Beaver Creek E249090	1,323	1,323	295	1,825	33	2,614	2,356	1,290	2
	Waneta	91	91	76	71	41	141	131	50	2
Dioxins and Furans, Total (pg/g dw)	Arrow Lake 200524	8.17	8.17	8.06	1.90	6.83	9.51	9.24	1.34	2
	Birchbank	17.17	11.81	15.70	9.38	11.71	28.00	24.76	5.41	3
	Genelle E249088	45.60	45.60	45.60	NA	45.60	45.60	45.60	NA	1
	Ryan Creek E249089	11.28	11.28	11.28	NA	11.28	11.28	11.28	NA	1
	Beaver Creek E249090	4.79	4.79	4.79	NA	4.79	4.79	4.79	NA	1
	Waneta	17.32	15.80	14.66	11.37	6.78	29.38	26.66	6.57	3

Table A1.3 Summary of metals in fish tissue collected from the Lower Columbia River, Birchbank to the international border (2000 to 2005).

Species	Year	n			Arsenic (µg/gww)		Cadmium (µg/gww)		Chromium (µg/gww)	
		BB[1]	WAN[2]		BB[1]	WAN[2]	BB[1]	WAN[2]	BB[1]	WAN[2]
Walleye	2000	8	2	Mean	<0.895	<0.870	<0.0895	<0.087	<1.07	1.35
				Range	<0.872-<0.908	<0.871-<0.888	<0.0872-<0.0936	<0.852-<0.888	<0.0896-1.75	0.60-2.11
	2001	NA	10	Mean	NA	<0.854	NA	<0.0854	NA	<0.109
				Range	NA	<0.832-<0.876	NA	<0.0832-<0.0876	NA	<0.0832-<0.211
	2002	10	9	Mean	<0.21	<0.2	<0.05	<0.05	<0.2	<0.2
				Range	<0.2 - 0.3	<0.2	<0.05	<0.05	<0.2	<0.2
	2003	10	10	Mean	<.21	<.2	<0.05	<0.05	<1.0	<1.0
				Range	<0.2-0.3	<0.2	<0.05	<0.05	<1.0	<1.0
	2004	12	12	Mean	0.58	0.56	<0.05	<0.05	<1.0	<1.0
				Range	0.5-0.6	0.4-0.7	<0.05	<0.05	<1.0	<1.0
	2005	12	12	Mean	<0.2	<0.2	<0.01	<0.01	<1.0	<1.0
				Range	<0.2	<0.2	<0.01	<0.01	<1.0	<1.0
Mountain Whitefish	2001	10	NA	Mean	<1.25	NA	<0.125	NA	<0.140	NA
				Range	<1.12-<1.40	NA	<0.112-<0.14	NA	<0.112-<0.257	NA
	2003	10	10	Mean	<0.2	<0.2	<0.05	<0.05	<1.0	<1.4
				Range	<0.2	<0.2	<0.05	<0.05	<1.0	<1.0-4
	2004	12	12	Mean	0.567	0.575	<0.05	<0.05	<1.08	<1
				Range	0.5-0.7	0.4-0.7	<0.05	<0.05	<1-2.0	<1
Rainbow Trout	2000	8	8	Mean	<1.25	<1.15	<0.125	<0.115	1.070	0.914
				Range	<1.13-<1.44	<0.972-<1.24	<0.113-<0.144	<0.0972-<0.124	0.646-1.66	0.354-2.02
	2003	10	10	Mean	<0.2	<0.2	<0.05	<0.05	<1.10	<1.0
				Range	<0.2	<0.2	<0.05	<0.05	<1.0-2.0	<1.0

[1] BB = Birchbank to Genelle.

[2] WAN= Beaver Creek to the interational border.

Table A1.3 (Cont'd.)

Species	Year	n			Lead (µg/gww)		Mercury (µg/gww)	
		BB[1]	WAN[2]		BB[1]	WAN[2]	BB[1]	WAN[2]
Walleye	2000	8	2	Mean	<0.895	<0.870	0.258	0.355
				Range	<0.884-<0.936	<0.852-<0.888	0.228-0.230	0.322-0.389
	2001	NA	10	Mean	NA	<0.854	NA	0.254
				Range	NA	<0.832-<0.876	NA	0.106-0.579
	2002	10	9	Mean	0.11	<0.1	0.322	0.24
				Range	<0.1-0.2	<0.1	0.21-0.56	0.08-0.48
	2003	10	10	Mean	<0.1	<0.1	0.352	0.351
				Range	<0.1	<0.1	0.26-0.53	0.21-0.53
	2004	12	12	Mean	<0.1	<0.1	0.4	0.36
				Range	<0.1	<0.1	0.19-0.58	0.16-0.61
	2005	12	12	Mean	<0.011	<0.01	0.32	0.34
				Range	<0.01-0.02	<0.01	0.14-0.56	0.18-0.67
Mountain Whitefish	2001	10	NA	Mean	<1.25	NA	0.0288	NA
				Range	<1.12-<1.4	NA	0.02-0.04	NA
	2003	10	10	Mean	<0.1	<0.1	<0.078	<0.083
				Range	<0.1	<0.1	<0.05-0.13	<0.05-0.17
	2004	12	12	Mean	<0.108	<0.108	<0.085	<0.0875
				Range	<0.1-0.2	<0.1-0.2	<0.05-0.16	<0.05-0.12
Rainbow Trout	2000	8	8	Mean	<1.25	<1.15	0.105	0.055
				Range	<1.13-<1.44	<0.972-<1.24	0.0554-0.148	0.036-0.0936
	2003	10	10	Mean	<0.1	<0.1	<0.083	<0.072
				Range	<0.1	<0.1	<0.05-0.21	<0.05-0.13

[1] BB = Birchbank to Genelle.

[2] WAN= Beaver Creek to the interational border.

Table A1.4 Summary of dioxins/furans in fish tissue collected from the Lower Columbia River, Birchbank to the international border (2000 to 2005).

Species	Year	n			2,3,7,8-T_4CDD TEQs		Total T_4CDD		Total T_4CDF	
		BB[1]	WAN[2]		BB[1]	WAN[2]	BB[1]	WAN[2]	BB[1]	WAN[2]
Mountain Whitefish	2000	10	10	Mean	0.86	0.92	0.46	0.43	6.25	6.4343
				Range	0.2-3.44	0.13-5.04	0.342-0.79	0.119-1.36	1.89-24.5	0.719-37.9
	2001	NA	10	Mean	NA	0.28	NA	0.29	NA	1.0758
				Range	NA	0.11-0.70	NA	0.121-0.58	NA	0.379-3.46
	2002	5	5	Mean	0.61	0.95	0.1454	0.20	2.11	4.2336
				Range	0.38-0.91	0.43-2.46	0.091-0.17	0.096-0.48	0.768-2.94	0.978-13.9
	2003	10	10	Mean	3.14	0.62	0.1155	0.15	1.59	2.6046
				Range	0.61-7.79	0.21-1.32	0.097-0.15	0.093-0.34	0.615-4.03	0.606-8.61
Rainbow Trout	2000	10	10	Mean	0.19	0.16	0.04	0.04	0.65	0.384
				Range	0.139-0.219	0.126-0.19	0.035-0.056	0.034-0.048	0.352-0.966	0.186-0.534

[1] BB = Birchbank to Genelle.

[2] WAN= Beaver Creek to the interational border.

Table A1.5 Summary of PBDEs and PCBs in fish tissue collected from the Lower Columbia River, Birchbank to the international border (2000 to 2005).

Species	Year	n			PeBDE (pg/g ww)		OcBDE (pg/g ww)		DeBDE (pg/g ww)	
		BB[1]	WAN[2]		BB[1]	WAN[2]	BB[1]	WAN[2]	BB[1]	WAN[2]
Mountain Whitefish	2002	5	5	Mean	54900	48900	2.44	3.35	67.6	71.7
				Range	36,400-77,900	35,600-64,900	0.909-6.0	0.749-6.0	41.9-95.0	44.3-146
	2004	12	12	Mean	72064	42902	14.67	11.42	35.58	60.17
				Range	31,600-15,2000	7,610-184,000	8.0-27	8.0-28	25-130	25-240
Rainbow Trout	2003	10	10	Mean	7,870	8,720	2.38	2.11	231	178
				Range	5,240-10,500	7,630-11,800	1.13-6.85	1.55-3.15	50-567	96.2-357

[1] BB = Birchbank to Genelle.
[2] WAN= Beaver Creek to the interational border.

Table A1.5 (Cont'd.)

Species	Year	n			Total PBDEs (pg/g ww)		Total PCBs (ng/gww)	
		BB[1]	WAN[2]		BB[1]	WAN[2]	BB[1]	WAN[2]
Mountain Whitefish	2002	5	5	Mean	107,000	90,800	30.32	29.5
				Range	69,500-142,000	67,900-117,000	8.84-88.9	5.77-114.5
				95% CL	25,300	19,400	12.7	18.9
	2004	12	12	Mean	130,000	85,500	NA	NA
				Range	60,100-279,000	15,900-351,000	NA	NA
				95% CL	35,300	93,200	NA	NA
Rainbow Trout	2003	10	10	Mean	18,400	17,300	NA	NA
				Range	10,500-33,900	14,400-22,600	NA	NA
				95%CL	5,080	1,750	NA	NA

[1] BB = Birchbank to Genelle.
[2] WAN= Beaver Creek to the interational border.

Appendix A2

Selected Criteria and Guidelines

Table A2.1 Summary of water quality guidelines.

Analyte	Unit	CCME[1]	AENV[2]		B.C.[3]		B.C. Contaminated Sites Regulation[4]	WQ Objectives for the Lower Columbia River[5]	
			Acute	Chronic	Maximum	30-day Average		Maximum	30-Day Average
Metals									
Aluminum (Al)	mg/L	0.005, 0.1 [a]	-	-	0.1 [k]	0.05 [k]	-	-	-
Antimony (Sb)	mg/L	-	-	-	*0.020*	-	0.2	-	-
Arsenic (As)	mg/L	0.0050	-	-	*0.005*	-	0.05	-	0.005
Barium (Ba)	mg/L	-	-	-	*5*	*1*	10	-	-
Beryllium (Be)	mg/L	-	-	-	-	*0.0053*	0.053	-	-
Bismuth (Bi)	mg/L	-	-	-	-	-	-	-	-
Boron (B)	mg/L	-	-	-	-	-	50	-	-
Cadmium (Cd)	mg/L	$10^{(0.86[\log(Hardness)-3.2])} \div 1000$	-	-	*$10^{(0.86[\log(Hardness)-3.2])} \div 1000$*	-	0.0001-0.0006 [x]	-	0.00003
Calcium (Ca)	mg/L	-	-	-	-	-	-	-	-
Chromium III (Cr^{3+})	mg/L	0.0089	-	-	*0.009*	-	0.09	-	0.001 [u]
Chromium VI (Cr^{6+})	mg/L	0.0010	-	-	*0.001*	-	0.01	-	
Cobalt (Co)	mg/L	-	-	-	*0.0009*	-	0.04	-	-
Copper (Cu)	mg/L	0.002-0.004 [b]	$e^{(0.979123[\ln(hardness)-8.64497])}$	0.007 [h]	(0.094[hardness+2]) ÷ 1000	0.00004, 002 [l]	0.02-0.09 [y]	0.00717	0.002
Gallium (Ga)	mg/L	-	-	-	-	-	-	-	-
Iron (Fe)	mg/L	0.300	-	-	*0.3*	-	-	-	-
Lead (Pb)	mg/L	0.001-0.007 [c]	-	-	$e^{(1.273[\ln(hardness)-1.46])} \div 1000m$	$(3.31 + e^{(1.273[\ln(hardness)-4.704])}) \div 1000m$	0.040-0.160 [y]	0.0379	0.0048
Lithium (Li)	mg/L	-	-	-	*5*	-	-	-	-
Magnesium (Mg)	mg/L	-	-	-	-	-	-	-	-
Manganese (Mn)	mg/L	-	-	-	0.01102(hardness+ 0.54)	-	-	-	-
Mercury (Hg)	mg/L	0.00026 [d]	0.000013	0.000005	0.0001	0.00002	0.001	-	-
Molybdenum (Mo)	mg/L	0.073	-	-	2	1	10	-	-
Nickel (Ni)	mg/L	0.025-0.150 [e]	-	-	*0.025-0.150* [e]	-	0.25-1.5 [y]	-	-
Phosphorus (P)	mg/L	-	-	-	-	-	-	-	-
Potassium (K)	mg/L	-	-	-	-	-	-	-	-
Rubidium (Rb)	mg/L	-	-	-	-	-	-	-	-
Selenium (Se)	mg/L	0.0010	-	-	-	0.00020	0.010	-	-
Silicon (Si)	mg/L	-	-	-	-	-	-	-	-
Silver (Ag)	mg/L	0.0001	-	-	0.0001, 0.003 [n]	0.00005, 0.0015 [n]	0.0005, 0.015 [y]	-	-
Sodium (Na)	mg/L	-	-	-	-	-	-	-	-
Strontium (Sr)	mg/L	-	-	-	-	-	-	-	-
Sulphur (S)	mg/L	-	-	-	-	-	-	-	-
Thallium (Tl)	mg/L	0.0008	-	-	*0.0003*	-	0.003	-	0.0008
Tin (Sn)	mg/L	-	-	-	-	-	-	-	-

Table A2.1 (Cont'd.)

Analyte	Unit	CCME[1]	AENV[2]		B.C.[3]		B.C. Contaminated Sites Regulation[4]	WQ Objectives for the Lower Columbia River[5]	
			Acute	Chronic	Maximum	30-day Average		Maximum	30-Day Average
Metals, cont'd.									
Titanium (Ti)	mg/L	-	-	-	*0.100*	-	1	-	-
Uranium (U)	mg/L	-	-	-	*0.300*	-	3	-	-
Vanadium (V)	mg/L	-	-	-	-	-	-	-	-
Zinc (Zn)	mg/L	0.030	-	-	(33+0.75[hardness-90]) ÷ 1000	(7.5+0.75[hardness-90]) ÷ 1000	0.075-2.4 [y]	0.007	-
Nutrients									
Total Kjeldahl Nitrogen (TKN)	mg/L	-	-	-	-	-		-	-
Total Organic Nitrogen	mg/L	-	-	-	-	-		-	-
Ammonia	mg/L	0.019 (un-ionized) [f]	-	-	0.752-27.7	0.102-2.08 [o]	1.31-200 [f]	-	0.102-2.08 [v]
Nitrate-N	mg/L	13	-	-	200	40	400	-	-
Nitrite-N	mg/L	0.060	-	-	0.06 [p]	0.02 [p]	0.2 [p]	-	-
Nitrite+Nitrate-N	mg/L	-	-	-	-	-	-	-	-
Total Nitrogen	mg/L	-	-	1.0	-	-	-	-	-
Ortho-phosphorus	mg/L	-	-	-	-	-	-	-	-
Total Dissolved Phosphorus	mg/L	-	-	-	-	-	-	-	-
Total Phosphorus	mg/L	See Canadian Trigger Ranges	-	0.05	0.005-0.015 for lakes		-	-	-
Conventionals									
pH	pH units	6.5-9.0	6.5-8.5 [i]	-	unrestricted change between pH 6.5 and 9.0 if background pH within this range		-	6.5-8.5	-
Dissolved oxygen	mg/L	5.5-9.5 [g]	5.0 (1-day min.)	6.5 (7-day mean) [j]	5-9 (min.) [q]	8-11 (min.) [q]	-	-	-
Temperature	°C	See narrative	no more than 3°C change above ambient T		See reference		-	-	-
Suspended Solids	mg/L	-	<10 mg/L change from background value		Δ 25 mg/L [r]	Δ 5 mg/L [r]	-	-	-
Turbidity	NTU	-	-	-	Δ 8 [s]	Δ 2 [s]	-	-	-
Ions									
Fluoride	mg/L	-	-	-	0.2-0.3 [t]	-	2, 3 [z]	-	-
Sulphate	mg/L	-	-	-	100, 50 (alert level)	-	1000	-	-
Sulphide (as H_2S)	mg/L	-	-	-	*0.002*	-	0.02	-	-
Organics									
Phenols (mono- and dihydric)	mg/L	0.0040	-	-	*0.3*	-	-	-	-
Phenolics	mg/L	-	-	0.005	-	-	-	-	-
Biological									
Total faecal coliforms	colonies/100 mL	-	-	-	-	-	-	-	10 [w]
Escherichia coli	colonies/100 mL	-	-	-	-	-	-	-	10 [w]
Enterococcus sp.	colonies/100 mL	-	-	-	-	-	-	-	3 [w]

Table A2.1 (Cont'd. - Table Notes)

[1] CCME 2005.
[2] AENV 1999.
[3] B.C. 2001. Working guidelines are shown in italics.
[4] B.C. 2005.
[5] MacDonald Environmental Sciences Ltd. 1997.
[a] 0.005 at pH <6.5, [Ca^{2+}] <4 mg/L, DOC <2 mg/L; and 0.100 at pH ±6.5, [Ca^{2+}] ≥4 mg/L, DOC ≥2 mg/L.
[b] 0.002 at [$CaCO_3$] = 0-120 mg/L; 0.003 at [$CaCO_3$] = 120-180 mg/L; and 0.004 at [$CaCO_3$] >180 mg/L.
[c] 0.001 at [$CaCO_3$] = 0-60 mg/L; 0.002 at [$CaCO_3$] = 60-120 mg/L; 0.004 at [$CaCO_3$] = 120-180 mg/L; and 0.007 at [$CaCO_3$] >180 mg/L.
[d] For inorganic mercury.
[e] 0.025 at [$CaCO_3$] = 0-60 mg/L; 0.065 at [$CaCO_3$] = 60-120 mg/L; 0.110 at [$CaCO_3$] = 120-180 mg/L; and 0.150 at [$CaCO_3$] >180 mg/L.
[f] Guidelines for total ammonia are temperature and pH dependent; see reference for additional information.
[g] For cold-water biota, 9.5 mg/L for early life stages, 6.5 mg/L for other life stages. For warm-water biota, 6.0 mg/L for early life stages, 5.5 mg/L for other life stages.
[h] Applicable only at water hardness ≥50 mg/L $CaCO_3$. Guideline applies to acid-extractable copper concentrations.
[i] Within the range 6.5 to 8.5 but not altered by more than 0.5 pH units from background values.
[j] See also narrative.
[k] For dissolved aluminum at pH ≥6.5. At pH <6.5, guidelines are $e^{(1.209-2.426*pH+0.286*pH^2)}$ (maximum concentration) and $e^{(1.6-3.327*median\ pH+0.402*pH^2)}$.
[l] Guideline is 0.002 at [$CaCO_3$] ≤50 mg/L; and 0.00004 at [CaCO]$_3$ ≥50 mg/L.
[m] At hardness greater than 8 mg/L $CaCO_3$.
[n] Lower guideline value is for hardness <100 mg/L $CaCO_3$.
[o] For ammonia-N at T=0 to 20oC; pH 6.5 to 9.0. See reference for specific values.
[p] When chloride <2 mg/L.
[q] Depends on life stage. See reference.
[r] When background is <25 mg/L; D 10% if above.
[s] When background is <80; D 10% if above.
[t] 0.2 at [$CaCO_3$] ≤50 mg/L; and 0.3 at [$CaCO_3$] ≥50 mg/L.
[u] Guideline is for total chromium.
[v] Guideline depends on pH and temperature. See reference.
[w] 90th percentile value.
[x] 0.0001 at [$CaCO_3$] ≤30 mg/L; 0.0003 at [$CaCO_3$] = 30-90 mg/L; 0.0005 at [$CaCO_3$] = 90-150 mg/L; and 0.0006 at [$CaCO_3$] = 150-210 mg/L.
[y] Hardness dependent; see reference.
[z] 0.2 at [$CaCO_3$] <50 mg/L; and 0.3 at [$CaCO_3$] ≥50 mg/L.

Table A2.2 Summary of sediment quality guidelines.

Analyte	Unit	Sediment Quality Objectives for the Lower Columbia	CCME[1]		B.C. Working Guidelines[2]		B.C. CSR[3]	
			ISQG	PEL	ISQG	PEL	Sensitive	Typical
Metals								
Aluminum (Al)	mg/kg	-	-	-	-	-	-	-
Antimony (Sb)	mg/kg	-	-	-	-	-	-	-
Arsenic (As)	mg/kg	5.7	5.9	17	5.9	17	11	20
Barium (Ba)	mg/kg	-	-	-	-	-	-	-
Berylium (Be)	mg/kg	-	-	-	-	-	-	-
Bismuth (Bi)	mg/kg	-	-	-	-	-	-	-
Boron (B)	mg/kg	-	-	-	-	-	-	-
Cadmium (Cd)	mg/kg	0.6	0.6	3.5	0.6	3.5	2.2	4.2
Calcium (Ca)	mg/kg	-	-	-	-	-	-	-
Chromium (Cr)	mg/kg	36.4	37.3	90	37	90	56	110
Cobalt (Co)	mg/kg	-	-	-	-	-	-	-
Copper (Cu)	mg/kg	35.1	35.7	197	36	197	120	240
Gallium (Ga)	mg/kg	-	-	-	-	-	-	-
Germanium (Ge)	mg/kg	-	-	-	-	-	-	-
Indium (In)	mg/kg	-	-	-	-	-	-	-
Iron (Fe)	mg/kg	-	-	-	21,200[a]	43,766[a]	-	-
Lead (Pb)	mg/kg	33.4	35	91.3	35	91	57	110
Lithium (Li)	mg/kg	-	-	-	-	-	-	-
Magnesium (Mg)	mg/kg	-	-	-	-	-	-	-
Manganese (Mn)	mg/kg	-	-	-	-	-	-	-
Mercury (Hg)	mg/kg	0.16	0.17	0.486	0.174	0.486	0.3	0.58
Molybdenum (Mo)	mg/kg	-	-	-	-	-	-	-
Nickel (Ni)	mg/kg	-	-	-	16[a]	75[a]	-	-
Phosphorus (P)	mg/kg	-	-	-	-	-	-	-
Potassium (K)	mg/kg	-	-	-	-	-	-	-
Selenium (Se)	mg/kg	-	-	-	5	-	-	-
Silver (Ag)	mg/kg	-	-	-	0.5	-	-	-
Sodium (Na)	mg/kg	-	-	-	-	-	-	-
Strontium (Sr)	mg/kg	-	-	-	-	-	-	-
Tellurium (Te)	mg/kg	-	-	-	-	-	-	-
Thallium (Tl)	mg/kg	-	-	-	-	-	-	-
Thorium (Th)	mg/kg	-	-	-	-	-	-	-
Tin (Sn)	mg/kg	-	-	-	-	-	-	-
Titanium (Ti)	mg/kg	-	-	-	-	-	-	-
Tungsten (W)	mg/kg	-	-	-	-	-	-	-
Uranium (U)	mg/kg	-	-	-	-	-	-	-
Vanadium (V)	mg/kg	-	-	-	-	-	-	-
Zinc (Z)	mg/kg	120	123	315	123	315	200	380
Zirconium (Zr)	mg/kg	-	-	-	-	-	-	-
PCBs								
2-MoCB	pg/g (d/w)	-	-	-	-	-	-	-
3-MoCB	pg/g (d/w)	-	-	-	-	-	-	-
4-MoCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2'-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3'-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
2,4-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
2,4'-DiCB	pg/g (d/w)	-	-	-	-	-	-	-

[1] CCME 2003.
[2] B.C. 2001.
[3] B.C. 2005.
[a] Lower value for a given analyte is lowest effect level based on screening level concentration; upper value is severe effects level based on screening level concentration.
[b] Guideline for no effect level is 0.02 mg/kg (approved provincial guideline) when sediment contains 1% organic carbon.

Table A2.2 (Cont'd.)

Analyte	Unit	Sediment Quality Objectives for the Lower Columbia	CCME[1]		B.C. Working Guidelines[2]		B.C. CSR[3]	
			ISQG	PEL	ISQG	PEL	Sensitive	Typical
PCBs, cont'd.								
2,5-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
2,6-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3'-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
3,4-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
3,5-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
4,4'-DiCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',5-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',6-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3'-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,4-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,4'-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,5-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,6-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',5-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',6-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,4',5-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,4',6-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2',3,5-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',5-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
3,4,4'-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
3,4,5-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
3,4',5-TriCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,5-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,5'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,6-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,6'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,5-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,5'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,6-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',5,5'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',6,6'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',5-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',5'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',6-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,4,4'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,4,5-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,4',5-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,4',6-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4,4'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4,5-TeCB	pg/g (d/w)	-	-	-	-	-	-	-

[1] CCME 2003.

[2] B.C. 2001.

[3] B.C. 2005.

[a] Lower value for a given analyte is lowest effect level based on screening level concentration; upper value is severe effects level based on screening level concentration.

[b] Guideline for no effect level is 0.02 mg/kg (approved provincial guideline) when sediment contains 1% organic carbon.

Table A2.2 (Cont'd.)

Analyte	Unit	Sediment Quality Objectives for the Lower Columbia	CCME[1]		B.C. Working Guidelines[2]		B.C. CSR[3]	
			ISQG	PEL	ISQG	PEL	Sensitive	Typical
PCBs, cont'd.								
2,3',4,5'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',5,5'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',5',6-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,4'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,5-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,5'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',5,5'-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
3,4,4',5-TeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',6-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,6-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,6'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4',5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,5,5'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,5,6-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,5,6'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,6,6'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,5',6-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,6,6'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4',5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,6-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4',6-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',5,5'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',5,6-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,4,4',5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4,4',5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4,5,5'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4,5',6-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2',3,3',4,5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2',3,4,4',5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,4',5-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,5,5'-PeCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,6'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',5,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',5,6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',5,6'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',6,6'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-

[1] CCME 2003.

[2] B.C. 2001.

[3] B.C. 2005.

[a] Lower value for a given analyte is lowest effect level based on screening level concentration; upper value is severe effects level based on screening level concentration.

[b] Guideline for no effect level is 0.02 mg/kg (approved provincial guideline) when sediment contains 1% organic carbon.

Table A2.2 (Cont'd.)

Analyte	Unit	Sediment Quality Objectives for the Lower Columbia	CCME[1]		B.C. Working Guidelines[2]		B.C. CSR[3]	
			ISQG	PEL	ISQG	PEL	Sensitive	Typical
PCBs, cont'd.								
2,2',3,4,5,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,5,6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,5',6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,6,6'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4',5,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4',5,6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4',5,6'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4',6,6'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,5,6,6'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,4',5,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,4',6,6'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4',5-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4',6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,5,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,5',6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4',5,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4',5',6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',5,5',6-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4,4',5,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,4',5,5'-HxCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5,5'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5,6'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5',6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,6,6'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4',5,6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',5,5',6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',5,6,6'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5,5'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5,6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5,6'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5',6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',6,6'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,5,6,6'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4',5,5',6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4',5,6,6'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4',5,5'-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4',5,6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4',5',6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,5,5',6-HpCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,5'-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,6-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,6'-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',6,6'-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5,5',6-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5',6,6'-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',5,5',6,6'-OcCB	pg/g (d/w)	-	-	-	-	-	-	-

[1] CCME 2003.

[2] B.C. 2001.

[3] B.C. 2005.

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Table A2.2 (Cont'd.)

Analyte	Unit	Sediment Quality Objectives for the Lower Columbia	CCME[1]		B.C. Working Guidelines[2]		B.C. CSR[3]	
			ISQG	PEL	ISQG	PEL	Sensitive	Typical
PCBs, cont'd.								
2,2',3,4,4',5,5',6-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5,6,6'-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4',5,5',6-OcCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,5',6-NoCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,6,6'-NoCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5,5',6,6'-NoCB	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,5',6,6'-DeCB	pg/g (d/w)	-	-	-	-	-	-	-
% Moisture	pg/g (d/w)	-	-	-	-	-	-	-
Total Monochloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Total Dichloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Total Trichloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Total Tetrachloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Total Pentachloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Total Hexachloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Total Heptachloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Total Octachloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Total Nonachloro Biphenyls	pg/g (d/w)	-	-	-	-	-	-	-
Decachloro Biphenyl	pg/g (d/w)	-	-	-	-	-	-	-
TOTAL PCBs	pg/g (d/w)	-	0.0341	0.277	0.034[b]	0.277	0.17	0.33
TEQ (WHO 1998) ND=0	pg/g (d/w)	-	-	-	-	-	-	-
TEQ (WHO 1998) ND=1/2DL	pg/g (d/w)	-	-	-	-	-	-	-
Dioxins/Furans								
Polychlorinated dibenzo-p-dioxins/dibenzo furans	ng TEQ/kg dw	-	0.85	21.5	-	-	-	-
PBDEs								
2-MoBDE	pg/g (d/w)	-	-	-	-	-	-	-
3-MoBDE	pg/g (d/w)	-	-	-	-	-	-	-
4-MoBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,4-DiBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,4'-DiBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,6-DiBDE	pg/g (d/w)	-	-	-	-	-	-	-
3,4-DiBDE	pg/g (d/w)	-	-	-	-	-	-	-
4,4'-DiBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4-TriBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,4,4'-TriBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,4,6-TriBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,4',6-TriBDE	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4-TriBDE	pg/g (d/w)	-	-	-	-	-	-	-
3,4,4'-TriBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,4'-TeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,5'-TeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,6'-TeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4,4'-TeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4',6-TeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,4,4',6-TeBDE	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,4'-TeBDE	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,5'-TeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4'-PeBDE	pg/g (d/w)	-	-	-	-	-	-	-

[1] CCME 2003.
[2] B.C. 2001.
[3] B.C. 2005.
[a] Lower value for a given analyte is lowest effect level based on screening level concentration; upper value is severe effects level based on screening level concentration.
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Table A2.2 (Cont'd.)

Analyte	Unit	Sediment Quality Objectives for the Lower Columbia	CCME[1]		B.C. Working Guidelines[2]		B.C. CSR[3]	
			ISQG	PEL	ISQG	PEL	Sensitive	Typical
PBDEs, cont'd.								
2,2',4,4',5-PeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,4',6-PeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4'-PeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,3,4,5,6-PeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,3',4,4',6-PeBDE	pg/g (d/w)	-	-	-	-	-	-	-
3,3',4,4',5-PeBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4'-HxBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5'-HxBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',6'-HxBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,4',5,5'-HxBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,4',5,6'-HxBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',4,4',6,6'-HxBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5,6-HpBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5',6-HpBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,3,3',4,4',5,6-HpBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,4,4',5,5',6-OcBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,5',6-NoBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,6,6'-NoBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,5,5',6,6'-NoBDE	pg/g (d/w)	-	-	-	-	-	-	-
2,2',3,3',4,4',5,5',6,6'-DeBDE	pg/g (d/w)	-	-	-	-	-	-	-
% Moisture	%	-	-	-	-	-	-	-
Sediment Toxicity								
Hyalella azteca 14-day survival	% (survival)	-	-	-	-	-	-	-
Hyalella azteca 14-day growth	mg	-	-	-	-	-	-	-

[1] CCME 2003.
[2] B.C. 2001.
[3] B.C. 2005.
[a] Lower value for a given analyte is lowest effect level based on screening level concentration; upper value is severe effects level based on screening level concentration.
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Table A2.3 Summary of fish tissue guidelines.

Analyte	Description	Unit	CCME	Tissue Residue Objectives for the Lower Columbia	B.C. Approved Guidelines	Other
Total Metals						
Aluminum	-	mg/kg ww	-	-	-	-
Antimony	-	mg/kg ww	-	-	-	-
Arsenic	-	mg/kg ww	-	0.471	-	-
Barium	-	mg/kg ww	-	-	-	-
Beryllium	-	mg/kg ww	-	-	-	-
Bismuth	-	mg/kg ww	-	-	-	-
Cadmium	-	mg/kg ww	-	0.9	-	-
Calcium	-	mg/kg ww	-	-	-	-
Chromium	-	mg/kg ww	-	0.94	-	-
Cobalt	-	mg/kg ww	-	-	-	-
Copper	-	mg/kg ww	-	-	-	-
Iron	-	mg/kg ww	-	-	-	-
Lead	-	mg/kg ww	-	0.16	0.8	-
Magnesium	-	mg/kg ww	-	-	-	-
Manganese	-	mg/kg ww	-	-	-	-
Mercury	-	mg/kg ww	0.033	0.1	-	0.5
Molybdenum	-	mg/kg ww	-	-	-	-
Nickel	-	mg/kg ww	-	-	-	-
Phosphorus Total	-	mg/kg ww	-	-	-	-
Potassium	-	mg/kg ww	-	-	-	-
Selenium	-	mg/kg ww	-	-	-	-
Silver	-	mg/kg ww	-	-	-	-
Sodium	-	mg/kg ww	-	-	-	-
Strontium	-	mg/kg ww	-	-	-	-
Thallium	-	mg/kg ww	-	-	-	-
Tin	-	mg/kg ww	-	-	-	-
Titanium	-	mg/kg ww	-	-	-	-
Uranium	-	mg/kg ww	-	-	-	-
Vanadium	-	mg/kg ww	-	-	-	-
Zinc	-	mg/kg ww	-	-	-	-
Dioxin/Furans						
Method		***wet weight***				
% lipids	-	%	-	-	-	-
DX TEQ (ND = 0)	-	pg/g	-	-	-	-
DX TEQ (ND = DL)	-	pg/g	-	-	-	-
2,3,7,8 T4CDD	-	pg/g	-	-	-	-
Total T4CDD	-	pg/g	-	-	-	-
1,2,3,7,8, P5CDD	-	pg/g	-	-	-	-
Total P5CDD	-	pg/g	-	-	-	-
1,2,3,4,7,8 H6CDD	-	pg/g	-	-	-	-
1,2,3,6,7,8 H6CDD	-	pg/g	-	-	-	-
1,2,3,7,8,9 H6CDD	-	pg/g	-	-	-	-
Total H6CDD	-	pg/g	-	-	-	-
1,2,3,4,6,7,8 H7CDD	-	pg/g	-	-	-	-
Total H7CDD	-	pg/g	-	-	-	-
Total 0CDD	-	pg/g	-	-	-	-
2,3,7,8 T4CDF	-	pg/g	-	-	-	-
2,3,7,8-TCDF	-	pg/g	-	-	-	-
Total T4CDF	-	pg/g	-	-	-	-
1,2,3,7,8 P5CDF	-	pg/g	-	-	-	-
2,3,4,7,8 P5CDF	-	pg/g	-	-	-	-
Total P5CDF	-	pg/g	-	-	-	-
1,2,3,4,7,8 H6CDF	-	pg/g	-	-	-	-
1,2,3,6,7,8 H6CDF	-	pg/g	-	-	-	-

Table A2.3 (Cont'd.)

Analyte	Description	Unit	CCME	Tissue Residue Objectives for the Lower Columbia	B.C. Approved Guidelines	Other
Dioxin/Furans, cont'd						
Method		***wet weight***				
2,3,4,6,7,8 H6CDF	-	pg/g	-	-	-	-
1,2,3,7,8,9 H6CDF	-	pg/g	-	-	-	-
Total H6CDF	-	pg/g	-	-	-	-
1,2,3,4,6,7,8 H7CDF	-	pg/g	-	-	-	-
1,2,3,4,7,8,9 H7CDF	-	pg/g	-	-	-	-
Total H7CDF	-	pg/g	-	-	-	-
Total 0CDF	-	pg/g	-	-	-	-
Polychlorinated dibenzo-p-dioxins/dibenzo furans	PCDD/Fs	ng TEQ/kg diet ww	0.79 (mammalian), 4.75 (avian)	-	-	15 pg T_4CDD TEQs/g wet muscle or 30 pg/g wet liver
PCBs						
IUPAC Name	***PCB #***					
2-MoCB	PCB-001	ng/g	-	-	-	-
3-MoCB	PCB-002	ng/g	-	-	-	-
4-MoCB	PCB-003	ng/g	-	-	-	-
	PCB-004/010	ng/g	-	-	-	-
2,3'-DiCB	PCB-006	ng/g	-	-	-	-
2,4-DiCB	PCB-007	ng/g	-	-	-	-
2,4'-DiCB	PCB-005/008	ng/g	-	-	-	-
2,5-DiCB	PCB-009	ng/g	-	-	-	-
3,3'-DiCB	PCB-011	ng/g	-	-	-	-
3,4-DiCB	PCB-012	ng/g	-	-	-	-
3,5-DiCB	PCB-014	ng/g	-	-	-	-
4,4'-DiCB	PCB-015	ng/g	-	-	-	-
2,2',3-TriCB	PCB-016/032	ng/g	-	-	-	-
2,2',4-TrCB	PCB-017	ng/g	-	-	-	-
2,2',5-TrCB	PCB-018	ng/g	-	-	-	-
2,2',6-TrCB	PCB-019	ng/g	-	-	-	-
2,3,4-TriCB	PCB-020/021/033	ng/g	-	-	-	-
2,3,4'-TrCB	PCB-022	ng/g	-	-	-	-
2,3,5-TriCB	PCB-023/034	ng/g	-	-	-	-
2,3,6-TriCB	PCB-024/027	ng/g	-	-	-	-
2,3',4-TrCB	PCB-025	ng/g	-	-	-	-
2,3',5-TrCB	PCB-026	ng/g	-	-	-	-
2,4',5-TriCB	PCB-028/031	ng/g	-	-	-	-
2,4,5-TrCB	PCB-029	ng/g	-	-	-	-
3,3',4-TrCB	PCB-035	ng/g	-	-	-	-
3,3',5-TrCB	PCB-036	ng/g	-	-	-	-
3,4,4'-TrCB	PCB-037	ng/g	-	-	-	-
3,4,5-TrCB	PCB-038	ng/g	-	-	-	-
3,4',5-TrCB	PCB-039	ng/g	-	-	-	-
2,2',3,3'-TeCB	PCB-040	ng/g	-	-	-	-
	PCB-041/071/072	ng/g	-	-	-	-
2,2',3,4'-TeCB	PCB-042	ng/g	-	-	-	-
2,2',3,5-TeCB	PCB-043	ng/g	-	-	-	-
2,2',3,5'-TeCB	PCB-044	ng/g	-	-	-	-
2,2',3,6-TeCB	PCB-045	ng/g	-	-	-	-
2,2',3,6'-TeCB	PCB-046	ng/g	-	-	-	-
2,2',4,4'-TeCB	PCB-047/062/075	ng/g	-	-	-	-
2,2',4,5-TeCB	PCB-048	ng/g	-	-	-	-
2,2',4,5'-TeCB	PCB-049	ng/g	-	-	-	-
2,2',4,6-TeCB	PCB-050	ng/g	-	-	-	-
2,2',4,6'-TeCB	PCB-051	ng/g	-	-	-	-
2,2',5,5'-TeCB	PCB-052	ng/g	-	-	-	-

Table A2.3 (Cont'd.)

Analyte	Description	Unit	CCME	Tissue Residue Objectives for the Lower Columbia	B.C. Approved Guidelines	Other
PCBs, cont'd.						
IUPAC Name	***PCB #***					
2,2',5,6'-TeCB	PCB-053	ng/g	-	-	-	-
2,2',6,6'-TeCB	PCB-054	ng/g	-	-	-	-
2,3,3',4-TeCB	PCB-055	ng/g	-	-	-	-
2,3,3',4'-TeCB	PCB-056	ng/g	-	-	-	-
2,3,3',5-TeCB	PCB-057	ng/g	-	-	-	-
2,3,3',5'-TeCB	PCB-058	ng/g	-	-	-	-
2,3,3',6-TeCB	PCB-059	ng/g	-	-	-	-
2,3,4,4'-TeCB	PCB-060	ng/g	-	-	-	-
2,3,4,5-TeCB	PCB-061	ng/g	-	-	-	-
	PCB-064/068	ng/g	-	-	-	-
2,3,5,6-TeCB	PCB-065	ng/g	-	-	-	-
	PCB-066/080	ng/g	-	-	-	-
2,3',4,5-TeCB	PCB-067	ng/g	-	-	-	-
2,3,4',5-TeCB	PCB-068	ng/g	-	-	-	-
2,3',4,6-TeCB	PCB-069/073	ng/g	-	-	-	-
2,3',4',5-TeCB	PCB-070	ng/g	-	-	-	-
2,4,4',5-TeCB	PCB-074	ng/g	-	-	-	-
2,3',4',5'-TeCB	PCB-076	ng/g	-	-	-	-
3,3',4,4'-TeCB	PCB-077	ng/g	-	-	-	-
3,3',4,5-TeCB	PCB-078	ng/g	-	-	-	-
3,3',4,5'-TeCB	PCB-079	ng/g	-	-	-	-
3,4,4',5-TeCB	PCB-081	ng/g	-	-	-	-
2,2',3,3',4-PeCB	PCB-082	ng/g	-	-	-	-
	PCB-083/109	ng/g	-	-	-	-
2,2',3,3',6-PeCB	PCB-084	ng/g	-	-	-	-
	PCB-085/124	ng/g	-	-	-	-
2,2',3,4,5-PeCB	PCB-086	ng/g	-	-	-	-
2,2',3,4,5'-PeCB	PCB-087	ng/g	-	-	-	-
2,2',3,4,6-PeCB	PCB-088	ng/g	-	-	-	-
	PCB-089/101/113	ng/g	-	-	-	-
2,2',3,4',5-PeCB	PCB-090	ng/g	-	-	-	-
2,2',3,4',6-PeCB	PCB-091	ng/g	-	-	-	-
2,2',3,5,5'-PeCB	PCB-092	ng/g	-	-	-	-
2,2',3,5,6-PeCB	PCB-093	ng/g	-	-	-	-
2,2',3,5,6'-PeCB	PCB-094	ng/g	-	-	-	-
	PCB-095/121	ng/g	-	-	-	-
2,2',3,6,6'-PeCB	PCB-096	ng/g	-	-	-	-
	PCB-097/125	ng/g	-	-	-	-
2,2',3,4',6'-PeCB	PCB-098	ng/g	-	-	-	-
2,2',4,4',5-PeCB	PCB-099	ng/g	-	-	-	-
2,2',4,4',6-PeCB	PCB-100	ng/g	-	-	-	-
2,2',4,5,6'-PeCB	PCB-102	ng/g	-	-	-	-
2,2',4,5',6-PeCB	PCB-103	ng/g	-	-	-	-
2,2',4,6,6'-PeCB	PCB-104	ng/g	-	-	-	-
2,3,3',4,4'-PeCB	PCB-105	ng/g	-	-	-	-
2,3,3',4,5-PeCB	PCB-106	ng/g	-	-	-	-
2,3,3',4',5-PeCB	PCB-107	ng/g	-	-	-	-
2,3,3',4,5'-PeCB	PCB-108	ng/g	-	-	-	-
	PCB-110/115	ng/g	-	-	-	-
	PCB-111/116/117	ng/g	-	-	-	-
2,3,3',5,6-PeCB	PCB-112	ng/g	-	-	-	-
2,3,4,4',5-PeCB	PCB-114	ng/g	-	-	-	-
2,3',4,4',5-PeCB	PCB-118	ng/g	-	-	-	-
2,3',4,4',6-PeCB	PCB-119	ng/g	-	-	-	-

Table A2.3 (Cont'd.)

Analyte	Description	Unit	CCME	Tissue Residue Objectives for the Lower Columbia	B.C. Approved Guidelines	Other
PCBs, cont'd.						
IUPAC Name	***PCB #***					
2,3',4,5,5'-PeCB	PCB-120	ng/g	-	-	-	-
2,3,3',4',5'-PeCB	PCB-122	ng/g	-	-	-	-
2,3',4,4',5'-PeCB	PCB-123	ng/g	-	-	-	-
3,3',4,4',5-PeCB	PCB-126	ng/g	-	-	-	-
3,3',4,5,5'-PeCB	PCB-127	ng/g	-	-	-	-
2,2',3,3',4,4'-HxCB	PCB-128	ng/g	-	-	-	-
2,2',3,3',4,5-HxCB	PCB-129	ng/g	-	-	-	-
2,2',3,3',4,5'-HxCB	PCB-130	ng/g	-	-	-	-
2,2',3,3',4,6-HxCB	PCB-131	ng/g	-	-	-	-
	PCB-132/146	ng/g	-	-	-	-
2,2',3,3',5,5'-HxCB	PCB-133/165	ng/g	-	-	-	-
2,2',3,3',5,6-HxCB	PCB-134	ng/g	-	-	-	-
2,2',3,3',5,6'-HxCB	PCB-135	ng/g	-	-	-	-
2,2',3,3',6,6'-HxCB	PCB-136	ng/g	-	-	-	-
2,2',3,4,4',5-HxCB	PCB-137	ng/g	-	-	-	-
	PCB-138/160	ng/g	-	-	-	-
	PCB-139/149	ng/g	-	-	-	-
2,2',3,4,4',6'-HxCB	PCB-140	ng/g	-	-	-	-
2,2',3,4,5,5'-HxCB	PCB-141	ng/g	-	-	-	-
2,2',3,4,5,6-HxCB	PCB-142	ng/g	-	-	-	-
2,2',3,4,5,6'-HxCB	PCB-143	ng/g	-	-	-	-
2,2',3,4,5',6-HxCB	PCB-144	ng/g	-	-	-	-
2,2',3,4,6,6'-HxCB	PCB-145	ng/g	-	-	-	-
2,2',3,4',5,6-HxCB	PCB-147	ng/g	-	-	-	-
2,2',3,4',5,6'-HxCB	PCB-148	ng/g	-	-	-	-
2,2',3,4',6,6'-HxCB	PCB-150	ng/g	-	-	-	-
2,2',3,5,5',6-HxCB	PCB-151	ng/g	-	-	-	-
2,2',3,5,6,6'-HxCB	PCB-152	ng/g	-	-	-	-
	PCB-153/168	ng/g	-	-	-	-
2,2',4,4',5,6'-HxCB	PCB-154	ng/g	-	-	-	-
2,2',4,4',6,6'-HxCB	PCB-155	ng/g	-	-	-	-
2,3,3',4,4',5-HxCB	PCB-156	ng/g	-	-	-	-
2,3,3',4,4',5'-HxCB	PCB-157	ng/g	-	-	-	-
2,3,3',4,4',6-HxCB	PCB-158	ng/g	-	-	-	-
2,3,3',4,5,5'-HxCB	PCB-159	ng/g	-	-	-	-
2,3,3',4,5',6-HxCB	PCB-161	ng/g	-	-	-	-
2,3,3',4',5,5'-HxCB	PCB-162	ng/g	-	-	-	-
	PCB-163/164	ng/g	-	-	-	-
2,3,4,4',5,6-HxCB	PCB-166	ng/g	-	-	-	-
2,3',4,4',5,5'-HxCB	PCB-167	ng/g	-	-	-	-
3,3',4,4',5,5'-HxCB	PCB-169	ng/g	-	-	-	-
	PCB-170/190	ng/g	-	-	-	-
2,2',3,3',4,4',6-HpCB	PCB-171	ng/g	-	-	-	-
	PCB-172/192	ng/g	-	-	-	-
2,2',3,3',4,5,6-HpCB	PCB-173	ng/g	-	-	-	-
2,2',3,3',4,5,6'-HpCB	PCB-174	ng/g	-	-	-	-
2,2',3,3',4,5',6-HpCB	PCB-175	ng/g	-	-	-	-
2,2',3,3',4,6,6'-HpCB	PCB-176	ng/g	-	-	-	-
2,2',3,3',4,5',6'-HpCB	PCB-177	ng/g	-	-	-	-
2,2',3,3',5,5',6-HpCB	PCB-178	ng/g	-	-	-	-
2,2',3,3',5,6,6'-HpCB	PCB-179	ng/g	-	-	-	-
	PCB-180/193	ng/g	-	-	-	-
2,2',3,4,4',5,6-HpCB	PCB-181	ng/g	-	-	-	-
	PCB-182/187	ng/g	-	-	-	-

Table A2.3 (Cont'd.)

Analyte	Description	Unit	CCME	Tissue Residue Objectives for the Lower Columbia	B.C. Approved Guidelines	Other
PCBs, cont'd.						
IUPAC Name	***PCB #***					
2,2',3,4,4',5',6-HpCB	PCB-183	ng/g	-	-	-	-
2,2',3,4,4',6,6'-HpCB	PCB-184	ng/g	-	-	-	-
2,2',3,4,5,5',6-HpCB	PCB-185	ng/g	-	-	-	-
2,2',3,4,5,6,6'-HpCB	PCB-186	ng/g	-	-	-	-
2,2',3,4',5,6,6'-HpCB	PCB-188	ng/g	-	-	-	-
2,3,3',4,4',5,5'-HpCB	PCB-189	ng/g	-	-	-	-
2,3,3',4,4',5',6-HpCB	PCB-191	ng/g	-	-	-	-
2,2',3,3',4,4',5,5'-OcCB	PCB-194	ng/g	-	-	-	-
2,2',3,3',4,4',5,6-OcCB	PCB-195	ng/g	-	-	-	-
	PCB-196/203	ng/g	-	-	-	-
2,2',3,3',4,4',6,6'-OcCB	PCB-197	ng/g	-	-	-	-
2,2',3,3',4,5,5',6-OcCB	PCB-198	ng/g	-	-	-	-
2,2',3,3',4,5,5',6'-OcCB	PCB-199	ng/g	-	-	-	-
2,2',3,3',4,5,6,6'-OcCB	PCB-200	ng/g	-	-	-	-
2,2',3,3',4,5',6,6'-OcCB	PCB-201	ng/g	-	-	-	-
2,2',3,3',5,5',6,6'-OcCB	PCB-202	ng/g	-	-	-	-
2,2',3,4,4',5,6,6'-OcCB	PCB-204	ng/g	-	-	-	-
2,3,3',4,4',5,5',6-OcCB	PCB-205	ng/g	-	-	-	-
2,2',3,3',4,4',5,5',6-NoCB	PCB-206	ng/g	-	-	-	-
2,2',3,3',4,4',5,6,6'-NoCB	PCB-207	ng/g	-	-	-	-
2,2',3,3',4,5,5',6,6'-NoCB	PCB-208	ng/g	-	-	-	-
2,2',3,3',4,4',5,5',6,6'-DeCB	PCB-209	ng/g	-	-	-	-
Homologs	***# Congeners***				-	-
Monochlorobiphenyls	3	ng/g	-	-	-	-
Dichlorobiphenyls	12	ng/g	-	-	-	-
Trichlorobiphenyls	24	ng/g	-	-	-	-
Tetrachlorobiphenyls	42	ng/g	-	-	-	-
Pentachlorobiphenyls	46	ng/g	-	-	-	-
Hexachlorobiphenyls	42	ng/g	-	-	-	-
Heptachlorobiphenyls	24	ng/g	-	-	-	-
Octachlorobiphenyls	12	ng/g	-	-	-	-
Nonachlorobiphenyls	3	ng/g	-	-	-	-
Decachlorobiphenyl	1	ng/g	-	-	-	-
Total PCB		*ng TEQ/kg diet ww*	*0.79*	-	*2.0 ug/g*	-
PolyBrominated Diphenyl Ethers						
	PBDE #		-	-	-	-
2-MoBDE	1	ng/g	-	-	-	-
3-MoBDE	2	ng/g	-	-	-	-
4-MoBDE	3	ng/g	-	-	-	-
2,4-DiBDE	7	ng/g	-	-	-	-
2,4'-DiBDE	8 + 11	ng/g	-	-	-	-
2,6-DiBDE	10	ng/g	-	-	-	-
3,3'-DiBDE	8 + 11	ng/g	-	-	-	-
3,4-DiBDE	12 + 13	ng/g	-	-	-	-
3,4'-DiBDE	12 + 13	ng/g	-	-	-	-
4,4'-DiBDE	15	ng/g	-	-	-	-
2,2',4-TriBDE	17 + 25	ng/g	-	-	-	-
2,4,4'-TriBDE	28 + 33	ng/g	-	-	-	-
2,4,6-TriBDE	30	ng/g	-	-	-	-
2,4',6-TriBDE	32	ng/g	-	-	-	-
3,3',4-TriBDE	35	ng/g	-	-	-	-
3,4,4'-TriBDE	37	ng/g	-	-	-	-
2,2',4,4'-TeBDE	47	ng/g	-	-	-	-

Table A2.3 (Cont'd.)

Analyte	Description	Unit	CCME	Tissue Residue Objectives for the Lower Columbia	B.C. Approved Guidelines	Other
PolyBrominated Diphenyl Ethers, cont'd.						
	PBDE #					
2,2',4,5'-TeBDE	49	ng/g	-	-	-	-
2,2',4,6'-TeBDE	51	ng/g	-	-	-	-
2,3',4,4'-TeBDE	66	ng/g	-	-	-	-
2,3',4',6-TeBDE	71	ng/g	-	-	-	-
2,4,4',6-TeBDE	75	ng/g	-	-	-	-
3,3',4,4'-TeBDE	77	ng/g	-	-	-	-
3,3',4,5'-TeBDE	79	ng/g	-	-	-	-
2,2',3,4,4'-PeBDE	85	ng/g	-	-	-	-
2,2',4,4',5-PeBDE	99	ng/g	-	-	-	-
2,2',4,4',6-PeBDE	100	ng/g	-	-	-	-
2,3,3',4,4'-PeBDE	105	ng/g	-	-	-	-
2,3,4,5,6-PeBDE	116	ng/g	-	-	-	-
2,3',4,4',6-PeBDE	119 + 120	ng/g	-	-	-	-
3,3',4,4',5-PeBDE	126	ng/g	-	-	-	-
2,2',3,3',4,4'-HxBDE	128	ng/g	-	-	-	-
2,2',3,4,4',5'-HxBDE	138 + 166	ng/g	-	-	-	-
2,2',3,4,4',6'-HxBDE	140	ng/g	-	-	-	-
2,2',4,4',5,5'-HxBDE	153	ng/g	-	-	-	-
2,2',4,4',5,6'-HxBDE	154	ng/g	-	-	-	-
2,2',4,4',6,6'-HxBDE	155	ng/g	-	-	-	-
2,3,3',4,4',5,-HxBDE	156	ng/g	-	-	-	-
2,2',3,4,4',5,6-HpBDE	181	ng/g	-	-	-	-
2,2',3,4,4',5',6-HpBDE	183	ng/g	-	-	-	-
2,2',3,4,4',6,6'-HpBDE	184	ng/g	-	-	-	-
2,3,3',4,4',5,6-HpBDE	190	ng/g	-	-	-	-
2,3,3',4,4',5',6-HpBDE	191	ng/g	-	-	-	-
2,2',3,3',4,4',6,6'-OcBDE	197	ng/g	-	-	-	-
2,2',3,3',4,4',5,6'-OcBDE	196	ng/g	-	-	-	-
2,2',3,4,4',5,5',6-OcBDE	203	ng/g	-	-	-	-
2,2',3,3',4,4',5,5',6-NoBDE	206	ng/g	-	-	-	-
2,2',3,3',4,4',5,6,6'-NoBDE	207	ng/g	-	-	-	-
2,2',3,3',4,5,5',6,6'-NoBDE	208	ng/g	-	-	-	-
2,2',3,3',4,4',5,5',6,6'-DeBDE	209	ng/g	-	-	-	-
Pentabromodiphenyl ether		µg/kg-day	-	-	-	2[a]
Octabromodiphenyl ether		µg/kg-day	-	-	-	3[a]
Decabromodiphenyl ether		µg/kg-day	-	-	-	10[a]

[a] Reference dose (dose not likely to result in noncancer health effects); Dr. Luanne K. Williams, North Carolina Department of Health and Human Services. http://www.epa.gov/waterscience/fish/forum/pdfs/NC_pbdTX.pdf

Appendix A3

QA/QC Data for Water and Sediments

Table A3.1 Sediment sample QA/QC (Waneta 1999).

Analytical Group	Unit	Waneta A Original	Waneta A Duplicate	% RPD
Total Organic Carbon				
Carbon, Total Organic	%	0.12	Not run	
Total Metals (ICPMS)				
Aluminum (Al)	µg/g	8,610	8,980	4
Antimony (Sb)	µg/g	80	64.3	22
Arsenic (As)	µg/g	19.7	22.7	14
Barium (Ba)	µg/g	914	905	1
Beryllium (Be)	µg/g	0.47	0.44	7
Bismuth (Bi)	µg/g	0.222	0.19	16
Boron (B)	µg/g	24	25	4
Cadmium (Cd)	µg/g	1.47	1.14	25
Calcium (Ca)	µg/g	22,400	21,900	2
Chromium (Cr)	µg/g	58	62	7
Cobalt (Co)	µg/g	34.9	35.7	2
Copper (Cu)	µg/g	1060	1110	5
Gallium (Ga)	µg/g	10.3	10.6	3
Germanium (Ge)	µg/g	10.5	6.47	47
Indium (In)	µg/g	9.08	8.95	1
Iron (Fe)	µg/g	79,400	82,900	4
Lead (Pb)	µg/g	216	203	6
Lithium (Li)	µg/g	7.83	7.75	1
Magnesium (Mg)	µg/g	3700	3940	6
Manganese (Mn)	µg/g	1870	1900	2
Mercury (Hg)	µg/g	0.03	0.02	40
Molybdenum (Mo)	µg/g	15.9	15.9	0
Nickel (Ni)	µg/g	13.3	13.7	3
Selenium (Se)	µg/g	0.9	0.9	0
Silver (Ag)	µg/g	4.24	6.17	37
Strontium (Sr)	µg/g	193	198	3
Tellurium (Te)	µg/g	0.06	0.05	18
Thallium (Tl)	µg/g	0.204	0.195	5
Thorium (Th)	µg/g	3.92	4.39	11
Tin (Sn)	µg/g	66.6	63.7	4
Titanium (Ti)	µg/g	645	690	7
Tungsten (W)	µg/g	4.34	3.83	12
Uranium (U)	µg/g	2.23	2.24	0
Vanadium (V)	µg/g	27.9	33.1	17
Zinc (Z)	µg/g	5520	5920	7

Table A3.2 Sediment sample QA/QC (Beaver Creek 2004).

Analytical Group	Unit	Beaver Creek	Beaver Creek Replicate	% RPD	Equipment Swab	MDL
Physical						
Gravel > 2.0 mm	%(W/W)	0.89	0.56	46	NA	NA
Sand <2.00 mm > 0.063 mm	%(W/W)	62.66	62.63	0	NA	NA
Silt < 0.063 mm > 0.004 mm	%(W/W)	28.45	29.05	2	NA	NA
Clay < 0.004 mm	%(W/W)	8	7.77	3	NA	NA
Moisture	%(W/W)	44.9	45.8	2	NA	0.1
Total Organic Carbons						
Organic Carbon - Total	µg/g	18000	16000	12	NA	
Inorganic Carbon - Total	µg/g	< 500	500	0	NA	500
Carbon - Total	µg/g	18,000	16,000	12	NA	500
Acid Volatile Sulfides	µg/g	10	14	33	NA	0.2
Acid Volatile Sulfides	µmol/g	0.326	0.451	32	NA	0.006
Total Metals (ICPMS)						
Aluminum (Al)	µg/g	11,200	10,200	9	< 100	100
Antimony (Sb)	µg/g	6.1	6.3	3	12.1	0.1
Arsenic (As)	µg/g	5.4	5.1	6	< 0.2	0.2
Barium (Ba)	µg/g	113	106	6	< 0.1	0.1
Berylium (Be)	µg/g	0.4	0.3	29	< 0.1	0.1
Bismuth (Bi)	µg/g	0.5	0.3	50	< 0.1	0.1
Cadmium (Cd)	µg/g	2.65	2.14	21	< 0.05	0.05
Calcium (Ca)	µg/g	7,000	6,920	1	< 100	100
Chromium (Cr)	µg/g	28	27	4	< 1	1
Cobalt (Co)	µg/g	8.8	8.3	6	0.5	0.3
Copper (Cu)	µg/g	72.9	68.3	7	< 0.5	0.5
Iron (Fe)	µg/g	25,700	24,200	6	< 100	100
Lead (Pb)	µg/g	96.2	83.6	14	< 0.1	0.1
Magnesium (Mg)	µg/g	6,780	6,310	7	< 100	100
Manganese (Mn)	µg/g	290	266	9	1.2	0.2
Mercury (Hg)	µg/g	0.14	0.21	40	NA	0.05
Molybdenum (Mo)	µg/g	0.7	0.7	0	< 0.1	0.1
Nickel (Ni)	µg/g	21	19.3	8	< 0.8	0.8
Phosphorus (P)	µg/g	1460	1340	9	11	10
Potassium (K)	µg/g	1,690	1,550	9	< 100	100
Selenium (Se)	µg/g	0.7	0.8	13	< 0.5	0.5
Silver (Ag)	µg/g	0.95	1.12	16	< 0.05	0.05
Sodium (Na)	µg/g	242	214	12	< 100	100
Strontium (Sr)	µg/g	50.3	45.7	10	< 0.1	0.1
Tellurium (Te)	µg/g	0.1	0.1	0	< 0.1	0.1
Thallium (Tl)	µg/g	0.35	0.3	15	< 0.05	0.05
Tin (Sn)	µg/g	4.5	3.6	22	< 0.1	0.1
Titanium (Ti)	µg/g	758	732	3	< 1	1
Vanadium (V)	µg/g	45	44	2	< 2	2
Zinc (Z)	µg/g	600	546	9	< 1	1
Zirconium (Zr)	µg/g	2.5	1.9	27	< 0.5	0.5
Simultaneously Extracted Metals						
Aluminum (Al)	µmol/g	414	390	6	-	0.04
Antimony (Sb)	µmol/g	0.04	0.04	0	-	0.02
Arsenic (As)	µmol/g	0.06	0.07	15	-	0.03
Barium (Ba)	µmol/g	0.806	0.759	6	-	0.0004
Berylium (Be)	µmol/g	0.045	0.042	7	-	0.001
Bismuth (Bi)	µmol/g	0.02	0.02	0	-	0.01
Boron (B)	µmol/g	0.28	0.28	0	-	0.04
Cadmium (Cd)	µmol/g	0.008	0.004	67	-	0.001
Calcium (Ca)	µmol/g	184	179	3	-	0.06
Chromium (Cr)	µmol/g	0.611	0.582	5	-	0.005
Cobalt (Co)	µmol/g	0.137	0.127	8	-	0.004
Copper (Cu)	µmol/g	1.05	1.18	12	-	0.004

Table A3.2 (Cont'd.)

Analytical Group	Unit	Beaver Creek	Beaver Creek Replicate	% RPD	Equipment Swab	MDL
Simultaneously Extracted Metals, cont'd.						
Iron (Fe)	µmol/g	525	494	6	-	0.001
Lead (Pb)	µmol/g	0.372	0.419	12	-	0.007
Magnesium (Mg)	µmol/g	258	243	6	-	0.1
Manganese (Mn)	µmol/g	5.8	5.49	5	-	0.001
Molybdenum (Mo)	µmol/g	0.007	0.006	15	-	0.003
Nickel (Ni)	µmol/g	0.32	0.3	6	-	0.01
Phosphorus (P)	µmol/g	41.6	38.4	8	-	0.2
Potassium (K)	µmol/g	42	38	10	-	1
Selenium (Se)	µmol/g	0.1	0.09	11	-	0.02
Silicon (Si)	µmol/g	0.008	0.026	106	-	0.005
Silver (Ag)	µmol/g	13.4	11.2	18	-	0.1
Sodium (Na)	µmol/g	0.6	0.57	5	-	0.0006
Strontium (Sr)	µmol/g	21.8	19.9	9	-	0.2
Sulfur (S)	µmol/g	0.04	0.04	0	-	0.02
Tellurium (Te)	µmol/g	0.013	0.014	7	-	0.007
Tin (Sn)	µmol/g	0.031	0.031	0	-	0.008
Titanium (Ti)	µmol/g	19.9	19.5	2	-	0.003
Vanadium (V)	µmol/g	0.985	0.927	6	-	0.005
Zinc (Z)	µmol/g	7.67	7.51	2	-	0.004
Zirconium (Zr)	µmol/g	0.01	0.005	67	-	0.003
PCBs						
2-MoCB	pg/g dw	2.69	2.74	2	4.54	NA
3-MoCB	pg/g dw	0.944	0.689	31	3.15	NA
4-MoCB	pg/g dw	2.91	1.56	60	5.52	NA
2,2'-DiCB	pg/g dw	2.57	2.66	3	11.7	NA
2,3-DiCB	pg/g dw	0.194	0.147	28	< 4.09	NA
2,3'-DiCB	pg/g dw	1.54	1.37	12	< 3.86	NA
2,4-DiCB	pg/g dw	1.77	0.442	120	< 3.81	NA
2,4'-DiCB	pg/g dw	6.66	6.8	2	18.3	NA
2,5-DiCB	pg/g dw	0.597	0.469	24	< 3.81	NA
2,6-DiCB	pg/g dw	0.107	0.13	19	< 3.91	NA
3,3'-DiCB	pg/g dw	3.87	4.34	11	29.6	NA
3,4-DiCB	pg/g dw	1.27	0.697	58	< 4.11	NA
3,5-DiCB	pg/g dw	0.12	0.124	3	< 3.95	NA
4,4'-DiCB	pg/g dw	7.15	6.43	11	9.13	NA
2,2',3-TriCB	pg/g dw	3.11	3.56	13	6.37	NA
2,2',4-TriCB	pg/g dw	3.56	4.32	19	6.97	NA
2,2',5-TriCB	pg/g dw	6.91	8.63	22	13.1	NA
2,2',6-TriCB	pg/g dw	0.974	0.903	8	4.81	NA
2,3,3'-TriCB	pg/g dw	15.7	16	2	21.2	NA
2,3,4-TriCB	pg/g dw	6.62	7.81	16	10.5	NA
2,3,4'-TriCB	pg/g dw	5.15	5.51	7	6.86	NA
2,3,5-TriCB	pg/g dw	< 0.0548	0.0496	10	< 0.63	NA
2,3,6-TriCB	pg/g dw	0.133	0.147	10	< 0.5	NA
2,3',4-TriCB	pg/g dw	1.01	1.25	21	1.89	NA
2,3',5-TriCB	pg/g dw	2.32	2.7	15	4.21	NA
2,3',6-TriCB	pg/g dw	0.595	0.617	4	1.53	NA
2,4',5-TriCB	pg/g dw	12	14.9	22	17.9	NA
2,4',6-TriCB	pg/g dw	1.95	2.14	9	4.37	NA
2',3,5-TriCB	pg/g dw	0.067	0.104	43	< 0.63	NA
3,3',4-TriCB	pg/g dw	0.412	0.374	10	0.736	NA
3,3',5-TriCB	pg/g dw	0.075	0.071	5	< 0.606	NA
3,4,4'-TriCB	pg/g dw	4.63	4.93	6	4.94	NA
3,4,5-TriCB	pg/g dw	0.207	0.228	10	< 0.638	NA
3,4',5-TriCB	pg/g dw	0.118	0.138	16	< 0.592	NA
2,2',3,3'-TeCB	pg/g dw	7.92	6.95	13	6.22	NA

Table A3.2 (Cont'd.)

Analytical Group	Unit	Beaver Creek	Beaver Creek Replicate	% RPD	Equipment Swab	MDL
PCBs, cont'd.						
2,2',3,4'-TeCB	pg/g dw	3.81	3.66	4	3.43	NA
2,2',3,5-TeCB	pg/g dw	0.586	0.541	8	< 0.834	NA
2,2',3,5'-TeCB	pg/g dw	31.1	20.9	39	15.6	NA
2,2',3,6-TeCB	pg/g dw	2.97	2.17	31	3.37	NA
2,2',3,6'-TeCB	pg/g dw	0.813	0.73	11	< 0.837	NA
2,2',4,5-TeCB	pg/g dw	3.03	3.1	2	2.85	NA
2,2',4,5'-TeCB	pg/g dw	13.6	11.8	14	9.44	NA
2,2',4,6-TeCB	pg/g dw	2	2.09	4	2.33	NA
2,2',5,5'-TeCB	pg/g dw	52.1	37.9	32	19.3	NA
2,2',6,6'-TeCB	pg/g dw	< 0.0467	0.0496	6	< 0.642	NA
2,3,3',4-TeCB	pg/g dw	0.251	0.396	45	< 1.24	NA
2,3,3',4'-TeCB	pg/g dw	8.29	6.74	21	5.06	NA
2,3,3',5-TeCB	pg/g dw	< 0.127	0.158	22	< 1.21	NA
2,3,3',5'-TeCB	pg/g dw	< 0.129	0.161	22	< 1.19	NA
2,3,3',6-TeCB	pg/g dw	1.21	1.24	2	1.34	NA
2,3,4,4'-TeCB	pg/g dw	4.64	3.56	26	2.89	NA
2,3,4,5-TeCB	pg/g dw	57	47.4	18	20.2	NA
2,3,4',5-TeCB	pg/g dw	0.855	0.736	15	< 1.17	NA
2,3,4',6-TeCB	pg/g dw	9.44	7.77	19	4.83	NA
2,3',4,4'-TeCB	pg/g dw	19.8	17.2	14	9.85	NA
2,3',4,5-TeCB	pg/g dw	0.465	0.475	2	< 1.08	NA
2,3',4,5'-TeCB	pg/g dw	1.07	0.236	128	< 1.11	NA
2,3',5,5'-TeCB	pg/g dw	0.136	0.183	29	< 1.16	NA
2,3',5',6-TeCB	pg/g dw	< 0.0467	0.0496	6	< 0.532	NA
3,3',4,4'-TeCB	pg/g dw	2.33	2.19	6	1.5	NA
3,3',4,5-TeCB	pg/g dw	< 0.131	0.163	22	< 1.29	NA
3,3',4,5'-TeCB	pg/g dw	0.769	0.658	16	< 1.07	NA
3,3',5,5'-TeCB	pg/g dw	< 0.117	0.145	21	< 1.15	NA
3,4,4',5-TeCB	pg/g dw	< 0.132	0.167	23	< 1.35	NA
2,2',3,3',4-PeCB	pg/g dw	9.95	5.98	50	1.04	NA
2,2',3,3',5-PeCB	pg/g dw	46	29.7	43	6.92	NA
2,2',3,3',6-PeCB	pg/g dw	23.4	12.1	64	2.97	NA
2,2',3,4,4'-PeCB	pg/g dw	14.1	9.68	37	2.06	NA
2,2',3,4,5-PeCB	pg/g dw	60.2	41.1	38	7.1	NA
2,2',3,4,6-PeCB	pg/g dw	10	6.3	45	2.08	NA
2,2',3,4,6'-PeCB	pg/g dw	0.623	0.364	52	< 0.73	NA
2,2',3,4',5-PeCB	pg/g dw	102	65.8	43	11.2	NA
2,2',3,5,5'-PeCB	pg/g dw	17	11.4	39	1.72	NA
2,2',3,5,6-PeCB	pg/g dw	68.9	46.2	39	7.97	NA
2,2',3,5,6'-PeCB	pg/g dw	0.297	0.161	59	< 0.741	NA
2,2',3,6,6'-PeCB	pg/g dw	0.309	0.191	47	< 0.5	NA
2,2',4,5',6-PeCB	pg/g dw	0.416	0.304	31	< 0.63	NA
2,2',4,6,6'-PeCB	pg/g dw	< 0.0467	0.0496	6	< 0.5	NA
2,3,3',4,4'-PeCB	pg/g dw	36.1	27	29	3.94	NA
2,3,3',4,5-PeCB	pg/g dw	< 0.115	0.126	9	< 0.5	NA
2,3,3',4',5-PeCB	pg/g dw	3.66	2.78	27	< 0.5	NA
2,3,3',4,6-PeCB	pg/g dw	6.3	4.74	28	1.01	NA
2,3,3',4',6-PeCB	pg/g dw	102	70.3	37	10.8	NA
2,3,3',5,5'-PeCB	pg/g dw	< 0.0467	0.0534	13	< 0.528	NA
2,3,3',5,6-PeCB	pg/g dw	< 0.0467	0.0568	20	< 0.528	NA
2,3,4,4',5-PeCB	pg/g dw	1.93	1.45	28	1.1	NA
2,3',4,4',5-PeCB	pg/g dw	86.9	64.1	30	9.5	NA
2,3',4,5,5'-PeCB	pg/g dw	0.09	0.107	17	< 0.526	NA
2,3',4,5',6-PeCB	pg/g dw	< 0.0467	0.0541	15	< 0.509	NA
2',3,3',4,5-PeCB	pg/g dw	1.01	0.797	24	< 0.5	NA
2',3,4,4',5-PeCB	pg/g dw	1.28	1.01	24	< 0.5	NA

Table A3.2 (Cont'd.)

Analytical Group	Unit	Beaver Creek	Beaver Creek Replicate	% RPD	Equipment Swab	MDL
PCBs, cont'd.						
3,3',4,4',5-PeCB	pg/g dw	0.39	0.366	6	< 0.5	NA
3,3',4,5,5'-PeCB	pg/g dw	0.197	0.151	26	< 0.5	NA
2,2',3,3',4,4'-HxCB	pg/g dw	24.3	14	54	1.45	NA
2,2',3,3',4,5-HxCB	pg/g dw	146	101	36	12	NA
2,2',3,3',4,5'-HxCB	pg/g dw	8.79	5.67	43	0.718	NA
2,2',3,3',4,6-HxCB	pg/g dw	1.67	1.25	29	< 0.569	NA
2,2',3,3',4,6'-HxCB	pg/g dw	43.9	27.2	47	2.84	NA
2,2',3,3',5,5'-HxCB	pg/g dw	1.56	1.18	28	< 0.575	NA
2,2',3,3',5,6-HxCB	pg/g dw	6.63	4.84	31	0.928	NA
2,2',3,3',5,6'-HxCB	pg/g dw	36.9	31	17	4.71	NA
2,2',3,3',6,6'-HxCB	pg/g dw	15.4	9.29	49	1.45	NA
2,2',3,4,4',5-HxCB	pg/g dw	7.47	3.99	61	0.751	NA
2,2',3,4,4',6-HxCB	pg/g dw	2.15	1.49	36	< 0.529	NA
2,2',3,4,5,5'-HxCB	pg/g dw	25.9	19.8	27	2.14	NA
2,2',3,4,5,6-HxCB	pg/g dw	< 0.197	0.144	31	< 0.589	NA
2,2',3,4,5',6-HxCB	pg/g dw	5.66	4.93	14	0.676	NA
2,2',3,4,6,6'-HxCB	pg/g dw	< 0.0467	0.0496	6	< 0.5	NA
2,2',3,4',5,5'-HxCB	pg/g dw	17	13.6	22	2.01	NA
2,2',3,4',5,6-HxCB	pg/g dw	94.2	81.5	14	8.63	NA
2,2',3,4',5,6'-HxCB	pg/g dw	0.087	0.079	10	< 0.5	NA
2,2',3,4',6,6'-HxCB	pg/g dw	0.121	0.084	36	< 0.5	NA
2,2',3,5,6,6'-HxCB	pg/g dw	0.098	0.07	33	< 0.5	NA
2,2',4,4',5,5'-HxCB	pg/g dw	102	81.1	23	10.2	NA
2,2',4,4',6,6'-HxCB	pg/g dw	0.057	0.0496	14	< 0.5	NA
2,3,3',4,4',5-HxCB	pg/g dw	17.6	10.6	50	1.36	NA
2,3,3',4,4',6-HxCB	pg/g dw	14.5	10.4	33	1.56	NA
2,3,3',4,5,5'-HxCB	pg/g dw	1.29	1.31	2	< 0.5	NA
2,3,3',4,5',6-HxCB	pg/g dw	< 0.141	0.103	31	< 0.5	NA
2,3,3',4',5,5'-HxCB	pg/g dw	0.458	0.315	37	< 0.5	NA
2,3,3',4',5',6-HxCB	pg/g dw	9.17	6.87	29	0.557	NA
2,3,3',5,5',6-HxCB	pg/g dw	< 0.15	0.11	31	< 0.5	NA
2,3',4,4',5,5'-HxCB	pg/g dw	5.34	3.45	43	< 0.5	NA
3,3',4,4',5,5'-HxCB	pg/g dw	< 0.225	0.149	41	< 0.5	NA
2,2',3,3',4,4',5-HpCB	pg/g dw	29.3	22.5	26	1.89	NA
2,2',3,3',4,4',6-HpCB	pg/g dw	9.3	7.41	23	0.691	NA
2,2',3,3',4,5,5'-HpCB	pg/g dw	5.56	4.82	14	< 0.5	NA
2,2',3,3',4,5,6'-HpCB	pg/g dw	31.5	28.1	11	2.42	NA
2,2',3,3',4,5',6-HpCB	pg/g dw	1.3	1.16	11	< 0.5	NA
2,2',3,3',4,6,6'-HpCB	pg/g dw	3.92	3.32	17	< 0.5	NA
2,2',3,3',4',5,6-HpCB	pg/g dw	18.3	16.7	9	1.29	NA
2,2',3,3',5,5',6-HpCB	pg/g dw	6.62	6.59	0	0.854	NA
2,2',3,3',5,6,6'-HpCB	pg/g dw	13	12.3	6	1.55	NA
2,2',3,4,4',5,5'-HpCB	pg/g dw	65.5	60.7	8	5.02	NA
2,2',3,4,4',5,6-HpCB	pg/g dw	0.295	0.163	58	< 0.5	NA
2,2',3,4,4',5,6'-HpCB	pg/g dw	0.244	0.154	45	< 0.5	NA
2,2',3,4,4',5',6-HpCB	pg/g dw	22	20.1	9	2.57	NA
2,2',3,4,4',6,6'-HpCB	pg/g dw	0.132	0.123	7	< 0.5	NA
2,2',3,4,5,6,6'-HpCB	pg/g dw	< 0.0467	0.0496	6	< 0.5	NA
2,2',3,4',5,5',6-HpCB	pg/g dw	45.6	45.8	0	3.86	NA
2,2',3,4',5,6,6'-HpCB	pg/g dw	0.054	0.087	47	< 0.5	NA
2,3,3',4,4',5,5'-HpCB	pg/g dw	1.24	0.913	30	< 0.5	NA
2,3,3',4,4',5,6-HpCB	pg/g dw	5.99	5.05	17	< 0.5	NA
2,3,3',4,4',5',6-HpCB	pg/g dw	1.09	1.06	3	< 0.5	NA
2,3,3',4,5,5',6-HpCB	pg/g dw	< 0.0467	0.0496	6	< 0.5	NA
2,2',3,3',4,4',5,5'-OcCB	pg/g dw	18.7	18.8	1	1.91	NA
2,2',3,3',4,4',5,6-OcCB	pg/g dw	6.02	5.59	7	0.764	NA

Table A3.2 (Cont'd.)

Analytical Group	Unit	Beaver Creek	Beaver Creek Replicate	% RPD	Equipment Swab	MDL
PCBs, cont'd.						
2,2',3,3',4,4',5,6'-OcCB	pg/g dw	8.84	9.69	9	1.29	NA
2,2',3,3',4,4',6,6'-OcCB	pg/g dw	3.22	G 3.84		< 0.5	NA
2,2',3,3',4,5,5',6-OcCB	pg/g dw	27.3	35.7	27	1.63	NA
2,2',3,3',4,5',6,6'-OcCB	pg/g dw	2.84	3.37	17	< 0.5	NA
2,2',3,3',5,5',6,6'-OcCB	pg/g dw	6.2	8.12	27	< 0.5	NA
2,2',3,4,4',5,5',6-OcCB	pg/g dw	16.8	20.7	21	1.26	NA
2,2',3,4,4',5,6,6'-OcCB	pg/g dw	< 0.0467	0.0496	6	< 0.5	NA
2,3,3',4,4',5,5',6-OcCB	pg/g dw	0.871	0.753	15	< 0.5	NA
2,2',3,3',4,4',5,5',6-NoCB	pg/g dw	24.5	48.7	66	< 2.78	NA
2,2',3,3',4,4',5,6,6'-NoCB	pg/g dw	1.93	2.09	8	< 2.17	NA
2,2',3,3',4,5,5',6,6'-NoCB	pg/g dw	7.73	16	70	< 2.33	NA
2,2',3,3',4,4',5,5',6,6'-DeCB	pg/g dw	7.33	18.6	87	1.23	NA
% Moisture	pg/g dw	50	50.9	2	0	NA
Total Monochloro Biphenyls	pg/g dw	6.54	4.99	27	10.1	NA
Total Dichloro Biphenyls	pg/g dw	25.7	23.4	9	68.7	NA
Total Trichloro Biphenyls	pg/g dw	65.4	74.3	13	98.3	NA
Total Tetrachloro Biphenyls	pg/g dw	224	178	23	90.9	NA
Total Pentachloro Biphenyls	pg/g dw	592	401	38	55.2	NA
Total Hexachloro Biphenyls	pg/g dw	588	435	30	46.9	NA
Total Heptachloro Biphenyls	pg/g dw	261	236	10	11.3	NA
Total Octachloro Biphenyls	pg/g dw	90.8	107	16	4.8	NA
Total Nonachloro Biphenyls	pg/g dw	34.2	66.8	65	< 2.78	NA
Decachloro Biphenyl	pg/g dw	7.33	18.6	87	1.23	NA
TOTAL PCBs	pg/g dw	1900	1540	21	387	NA
TEQ (WHO 1998) ND=0	pg/g dw	0.0616	0.0155	120	0.00189	NA
TEQ (WHO 1998) ND=1/2DL	pg/g dw	0.0627	0.0243	88	0.0297	NA
PBDEs						
2-MoBDE	pg/g	NQ	NQ	NA	NQ	NA
3-MoBDE	pg/g	NQ	NQ	NA	NQ	NA
4-MoBDE	pg/g	NQ	NQ	NA	NQ	NA
2,4-DiBDE	pg/g	< 0.516	1.28	85	< 1.01	NA
2,4'-DiBDE	pg/g	< 0.896	0.722	22	< 1	NA
2,6-DiBDE	pg/g	NQ	NQ		NQ	NA
3,4-DiBDE	pg/g	< 0.324	0.366	12	1.88	NA
4,4'-DiBDE	pg/g	0.891	0.779	13	1.42	NA
DiBDE		2.6	3.1	18	NA	NA
2,2',4-TriBDE	pg/g	13.6	13.3	2	2	NA
2,4,4'-TriBDE	pg/g	6.48	6.02	7	5.8	NA
2,4,6-TriBDE	pg/g	< 0.414	0.532	25	< 1.15	NA
2,4',6-TriBDE	pg/g	< 0.327	0.42	25	< 1	NA
3,3',4-TriBDE	pg/g	0.824	0.668	21	1.7	NA
3,4,4'-TriBDE	pg/g	0.419	0.393	6	4.53	NA
TriBDE		22.1	21.3	3	NA	NA
2,2',4,4'-TeBDE	pg/g	538	501	7	95.3	NA
2,2',4,5'-TeBDE	pg/g	23.8	24.9	5	3.06	NA
2,2',4,6'-TeBDE	pg/g	1.53	1.46	5	< 1.21	NA
2,3',4,4'-TeBDE	pg/g	18.4	15.5	17	< 1.82	NA
2,3',4',6-TeBDE	pg/g	3.55	3.25	9	< 1.64	NA
2,4,4',6-TeBDE	pg/g	0.835	0.824	1	< 1.38	NA
3,3',4,4'-TeBDE	pg/g	0.392	0.344	13	< 1.12	NA
3,3',4,5'-TeBDE	pg/g	3.34	3.16	6	< 1.28	NA
TeBDE		589.8	550.4	7	NA	NA
2,2',3,4,4'-PeBDE	pg/g	34.9	26.6	27	7.52	NA
2,2',4,4',5-PeBDE	pg/g	612	578	6	81.1	NA
2,2',4,4',6-PeBDE	pg/g	147	129	13	18.4	NA
2,3,3',4,4'-PeBDE	pg/g	< 2.67	2.55	5	< 4.72	NA

Table A3.2 (Cont'd.)

Analytical Group	Unit	Beaver Creek	Beaver Creek Replicate	% RPD	Equipment Swab	MDL
PBDEs, cont'd.						
2,3,4,5,6-PeBDE	pg/g	< 3.31	3.16	5	< 6.76	NA
2,3',4,4',6-PeBDE	pg/g	1.86	2.44	27	< 4.31	NA
3,3',4,4',5-PeBDE	pg/g	< 1.03	1	3	< 2.3	NA
PeBDE		802.8	742.8	8	125.11	NA
2,2',3,3',4,4'-HxBDE	pg/g	< 3.22	3.49	8	< 7.78	NA
2,2',3,4,4',5'-HxBDE	pg/g	9.48	5.84	48	< 2.57	NA
2,2',3,4,4',6'-HxBDE	pg/g	3.5	2.24	44	< 1.73	NA
2,2',4,4',5,5'-HxBDE	pg/g	74.9	57	27	11.6	NA
2,2',4,4',5,6'-HxBDE	pg/g	62.7	50.9	21	6.39	NA
2,2',4,4',6,6'-HxBDE	pg/g	3.69	3.33	10	2.67	NA
HxBDE		157.49	122.8	25	NA	NA
2,2',3,4,4',5,6-HpBDE	pg/g	< 0.811	0.928	13	< 3.25	NA
2,2',3,4,4',5',6-HpBDE	pg/g	9.41	10.3	9	6.2	NA
2,3,3',4,4',5,6-HpBDE	pg/g	< 1.27	1.45	13	< 4.53	NA
HpBDE		11.491	12.678	10	NA	NA
2,2',3,4,4',5,5',6-OcBDE	pg/g	2.47	1.22	68	7.17	NA
OcBDE		NA	NA	NA	NA	NA
2,2',3,3',4,4',5,5',6-NoBDE	pg/g	9.77	5.8	51	70.1	NA
2,2',3,3',4,4',5,6,6'-NoBDE	pg/g	7.74	3.43	77	89.7	NA
2,2',3,3',4,5,5',6,6'-NoBDE	pg/g	9.33	4.35	73	71.2	NA
NoBDE		26.84	13.58	66	NA	NA
2,2',3,3',4,4',5,5',6,6'-DeBDE	pg/g	998	NQ	NA	1110	NA
% Moisture	%	47.8	51	6	0	NA

Table A3.3 Water sample QA/QC (Birchbank 2000 to 2003).

Parameter		Unit	2000					2002			2003					
			15-Nov					16-Dec			17-Feb			13-May		
			Field Blank (with preservative)	Field Blank	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD
General																
Flow		kcfs	61	61	64.8	61	6	82	87	6	34	34	0	44	44	0
Temp		°C	-	-	-	-	NA	5		NA	3.8	3.8	0	9.6	9.6	0
Specific Conductance		µS/cm	-	-	-	-	NA	119		NA	147	147	0	106	106	0
Diss Oxy		mg/L	-	-	-	-	NA	9		NA	10.1	10.1	0	12.3	12.3	0
pH		pH units	-	-	7.83	-	NA	8	7.8	0	8	7.9	0	8	8	0
Field pH		pH units	-	-	-	-	NA	7		NA	7.52	7.52	0	8	8	0
Turbidity		NTU	-	-	0.09	-	NA	0.3	0.29	16	0.3	0.43	42	0.29	0.3	3
Physical																
Hardness Total (T)		mg/L	-	-	59.9	59.5	1	58	59.5	2	69.2	69.8	1	70.5	70.1	1
Residue Non-filterable		mg/L	-	-	5	-	NA	4	4	0	4	4	0	4	4	0
Metals (ICPMS)																
Aluminum Al	T	µg/L	0.2	0.2	9.1	8.9	2	-	-	NA	7.9	10	23	12.1	12.6	4
Antimony Sb	T	µg/L	0.062	0.129	0.035	0.055	44	-	-	NA	0.037	0.037	0	0.055	0.053	4
Arsenic As	T	µg/L	0.1	0.1	0.1	0.1	0	-	-	NA	0.1	0.1	0	0.2	0.2	0
Barium Ba	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Barium Ba	T	µg/L	0.02	0.02	17.97	18	0	-	-	NA	19.6	19.6	0	22.6	23.2	3
Beryllium Be	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Beryllium Be	T	µg/L	0.002	0.002	0.002	0.002	0	-	-	NA	0.02	0.02	0	0.02	0.02	0
Bismuth Bi	T	µg/L	0.02	0.02	0.02	0.02	0	-	-	NA	0.02	0.02	0	0.02	0.02	0
Boron B	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Boron B	T	µg/L	2	2	2	2	0.00	-	-	NA	-	-	NA	-	-	NA
Cadmium Cd	E	µg/L	-	-	-	-	NA	0.02	-	NA	-	-	NA	-	-	NA
Cadmium Cd	T	µg/L	0.01	0.01	0.01	0.01	0	0.10	-	NA	0.12	0.13	8	0.02	0.02	0
Chromium Cr	E	µg/L	-	-	-	-	NA	0.10	-	NA	-	-	NA	-	-	NA
Chromium Cr	T	µg/L	0.2	0.2	0.2	0.2	0	0.20	-	NA	0.2	0.2	0	0.2	0.2	0
Cobalt Co	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Cobalt Co	T	µg/L	0.005	0.007	0.022	0.018	20	-	-	NA	0.005	0.005	0	0.005	0.005	0
Copper Cu	E	µg/L	-	-	-	-	NA	0.49	-	NA	-	-	NA	-	-	NA
Copper Cu	T	µg/L	0.05	0.05	0.29	0.31	7	0.40	-	NA	0.35	0.51	37	0.33	0.35	6
Gallium Ga	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Lanthanum La	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Lead Pb	E	µg/L	-	-	-	-	NA	0.08	-	NA	-	-	NA	-	-	NA
Lead Pb	T	µg/L	0.01	0.01	0.05	0.03	50	0.20	-	NA	0.06	0.11	59	0.05	0.06	18
Lithium Li	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Lithium Li	T	µg/L	0.05	0.05	0.89	0.95	7	-	-	NA	0.92	1.14	21	1.12	1.09	3
Magnesium Mg	T	µg/L	0.05	0.05	3800	3810	0	-	-	NA	-	4.63	NA	-	4.71	NA
Manganese Mn	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Manganese Mn	T	µg/L	0.005	0.005	1.031	0.965	7	-	-	NA	1.42	1.46	3	2.88	2.91	1
Molybdenum Mo	T	µg/L	0.07	0.16	0.49	0.5	2	-	-	NA	0.49	0.49	0	0.56	0.56	0
Nickel Ni	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Nickel Ni	T	µg/L	0.05	0.05	0.59	0.61	3	-	-	NA	0.3	0.29	3	0.05	0.05	0
Rubidium Rb	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Selenium Se	T	µg/L	0.2	0.2	0.2	0.2	0	-	-	NA	0.2	0.2	0	0.2	0.2	0

Table A3.3 (Cont'd.)

Parameter		Unit	2000					2002			2003					
			15-Nov					16-Dec			17-Feb			13-May		
			Field Blank (with preservative)	Field Blank	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD
Metals (ICPMS), cont'd.																
Silver Ag	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Silver Ag	T	µg/L	0.02	0.02	0.02	0.02	0	-	-	NA	0.02	0.02	0	0.02	0.02	0
Strontium Sr	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Strontium Sr	T	µg/L	0.012	0.019	102	103	1	-	-	NA	107	108	1	105	109	4
Thallium Tl	E	µg/L	-	-	-	-	NA	0	-	NA	-	-	NA	-	-	NA
Thallium Tl	T	µg/L	0.002	0.003	0.002	0.002	0	-	-	NA	0.002	0.002	0	0.002	0.002	0
Tin Sn	T	µg/L	0.3	0.24	0.01	0.02	67	-	-	NA	0.01	0.02	67	0.01	0.01	0
Uranium U	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Uranium U	T	µg/L	0.002	0.003	0.424	0.428	1	-	-	NA	0.465	0.465	0	0.497	0.497	0
Vandium V	E	µg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Vandium V	T	µg/L	0.05	0.05	0.18	0.14	25	-	-	NA	0.47	0.51	8	0.21	0.25	17
Zinc Zn	E	µg/L	-	-	-	-	NA	1	-	NA	-	-	NA	-	-	NA
Zinc Zn	T	µg/L	0.1	0.1	0.1	0.1	0	1	-	NA	0.9	1.2	29	1.4	1.5	7
Metals (ICP)																
Aluminum Al	E	mg/L	-	-	0.05	0.05	0	-	-	NA	-	-	NA	-	-	NA
Antimony Sb	E	mg/L	-	-	0.05	0.05	0	-	-	NA	-	-	NA	-	-	NA
Arsenic As	E	mg/L	-	-	0.05	0.05	0	-	-	NA	-	-	NA	-	-	NA
Barium Ba	E	mg/L	-	-	0.02	0.02	0	-	-	NA	-	-	NA	-	-	NA
Beryllium Be	E	mg/L	-	-	0.001	0.001	0	-	-	NA	-	-	NA	-	-	NA
Boron B	E	mg/L	-	-	0.01	0.01	0	-	-	NA	-	-	NA	-	-	NA
Cadmium Cd	E	mg/L	-	-	0.005	0.005	0	-	-	NA	-	-	NA	-	-	NA
Calcium Ca	E	mg/L	-	-	17.1	17	1	-	-	NA	-	-	NA	-	-	NA
Calcium Ca	T	mg/L	0.1	0.1	16.5	17	3	17	17.5	2	20.1	-	NA	20.5	-	NA
Chromium Cr	E	mg/L	-	-	0.006	0.005	18	-	-	NA	-	-	NA	-	-	NA
Cobalt Co	E	mg/L	-	-	0.005	0.005	0	-	-	NA	-	-	NA	-	-	NA
Copper Cu	E	mg/L	-	-	0.005	0.005	0	-	-	NA	-	-	NA	-	-	NA
Iron Fe	E	mg/L	-	-	0.023	0.023	0	-	-	NA	-	-	NA	-	-	NA
Iron Fe	T	mg/L	0.006	0.006	0.015	0.021	33	-	-	NA	-	-	NA	-	-	NA
Lead Pb	E	mg/L	-	-	0.05	0.05	0	-	-	NA	-	-	NA	-	-	NA
Magnesium Mg	E	mg/L	-	-	4.1	4.1	0	-	-	NA	-	-	NA	-	-	NA
Magnesium Mg	T	mg/L	-	-	-	-	NA	3.77	3.84	2	4.62	-	NA	4.68	-	NA
Manganese Mn	E	mg/L	-	-	0.001	0.001	0	-	-	NA	-	-	NA	-	-	NA
Molybdenum Mo	E	mg/L	-	-	0.01	0.01	0	-	-	NA	-	-	NA	-	-	NA
Nickel Ni	E	mg/L	-	-	0.02	0.02	0	-	-	NA	-	-	NA	-	-	NA
Phosphorus P	E	mg/L	-	-	0.1	0.1	0	-	-	NA	-	-	NA	-	-	NA
Phosphorus P	T	mg/L	0.1	0.1	0.1	0.1	0	-	-	NA	-	-	NA	-	-	NA
Potassium K	E	mg/L	-	-	0.6	0.6	0	-	-	NA	-	-	NA	-	-	NA
Potassium K	T	mg/L	0.1	0.1	0.6	0.6	0	-	-	NA	-	-	NA	-	-	NA
Selenium Se	E	mg/L	-	-	0.05	0.05	0	-	-	NA	-	-	NA	-	-	NA
Silicon Si	E	mg/L	-	-	1.64	1.62	1	-	-	NA	-	-	NA	-	-	NA
Silicon Si	T	mg/L	0.06	0.06	1.63	1.69	4	-	-	NA	-	-	NA	-	-	NA
Silver Ag	E	mg/L	-	-	0.01	0.01	0	-	-	NA	-	-	NA	-	-	NA

Table A3.3 (Cont'd.)

Parameter		Unit	2000					2002			2003					
			15-Nov					16-Dec			17-Feb			13-May		
			Field Blank (with preservative)	Field Blank	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD
Metals (ICP), cont'd.																
Sodium Na	E	mg/L	-	-	1.4	1.4	0	-	-	NA	-	-	NA	-	-	NA
Sodium Na	T	mg/L	0.1	0.1	1.3	1.4	7	-	-	NA	-	-	NA	-	-	NA
Strontium Sr	E	mg/L	-	-	0.107	0.106	1	-	-	NA	-	-	NA	-	-	NA
Sulphur S	E	mg/L	-	-	3.58	3.55	1	-	-	NA	-	-	NA	-	-	NA
Sulphur S	T	mg/L	0.06	0.06	3.67	3.76	2	-	-	NA	-	-	NA	-	-	NA
Tin Sn	E	mg/L	-	-	0.05	0.05	0	-	-	NA	-	-	NA	-	-	NA
Tin Sn	T	mg/L	-	-	-	-	NA	-	-	NA	-	-	NA	-	-	NA
Titanium Ti	E	mg/L	-	-	0.003	0.003	0	-	-	NA	-	-	NA	-	-	NA
Titanium Ti	T	mg/L	0.002	0.002	0.002	0.002	0	-	-	NA	-	-	NA	-	-	NA
Vandium V	E	mg/L	-	-	0.01	0.01	0	-	-	NA	-	-	NA	-	-	NA
Zinc Zn	E	mg/L	-	-	0.002	0.002	0	-	-	NA	-	-	NA	-	-	NA

Table A3.4 Water sample QA/QC (downstream STP 2003 to 2005).

Parameter		Unit	2003												
			17-Feb				13-May				4-Dec				
			Blank	Original Sample	Replicate	RPD	Blank	Original Sample	Replicate	RPD	Field Blank	Preservative Blank	Original Sample	Replicate	RPD
General															
Flow		kcfs	34	33.6	33.6	0.0	46.3	46.3	46.3	0.0	80	80	80	80	0
Temp		°C	-	3.9	3.9	0.0	-	9.9	9.9	0.0	-	-	4.9	-	NA
Specific Conductance		µS/cm	-	151	151	0.0	-	105	105	0.0	-	-	141	-	NA
Diss Oxy		mg/L	-	10.4	10.4	0.0	-	12.8	12.8	0.0	-	-	10.8	-	NA
pH		pH units	-	7.9	7.9	0.0	-	8	8	0.0	-	-	7.9	7.9	NA
Field pH		pH units	-	7.69	7.69	0.0	-	7.91	7.91	0.0	-	-	7.66	-	NA
Turbidity		NTU	-	0.26	0.23	12	-	0.36	0.36	0.0	-	-	0.37	0.28	28
Physical															
Hardness Total (T)		mg/L	-	69.5	69.7	0	-	72.6	-	NA	0.4	0.4	63.4	63.8	1
Residue Non-filterable		mg/L	-	4	4	0	-	4	-	NA	-	-	4	4	0
Metals (ICPMS)															
Aluminum Al	T	µg/L	-	9.9	9.8	1.0	1.3	13.8	-	NA	0.3	0.05	11.2	11.4	1.8
Antimony Sb	T	µg/L	-	0.195	0.227	15.2	0.005	0.26	-	NA	0.005	0.005	0.083	0.076	8.8
Arsenic As	T	µg/L	-	0.2	0.2	0.0	0.1	0.3	-	NA	0.1	0.1	0.1	0.1	0.0
Barium Ba	T	µg/L	-	20.2	19.9	1.5	0.02	22.5	-	NA	0.02	0.06	18.7	18.7	0.0
Beryllium Be	T	µg/L	-	0.02	0.02	0.0	0.02	0.02	-	NA	0.02	0.02	0.04	0.02	66.7
Bismuth Bi	T	µg/L	-	0.02	0.02	0.0	0.02	0.02	-	NA	0.02	0.02	0.02	0.02	0.0
Cadmium Cd	T	µg/L	-	0.11	0.1	9.5	0.01	0.06	-	NA	0.01	0.01	0.02	0.01	66.7
Chromium Cr	T	µg/L	-	0.2	0.2	0.0	0.2	0.2	-	NA	0.2	0.2	0.02	0.3	175.0
Cobalt Co	T	µg/L	-	0.005	0.005	0.0	0.005	0.009	-	NA	0.005	0.005	0.005	0.005	0.0
Copper Cu	T	µg/L	-	0.59	0.61	3.3	0.14	0.51	-	NA	0.38	1.31	1.02	0.63	47.3
Lead Pb	T	µg/L	-	0.13	0.06	73.7	0.01	0.16	-	NA	0.02	0.1	0.16	0.17	6.1
Lithium Li	T	µg/L	-	0.58	0.61	5.0	0.05	1.08	-	NA	0.05	0.05	0.92	0.94	2.2
Manganese Mn	T	µg/L	-	2.12	2.09	1.4	0.008	3.31	-	NA	0.023	0.051	1.74	1.63	6.5
Molybdenum Mo	T	µg/L	-	0.25	0.25	0.0	0.05	0.58	-	NA	0.05	0.05	0.47	0.49	4.2
Nickel Ni	T	µg/L	-	0.26	0.27	3.8	0.05	0.05	-	NA	0.05	0.05	0.21	0.23	9.1
Selenium Se	T	µg/L	-	0.2	0.2	0.0	0.2	0.2	-	NA	0.2	0.2	0.2	0.2	0.0
Silver Ag	T	µg/L	-	0.02	0.02	0.0	0.02	0.02	-	NA	0.02	0.02	0.02	0.02	0.0
Strontium Sr	T	µg/L	-	115	116	0.9	0.025	108	-	NA	0.081	0.091	112	111	0.9
Thallium Tl	T	µg/L	-	0.026	0.039	40.0	0.002	0.018	-	NA	0.002	0.002	0.009	0.008	11.8
Tin Sn	T	µg/L	-	0.03	0.02	40.0	0.01	0.01	-	NA	0.01	0.01	0.03	0.03	0.0
Uranium U	T	µg/L	-	0.443	0.443	0.0	0.002	0.506	-	NA	0.002	0.002	0.428	0.443	3.4
Vandium V	T	µg/L	-	0.58	0.59	1.7	0.06	0.17	-	NA	0.06	0.06	0.11	0.17	42.9
Zinc Zn	T	µg/L	-	5.3	3.7	35.6	0.3	2.5	-	NA	1.1	1.2	2.6	2.2	16.7
Metals (ICP)															
Calcium Ca	T	mg/L	-	20.2	20.3	0.5	0.05	21.3	-	NA	0.09	0.07	18.5	18.6	0.5
Magnesium Mg	T	mg/L	-	4.62	4.61	0.2	0.05	4.72	-	NA	0.05	0.05	4.18	4.21	0.7
Nitrogen															
Ammonia Dissolved		mg/L	-	0.1	0.042	81.7	-	0.026	-	NA	-	-	0.107	0.009	169.0
Microbial Indicators															
Total Coliform		CFU/100 mL	1	42	72	52.6	-	120	2	193.4	-	-	30	75	85.7
Fecal Coliform		CFU/100 mL	1	24	33	31.6	-	1	2	66.7	-	-	17	16	6.1
E.coli		CFU/100 mL	1	17	16	6.1	-	1	2	66.7	-	-	6	7	15.4
Enterococcus		CFU/100 mL	1	22	29	27.5	-	9	2	127.3	-	-	4	14	111.1

Table A3.4 (Cont'd.)

Parameter		Unit	2004					2005				
			18-Feb					27-Apr				
			Blank	Blank	Original Sample	Replicate	RPD	Field Blank	Lab Blank	Original Sample	Replicate	RPD
General												
Flow		kcfs	45.1	45.1	45.1	45.1	0	42	42	42	42	0
Temp		°C	-	-	2.4	-	NA	7.7	7.7	7.65	7.7	1
Specific Conductance		µS/cm	-	-	143	-	NA	120	120	119	120	1
Diss Oxy		mg/L	-	-	12.6	-	NA	11	11	11.4	11	4
pH		pH units	-	-	7.9	7.9	0	7.3	6.3	7.9	7.9	0
Field pH		pH units	-	-	7.79	-	NA	8	8	7.96	8	1
Turbidity		NTU	-	-	0.16	0.24	40	0.1	0.1	0.7	0.8	13
Physical												
Hardness Total (T)		mg/L	-	-	72	72.1	0	-	-	55.73	66.27	17
Residue Non-filterable		mg/L	-	-	4	4	0	4	4	4	4	0
Metals (ICPMS)												
Aluminum Al	T	µg/L	-	-	9.9	10	1.0	0.3	0.3	20.6	22.3	7.9
Antimony Sb	T	µg/L	-	-	0.096	0.096	0.0	0.005	0.005	0.163	0.167	2.4
Arsenic As	T	µg/L	-	-	0.1	0.1	0.0	0.1	0.1	0.2	0.2	0.0
Barium Ba	T	µg/L	-	-	23.5	23.8	1.3	0.02	0.02	20.5	21.6	5.2
Beryllium Be	T	µg/L	-	-	0.02	0.02	0.0	0.02	0.02	0.02	0.02	0.0
Bismuth Bi	T	µg/L	-	-	0.02	0.02	0.0	0.02	0.02	0.02	0.02	0.0
Cadmium Cd	T	µg/L	-	-	0.09	0.09	0.0	0.01	0.01	0.02	0.02	0.0
Chromium Cr	T	µg/L	-	-	0.9	1.0	10.5	0.2	0.2	0.2	0.2	0.0
Cobalt Co	T	µg/L	-	-	0.005	0.005	0.0	0.005	0.005	0.012	0.016	28.6
Copper Cu	T	µg/L	-	-	0.43	0.49	13.0	0.49	0.05	0.39	0.41	5.0
Lead Pb	T	µg/L	-	-	0.21	0.22	4.7	0.02	0.01	0.08	0.12	40.0
Lithium Li	T	µg/L	-	-	1.27	1.24	2.4	0.05	0.07	1.03	1.13	9.3
Manganese Mn	T	µg/L	-	-	2.02	2.08	2.9	0.008	0.008	2.55	2.8	9.3
Molybdenum Mo	T	µg/L	-	-	0.52	0.52	0.0	0.05	0.05	0.59	0.5	16.5
Nickel Ni	T	µg/L	-	-	0.05	0.05	0.0	0.05	0.05	0.24	0.25	4.1
Selenium Se	T	µg/L	-	-	0.2	0.2	0.0	0.2	0.2	0.2	0.2	0.0
Silver Ag	T	µg/L	-	-	0.02	0.02	0.0	0.02	0.02	0.02	0.02	0.0
Strontium Sr	T	µg/L	-	-	108	109	0.9	0.018	0.005	95.5	97.1	1.7
Thallium Tl	T	µg/L	-	-	0.035	0.033	5.9	0.002	0.002	0.041	0.045	9.3
Tin Sn	T	µg/L	-	-	0.14	0.09	43.5	0.01	0.01	0.01	0.02	66.7
Uranium U	T	µg/L	-	-	0.494	0.483	2.3	0.002	0.002	0.515	0.523	1.5
Vandium V	T	µg/L	-	-	0.35	0.35	0.0	0.06	0.06	0.06	0.11	58.8
Zinc Zn	T	µg/L	-	-	3.8	4	5.1	0.3	0.1	1.6	1.3	20.7
Metals (ICP)												
Calcium Ca	T	mg/L	-	-	21	21	0.0	0.05	0.05	19.5	19.7	1.0
Magnesium Mg	T	mg/L	-	-	4.75	4.78	0.6	0.05	0.05	4.06	4.13	1.7
Nitrogen												
Ammonia Dissolved		mg/L	-	-	0.023	0.03	26.4	0.005	0.005	0.007	0.006	15.4
Microbial Indicators												
Total Coliform		CFU/100 mL	1	1	91	107	16.2	-	-	-	-	NA
Fecal Coliform		CFU/100 mL	1	1	7	4	54.5	1	1	4	6	40.0
E.coli		CFU/100 mL	1	1	8	3	90.9	1	1	3	4	28.6
Enterococcus		CFU/100 mL	2	2	2	4	66.7	1	1	2	4	66.7

Table A3.5 Water sample QA/QC (Waneta 2002 to 2005).

Parameter		Unit	2002			2003									2004			2005		
			16-Dec			17-Feb			13-May			4-Dec			18-Feb			27-Apr		
			Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD	Original Sample	Replicate	RPD
General																				
Flow		kcfs	82	82.0	0	33.6	33.6	0	46.3	46.3	0	80	80	0	45.1	45.1	0	42	42	0
Temp		°C	6	-	NA	3.9	3.9	0	9.7	9.7	0	5.1	-	NA	3.1	3.1	0	7.55	7.55	0
Specific Conductance		µS/cm	116	-	NA	150	150	0	104	104	0	138	-	NA	138	138	0	126	126	0
Diss Oxy		mg/L	10.1	-	NA	10.4	10.4	0	12.2	12.2	0	10.1	-	NA	12.4	12.4	0	11.6	11.6	0
pH		pH units	7.8	-	NA	7.9	7.9	0	7.9	8	1	7.9	-	NA	7.8	7.9	1	7.9	7.9	0
Field pH		pH units	7.38	-	NA	7.37	7.37	0	7.93	7.93	0	7.6	-	NA	7.81	7.81	0	7.62	7.62	0
Turbidity		NTU	0.28	-	NA	0.27	0.27	0	0.3	0.35	15	0.4	-	NA	0.016	0.23	174	0.5	0.5	0
TGP		%	101.556	-	NA	101	-	NA	104	-	NA	101	-	NA	100	-	NA	*103*	103	0
Physical																				
Hardness Total (T)		mg/L	58.2	-	NA	68.8	69.4	1	69.8	70.1	0	63.8	-	NA	71.4	72.1	1	64.0	66.6	4
Residue Non-filterable		mg/L	4	-	NA	4	4	0	4	4	0	4	-	NA	4	4	0	4	4	0
Metals (ICPMS)																				
Aluminum Al	T	µg/L	-	-	NA	7.9	9.4	17	12.7	13	2	11.7	-	NA	10.4	11.3	8	22.6	19.1	17
Antimony Sb	T	µg/L	-	-	NA	0.206	0.198	4	0.341	0.359	5	0.081	-	NA	0.112	0.115	3	0.183	0.192	5
Arsenic As	T	µg/L	0.2	-	NA	0.3	0.2	40	0.3	0.2	40	0.2	-	NA	0.2	0.1	67	0.2	0.2	0
Barium Ba	T	µg/L	-	-	NA	20	20.3	1	22.8	22.6	1	18.2	-	NA	23.5	23.1	2	21.1	19.3	9
Beryllium Be	T	µg/L	-	-	NA	0.02	0.02	0	0.02	0.02	0	0.02	-	NA	0.02	0.02	0	0.02	0.02	0
Bismuth Bi	T	µg/L	-	-	NA	0.02	0.02	0	0.02	0.04	67	0.02	-	NA	0.02	0.02	0	0.02	0.02	0
Cadmium Cd	T	µg/L	-	-	NA	0.25	0.15	50	0.04	0.04	0	0.02	-	NA	0.07	0.07	0	0.02	0.03	40
Chromium Cr	T	µg/L	-	-	NA	0.2	0.2	0	0.2	0.02	164	0.2	-	NA	1	1.0	0	0.2	0.02	164
Cobalt Co	T	µg/L	0.66	-	NA	0.005	0.005	0	0.005	0.005	0	0.005	-	NA	0.005	0.005	0	0.0	0.013	60
Copper Cu	T	µg/L	-	-	NA	0.31	0.41	28	0.6	0.51	16	0.88	-	NA	0.54	0.48	12	0.37	0.72	64
Lead Pb	T	µg/L	-	-	NA	0.1	0.15	40	0.19	0.18	5	0.15	-	NA	0.38	0.39	3	0.1	0.09	11
Lithium Li	T	µg/L	-	-	NA	0.27	0.43	46	1.17	1.06	10	1.12	-	NA	1.16	1.11	4	1	1.03	3
Manganese Mn	T	µg/L	-	-	NA	1.84	2.07	12	3.29	3.16	4	1.7	-	NA	2.02	2.05	1	2.7	2.31	16
Molybdenum Mo	T	µg/L	-	-	NA	0.23	0.25	8	0.58	0.58	0	0.47	-	NA	0.5	0.52	4	0.69	0.57	19
Nickel Ni	T	µg/L	-	-	NA	0.24	0.25	4	0.05	0.05	0	0.22	-	NA	0.05	0.05	0	0.23	0.24	4
Selenium Se	T	µg/L	-	-	NA	0.2	0.2	0	0.3	0.2	40	0.2	-	NA	0.3	0.2	40	0.3	0.4	29
Silver Ag	T	µg/L	-	-	NA	0.02	0.02	0	0.02	0.02	0	0.02	-	NA	0.02	0.02	0	0.02	0.02	0
Strontium Sr	T	µg/L	-	-	NA	115	115	0	108	105	3	111	-	NA	109	109	0	94.1	87.4	7
Thallium Tl	T	µg/L	-	-	NA	0.04	0.035	13	0.025	0.025	0	0.015	-	NA	0.045	0.044	2	0.08	0.07	13
Tin Sn	T	µg/L	-	-	NA	0.02	0.07	111	0.01	0.01	0	0.01	-	NA	0.67	0.25	91	0.01	0.01	0
Uranium U	T	µg/L	-	-	NA	0.435	0.439	1	0.48	0.498	4	0.427	-	NA	0.483	0.494	2	0.522	0.471	10
Vandium V	T	µg/L	3.95	-	NA	0.45	0.59	27	0.23	0.24	4	0.14	-	NA	0.37	0.34	8	0.08	0.06	29
Zinc Zn	T	µg/L	-	-	NA	6.5	5.3	20	3.5	3	15	3.3	-	NA	3.8	4.4	15	1.4	3.7	90
Metals (ICP)																				
Calcium Ca	T	mg/L	17.1	17.3	1	20	20	0	20.3	20.4	0	18.6	-	NA	20.8	21	1	19	19.8	4
Magnesium Mg	T	mg/L	3.76	3.79	1	4.57	4.57	0	4.46	4.65	4	4.21	-	NA	4.72	4.77	1	4	4.15	4
Nitrogen																				
Ammonia Dissolved		mg/L	0.005	0.005	0	0.034	-	NA	0.005	0.005	0	0.037	-	NA	0.017	0.016	6	0.005	0.005	0
Microbial Indicators																				
Total Coliform		CFU/100 mL	23	18	24	28	15	60	43	24	57	12	11	9	218	231	6	-	-	NA
Fecal Coliform		CFU/100 mL	6	8	29	3	2	40	1	1	0	5	2	86	34	40	16	5	6	18
E.coli		CFU/100 mL	3	5	50	2	1	67	1	1	0	3	2	40	29	30	3	5	5	0
Enterococcus		CFU/100 mL	5	7	33	3	3	0	1	2	67	1	6	143	10	9	11	3	4	29

Appendix A4

Selected Historical Data for Comparison

(from MacDonald Environmental Sciences Ltd. 1997)

Table 10.1. Water Quality Characteristics of the Columbia River at Birchbank for the Period of January 1990-September 1995.

Variable	Units	Mean	SD	Max	90th Percentile	Min	Number of Records
General Parameters							
pH	pH units	7.80	NA	8.2	8	5.5	173
Suspended Solids (TSS)	mg/L	10	NA	10	10	10	1
Specific Conductivity	µS/cm	119	19.1	154	140	75	147
Turbidity	NTU	0.591	1.21	14	1.1	0.05	171
Alkalinity-T ($CaC0_3$)	mg/L	54.3	4.55	64	60.1	45	147
Hardness-T ($CaC0_3$)	mg/L	62.9	6.13	76.4	72	49.6	131
Temperature	degrees C	13.6	7.24	23.5	22.4	2	94
Major Ions							
Calcium-D	mg/L	17.5	3.06	21.1	19.9	7.81	16
Carbon inorganic-T	mg/L	12.0	1.83	15	14	8	21
Carbon-organic-T	mg/L	3.5	0.71	4	3.9	3	2
Chloride-D	mg/L	0.780	0.28	1.7	1.15	0.1	152
Flouride-D	mg/L	0.08	0.02	0.12	0.1	0.02	118
Silica-D	mg/L	3.5	1.06	4.6	4.2	0.5	11
Sodium-D	mg/L	1.58	0.32	1.97	1.90	1.21	5
Sulfate-D	mg/L	9.20	2.26	13.9	11.2	0.5	152
Major Nutrients							
Phosphorous-T	µg/L	7.49	4.46	22.3	14.3	2	138
Phosphorous ortho-D	µg/L	3.26	0.94	9	4	<3	223
Nitrogen-T	µg/L	171	56.7	210	205	71	5
Ammonia-D	µg/L	5.94	2.53	27	8	<1	229
Nitrite-D	µg/L	5	0	5	5	<5	34
Nitrate-D	µg/L	85.2	38.4	173	132	<2	34
Nitrites & Nitrates-D	µg/L	0.096	0.02	0.14	0.12	<0.06	15
Metals and Metalloids							
Aluminum-T	µg/L	37.4	25.4	133	74	<2	151
Arsenic-T	µg/L	2.09	8.48	40	0.43	<0.1	148
Barium-T	µg/L	20.1	6.40	40	23.1	0.2	143
Beryllium-T	µg/L	47.2	11.3	50	50	1	142
Cadmium-T	µg/L	2.68	3.57	10	10	<0.1	17
Cobalt-T	µg/L	51.9	49.6	100	100	<3	16
Chromium-T	µg/L	4.75	3.07	10	10	<2	16
Copper-T	µg/L	1.02	3.39	32.8	1	<0.2	134
Lead-T	µg/L	0.29	0.22	1.3	0.5	<0.2	134
Lithium-T	µg/L	1.27	0.33	1.8	1.6	0.1	134
Manganese-T	µg/L	2.24	0.96	6.1	3.47	<0.1	134

Table 10.1. Water Quality Characteristics of the Columbia River at Birchbank for the Period of January 1990-September 1995.

Variable	Units	Mean	SD	Max	90th Percentile	Min	Number of Records
Metals and Metalloids cont'd							
Mercury-T	µg/L	0.014	0.018	0.114	0.021	<0.005	129
Molybdenum-T	µg/L	0.46	0.11	0.7	0.57	<0.1	134
Nickel-T	µg/L	0.32	0.19	1.6	0.5	<0.2	134
Selenium-E	µg/L	0.14	0.05	0.2	0.2	0.1	14
Selenium-T	µg/L	0.13	0.09	0.9	0.2	0.1	120
Strontium-T	µg/L	105	23.7	121	118	0.1	134
Thallium-T	µg/L	0.27	0.28	1.6	0.2	<0.2	46
Zinc-T	µg/L	1.86	3.30	37.5	3	0.2	134
Microbial Indicators							
Total feacal coliforms	CFU/100 mL	3.48	9.91	115	5	0	237
Escherichia coli	CFU/100 mL	1.00	1.48	8	2	0	73
Enterococcus sp.	CFU/100 mL	2	1.29	7	2	1	19

T = total; D = dissolved; E = extractable; NA = not applicable; SD = standard deviation; CFU= colony forming units/100 mL.
Compiled from BCMOELP and Environment Canada unpublished data.
Note: median is reported for pH

Table 10.2. Water Quality Characteristics of the Columbia River at West Trail (Old Trail Bridge) from September 1991 to October 1992.

Variables	Units	Mean	SD	Max	90th Percentile	Min	Number of Records
General Parameters							
pH	pH units	7.75	NA	8.7	8.3	7.3	16
Specific Conductance	µS/cm	132	8.56	147	144	116	16
Turbidity	NTU	0.55	0.239	1.1	0.9	0.3	16
Alkalinity-T ($CACO_3$)	mg/L	54.2	4.06	62.5	58.1	46.3	16
Hardness-T	mg/L	63.4	7.13	76.2	72.2	53.9	15
Temperature	degrees C	11.0	4.89	18.5	17.2	4.1	16
Dissolved Oxygen	ppm	11.0	1.10	12.4	12.3	9.4	15
Major Ions							
Calcium-T	mg/L	18.8	2.15	23.6	21.1	16	16
Chlorine-D	mg/L	0.856	0.237	1.3	1.2	0.5	16
Fluoride-D	mg/L	0.149	0.054	0.26	0.225	0.1	16
Silica-D	mg/L	3.63	1.06	5.1	4.65	0.5	16
Sodium-D	mg/L	1.48	0.298	2	1.95	1	16
Sulfate-D	mg/L	11.9	3.45	23	14.8	8.9	16
Major Nutrients							
Phosphorous ortho-D	µg/L	51.9	81.5	311	124	<3	16
Phosphorous-T	µg/L	65.4	90.8	343	150	5	15
Potassium-D	µg/L	625	44.7	700	700	600	16
Nitrogen-T	µg/L	265	101	530	375	160	16
Nitrogen organic-T	µg/L	90.7	41.5	170	146	30	15
Nitrogen Kjeldahl-T	µg/L	167	85.8	400	255	60	16
Ammonia-D	µg/L	81.9	69.7	227	175	7	16
Nitrites & Nitrates-D	µg/L	98.1	25.6	140	135	60	16
Metals and Metalloids							
Aluminum-T	µg/L	44	15.5	65	60	<20	16
Arsenic-T	µg/L	1	0	1	1	<1	16
Barium-T	µg/L	20.9	3.61	29	26	16	16
Cadmium-T	µg/L	0.656	0.322	1.7	0.95	<0.5	16
Cobalt-T	µg/L	3	0	3	3	<3	16
Chromium-T	µg/L	3.13	2.22	11	4	<2	16
Copper-T	µg/L	2.75	1.65	7	4.5	<1	16
Iron-T	µg/L	81.4	57.4	237	146	32	16
Lead-T	µg/L	10.8	7.31	31	17.5	<1	16
Magnesium-T	µg/L	3971	478	4960	4390	3220	16
Manganese-T	µg/L	5.5	2.50	11	8.5	2	16

Table 10.2. Water Quality Characteristics of the Columbia River at West Trail (Old Trail Bridge) from September 1991 to October 1992.

Variables	Units	Mean	SD	Max	90th Percentile	Min	Number of Records
Metals and Metalloids cont'd							
Mercury-T	µg/L	0.059	0.022	0.12	0.08	<0.05	11
Molybdenum-T	µg/L	4	0	4	4	<4	16
Nickel-T	µg/L	8.06	0.25	9	8	<8	16
Thallium-T	µg/L	3.4	0.910	6	4.6	<3	15
Vanadium-T	µg/L	3	0	3	3	<3	16
Zinc-T	µg/L	29.5	18.7	83	44	5	16
Microbial Indicators							
Total feacal coliforms	CFU/100 mL	16.3	10.5	33	29	1	16
Escherichia coli	CFU/100 mL	15.3	10.3	30	29.1	1	14
Enterococcus sp.	CFU/100 mL	4.86	5.02	21	6.7	1	14

T = total; D = dissolved; SD = standard deviation; CFU = colony forming units/100 mL.
Data adapted from NECL (1993.)
Note: median is reported for pH.

Table 10.3. Water quality characteristics of the Columbia River at East Trail (Old Trail Bridge) from September 1991 to October 1992.

Variables	Units	Mean	SD	Max	90th Percentile	Min	Number of Records
General Parameters							
pH	pH units	8.05	NA	8.7	8.35	7.1	16
Specific Conductivity	µS/cm	129	10.6	147	141	110	16
Turbidity	NTU	0.475	0.153	0.8	0.65	0.2	16
Alkalinity-T ($CACO_3$)	mg/L	55.0	3.90	63	58.9	47.9	16
Hardness-T	mg/L	61.3	7.44	73.7	69.1	48.8	15
Temperature	degrees C	11.1	4.89	18.5	17.15	4.3	16
Dissolved Oxygen	ppm	11.0	1.17	12.8	12.2	9.3	15
Major Ions							
Calcium-T	mg/L	17.9	2.14	21.4	20.5	14.2	16
Chlorine-D	mg/L	0.793	0.191	1.2	0.96	0.5	15
Fluoride-D	mg/L	0.102	0.007	0.13	0.1	0.1	16
Silica-D	mg/L	3.56	1.08	5.1	4.65	0.5	16
Sodium-D	mg/L	1.31	0.212	1.7	1.56	0.9	15
Sulfate-D	mg/L	9.5	1.08	11.6	11	7.7	16
Major Nutrients							
Phosphorous ortho-D	µg/L	3	0	3	3	<3	16
Phosphorous-T	µg/L	5	3.32	15	8.4	<3	15
Potassium-D	µg/L	606	44.3	700	650	500	16
Nitrogen-T	µg/L	176	54.9	320	240	110	16
Nitrogen organic-T	µg/L	71.9	38.2	140	135	<40	16
Nitrogen Kjeldahl-T	µg/L	80	45.0	190	140	<40	16
Ammonia-D	µg/L	10.3	11.7	51	17	<5	16
Nitrites and Nitrates-D	µg/L	95.6	25.6	140	130	60	16
Metals and Metalloids							
Aluminum-T	µg/L	39.3	13.1	64	50	20	16
Arsenic-T	µg/L	1	0	1	1	<1	16
Barium-T	µg/L	18.1	2.13	22	20.5	15	16
Cadmium-T	µg/L	0.5	0	0.5	0.5	<0.5	16
Cobalt-T	µg/L	3	0	3	3	<3	16
Chromium-T	µg/L	2.88	2.00	10	3.5	<2	16
Copper-T	µg/L	1.38	0.619	3	2	<1	16
Iron-T	µg/L	29.9	10.9	45	42.5	10	16
Lead-T	µg/L	1.75	1.24	5	3.5	<1	16
Magnesium-T	µg/L	3922	523	4930	4390	3200	16

Table 10.3. Water quality characteristics of the Columbia River at East Trail (Old Trail Bridge) from September 1991 to October 1992.

Variables	Units	Mean	SD	Max	90th Percentile	Min	Number of Records
Metals and Metalloids cont'd							
Manganese-T	µg/L	2.56	0.892	5	3.5	<2	16
Mercury-T	µg/L	0.056	0.014	0.09	0.08	<0.05	11
Molybdenum-T	µg/L	4	0	4	4	<4	16
Nickel-T	µg/L	8	0	8	8	<8	16
Thallium-T	µg/L	3.53	1.60	9	4.2	<3	15
Vanadium-T	µg/L	3	0	3	3	<3	16
Zinc-T	µg/L	9.31	7.18	26	19.5	<2	16
Microbial Indicators							
Total feacal coliforms	CFU/100 mL	4.81	5.74	22	11.5	1	16
Escherichia coli	CFU/100 mL	5	5.17	16	13.1	1	14
Enterococcus sp.	CFU/100 mL	2.43	1.87	8	4.1	1	14

T = total; D = dissolved; SD = standard deviation; CFU = colony forming units/100 mL.
Data adapted from NECL (1993).
Note: median is reported for pH

Table 10.4. Water Quality Characteristics in the Columbia River at Waneta for the Period of January 1990 to April 1996.

Variables	Units	Mean	SD	Max	90th Percentile	Min	Number of Records
General Parameters							
pH	pH units	7.9	NA	9.6	8.1	5.6	483
Specific Conductance	µs/cm	129	30.8	277	149	1	422
Temperature	degrees C	9.92	7.54	61.3	16.5	0.22	240
Turbidity	NTU	0.639	1.55	18	1.03	0.05	285
Alkalinity ($CaCO_3$)-T	mg/L	54.2	4.46	64.7	60	43	285
Hardness ($CaCO_3$)-T	mg/L	64.0	6.24	80.6	72.9	47.8	280
Major Ions							
Calcium-D	mg/L	18.6	0.446	19.8	19.1	18.1	21
Carbon inorganic-T	mg/L	10.8	3.98	15.0	15.0	2.0	30
Carbon organic-T	mg/L	3.01	1.77	5.0	5.0	0.740	8
Chloride-D	mg/L	0.823	0.356	5.0	1.2	<0.07	290
Flouride-D	mg/L	0.103	0.031	0.22	0.14	<0.02	283
Silica-D	mg/L	1.92	0.597	4.0	2.48	<0.05	156
Sodium-D	mg/L	1.74	0.560	3.25	1.93	1.21	11
Sulphate-D	mg/L	10.3	2.44	18.0	12.9	<0.5	345
Major Nutrients							
Phosphorous-T	µg/L	16.2	21	207	28.7	<2.0	276
Phosphorous ortho-D	µg/L	8.63	15.3	180	15.6	3.0	425
Potassium-D	µg/L	513	173	600	600	100	8
Nitrogen-T	µg/L	210	26.3	243	237	149	10
Nitrogen-D	µg/L	160	56.7	470	225	10.0	266
Ammonia-D	µg/L	25.6	31.1	111	100	2.67	452
Nitrogen Nitrites and Nitrates-D	µg/L	113	50.5	487	161	2.0	237
Nitrogen Nitrite-D	µg/L	7.20	12.6	97	5.0	5.0	65
Nitrogen Nitrate-D	µg/L	89.4	33.8	150	133	2.0	62
Metals and Metalloids							
Aluminum-T	µg/L	44.8	34.6	310	81.7	<0.2	304
Arsenic-T	µg/L	1.69	6.13	40.0	5.0	<0.1	305
Barium-T	µg/L	20.2	4.73	50	23.8	<0.2	302
Beryllium-T	µg/L	45.6	14.3	70.0	50.0	<0.1	295
Cadmium-T	µg/L	0.617	1.48	10.0	1.93	<0.1	328
Cobalt-T	µg/L	3.40	17.0	100	4.0	<0.1	302
Chromium-T	µg/L	0.962	2.28	31.4	2.0	<0.1	302
Copper-T	µg/L	3.40	6.33	76.9	5.0	<0.2	312
Iron-T	µg/L	51.6	40.7	385	92.1	<0.4	304
Lead-T	µg/L	1.78	1.77	16.4	3.2	<0.1	269

Table 10.4. **Water Quality Characteristics in the Columbia River at Waneta for the Period of January 1990 to April 1996.**

Variables	Units	Mean	SD	Max	90th Percentile	Min	Number of Records
Metals and Metalloids cont'd							
Lithium-T	µg/L	1.31	0.280	2.0	1.6	<0.1	269
Magnesium-T	µg/L	3320	1723	4729	4450	20.0	35
Manganese-T	µg/L	3.43	1.78	12.7	5.09	<0.1	302
Mercury-T	µg/L	14.8	31.8	430.0	27.2	<0.05	330
Molybdenum-T	µg/L	1.05	1.84	10.0	4.0	<0.1	302
Nickel-T	µg/L	0.350	0.192	1.2	0.6	<0.1	268
Selenium-T	µg/L	0.623	7.38	115	0.2	<0.1	242
Strontium-T	µg/L	108	18.9	129	118	<0.1	268
Thallium-T	µg/L	0.367	0.183	0.7	0.6	<0.1	24
Vanadium-T	µg/L	0.201	0.214	3.3	0.3	<0.1	269
Zinc-T	µg/L	7.50	5.14	50.0	11.4	<0.1	269
Microbial Indicators							
Total feacal coliforms	CFU/100 mL	14.5	27.7	325	40.0	0	359
Escherichia coli	CFU/100 mL	9.18	12.6	47.0	22.6	1	17
Entercoccus sp.	CFU/100 mL	4.06	5.43	22.0	8.6	1	17
Resin Acids							
Dehydroabietic acid	µg/L	0.921	0.187	1	1	0.5	19

T = total; D = dissolved; NA = not applicable; SD = standard deviation; CFU = colony forming units/100 mL.
From BCMOELP and Environment Canada unpublished data.
Note: median is reported for pH.

Table 11.1. Concentrations (mg/kg dry weight) of Selected Metals in Sediment Collected from the Columbia River in July 1976 (BCMOE 1979).

Site		Arsenic	Cadmium	Copper	Lead	Mercury	Zinc
Columbia River at Stoney Creek		<2.0	<0.5	29	19	0.4	44.3
Columbia River at Trail*	West Side	**45.0**	**5.3**	**1930**	**866**	2.5	**12600**
	East Side	<2.0	<0.5	26	**48**	0.3	**218**
Columbia River at Bear Creek*	West Side	**12.0**	**5.6**	**1050**	**657**	1.6	**9320**
	East Side	3.0	<0.5	**109**	**79**	0.8	**854**
Columbia River at Beaver Creek*	West Side	**7.0**	**8.3**	**159**	**397**	1.8	**1560**
	East Side	<2.0	<0.5	**95**	**57**	0.3	**999**
Columbia River at Waneta*	West Side	**6.0**	<0.5	**610**	**179**	0.3	**5950**
	East Side	**6.0**	**0.7**	**710**	**238**	0.5	**7320**

* downstream of Cominco.
Values in bold typeface indicate an exceedence of the provisional sediment quality objective.

Table 11.2. Concentrations of Selected Metals in Sediments below Birchbank in 1992 (NECL 1993).

	Units	Arrow Lake at Renata Creek (Site I-1)	Columbia River D/S Celgar (Site II-2)	Columbia River at Birchbank (Site III-3)	Columbia River at Ryan Creek (Site IV-1)	Columbia River at Beaver Creek (Site Cr IV-2)	Columbia River at Waneta (Site IV-3)
General Parameters							
Number of Samples		4	1	1	1	1	3
Moisture	%	65.7	49.3	29.3	40.2	27	54.7
TOC	%	2.1	1.1	0.5	1.6	0.2	1.0
Metals and Metalloids							
Number of Samples		4	1	1	1	1	3
Aluminum	mg/kg DW	37750	8900	7270	18400	11300	13433
Antimony	mg/kg DW	1.7	<1.5	<1.5	3	8.9	2.4
Arsenic	mg/kg DW	**9.9**	1.6	2.0	**26.0**	**55.0**	**18.0**
Barium	mg/kg DW	383	91	65	377	1540	618
Beryillium	mg/kg DW	1.5	0.4	0.4	0.6	0.6	0.7
Bismuth	mg/kg DW	<2	<2	<2	<2	15	<2
Cadmium	mg/kg DW	**1.1**	0.3	0.5	**7.1**	**6**	**9.8**
Cobalt	mg/kg DW	17.6	6.0	4.6	10.8	32.9	9.0
Copper	mg/kg DW	**50.5**	11.3	8.3	**209**	**2520**	**466**
Chromium	mg/kg DW	33.4	**42.2**	22.1	**41.9**	**55.9**	**51.7**
Iron	mg/kg DW	43 800	14 300	14 900	29 100	86 700	32 200
Lead	mg/kg DW	**74.3**	8.0	15.0	**576**	**546**	**535**
Magnesium	mg/kg DW	11 300	4980	3960	7710	3910	5343
Manganese	mg/kg DW	802	214	200	402	1720	396
Mercury	mg/kg DW	0.06	<0.05	<0.05	**0.68**	**0.49**	**1.5**
Molybdenum	mg/kg DW	<0.4	<0.4	<0.4	1.2	13.1	1.9
Nickel	mg/kg DW	50.6	18.8	11.4	32.3	24.3	18.8

Table 11.2. Concentrations of Selected Metals in Sediments below Birchbank in 1992 (NECL 1993).

	Units	Arrow Lake	Columbia River				
		at Renata Creek (Site I-1)	D/S Celgar (Site II-2)	at Birchbank (Site III-3)	at Ryan Creek (Site IV-1)	at Beaver Creek (Site Cr IV-2)	at Waneta (Site IV-3)
Metals and Metalloids (continued)							
Selenium	mg/kg DW	<1	<1	<1	1	<1	1.0
Silver	mg/kg DW	<1	<1	<1	2	17	4
Strontium	mg/kg DW	89.4	59.0	46.8	95.1	170.0	85.0
Sulphur	mg/kg DW	405	763	336	2440	3030	3240
Tellurium	mg/kg DW	<2	<2	<2	<2	<2	<2
Thallium	mg/kg DW	<0.3	<0.3	<0.3	<0.3	<0.3	1.4
Tin	mg/kg DW	6.5	2.0	3.0	4.0	5.0	4.5
Titanium	mg/kg DW	2010	1270	1080	1500	380	749
Vanadium	mg/kg DW	63.1	31.5	32.8	52.9	50.4	45.9
Zinc	mg/kg DW	**156**	58	90	**1130**	**6520**	**1990**
Zirconium	mg/kg DW	6.0	1.6	1.3	7.6	11.9	5.7

DW = dry weight; TOC = total organic carbon.
Values in bold typeface indicate an exceedence of the sediment quality objective (SQOs); SQOs were established for arsenic, cadmium, chromium, copper, mercury, and zinc only.

Table 11.3. Mean Concentrations (mg/kg dry weight) of Selected Metals in Bed and Suspended Sediment Collected from the Columbia River in 1990-1991 (Tuominen *et al.* 1994).

	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc
Bed Sediment (n=6)								
Arrow Lake	5	1	76	35	38	0.04	0.5	216
Columbia River at Celgar	1	1	67	8	20	0.02	0.2	162
Columbia River at Waneta	16	5	77	939	359	0.62	1.6	4939
Suspended Sediment (n=4)								
Arrow Lake	6	1	66	71	51	0.05	1.4	228
Columbia River at Celgar	5	2	354	48	49	0.11	1.3	305
Columbia River at Waneta	40	17	157	243	780	4.01	2.1	1547

n = number of samples.

Table 11.8. **Concentrations of Selected Organic Compounds in Sediments below Birchbank in 1992 (NECL 1993).**

	Units	Arrow Lake at Renata Creek (Site I-1)	Columbia River D/S Celgar (Site II-2)	Columbia River at Birchbank (Site III-3)	Columbia River at Ryan Creek (Site IV-1)	Columbia River at Waneta (Site IV-3)
Resin Acids						
Number of Samples		*2*	*1*	*1*	*1*	*2*
Abietic Acid	μg/kg DW	31	2900	14	60	320
Chlorodehydroabietic Acid	μg/kg DW	<0.9	4	<0.3	<0.4	2.2
Dehydroabietic Acid	μg/kg DW	114	18 000	54	130	315
Dehydroisopimaric Acid	μg/kg DW	<2.6	<1.0	<1.3	<2.2	<2.1
Dichlorodehydroabietic Acid	μg/kg DW	<2.4	<3.5	<1.2	<1.6	7.8
Isopimaric Acid	μg/kg DW	27	640	8.3	33	225
Neoabietic Acid	μg/kg DW	<.7	390	<0.6	<0.6	12
Palustric Acid	μg/kg DW	<2.5	490	<1.7	<0.8	122
Pimaric Acid	μg/kg DW	7.5	74	<0.3	<0.3	21
Sandaracopimaric Acid	μg/kg DW	35.5	630	32	13	<0.3
Fatty Acids						
Number of Samples		*2*	*1*	*1*	*1*	*1*
Arachidic Acid	μg/kg DW	765	2900	280	1000	1300
Behenic Acid	μg/kg DW	1565	13 000	640	970	3900
Lauric Acid	μg/kg DW	1750	1600	850	1200	85 000
Lignoceric Acid	μg/kg DW	1200	11 000	230	<200	3600
Linoleic Acid	μg/kg DW	<400	<300	3000	4200	34 000
Linolenic Acid	μg/kg DW	<500	<300	<200	<200	<300
Myristic Acid	μg/kg DW	5350	5200	2400	3100	35 000
Oleic Acid	μg/kg DW	<400	<300	3000	4200	34 000
Palmitric Acid	μg/kg DW	12 000	13 000	5100	12 000	43 000
Stearic Acid	μg/kg DW	4800	2900	770	2600	21 000

Table 11.8. **Concentrations of Selected Organic Compounds in Sediments below Birchbank in 1992 (NECL 1993).**

	Units	Arrow Lake at Renata Creek (Site I-1)	Columbia River D/S Celgar (Site II-2)	Columbia River at Birchbank (Site III-3)	Columbia River at Ryan Creek (Site IV-1)	Columbia River at Waneta (Site IV-3)
Other Organic Substances						
Number of Samples		*2*	*1*	*2*	*1*	*1*
2,3,4,5-tetrachlorophenol	µg/kg DW	<0.4	<0.3	<0.25	<0.5	<0.3
2,3,4,6-tetrachlorophenol	µg/kg DW	<0.85	1.3	<0.25	<0.5	<0.3
2,3,4-trichlorophenol	µg/kg DW	<0.3	<0.2	<0.3	<0.5	<0.4
2,3,5,6-tetrachlorophenol	µg/kg DW	<0.6	<0.3	<0.15	<0.4	<0.2
2,3,5-trichlorophenol	µg/kg DW	<0.25	<0.3	<0.3	<0.5	<0.5
2,3,6-trichlorophenol	µg/kg DW	<0.3	<0.4	<0.4	<0.6	<0.5
2,3-dichlorophenol	µg/kg DW	<0.3	<0.5	<0.35	<0.7	<1.1
2,4,5-trichlorophenol	µg/kg DW	<0.25	<0.2	<0.25	<0.4	<0.4
2,4,6-trichlorophenol	µg/kg DW	<0.25	4.6	<0.3	<0.4	<0.4
2,4/2,5-dichlorophenol	µg/kg DW	<0.35	4	<0.45	<0.6	<0.5
2,6-dichlorophenol	µg/kg DW	<0.35	<0.7	<0.45	<0.9	<0.4
3,4,5,6-tetrachlorocatechol	µg/kg DW	<1.8	29	<22	<20	<13
3,4,5,6-tetrachloroguaiacol	µg/kg DW	<0.45	3.4	<0.25	<0.3	<0.3
3,4,5,6-tetrachloroveratrole	µg/kg DW	<0.5	2.2	<1	<1.4	<1.3
3,4,5-trichlorocatechol	µg/kg DW	<1.2	13	<3.6	<5	8.4
3,4,5-trichloroguaiacol	µg/kg DW	<0.45	5.5	0.35	<0.3	0.5
3,4,5-trichlorophenol	µg/kg DW	<0.3	<0.2	<0.25	<0.5	<0.4
3,4,5-trichlorosyringol	µg/kg DW	<1.35	<1.2	<0.7	<1.6	<0.9
3,4,5-trichloroveratrole	µg/kg DW	<0.4	2.2	<0.8	<1	<0.8
3,4,6-trichloroveratrole	µg/kg DW	<0.4	0.6	<0.8	<1	<0.8
3,4-dichlorocatechol	µg/kg DW	<0.5	<0.3	<0.45	<1	<0.5
3,4-dichloroguaicol	µg/kg DW	<0.65	<0.7	<0.5	<0.7	<0.5
3,4-dichlorophenol	µg/kg DW	<0.25	<0.3	<0.3	<0.5	<0.3
3,5-dichlorocatechol	µg/kg DW	<0.45	1.8	<0.6	<1.4	0.9

Table 11.8. Concentrations of Selected Organic Compounds in Sediments below Birchbank in 1992 (NECL 1993).

	Units	Arrow Lake at Renata Creek (Site I-1)	Columbia River D/S Celgar (Site II-2)	Columbia River at Birchbank (Site III-3)	Columbia River at Ryan Creek (Site IV-1)	Columbia River at Waneta (Site IV-3)
Other Organic Substances (continued)						
3,5-dichlorophenol	µg/kg DW	<0.3	<0.5	<0.35	<0.6	<0.4
3,5-dichlorosyringol	µg/kg DW	<3.9	<3.6	<4.3	<2	<1.2
3,6-dichlorocatechol	µg/kg DW	<0.55	0.4	<0.7	<1.5	<0.8
3-chlorocatechol	µg/kg DW	<1.0	<1	<0.75	<1.5	<1.2
3-chlorosyringol	µg/kg DW	<4	<4.5	<2.5	<4	<3
4,5,6-trichloroguaiacol	µg/kg DW	<0.35	0.9	<0.1	<0.2	<0.1
4,5-dichlorocatechol	µg/kg DW	<0.6	1.4	<0.85	<2	1.1
4,5-dichloroguaicol	µg/kg DW	<0.5	3.8	<0.4	<0.6	<0.5
4,5-dichloroveratrole	µg/kg DW	<0.53	<0.2	<0.7	<0.5	<0.6
4,6-dichloroguaicol	µg/kg DW	<0.7	<0.6	<0.5	<0.7	<0.5
4-chlorocatechol	µg/kg DW	<1.0	<1	<1.25	<1.8	<1.3
4-chloroguaiacol	µg/kg DW	<1.3	<1.8	<1.75	<2.8	<1.7
4-chlorophenol	µg/kg DW	<0.6	<1.4	<0.9	<1.3	<0.8
5,6-dichlorovanillin	µg/kg DW	<1.2	1.6	<2.75	<2.2	<4.8
5-chloroguaiacol	µg/kg DW	<1.1	<1.6	<1.55	<2.5	<1.5
5-chlorovanillin	µg/kg DW	<1.35	-<0.9	<1.05	<3.5	<1.3
6-chloroguaiacol	µg/kg DW	<1.4	<2.7	<2.6	<4.1	<1
6-chlorovanillin	µg/kg DW	<1.3	3.5	<2.25	<7.6	<2.8
Pentachlorophenol	µg/kg DW	<0.8	<0.3	<0.65	<1	<0.6
Furans and Dioxins						
Number of Samples		*5*	*1*	*1*	*1*	*1*
2,3,7,8 T_4CDD TEQ	ng/kg DW	1	24.4	1	1.3	7.8

DW = dry weight; D/S = downstream; T_4CDD TEQ = tetrachlorodibenzo-*p*- dioxin toxic equivalent.

Table 11.9. Mean Concentration (ng/kg dry weight) of PCDDs and PCDFs, expressed as 2,3,7,8-T_4CDD TEQs, in Bed and Suspended Sediment Collected from the Columbia River in 1990-1991 (Tuominen *et al.* 1994).

	Otober 1990	March 1991	June 1991
Bed Sediment			
Arrow Lake[1]	0	1.08	0.45
Columbia River at Celgar[1]	2.15	7.79	6.5
Columbia River at Waneta[1]	0	1.1	4.36
Suspended Sediment			
Arrow Lake[1]	0	0.055	0.035
Columbia River at Celgar[1]	1902	9.91	10.7
Columbia River at Waneta[1]	87.8	0.04	11.2

[1] Average value of 2 samples or composite of 2 samples.

Table 12.6. Levels of Metals in Muscle Tissue of Fish Collected in the Columbia River Basin in 1976 (BCMOE 1979).

Species	Location	Sample	Arsenic (mg/kg WW)	Cadmium (mg/kg WW)	Copper (mg/kg WW)	Lead (mg/kg WW)	Mercury (mg/kg WW)	Zinc (mg/kg WW)
Largescale sucker	LAL	mean	<0.35	NR	0.35	NR	0.22	4.55
Catostomus macrocheilus		range	NR	<0.09 - <0.14	0.31 - 0.39	<0.96 - <1.45	0.18 - 0.24	3.59 - 5.65
	CR1	mean	<0.43	NR	0.62	NR	0.10	4.64
		range	NR	<0.11 - <0.17	0.54 - 0.70	<1.02 - <1.81	0.07 - 0.13	3.50 - 5.85
	CR2	mean	<0.37	NR	0.56	NR	0.11	6.49
		range	NR	<0.07 - 0.28	0.50 - 0.63	<0.72 - 2.09	0.05 - 0.2	4.87 - 5.98
Peamouth	LAL	mean	<0.33	NR	0.35	NR	0.15	6.91
Mylocheilus caurinus		range	NR	<0.10 - <0.15	0.35 - 0.38	<1.04 - <1.52	0.13 - 0.19	5.23 - 8.05
	CR1	mean	NR	NR	NR	NR	NR	NR
		range	NR	NR	NR	NR	NR	NR
	CR2	mean	<0.36	NR	0.45	NR	0.15	5.70
		range	NR	<0.05 - <0.11	0.40 - 0.47	<0.51 - 0.90	0.10 - 0.23	4.36 - 8.80
Kokanee	LAL	mean	<0.51	NR	0.56	NR	<0.05	7.50
Oncorhynchus nerka		range	NR	<0.10 - <0.15	0.44 - 0.77	<0.97 - <1.54	NR	6.43 - 8.65
	CR1	mean	<0.55	NR	0.50	NR	0.07	6.93
		range	NR	<0.08 - <0.11	0.41 - 0.58	<0.83 - <1.10	0.06 - 0.08	4.69 - 10.4
	CR2	mean	<0.51	NR	0.02	NR	0.09	4.66
		range	NR	<0.08 - <0.13	NR	<0.61 - <1.18	NR	3.92 - 5.71

Table 12.6. Levels of Metals in Muscle Tissue of Fish Collected in the Columbia River Basin in 1976 (BCMOE 1979).

Species	Location	Sample	Arsenic (mg/kg WW)	Cadmium (mg/kg WW)	Copper (mg/kg WW)	Lead (mg/kg WW)	Mercury (mg/kg WW)	Zinc (mg/kg WW)
Mountain whitefish	LAL	mean	<0.46	NR	0.44	NR	0.07	3.63
Prosopium williamsoni		range	NR	<0.09 - <0.18	0.35 - 5.15	<0.98 - <1.87	0.06 - 0.08	2.90 - 4.74
	CR1	mean	<0.54	NR	0.44	NR	0.07	3.25
		range	NR	<0.14 - <0.16	0.42 - 0.47	<1.30 - <1.65	0.06 - 0.08	2.90 - 3.52
	CR2	mean	<0.49	NR	0.42	NR	0.07	3.88
		range	NR	<0.05 - <0.12	0.37 - 0.47	<0.49 - <0.59	0.05 - 0.10	2.96 - 6.42
Rainbow trout	LAL	mean	<0.45	NR	0.52	NR	0.11	5.38
Oncorhynchus mykiss		range	NR	<0.09 - <0.16	0.45 - 0.56	<0.90 - <1.57	0.06 - 0.14	4.30 - 5.82
	CR1	mean	<0.42	<0.01	NR	<1.05	NR	5.10
		range	NR	NR	NR	NR	NR	NR
	CR2	mean	<0.49	NR	0.44	NR	<0.05	4.27
		range	NR	<0.49 - <0.10	NR	<0.62 - <0.89	NR	NR

LAL= Lower Arrow Lake.
CR1= Columbia River downstream of Canadian Cellulose.
CR2= Columbia River downstream of Cominco.
NR= not recorded; WW = wet weight.

Table 12.9. Tissue Metal Concentrations from Muscle of Walleye (*Stizostedion vitreum*) from the Columbia River 1980-1988.

Year	N		Cadmium (mg/kg WW)	Copper (mg/kg WW)	Lead (mg/kg WW)	Mercury (mg/kg WW)	Zinc (mg/kg WW)
1980	3	mean	0.017	0.69	0.026	0.21	4.6
		range	<0.01 - 0.03	0.56 - 0.79	<0.01 - 0.065	0.16 - 0.25	4.5 - 4.8
1980[b]	7	mean	NR	NR	NR	0.31	NR
		range	NR	NR	NR	0.18 - 0.48	NR
1981	4	mean	0.006	0.72	0.016	0.4	5.5
		range	<0.01 - 0.01	0.52 - 0.86	0.01 - 0.022	0.31 - 0.49	5.0 - 6.1
1981[a]	9	mean	0.005	0.99	0.039	0.31	4.8
		range	NR	0.4 - 1.9	0.022 - 0.06	0.21 - 0.55	4.0 - 6.3
1986	11**	mean	<0.02	0.26	<0.1	0.36	4.6
		range	<0.02 - <0.02	<0.2 - 0.41	<0.1 - <0.1	0.2 - 0.76	3.8 - 6.2
1987	18**	mean	<0.02	0.59	<0.1	0.32	5.5
		range	<0.02 - <0.02	0.23 - 1.7	<0.1 - 0.05	0.07 - 1.02	4.7 - 6.4
1988	15	mean	<0.02	0.42	0.07	0.35	4.8
		range	<0.02 - <0.02	<0.2 - 0.63	<0.1 - 0.42	0.16 - 0.68	3.5 - 5.9

[a] = Collected by R.L.&L. Environmental Services Ltd.
[b] = Collected by Cominco.
note: half detection limit used for mean calculations when analyzed levels were at detection limits.
** = mercury sample sizes were 13 (1986) and 37 (1987).
NR = not recorded; WW = wet weight; N = number of samples.
Table adapted from Smith (1987) and NECL (1989).

Table 12.10. Tissue Metal Concentrations from Muscle of Mountain whitefish (*Prosopium williamsoni*) from the Columbia River 1980-1988.

Year	n		Cadmium (mg/kg WW)	Copper (mg/kg WW)	Lead (mg/kg WW)	Mercury (mg/kg WW)	Zinc (mg/kg WW)
1980	11	mean	0.019	0.94	0.12	0.12	4.9
		range	<0.011 - 0.051	0.62 - 1.6	<0.014 - 0.36	0.05 - 0.21	4.0 - 6.5
1981	11	mean	0.018	1.1	0.15	0.16	4.8
		range	<0.01 - 0.053	0.74 - 2.3	0.026 - 0.53	<0.05 - 0.27	3.8 - 6.2
1981[a]	10	mean	0.006	0.77	0.068	0.13	4.8
		range	<0.013 - 0.015	0.48 - 1.2	0.013 - 0.18	0.009 - 0.21	3.6 - 6.2
1983	13	mean	0.02	0.45	0.1	0.08	5.8
		range	<0.02 - 0.1	0.23 - 0.66	<0.1 - 0.3	<0.05 - 0.22	3.6 - 8.0
1986	14	mean	0.021	0.78	0.08	0.11	7.9
		range	<0.02 - 0.05	0.39 - 2.5	<0.1 - 0.29	<0.05 - 0.18	3.3 - 37
1987	15	mean	0.015	0.78	0.09	0.13	5.7
		range	<0.02 - 0.04	0.53 - 1.3	<0.1 - 0.18	<0.05 - 0.22	4.2 - 8.3
1988	15	mean	0.02	0.7	0.08	0.14	4.6
		range	<0.02 - 0.05	0.37 - 0.98	<0.1 - 0.42	0.09 - 0.22	3.5 - 5.8

[a] = Collected by R.L.&L. Environmental Services Ltd.
note: half detection limit used for mean calculations when analyzed levels were at detection limits.
WW = wet weight; N = number of samples.
Table adapted from Smith (1987) and NECL (1989).

Table 12.11. Tissue Metal Concentrations from Muscle of Rainbow trout (*Oncorhynchus mykiss*) from the Columbia River 1980-1988.

Year	N		Cadmium (mg/kg WW)	Copper (mg/kg WW)	Lead (mg/kg WW)	Mercury (mg/kg WW)	Zinc (mg/kg WW)
1980	2	mean	NR	NR	NR	0.1	NR
		range	NR	NR	NR	<0.05 - 0.17	NR
1980[b]	30	mean	NR	NR	NR	0.07	NR
		range	NR	NR	NR	0.01 - 0.55	NR
1981	1	mean	0.02	0.89	0.058	0.12	5.6
		range	NR	NR	NR	NR	NR
1983	15	mean	<0.02	0.59	<0.1	0.04	6.3
		range	<0.02 - <0.02	0.29 - 0.82	<0.1 - 0.2	<0.05 - 0.1	3.6 - 9.7
1987	7	mean	<0.02	1.2	<0.1	0.05	6.4
		range	<0.02 - <0.02	0.59 - 2.0	<0.1 - <0.1	<0.05 - 0.06	5.5 - 7.3
1988	3	mean	<0.02	0.7	<0.1	0.08	3.6
		range	<0.02 - <0.02	0.51 - 0.82	<0.1 - <0.1	0.07 - 0.09	3.2 - 4.2

[b] = Collected by Cominco
Table adapted from Smith (1987) and NECL (1989).
NR = not recorded; WW = wet weight; N = number of samples.
note: half detection limit used for mean calculations when analyzed levels were at detection limits.
< sample equal to detection limit.

Table 12.13. Concentrations of Mercury (mg/kg wet weight) Measured in Muscle Tissue of Fish from the Columbia River.

Species	Year	N	Mean	Standard Deviation	Range
Kokanee *Oncorhynchus nerka*	1981	15	0.06	0.049	< 0.05 - 0.16
Largescale sucker *Catostomus macrocheilus*	1980	18	0.16	0.038	0.09 - 0.22
	1981	11	0.15	0.038	0.10 - 0.22
	1981*	4	0.10	0.064	< 0.05 - 0.18
Moutain whitefish *Prosopium williamsoni*	1980	12	0.12	0.050	< 0.05 - 0.21
	1981	11	0.16	0.067	< 0.05 - 0.27
	1981*	10	0.13	0.045	0.09 - 0.21
	1983	20	0.08	0.071	< 0.05 - 0.22
Northern squawfish *Ptychocheilus oregonensis*	1980	5	0.57	0.30	0.24 - 0.86
	1981	4	0.62	0.21	0.45 - 0.91
	1981*	8	0.48	0.163	0.32 - 0.82
Peamouth *Mylocheilus caurinus*	1980	4	0.24	0.040	0.20 - 0.27
Rainbow trout *Oncorhynchus mykiss*	1980	2	0.10	0.10	< 0.05 - 0.17
	1980**	30	0.07	0.097	0.01 - 0.55
	1981	1	0.12	NR	NR
	1983	15	0.04	0.023	< 0.05 - 0.10

Table 12.13. Concentrations of Mercury (mg/kg wet weight) Measured in Muscle Tissue of Fish from the Columbia River.

Species	Year	N	Mean	Standard Deviation	Range
Walleye	1980	3	0.21	0.047	0.16 - 0.25
Stizostedion vitreum	1980**	7	0.31	0.12	0.18 - 0.48
	1981	4	0.40	0.082	0.31 - 0.49
	1981*	9	0.31	0.104	0.21 - 0.55

* = R.L.&L. Environmental Services Ltd. (1982).
** = Smith (1987).
NR = not recorded; N = number of samples.
data adapted from Smith (1987).

Table 12.14. Concentrations of 2,3,7,8-T_4CDD TEQs in the Muscle Tissue of Columbia River Lake whitefish 1988 and Mountain whitefish 1990-1992.

Species	Year	Site	N		2,3,7,8-T_4CDD TEQs (ng/kg WW)	Weight g	Length cm
Lake whitefish	1988 [1]	U/S Celgar	7	mean	7.2**	1183	39.1
Coregonus clupeaformis				range	NR	228.5 - 2137.8	27.4 - 50.8
		D/S Celgar	7	mean	109**	1313	46.95
				range	NR	1161.5 - 1465.3	46.0 - 47.9
Mountain whitefish	1990/91 [2]	U/S Trail	6	mean	26.1	554	35.7
Prosopium williamsoni				range	6.5 - 23.3	408 - 623	31.6 - 38.9
		D/S Trail	9	mean	34.3	523	33.9
				range	NR	NR	NR
Mountain whitefish	1992 [2]	Genelle	14	mean	10.3	361	32.1
Prosopium williamsoni				range	0.8 - 44.8	212 - 504	26 - 35.7
		Beaver Creek	13	mean	9.1	397	31.5
				range	0.9 - 25.2	250 - 521	26 - 36.7
Mountain whitefish	1992 [3]	Genelle	10	mean	4.91	NR	NR
Prosopium williamsoni				range	0.07 - 38.3	NR	NR
	1992 [3]	Beaver Creek	10	mean	1.47	NR	NR
				range	0.06 - 7.21	NR	NR

**Values calculated using half detection limits and higher international toxic equivalence factor (I-TEF) for total polychlorinated dibenzofurans (P_5CDF).

[1] Mah *et al*. 1989; [2] Liebe *et al.* 1994; [3] Antcliffe *et al.* 1997.

NR = not recorded; D/S = downstream; U/S = upstream; WW = wet weight.

T_4CDD TEQ = tetrachlorodibenzo-*p*- dioxin toxic equivalents.

Appendix A5

Detection Limits for Water, Sediments and Tissue Samples

Table A5.1 Lower Columbia Water Quality Detection Limits.

	Units	1997	1998	1999	2000	2001	2002 (January)	2002 (November)	2003	2004	2005
Total Metals ICPMS[1]											
Arsenic (As)	µg/L	0.1	0.2	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cadmium (Cd)	µg/L	0.01	0.05	0.01	0.01	0.01	0.01	0.1	0.01	0.01	0.01
Chromium (Cr)	µg/L	NA	0.1	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Copper (Cu)	µg/L	NA	0.4	0.5	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Lead (Pb)	µg/L	0.1	0.07	0.5	0.01	0.01	0.01	0.2	0.01	0.01	0.01
Mercury (Hg)	µg/L	NA	0.01	-	-	-	-	-	-	-	-
Thallium (Tl)	µg/L	0.002	0.05	0.1	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Zinc (Zn)	µg/L	NA	1.0	NA	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Nutrients											
Ammonia	mg/L	0.005	0.005	0.02	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Total Nitrogen	mg/L	0.01	NS	NS	NS	NS	NS	NS	NS	NS	NS
Total Dissolved Phosphorous	mg/L	0.001	0.002	0.002	0.1	NS	NS	NS	NS	NS	NS
Microbial											
Fecal Coliform	CFU/100 mL	1	1	2	2	1	1	1	1	1	1
E. Coli	CFU/100 mL	1	1	2	2	1	1	1	1	1	1
Enterococcus	CFU/100 mL	1	1	2	2	1	1	1	1	1	1

1. 1998 metals were measured using ICP, not ICPMS, which results in higher detection limits..

NA = not available (and all measurements were greater than the detection limit).

NS = not sampled or not assessed.

Table A5.2 Lower Columbia Sediment Quality Detection Limits.

	Units[1]	1999	2000	2001	2002	2004
TOC						
Carbon, Total Organic	%	NA	0.05	0.05	0.05	0.05
Simultaneously Extractable Metals						
Cadmium (Cd)	µmol/g	-	-	0.005	-	0.001
Copper (Cu)	µmol/g	-	-	0.005	-	0.004
Lead (Pb)	µmol/g	-	-	0.02	-	0.007
Nickel (Ni)	µmol/g	-	-	0.02	-	0.01
Zinc (Z)	µmol/g	-	-	0.02	-	0.004
Acid Volatile Sulphides						
Sulphides, Acid Volatile	µmol/g	-	-	0.2	-	0.2
Dioxins and Furans						
2,3,7,8 T4CDD	pg/g	-	0.2	0.2	var	-
Total T4CDD	pg/g	-	0.2	0.2	var	-
2,3,7,8 T4CDF	pg/g	-	0.2	0.2	var	-
Total T4CDF	pg/g	-	0.2	0.2	var	-
Total Metals (ICP)						
Arsenic (As)	µg/g	-	8	8	-	-
Cadmium (Cd)	µg/g	-	0.8	0.8	-	-
Chromium (Cr)	µg/g	-	0.8	0.8	-	-
Copper (Cu)	µg/g	-	0.8	0.8	-	-
Lead (Pb)	µg/g	-	8	8	-	-
Zinc (Z)	µg/g	-	0.3	0.3	-	-
Total Metals (ICPMS)						
Arsenic (As)	µg/g	NA	-	0.1	0.2	0.2
Cadmium (Cd)	µg/g	NA	-	0.01	0.05	0.05
Chromium (Cr)	µg/g	NA	-	0.2	0.2	1
Copper (Cu)	µg/g	NA	-	0.05	0.5	0.5
Lead (Pb)	µg/g	NA	-	0.01	0.1	0.1
Mercury (Hg)	µg/g	0.02	0.008	0.008	0.05	0.05
Thallium (Tl)	µg/g	NA	-	0.002	0.05	0.05
Zinc (Z)	µg/g	NA	-	0.1	0.5	1

1. All units provided on the basis of dry weight sediments unless otherwise noted.

NA = Not available (and all measurements were greater than the detection limit).

-- = Not analyzed

var = Varies per sample

Table A5.2 (Cont'd.)

	Units[1]	1999	2000	2001	2002	2004
Fatty Acids						
(individual FAs)	µg/g	-	0.05	0.05	var	-
Resin Acids						
(individual RAs)	µg/g	-	0.05	0.05	var	-
PBDEs						
(individual PBDE congeners)	pg/g	-	-	-	var	var
PCBs						
(individual PCB congeners)	µg/g	-	-	0.005	var	var
Halogenated Chlorophenols						
2,3,4,5-Tetrachlorophenol	µg/g	-	-	0.0005	-	-
2,3,4,6-Tetrachlorophenol	µg/g	-	-	0.0005	-	-
Pentachlorophenol	µg/g	-	-	0.0002	-	-
Non-Halogenated Organics						
(individual PAHs)	µg/g	-	-	0.02	-	-

1. All units provided on the basis of dry weight sediments unless otherwise noted.

NA = Not available (and all measurements were greater than the detection limit).

-- = Not analyzed

var = Varies per sample

Table A5.3 Lower Columbia Tissue Residue Detection Limits (Metals).

		Walleye						Mountain Whitefish				Rainbow Trout	
		2000	2001	2002	2003	2004	2005	2001	2002	2003	2004	2000	2003
Parameter	**Unit**												
		ICP	ICP	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP	ICP-MS	ICP-MS	ICP-MS	ICP	ICP-MS
Arsenic	µg/g wet[1]	4	4	0.2	0.2	0.2	0.2	4	4	0.2	0.2	4	0.2
Cadmium	µg/g wet[1]	0.4	0.4	0.05	0.05	0.05	0.05	0.4	0.4	0.05	0.05	0.4	0.05
Chromium	µg/g wet[1]	0.4	0.4	0.2	1	1	1	0.4	0.4	1	1	0.4	1
Lead	µg/g wet[1]	4	4	0.1	0.1	0.1	0.1	4	4	0.1	0.1	4	0.1
Mercury	µg/g wet[1]	0.06	0.02	0.05	0.05	0.05	0.05	0.02	0.02	0.05	0.05	0.02	0.05

1. µg/g wet except for 2000 and 2001 data, which was provided as µg/g dry.

Table A5.4 Lower Columbia Tissue Residue Detection Limits (Dioxins/Furans).

		Mountain Whitefish					Rainbow Trout
		2000	2001	2002	2003	2004	2000
Parameter	**Unit**						
Total T4CDD	pg/g wet1	0.1	0.01	0.1	0.1	0.03	0.1
Total T4CDF	pg/g wet1	0.1	0.01	0.1	0.1	0.03	0.1

1. µg/g wet except for 2000 and 2001 data, which was provided as µg/g dry.