COLUMBIA RIVER INTEGRATED ENVIRONMENTAL MONITORING PROGRAM (CRIEMP)

1991–1993 Interpretive Report

Prepared for:

CRIEMP COORDINATING COMMITTEE -
BC Ministry of Environment, Lands and Parks
Environment Canada
Department of Fisheries & Oceans
Cities of Castlegar & Trail
BC Hydro
Celgar Pulp Company
Cominco Limited

Prepared by:

AQUAMETRIX RESEARCH LTD.
204 - 2527 Beacon Ave.
Sidney, B.C.
CANADA V8L 1Y1

JUNE 1994

Julia Beatty Spence R.P.Bio.

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EXECUTIVE SUMMARY

The primary objective of this report is to define the current aquatic environmental status within the lower Columbia River from the Hugh Keenleyside Dam to the International Boundary. The Columbia River Integrated Environmental Monitoring Program (CRIEMP) 1991–1993 data is interpreted and evaluated. Modifications to the CRIEMP study design, appropriate for long-term monitoring, are also proposed.

The 1991–1993 CRIEMP survey incorporated a number of monitoring components which were considered appropriate to examine ecosystem conditions within the lower Columbia River. The integrated sampling effort evaluated water quality and sediment quality, as well as a number of *in situ* biological indicators of environmental conditions.

The CRIEMP survey results provided important insights into environmental conditions within the lower Columbia River. This survey has identified particular aspects of the monitoring program design which should be modified to improve the sensitivity in measuring spatial and/or temporal changes in environmental quality within the lower Columbia River.

The following summary presents the major findings of this initial CRIEMP survey, and the conclusions which can be drawn from these data.

WATER QUALITY CONDITIONS

Water quality monitoring indicated that the entire lower Columbia River system contained a variety of organic and inorganic contaminants, although their concentrations were generally below provincial and national water quality criteria and guidelines established for the protection of aquatic life. In addition to the influences of chemical constituents of the water column, the CRIEMP survey documented the impacts of total dissolved gas (TDG) associated with hydro-electric facilities in this portion of the lower Columbia River. Bacterial concentrations met all criteria set for drinking water and recreation.

Contaminant Levels

Chlorinated dioxins and furans were not detected within the water column at any of the stations sampled, although levels of specific fatty acid compounds such as arachidic acid were elevated immediately downstream of Celgar in contrast to the other stations sampled. Average and maximum levels of these organic compounds remained at levels below water quality criteria and guidelines at all stations sampled within the lower Columbia River.

Water quality criteria and guidelines were exceeded for metals including cadmium, chromium, mercury, lead, zinc, and copper. Water quality criteria for these metals were most frequently exceeded in samples collected downstream of Cominco. For example chromium and zinc exceeded criteria in about 40% of the samples. In general, annual *average* concentrations for trace metals in the water column within the study area were below water quality guidelines/ criteria/objectives levels. The data, however, suggested highly variable input of these metals, with occasional levels in excess of these 'acceptable' criterion limits. The cause of this variability was likely related to temporal changes in wastewater discharge quality and water flow.

For metals, the relationship between flow rate and concentration was apparent for a few of the sampling periods, but it did not explain the majority of fluctuations in the water quality data. Higher concentrations reported within high flow periods suggested an increase in loadings to the river, associated with possible changes in effluent composition and/or volume as a result of operational changes in discharges or in other contaminant sources.

Flow rate along the lower Columbia River is determined primarily through the controlled operation of the Hugh Keenleyside and Brilliant dams. Flow is an important physical factor in determining the dilution potential for the river, and can also have a direct impact on the biological resources of this system. The non-synchronized discharges associated with dams results in two distinct aquatic environments within this portion of the Columbia River, one upstream of the Kootenay-Columbia confluence, and the second downstream from this point. The former region is influenced primarily by the flow of the Hugh Keenleyside Dam, while the latter portion is influenced by the combined discharges of these dams.

Additional water quality effects associated with the dam operations include those associated with total dissolved gases (TDG). Monitoring of TDG during this survey indicated a level of supersaturation downstream of the Hugh Keenleyside Dam at Robson in excess of the provincial criterion during all months except August, September and October. Levels averaged 114% during November through July, resulting in TDG which may have significant biological effects in addition to those associated with other water quality parameters.

SEDIMENT QUALITY CONDITIONS

Elevated levels of trace metals within lower Columbia River sediments were restricted primarily to the region downstream of Trail. Metal concentrations exceeded those found at either reference site by up to 40-fold. The significance of these elevated levels in terms of potential impacts to aquatic life, given the lack of sediment quality criteria or objectives and the limited amount of sediment toxicity information, is uncertain at this time. Clearly, the existence of high concentrations of metals within sediments downstream of Cominco, and at the International Boundary, is of primary concern and importance for future monitoring efforts.

The CRIEMP data indicated that elevated sediment metal levels occured mainly at stations downstream of Trail. Higher levels were reported from the Beaver Creek station, an area that appears to be composed primarily of slag from the Cominco operation. Data confirmed the localized nature of sediment deposition zones within the lower Columbia River, and the difficulties associated with sediment monitoring. Analysis of sub-samples of reference site samples indicated that composited samples had a variability of about 5–10% for key metals (Cu, Pb, Zn).

The spatial distribution of organic compounds found within sediments of the lower Columbia River also confirmed the difficulties inherent in monitoring the depositional environment of this system. Although resin acids immediately downstream of Celgar were predictably higher than background reference levels, levels of this contaminant were also elevated at the sediment sampling site near Waneta, indicating long-range transport. Sediment levels of compounds such as lauric acid, myristic acid, oleic acid, palmitric acid, and stearic acid were not only higher than reference, but were reported in excess of those levels documented for the Celgar site.

The scarcity of depositional sites for sediment quality monitoring was further compounded by the different kinds of sediments at the few stations which were assessed by the initial CRIEMP survey. Levels of acid volatile sulfide (AVS) were dramatically different between stations, suggesting a potential difference in the bioavailability of trace metals between these sites. Similar differences were apparent in levels of total organic carbon (TOC), which can determine the binding potential of organic contaminants within the sediment medium.

BIORECONNAISSANCE

The biological impacts of water and sediment quality within the lower Columbia River were documented using benthos and periphyton community structural analysis, bioaccumulation of contaminants in macroinvertebrates and macrophytes, and by sediment bioassays. This component of the 1991–1993 CRIEMP survey used a bioreconnaissance approach designed to examine the utility of these various biological indicators for future monitoring programs.

Plant-Based Components

The bioaccumulation of metals within macrophytes effectively demonstrated spatial differences, and thus may be a suitable biological indicator for monitoring metals in the system. The use of periphyton monitoring, macrophyte distributions, and the macrophyte bioaccumulation components of this initial CRIEMP survey were considered of minimal value, as implemented, in monitoring the environmental condition of the river during this initial CRIEMP survey.

The use of periphyton community structure on fixed, natural substrates was considered inappropriate as a biological monitoring tool given the regulated flow of the river. As a photosynthetic group, many of the periphyton taxa are much more sensitive than benthos to (i) subtle changes in turbidity; (ii) amount of sunlight, and thus depth fluctuations; and (iii) other factors which do not necessarily relate specifically to contaminant inputs to the river. These factors preclude the effective use of a fixed-level (vertical bank position) sampling approach given the rapid, unpredictable changes in water level in the river.

Despite the above-noted limitations, moss beds occur extensively and almost exclusively downstream of Cominco (Norecol Ltd., 1993), and may be a useful indicator of the effects of nutrients and possibly other variables such as pH downstream of the Cominco fertilizer plant outfall, especially for monitoring changes expected when operations switch from phosphate to sulfate-based products.

Benthic Invertebrate Community Structure

The documentation of macrobenthos community structure provided a useful tool for monitoring environmental impacts within the lower Columbia River. Replicate sampling (n=5) suggested low within-station variability, thereby allowing considerable potential for quantitatively assessing spatial differences at appropriate sites along the river. The results of this initial CRIEMP survey suggest a number of problems with the present design, including the number and location of sampling stations, placement of sampler, and substrate stratification. Recommendations for modifying this survey component are proposed.

The combination of multivariate classification/ordination methods employed in this report has provided valuable insight into community variability within the lower Columbia River, and has presented a possible use of such methods in integrating the water and sediment quality components with the biological measures of environmental impact. Although provided primarily as an example of such an approach, the clustering and ordination techniques suggest that three community 'types' existed among the stations sampled within this CRIEMP survey. Type I was characterized by a diverse macroinvertebrate community (over 50 taxa) and was represented by the Kootenay reference station, Robson, and by Birchbank. The Type II community comprised a species assemblage of just over 20 taxa, and was found at only the station upstream of Celgar. Community Type III represented a combination of Ryan Creek (just downstream of Cominco) and Waneta.

Differences in the community types were related to a combination of substrate composition and sediment/water quality conditions at the various sites surveyed. Substrate composition differed between each of the three community types, although the Type II community was defined by the combined effects of substrate and lower water flow (current velocity). Analysis illustrated that environmental conditions upstream of Cominco were very different from those downstream (stations at Ryan Creek and Waneta), and that the sediment contaminants associated with the observed community differences included copper, lead, antimony, strontium and zinc.

Sediment Bioassays

Sediment bioassays were implemented on a limited scale for this initial CRIEMP survey. The single, unreplicated test completed for each of the nine sediment sampling stations provided inconclusive results using Microtox, while the amphipod survival test provided evidence that sediments immediately downstream of both Celgar and Cominco were toxic (33% and 27% survival, respectively). Sediment bioassays provide a useful method by which the effects of measured sediment quality can be ascertained. An expanded bioassay program integrating sediment quality data is recommended for a revised CRIEMP.

Contaminant Bioaccumulation in Macroinvertebrates

Contaminant data from adult caddisfly and freshwater bivalve tissue analyses provided useful information on bioaccumulation of contaminants. However, this sampling component was too limited in coverage of the study area with only three stations, including the reference site. Without sample replication, and thus an estimate of sample variability, results of these analyses were considered inconclusive.

Caddisfly results provided supportive evidence that the Waneta site was influenced by trace metal contaminants indicating, for example, that lead and antimony levels were over four times higher than those reported for the reference station. These tissue analyses also indicated that levels of total T4CDD and 2,3,7,8 T4CDD were 5 to 7 times those of background levels reported.

The small number of caddisfly sampling stations between Celgar and the International Boundary prohibited a comprehensive evaluation of the spatial response to contaminants discharged to the lower Columbia River. Although the study confirmed the potential for this CRIEMP monitoring component, expansion in the program sampling effort in terms of the number of sampling sites should be considered.

Organics and metal analysis of composite mussel tissues (n=5) at three sites provided similar results to those using the caddisfly tissues. Tissue levels of metals such as zinc, copper and lead at the Waneta site were 4, 10 and 60 times greater than those reported at the Kootenay reference site. These concentrations supported the sediment quality results suggesting that many of these metals are significantly higher at stations downstream of Trail than at other sampling stations within the lower Columbia River. However, organic chemicals such as some chlorophenols, dioxins and furans were significantly higher at the Kootenay reference site compared to locations on the lower Columbia at Waneta or downstream of Celgar. Historic use of chlorophenate-based wood preservatives may be implicated by this contamination.

Recent process changes at Celgar and Cominco have resulted in dramatic changes in wastewater composition and subsequently in the quality of effluent discharged to the Columbia River. Since these process changes were initiated after the CRIEMP study, it is anticipated that the improvements to the wastewater discharges will have a direct influence on the water, sediment and biological quality of the Columbia River. With these effluent improvements it is also expected that the maximum levels (spikes) detected for many of the parameters assessed will be significantly reduced in magnitude and frequency. Water quality concerns at and below the International Boundary (e.g., elevated lead levels) are also expected to be reduced as a result of these improvements.

Although significant improvements in receiving water quality are anticipated with the process changes, it must be realized that the magnitude of these improvements within the receiving environment will only be quantifiable following additional monitoring.

The 1991–1993 CRIEMP survey provided useful information regarding possible spatial impact within the lower Columbia River, and provided a base-line from which to measure future environmental responses. It has appropriately 'field-tested' each program component so that decisions can be made regarding a revised CRIEMP survey design for future monitoring efforts. This initial survey confirmed the premise upon which the program was designed, i.e., to provide an integrated evaluation of the environmental conditions of the lower Columbia River. The monitoring approach has demonstrated that contaminant loads to the lower Columbia River are interacting with the biological components and that downstream bioavailability of these contaminants are affecting community structure.

A revised program should incorporate elements to differentiate both spatial and temporal changes in biological integrity. Recommendations for modifications to the existing CRIEMP survey, to address design and implementation inadequacies of the 1991–1993 survey, are presented in this document.

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ACKNOWLEDGEMENTS

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Aquametrix Research would like to thank the following personnel for their contributions to this report: Stephen Cross, Deedee Kathman, Allan Arthur, K.T. Pirquet, Tim Gouch and Ann Fearon-Wood. The report was prepared under the direction of the CRIEMP Coordinating Committee. Aquametrix was not involved with the design of the initial CRIEMP survey nor with its implementation. Background material and written descriptions for various sections were provided by the following: hydrology, fisheries and fish habitat, and total dissolved gases by BC Hydro (G. Ash); water uses by the Regional Office, Ministry of Environment, Lands and Parks (J. Beatty Spence and Paul Cobban); Cominco plant history by B. Abbey; and Celgar history and operations by F. Mackay.

SECTION A:

BACKGROUND

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A-1 INTRODUCTION

The following document was prepared by Aquametrix Research Ltd. under contract to the Columbia River Integrated Environmental Monitoring Program (CRIEMP) Coordinating Committee. The CRIEMP Coordinating Committee comprises representatives of the British Columbia Ministry of Environment, Lands and Parks, Department of Fisheries and Oceans, Environment Canada, the cities of Castlegar and Trail, BC Hydro, Celgar Pulp Company and Cominco Limited.

CRIEMP OBJECTIVES

The primary objective of CRIEMP was to collect data which would provide a quality-assured, quantitative environmental information base. Upon this base, the status and trends of ecosystem health within the lower Columbia River can be documented, evaluated and shared among local stakeholders. This 'overall' objective was considered an appropriate goal upon which assessments of spatial and temporal trends in the environmental condition of the lower Columbia River system could be designed and conducted.

The specific objectives of CRIEMP, as stated in the CRIEMP 1991–1993 Data Report (Baturin, 1993), included:

- To assess the cumulative effects of Celgar, Cominco, municipalities, and other sources of pollution;
- To provide statistically valid and quality assured data for trend analysis on contaminants from Celgar's pulp mill and Cominco's smelter and fertilizer operation;
- To identify sentinel species for short and long-term trend assessment of bioaccumulation of toxic compounds; and
- To provide information on the contamination of non-migratory fish species.

REPORT OBJECTIVES

This report provides a summary, analysis and interpretation of the Columbia River Integrated Environmental Monitoring Program data acquired during the 1991–1993 Program. Evaluation of the data, including water and sediment quality, contaminant bioaccumulation and toxicity, benthos/periphyton community structure, and macrophyte distribution, is intended as an avenue for defining the environmental status (Beatty Spence, pers. comm.) within the lower Columbia River. The data assessment will also provide the technical information necessary to assess initial program components and to recommend modifications to the CRIEMP study design which will be appropriate for long-term monitoring.

A-2 STUDY AREA

The Columbia River Integrated Environmental Monitoring Program (CRIEMP) was implemented in a survey area covering the Columbia River downstream of the Hugh Keenleyside Dam to the International Boundary (Figure A-1), a distance of about 60 km. The hydrological characteristics and aquatic resources of this area are summarized below.

A-2.1 HYDROLOGY

The Columbia River within the CRIEMP study area has been greatly influenced by regulated flows from the operation of upstream storage dams on the Columbia River (i.e., Mica, Revelstoke and Hugh Keenleyside dams), on the Kootenay River system (i.e., Libby, Duncan and Corra Lynn dams), and on the Pend d'Oreille River. In addition, numerous other smaller dams and run-of-the-river reservoirs are located on these tributary systems.

The Hugh Keenleyside Dam, 7 km upstream of Castlegar, forms the outlet of Lower Arrow Lake at the upper end of the CRIEMP study area. Built as one of the Columbia River Treaty projects, it was completed in 1968, and is presently operated by BC Hydro. The Brilliant Dam, completed in 1944, is the lowermost dam on the Kootenay River, 3 km upstream of the Kootenay–Columbia confluence. The Waneta Dam, located on the Pend d'Oreille River 0.5 km upstream of its confluence with the Columbia River, was completed in 1954. Both the Brilliant and the Waneta dams are owned by Cominco Limited and operated by West Kootenay Power Ltd.

Butcher (1992) provides an annual streamflow balance for the lower Columbia River, indicating the contributions of each of the major tributaries to the total flow at the International Boundary. This summary estimates that outflow from the Hugh Keenleyside Dam contributes 39% of the total flow at the U.S. border. The Kootenay River supplies an additional 30% to this flow and the Pend d'Oreille River, which enters the Columbia River mainstem just up-stream of the International Boundary, contributes 27% to the total flow. The final 4% of the flow at the border is contributed by groundwater discharges and a number of small, unregulated tributaries including Norns, Champion, Blueberry, China, Murphy, Ryan, Bear, and Beaver creeks.

Average water velocity and travel time of water through the study area is dependent on discharge. However, based on hydraulic modelling (HEC-2) conducted during the early 1980s (BC Hydro, 1984), at the mean annual flow of the Columbia River, the mean velocity of the section from Hugh Keenleyside Dam to the Kootenay River confluence is about 0.5 m/s with a travel time of about 4 to 6 hours. For the section from the Kootenay River confluence to just downstream of Birchbank, the mean velocity increases to about 1.6 m/s with average travel times similar to the upper section (BC Hydro, 1984). Between Birchbank and the International Boundary, the average velocity is also about 1.6 m/s, with a travel time of about 4 hours (BC Hydro, unpubl. data).

Regulation of the Columbia River has altered the natural discharge regime, resulting in higher winter flows and lower spring and summer flows than would be experienced under natural conditions. Since construction of the mainstem Columbia River Treaty storage projects (i.e., Mica and Hugh Keenleyside dams), there has been a significant reduction in peak (flood) flows:

Maximum Daily Discharge in m^3/s

	Castlegar Ferry	Birchbank	International Boundary
Before 1968	5,380	10,600	15,500
After 1972	4,020	5,410	8,100

(data from Water Survey of Canada, 1991)

Although regulation has dampened the magnitude of the seasonal fluctuations in flow, operation of the projects under the Columbia River Treaty and the more recent Non-Treaty Storage Agreement has resulted in greater short-term (daily to weekly) fluctuations in flow. In addition, the Brilliant and Waneta dams are often used to meet energy loads during peak usage hours resulting in daily fluctuations in flow below these facilities.

The lower Columbia River represents a very complex system as a result of water regulation. Figure A-1 provides hydrographs for each of the major source controls (at Hugh Keenleyside, Brilliant and Waneta dams), illustrating the variability in discharge rates over the year, and the effects on the mainstem Columbia River flow rate as a result of these individual discharges.

A-2.2 AQUATIC RESOURCES

Physical Habitat

During fisheries studies conducted from 1990 to 1993, R.L. & L. Environmental Services identified and mapped fish habitats of the Columbia River between Hugh Keenleyside Dam and the Canada/USA border (R.L. & L, 1993a). In defining fish habitat within this section of the Columbia River, seven reaches were assigned, based on habitat characteristics such as flow regime, depth, and substrate composition. These fisheries reaches (slightly different than those provided for in the initial CRIEMP sampling design) are as follows:

- Reach 1 (from Km 0 to Km 8.0);
- Reach 2 (from Km 8.0 to Km 14.0);
- Reach 3 (from Km 14.0 to Km 23.0);
- Reach 4 (from Km 23.0 to Km 27.0);
- Reach 5 (from Km 27.0 to Km 38.0);
- Reach 6 (from Km 38.0 to Km 51.5);
- Reach 7 (from Km 51.5 to Km 56.5).

Reach 1, the uppermost reach, extends from Hugh Keenleyside Dam downstream for 8 km to the upstream end of Tincup Rapids. This reach is characterized by a low gradient and corresponding low water velocities and, in general, exhibits lake-like conditions during periods of low dam discharge. Reach 1 possesses the greatest depths within the upper section, with average depths ranging from 18 to 20 m. Substrates consist predominately of fines (i.e., sands and silts), although extensive sections along the bank have been armoured with large riprap. This reach encompasses what was the downstream end of the natural Lower Arrow Lake before regulation by the Hugh Keenleyside Dam.

Reach 2 extends from the upstream end of Tincup Rapids (Km 8.0) to downstream of Kinnaird Bridge (Km 14.0). This reach exhibits high water velocities due to relatively shallow depths (average thalweg or centreline depths of 2 to 6 m). Substrates in this reach are predominately boulders and large cobbles. Tincup Rapids was the natural outlet of Lower Arrow Lake before construction of Hugh Keenleyside Dam. A limited degree of channel braiding is present in the form of Waldies Island (Km 8.5) and Zuckerberg Island (Km 10.5). Reach 2 contains considerably more shallow water habitats than are available in either Reach 1 or Reach 3.

Reach 3 extends from Km 14 downstream to Km 23 at Champion Creek. This reach is characterized by lower flow velocities than Reach 2, but higher than Reach 1. Reach 3 is characterized by a single, relatively straight channel confined between steep, eroding valley walls; average channel thalweg depths range from 6 to 10 m. Substrates predominately consist of cobbles, boulders, and coarse gravels. Small localized areas of sand deposition occur infrequently. Nearshore habitats generally exhibit a steeply sloping profile.

Reach 4 (Km 23.0 to Km 27.0) consists of a braided depositional island complex. Velocities are moderate, depths generally shallow (1 to 4 m), and substrate consist mainly of cobbles and gravels. The gently sloping nature of the depositional bars and shallow side channels provide an abundance of shallow nearshore habitats.

Reach 5 extends from Km 27.0 to Km 38.0 and is characterized by a narrow, deep channel confined between high steep valley walls; bedrock outcrops are frequent along the banks. Velocities are generally moderate to high, and average thalweg depths range from 6 to 12 m. Shallow water habitats are limited within the reach.

Reach 6 extends from Km 38.0 to Km 51.5 and is relatively uniform in terms of channel form, depth, velocity, and substrate. Substrates consist mainly of cobbles and small boulders although localized areas of gravels are found associated with side-bar formation and the alluvial outwash fans of tributaries. Depths are generally shallow with the average thalweg depths ranging from 3 to 8 m. Velocities are generally moderate, although localized sections of low and high velocities are present. A unique feature is the Rock Island area (Km 43.5) where a transverse escarpment of bedrock produces an area of deep turbulent habitat. In general, the availability of shallow water habitats has been classed as moderate (i.e., greater availability than in Reach 5 and lower than in Reach 4).

Reach 7 extends from Fort Shepherd Eddy (Km 51.5) downstream to the Canada/USA border (Km 56.5). With the exception of two large eddy pools (i.e., Fort Shepherd Eddy at Km 52.5 and Waneta Eddy at Km 55.0), the reach is typified by shallow depths, high water velocities, and boulder/cobble substrate. Rapids are present immediately above and below Fort Shepherd Eddy and immediately above Waneta Eddy. Average depths range from 3 to 6 m. The two eddies provide localized areas of lower water velocity and greater depth. Maximum depths are approximately 50 m in Fort Shepherd Eddy and 20 m in Waneta Eddy. Nearshore shallow water habitats are limited.

Fisheries

During the course of fisheries studies conducted by R.L. & L. Environmental Services Ltd. throughout 1980 to 1984 and 1990 to 1993, 24 fish species were recorded from the lower Columbia River system between Hugh Keenleyside Dam and the Canada-USA border (Ash *et al.*, 1981; R.L. & L., 1984b; R.L. & L.,1985; Hildebrand, 1991; R.L. & L., 1993a and 1993b). Eleven species were classified as sportfish and thirteen were classified as non-sportfish. Some recent fisheries studies in the Columbia River include winter fish sampling below the Cominco smelter at Trail (R.L. & L., 1992), rainbow trout spawning with emphasis on Norns Creek (R.L. & L., 1994), and status of white sturgeon in the Columbia River (R.L. & L., 1993c).

The sportfish species encountered in the Columbia River system include white sturgeon, mountain whitefish, lake whitefish, rainbow trout, cutthroat trout, bull trout, brown trout, brook trout, kokanee, walleye, and burbot. Non-sportfish species include redside shiner, largescale sucker, longnose sucker, bridgelip sucker, Umatilla dace, longnose dace, prickly sculpin, torrent sculpin, shorthead sculpin, mottled sculpin, peamouth, northern squawfish, and carp. Of these, the Council on the Status of Endangered Wildlife in Canada (COSEWIC) has listed white sturgeon and Umatilla dace as being 'vulnerable,' and shorthead sculpin has been listed as 'threatened.'

Several sportfish and non-sportfish species have displayed appreciable changes in their contribution to the catch since the fisheries studies began in the early 1980s. In general, mountain whitefish have remained the dominant sportfish species encountered in the Columbia River system; their contribution to the overall sportfish catch, however, has declined from 80% during the combined 1980 to 1984 studies to 57% during the 1990 to 1993 studies.

Burbot have displayed a consistent decrease in relative abundance since the 1980s. In the 1980 to 1984 studies, burbot contributed 1.8% to the sportfish catch, but less than 0.1% in the 1990 to 1993 period, in spite of greater sampling intensity. Over-harvest of burbot in the early 1980s and increased predation by walleye may be factors that have contributed to the low numbers of burbot presently recorded in the Columbia River mainstem.

Both rainbow trout and walleye have increased in relative abundance in catches since the 1980s. Rainbow trout have increased from 2.1% of the sportfish catch in the 1980 to 1984 studies, to approximately 20% in the 1990 to 1993 studies. Walleye have increased substantially in the Columbia River mainstem since the early 1980s. In the 1980 to 1984 studies, walleye contributed between 0.1 and 0.8% to the total sportfish catch, whereas in the 1990 to 1993 studies, they contributed between 18 and 24% to the total sportfish catch. The increase in walleye, a relatively recent introduction to the species assemblage, may have contributed to the gradual decrease in abundance of resident fish species such as mountain whitefish and redside shiner.

Fish movements in the Columbia River mainstem were investigated using mark-recapture data for largescale sucker, longnose sucker, mountain whitefish, northern squawfish, rainbow trout, walleye, and white sturgeon. With the exception of rainbow trout and walleye, these fish species were not observed to move long distances. Walleye and rainbow trout moved, on average, much farther than the other species, and numerous occurrences of movements out of the study area into Lake Roosevelt were recorded.

Radio telemetry studies were used to identify movement of rainbow trout, walleye, and white sturgeon within the Columbia River system. Radio-tracking results from rainbow trout indicate a portion of the population that spawns in the Columbia River mainstem between Hugh Keenleyside Dam and the International Boundary exhibit post-spawning migrations to downstream areas in the USA. In addition, a substantial portion of the spawning population utilizes feeding and overwintering habitats in USA sections of the Columbia River mainstem and in Lake Roosevelt. The Marcus area above Kettle Falls appears to provide important feeding habitats for post-spawners that move into the USA. In the Canadian portion of the Columbia River, most feeding activity by post-spawners occurs in the middle and lower reaches.

Results of radio-tagging conducted by R.L. & L. Environmental Services Ltd. on walleye indicate that although some walleye remain in the study area year-round, most migrate upstream into the Canadian portion of the Columbia River from overwintering and spawning areas in or adjacent to Lake Roosevelt (e.g., Spokane Arm) and the Spokane River. Movements into the Canadian portion of the Columbia River are apparently related to feeding activities by sub-adult and adult cohorts. Available evidence suggests walleye do not spawn in the Columbia River mainstem between Hugh Keenleyside Dam and the International Boundary.

Studies on white sturgeon movements in the Columbia River mainstem indicate the majority of radio-tagged individuals resided in preferred habitat areas for long periods, although localized movements of less than 10 km occurred within and between preferred areas. Movements greater than 40 km were recorded for a few individuals, of which several displayed movements into the section of the Columbia River in Washington State. White sturgeon spawning was recorded in the Columbia River at the Pend d'Oreille River confluence below the Waneta Dam tailrace area. Available evidence suggests the Waneta area may provide the best conditions for white sturgeon spawning in the Columbia River between Hugh Keenleyside Dam and the International Boundary.

Examination of data obtained from mitochondrial DNA analysis, life history parameters, and movement studies indicated that the rainbow trout spawning populations in each of the main spawning areas were not genetically distinct. Available evidence suggests intermixing between the various rainbow trout spawning populations with non-native stocks. The likelihood that a pure 'native' rainbow trout stock still persists in the Columbia River was considered to be low.

Habitat Use by Fish

The fish species in the Columbia River use a variety of habitats. Mountain whitefish tend to select the deeper habitats usually associated with cobble, boulder, or bedrock substrates. Water velocities adjacent to the bank in these areas are usually moderate to high, with instream cover provided by backwater areas, eddy pools behind submerged boulders, and substrate interstices. This species also displays a preference for riffle and run areas adjacent to cobble and boulder depositional areas (i.e., bar formations and shoal habitat).

Rainbow trout juveniles and adults, and walleye adults, have been recorded most frequently in association with steeply sloped banks, with large boulder, bedrock, or rip-rap substrates, and to a lesser extent with shallow sloping shoreline areas with cobble and small boulder substrates. Water velocities adjacent to the bank in these areas are predominately moderate to high with instream cover provided by substrate interstices, backwater areas, and eddy pools behind submerged boulders.

White sturgeon exhibit a definite selection for deep water habitats (i.e., greater than 18 m depth) usually associated with deep eddy pools, spillway areas below dams, or larger tributary confluences. Major holding and feeding areas for white sturgeon are the 8-km section below the Hugh Keenleyside Dam, the Kootenay-Columbia confluence area, Fort Shepherd Eddy and the Pend d'Oreille–Columbia confluence (Waneta Eddy).

Suckers and northern squawfish are generalists in habitat preference within the Columbia River, whereas bull trout primarily occupy confluence habitats. Sculpins are most commonly associated with cobble and small boulder banks, consisting of a series of outcrops that produce moderate to low velocity backwater habitats. Adult redside shiner were recorded in large boulder, bedrock habitats that produce an irregular shoreline with an abundance of backwater areas. This species also display a preference for low flow, low gradient reaches located in the upper section of the Columbia River. Northern squawfish juveniles, dace species, and sucker fry are generally found in shallow water habitats with moderate to low flows.

In general, the adult cohorts of most fish species usually occupy deeper water habitats during the day and move into shallow water habitats for feeding at night. Young-of-the-year and juvenile fish select shallow shoreline habitats, where food and cover availability is greatest, and protection from predators is provided; however, during periods of high dissolved gas levels, use of the shallow water habitats by fish is restricted.

Important habitats identified in the Columbia River system include rainbow trout spawning areas in the Norns Creek confluence area, the lower end of Tincup Rapids (along the west bank), and in the braided channel area below Genelle. Spawning by rainbow trout from the Columbia River also occurs in the Kootenay River below the Highway 3A bridge (downstream from Brilliant Dam), in Norns Creek proper and, to a substantially lesser degree, in several minor tributaries to the mainstem (i.e., Murphy Creek, Blueberry Creek, Beaver Creek, China Creek, and Champion Creek). White sturgeon spawning has been documented in the Pend d'Oreille–Columbia rivers confluence area. Spawning by sucker species has been recorded in the Norns Creek fan area, the oxbow channel in the Kootenay River, the Genelle area, and in Norns Creek. Important kokanee spawning habitat was identified in Norns Creek proper; possible spawning use of the mainstem Columbia River below Genelle and the Kootenay River upstream from the confluence with the Columbia River was suspected but not confirmed. Spawning areas for mountain whitefish were recorded in the Columbia River below Norns Creek Fan (Tincup Rapids area), downstream of the Kootenay River confluence, Blueberry Creek to China Creek, the braided channel area below Genelle, downstream of Beaver Creek to Waneta Eddy, and the Kootenay River from below the Brilliant Dam to the confluence with the Columbia River. These locations were identified based on the presence of mountain whitefish eggs, and therefore may represent either actual mountain whitefish spawning locations, or deposition areas of eggs from upstream spawning areas.

Spawning in the study area generally occurs from April to June for rainbow trout, May to June for sucker species, June to July for white sturgeon, August to September for kokanee, and October to February for mountain whitefish and lake whitefish. Walleye spawning has not been recorded in the study area.

Important rearing areas for rainbow trout are located in the lower Kootenay River, in the Columbia River below Norns Creek fan (Waldies Island area), Tincup Rapids, from Billy Creek to Gyro Park, and from Fort Shepherd Eddy to Waneta Eddy, as well as many of the minor tributaries to the Columbia River. Rearing use of shallow water mainstem habitats by other sportfish species (i.e., kokanee, mountain whitefish, white sturgeon, walleye, bull trout) appears to be limited.

Sport Fishing

A detailed sport fishing and boating survey was conducted on the Columbia River between the Hugh Keenleyside Dam and the Canada-USA border during the period May 1990 to April 1991 (ARA, 1992). From these studies, it was estimated that anglers spent 12,605 recreation days on the river for a total of 26,260 angler-hours. During this period, anglers caught an estimated 8012 fish, of which 5931 were kept by the anglers, and 2081 were released.

Walleye was the primary sport fish caught by anglers during the study (48% of the catch), followed closely by rainbow trout (46%). White sturgeon contributed about 2.5%, and other species such as mountain whitefish, lake whitefish, bull trout, kokanee, and several non-sport species contributed the remainder of the catch.

Angling success rates for the three main species during the study were 0.14 rainbow trout per angler-hour (0.293 per angler-day), 0.147 walleye per angler-hour (0.306 per angler-day), and 0.008 white sturgeon per angler-hour (0.016 per angler-day).

The majority (80%) of the anglers interviewed during the study were local residents; 10% of the anglers were from other areas of BC, 3% were Canadian residents living outside BC, and 7% were from out of country (primarily from Washington State).

Other Water Uses

This portion of the Columbia River is part of a 500-km stretch of navigable water used by boaters for general recreation. Within the CRIEMP study area, swimming and wading occurs at Pass Creek Regional Park, Beaver Creek Provincial Park and at sites frequented by local families and area residents (Butcher, 1992).

Celgar Pulp Company operates a water pumping station on the Lower Arrow Lake which supplies water to the pulp mill, Pope & Talbot Ltd., and the City of Castlegar. Cominco withdraws water from the river; this source also supplies the communities of Warfield and Tadanac.

Municipal

Several municipal sewage treatment plants discharge directly to the Columbia River. The two largest direct discharges, from the cities of Castlegar and Trail, are authorized under permit with BC. Environment pursuant to the Waste Management Act. The City of Castlegar has two secondary treated sewage discharges: one located near the north side of the river about 1 km downstream of the CPR railway bridge, and the other near the south shore of the river 2 km downstream of the Kootenay–Columbia confluence. The Regional District of Kootenay Boundary operates a primary sewage treatment plant that services the greater Trail area. The plant and discharge to the Columbia River are approximately 10 km below the Old Trail Bridge.

During the CRIEMP sampling program, Celgar Pulp Company held a permit with BC Environment which authorized the discharge of secondary treated effluent directly to the Columbia River on the south shore of the river upstream of the main effluent diffuser. Celgar's domestic sewage plant also treated sewage from Pope & Talbot Ltd. Since the upgrade of the mill in 1993, treated sewage from both operations has been directed to Celgar's effluent treatment works and is now discharged via Celgar's main diffuser to the Columbia River. Selkirk College and the Lion's Head Neighbourhood Pub, both in the Robson area, contribute relatively small amounts of treated sewage which are permitted for direct discharge to the Columbia River.

Several additional treated sewage effluents, under permit with BC Environment, discharge to tributaries of the Columbia River. The Kootenay River receives treated sewage from the City of Nelson just below Grohman Narrows, as well as a much smaller sewage discharge from Stralaeff's Mobile Home Park near the confluence with the Columbia River. Beaver Creek, which enters the Columbia River approximately 20 km below the Old Trail Bridge, receives two discharges of secondary treated sewage from the villages of Fruitvale and Montrose.

A-3 ENVIRONMENTAL CONCERNS

Environmental concerns within the lower Columbia River stem from the operation of the industrial and municipal facilities which discharge a variety of wastewater streams to the river, as well as the operation of hydroelectric dams which produce increases in dissolved gases and dramatic short-term fluctuations in water level. The posting of Fish Consumption Advisories within this portion of the Columbia River since 1991 has added to such concerns with respect to water quality and the industrial and municipal activities which may contribute to the problems.

Environmental monitoring efforts within the lower Columbia River have, historically, concentrated on water quality issues. Until about 1986, studies focussed primarily on metals contamination, with a shift of interest since then to include the environmental effects of effluent discharged from the pulping process.

Environmental monitoring conducted within the lower Columbia River has included programs implemented by both the federal and the provincial governments, at permanent sampling stations, to document temporal changes in water quality (primarily metals, and more recently organochlorines). Provincial assessment of water quality conditions in the lower Columbia (from Hugh Keenleyside Dam to Birchbank) have culminated in the development of Water Quality Objectives for this portion of the river (Butcher, 1992). A second, comparable objectives document is presently being prepared jointly by the federal and provincial governments for the reach extending from Birchbank to the International Boundary.

Other studies have assessed specific discharges and/or proposed developments within the lower Columbia River. Examples of such studies include those completed by Brown (1985), Dwernychuk (1980; 1983; 1984; 1986; 1988), EVS/Cirrus (1989), IEC (1984), Kerr Wood Leidal Associates (1984), Maxwell (1985), Norecol Ltd. (1989), Smith (1986; 1987), and Sheehan and Lamb (1987).

Historical studies, although comprehensive in dealing with specific environmental issues, did not typically provide information on environmental conditions for the entire lower Columbia River system. The studies were related to specific developments or to general water quality conditions within the receiving environment of a particular wastewater discharge.

A-3.1 PHYSICAL

The physical effects of flow regulation at the upstream dams have a direct impact on the development and maintenance of biological communities along the lower Columbia River. These impacts, due to changes in wetted area, velocity and depth, are attributable, in part, to desiccation, changes in available light penetration, and changes in temperature. Rapid fluctuations in water level will affect periphyton species assemblages, benthic invertebrates, and habitat conditions for fish, thereby resulting in reduced productivity of the system. Water level fluctuations also can affect fish directly, by exposure and desiccation or freezing of fish eggs deposited in shallow areas.

Total Dissolved Gases

One of the primary environmental concerns associated with the operation of the dams is the increased total dissolved gas (TDG) below these facilities. High dissolved gas levels occur at dams when spilled water traps air bubbles and carries them to depth in the 'plunge pool' or 'stilling basin' immediately below the dam. Hydrostatic pressure at depth (due to the weight of the water above) causes the gases in the bubbles to dissolve. When the water returns to the surface where pressure is much lower, the water becomes supersaturated with dissolved gases. The extent of supersaturation is often reported as percent saturation, which is total gas pressure (TGP) expressed as a percentage of barometric pressure. Another way to express this is as ΔP, the difference between TGP and barometric pressure. Supersaturated water will eventually equilibrate back to saturation level as the dissolved gasses comes out of solution, but this can require considerable time in a large river system such as the Columbia River.

The constituents that contribute to the total gas pressure include the partial pressures of all dissolved gases including nitrogen, oxygen, carbon dioxide, argon, other trace gases, and water vapour. In cases where dissolved gas supersaturation is produced by dams, the ratio of supersaturated nitrogen to supersaturated oxygen is approximately the same as the ratio of nitrogen to oxygen in air (Sigma Engineering Ltd., 1990).

Supersaturation of dissolved gases can also be caused by other mechanisms. Thermal heating can be the cause when saturated cold water is rapidly heated in a waterbody (for instance, in a lake or reservoir in the spring). Since dissipation of the dissolved gas to the atmosphere occurs only at the air-water interface (which is very small in comparison to the total volume of water), supersaturation can persist for several months. Total dissolved gas supersaturation can also occur as a result of photosynthetic production of oxygen by phytoplankton.

The Columbia River below the Hugh Keenleyside Dam has been identified as having the highest total dissolved gas concentrations of the 35 major rivers or lakes examined in British Columbia (Clark, 1977). TDG levels up to 144% saturation were measured below Hugh Keenleyside Dam on 17 August 1976. The deleterious effects of high TDG levels on fish in shallow water (referred to as gas bubble trauma) have been well documented (Weitkamp and Katz, 1980; Fiekeisen and Montgomery, 1978; Ebel *et al.*, 1975; Fidler, 1988). Potential effects of high TDG levels in the Columbia River study area were first described by Ash *et al.* (1981). Studies since that time have demonstrated that the high dissolved gas levels were attributable primarily to the use of the spillway as the mode of discharge, which is necessary when differential heads between the reservoir and river were above 10.6 m. At lower differential heads, water is normally discharged through the lower level ports which results in lower TDG levels in downstream waters.

In 1992, BC Hydro initiated a study to investigate potential operational changes that could reduce the degree of increased TDG levels at the Hugh Keenleyside Dam. The results of the first year of the study (Klohn-Crippen Integ., 1993) have shown that, due to the unique design of the energy dissipater below the dam, higher TDG levels generally result when water is discharged through the four south ports than through the four north ports, although the difference appeared to be related to other factors, such as tail-water level or differential head. The ongoing study is concentrating on the potential for using the low-level ports at greater differential heads, thereby reducing the temporal extent and magnitude of the high TDG levels.

High dissolved gas levels also occur downstream of Brilliant Dam on the Kootenay River and below Waneta Dam on the Pend d'Oreille River during periods of spill at these facilities (normally May through June). Although TDG levels are not as high as below Hugh Keenleyside Dam, saturation levels in the range of 115% to 125% are not uncommon (R.L. & L. Environmental Services Ltd., unpubl. data). The high total dissolved gases in flows from these systems therefore can contribute to effects of high TDG on aquatic organisms in downstream reaches of the Columbia River.

A-3.2 CHEMICAL

The lower Columbia River system is influenced by the effluent discharged by two primary industrial facilities, as well as a number of permitted municipal waste discharges. A description of the point-source discharges, including historical effluent characteristics (quality/quantity) and recent (or projected) changes to effluent quality, given process improvements, is provided in the following sections for each of the principal waste discharge sources, i.e., Celgar, Cominco, and municipal waste.

Celgar Pulp Company

Historical Mill Operations

The Celgar Pulp Company is located downstream of the Hugh Keenleyside Dam and upstream of the confluence of the Columbia and Kootenay rivers at Castlegar, BC. When operations commenced in early 1961 it was the first bleached kraft mill in the interior of the province. The mill was designed for 454 ADtpd (air-dry tonnes per day) of fully bleached softwood kraft pulp, incorporating the best available technology for both pulp manufacture and pollution control of the time. Pollution control works used up to 1993 were:

- a 30-metre diameter clarifier to remove solids from the woodroom hydraulic debarker effluent;
- a side hill screen to remove fibre from the general pulping group sewer; and
- a foam trap and a submerged outfall equipped with a six-port diffuser through which the effluent flowed to the Columbia River.

Present Mill Operations

In 1989, the company announced its intention to replace the original bleached kraft pulp mill with a new 1200 ADtpd bleached kraft mill. The new mill would incorporate best available technology and would meet all current and foreseeable environmental requirements. The original mill would continue to operate until the new mill was built, when the original mill would be permanently shut down, leaving only the pulp machine and the two power boilers operating. One boiler would be placed on standby, burning only natural gas, while the other would be equipped with an electrostatic precipitator and would continue to burn wood waste.

This proposed $700 million project was subjected to an intensive environmental and socio-economic review. It was the first project to undergo a review under BC's then-recently introduced Major Project Review Process (MPRP). The review was conducted jointly with the federal government's Environmental Assessment and Review Process (EARP). Obtaining approval under the combined environmental review processes, which included formal public hearings before a government-appointed review panel, took about 12 months. The Review Panel's preliminary report to the federal and provincial governments, which essentially recommended approval of the project subject to a number of conditions, was issued in December 1990. The final report, issued in February 1991, cleared the way for construction of the new mill to proceed.

Various components of the new mill (e.g., lime kiln, recausticizing plant, ClO_2 generator, effluent treatment system, pulp machine, evaporators and recovery boiler) were brought into operation in stages to service the original mill during the construction period from February 1991 to May 1993. CRIEMP river sampling commenced during the construction phase of the expansion. The start-up of the new fibre line in June 1993, following the permanent closure of the original kraft mill one month earlier, signified the commencement of the new production facilities.

Effluent from the pulp mill is treated in an air-activated sludge treatment system. The process sewers are mixed, neutralized and then pumped to the primary clarifier located 2.5 km west of the mill site. The clarified effluent overflows the weirs and enters the 18-hour cooling pond where the temperature is reduced from 50–60°C to 35–40°C. From the cooling pond, the effluent is then treated in a 36-hour-aeration biological basin. Ammonia and phosphoric acid are available for nutrient requirements, if necessary. The treated effluent, mixed with the bacterial sludge, enters into two secondary clarifiers where the sludge is separated and returned to the basin. Treated clarified effluent then overflows the clarifiers and is discharged to the Columbia River. Clean cooling-water is mixed with the effluent just prior to discharge.

When a spill is detected in the process effluent, the entire effluent flow can be diverted to one of two 12-hour-retention spill ponds.

A portion of the recycled bacterial sludge is wasted daily and is mixed with the primary sludge prior to dewatering. The dewatered sludge is then incinerated in the No. 2 power boiler.

Effluent Quality

Effluent discharged from the mill enters the river through a submerged diffuser located mid-channel, directly off the pulp mill. The effluent from the old mill was characterized by suspended solids, colour, nitrogen, phosphorus, biological oxygen demand (BOD), resin/fatty acids, adsorbable organic halogens (AOX), chlorinated phenolic compounds and chlorinated dioxins/furans (Table A-1). During the CRIEMP sampling phase, the effluent discharged to the river was acutely toxic to rainbow trout (96-hour LC50 results 8–28%).

The new mill, with complete substitution of chlorine dioxide for chlorine and the biological wastewater treatment process, has resulted in substantial improvements in effluent quality (see table below). Loadings of resin/fatty acids, BOD and AOX have been substantially reduced. The mill now meets the BC Ministry of Environment, Lands and Parks permit requirement of 1.5 kg of AOX/Air Dry metric tonne of pulp, and complies with federal dioxin and furan regulations. Levels of dioxins and furans are now below analytical detection limits. Since the start-up, effluent from the new mill has been non acutely toxic to rainbow trout (96-hour LC50 results greater than 100%).

MAJOR PROCESS CHANGES AT THE CELGAR PULP FACILITY AND THE EFFECT ON ORGANICS LOADING TO THE COLUMBIA RIVER

YEAR	PROCESS CHANGE	EFFECT ON ORGANICS LOADING
1989	• Terminated use of defoamers which contain PCDD/PCDF precursors. • Began 20-40% chlorine dioxide substitution for chlorine in bleaching process. • Began using high shear mixers in the chlorination process.	Initial reduction in dioxin and furan congeners within wastewater streams.
1991	• Removed recovery boiler scrubber water, which contained dibenzofuran, from bleach plant. • Utilized 40% chlorine dioxide substitution for chlorine in the bleaching process. • Began using hydrogen peroxide in the delignification process.	Reduction in dibenzofuran compounds and continued reduction in chlorinated organics.
1993	• Old bleach plant off-line in May 1993; new bleach plant on-line in mid-1993. • Instituted 100% chlorine dioxide substitution for chlorine. • Began secondary (biological) treatment of mill effluent.	Reduction of dioxin and furans to levels well below detection in the effluent. AOX levels below 1.5 kg per tonne of pulp. Removed acute toxic effect on test fish.

Cominco

Smelting and refining have been carried out at Trail since the early 1900s. Developed from a turn-of-the-century copper and gold smelter, the integrated metallurgical operation now produces primarily zinc and lead. Minor quantities of metals such as cadmium, silver, gold, bismuth, and copper sulphate are produced from the impurities in the zinc/lead ore. Over the years, the processes and plants have been modified many times with advances in technology (Cominco, 1992).

The Trail smelter was originally built to process ores from local mines. Concentrates are now purchased from mines in BC, Washington State, Idaho, Montana, Colorado, Alaska, and many other parts of the world. The rock dug up in these mines is ground into fine powder so the metal bearing particles can be separated and concentrated. Over 700,000 tonnes of these concentrates are processed at Trail each year (Cominco, 1992).

The Fertilizer Operations serve primarily as the means of converting surplus sulphuric acid into useful products. Phosphate rock from Montana and ammonia from Alberta are combined with sulphuric acid produced during processing at the Zinc Operations to make ammonium phosphate fertilizer. Ammonium sulphate fertilizer is made from the solution produced by the scrubbing process that removes the sulphur dioxide from the smelter smoke stacks (Cominco, 1992).

In 1981 an effluent treatment plant was installed to remove metals from contaminated process water. This was the start of many changes made over succeeding years as part of a major operations modernization to improve the quality of effluent discharged to the Columbia River.

Waste water produced from the integrated metallurgical and fertilizer operation is released from a series of outfalls to the river, associated with the various plants within the industrial complex. This water is classified into uncontaminated and contaminated. Uncontaminated water is a combination of cooling water, area run-off and rain water, and goes directly to the river. Contaminated water constitutes those process streams or runoff that have been in contact with the smelting process and therefore contains metals. This water is directed to the effluent treatment plant for removal of solids and dissolved metals before discharge to the river. Since 1981 changes at Cominco have resulted in a reduction in key elements discharged to the Columbia River (see the tables below).

Through a process change in October 1993, contaminants historically present in O7 Outfall effluent have been eliminated. This improvement has resulted in an overall reduction of 60% in cadmium and mercury, 50% in lead and 20% in arsenic discharged by Cominco into the Columbia River. Significant reductions in the phosphorus, gypsum and mercury entering the Columbia River occurred in 1994 when ammonium phosphate fertilizer production ended. The completion of a project to collect and treat accumulated rain water and water used to wash down roads was also realized in 1994. This water is now classed as contaminated and must be treated as a result of acquiring metals from running along the ground.

Additional improvements in effluent quality will be achieved by the end of 1995 when slag discharge to the river is removed. This will result in low levels of both solids and dissolved elements discharged into the river.

MAJOR PROCESS CHANGES AT COMINCO
AND EFFECT ON METALS LOADING TO THE COLUMBIA RIVER

YEAR	PROCESS CHANGE	EFFECT ON METAL LOADING
1981	• Addition of effluent treatment plant. • Modernization of zinc plant. • Diversion of electrolyte purge to fertilizer operations.	Reduction in lead, zinc, arsenic, cadmium, and mercury. Reduction in zinc. Reduction in zinc.
1989	• Elimination of electrolyte stripping discharge.	Reduction in dissolved zinc.
1993	• Elimination of contaminants within Outfall 07 discharge.	Reduction in lead, zinc, copper, arsenic, cadmium, and mercury.
1994 (ongoing)	• Installation of 42 000 m^3 lagoon and effluent treatment plant, and collection of surface water runoff. • Elimination of phosphate plant.	Reduction of nutrients, particulates, fluoride, and all metals. Shift in pH towards neutral, and elimination of gypsum.
1995 (proposed)	• Elimination of slag discharge to the river.	Reduction in zinc, copper, and lead.

EXAMPLES OF RECENT METAL LOADING REDUCTIONS
FROM COMINCO EFFLUENTS

YEAR	DISSOLVED LEAD kg/day	DISSOLVED ZINC kg/day	TOTAL MERCURY kg/day
1989	58	1524	5.6
1990	28	339	1.6
1991	25	340	1.3
1992	26	275	1.4
1993	27	288	1.2
1994 (est)	19	267	0.5
1995 (est)	19	250	0.45

Municipal Waste Discharges

The treated sewage effluents discharged directly to the Columbia River from the cities of Castlegar and Trail (see Section A-2.2) are considered to be relatively minor contributors of nutrients and other contaminants. The very high flow volumes of the river compared with effluent discharges, results in high dilution of these effluents even during low flow conditions. The only concern that may arise is from possible bacterial contamination of river water in areas just below these discharges, where people may come into contact with water in the course of recreational activities.

The smaller treated municipal discharges to the river, both direct and indirect, are not thought to impact significantly on overall water quality of the Columbia River.

Other Environmental Concerns

Other contaminant inputs to the lower Columbia River system include a variety of point and non-point sources. Overland runoff from urban areas (Trail, Castlegar) and industrial lands (e.g., Cominco property, Pope & Talbot sawmill operation), leachate from landfill sites, lateral transfer of wastes from improperly placed septic fields, and runoff from agricultural land, for example, all contribute to present water/sediment levels of organics and metals within the Columbia River.

Extensive use of foreshore upstream of Celgar for log storage and handling also results in a variety of impacts to this aquatic system. In addition to the physical impacts of wood debris (bark, chips and submerged logs), the natural deterioration of these materials could contribute to oxygen demand impacts, long-term leaching of organic constituents from the wood, and nutrient enrichment (Butcher, 1992).

A-3.3 BIOLOGICAL

The environmental impacts associated with the various physical (hydroelectric facility operations) and chemical inputs (contaminant loadings) to this aquatic system produce concerns on two distinct spatial scales. These scales include one which is localized, and the other which extends downstream and may elicit combined effects within the biological component of the receiving environment. The environmental concerns associated with these potential impact scales are provided below.

Localized Ecosystem Impacts

Localized ecosystem impacts are associated with each of the primary wastewater discharges to the Columbia River. Depending upon the loading of contaminants in the effluent discharged, the specific location of the outfall structure, and the flow volume of the receiving waters, each wastewater stream entering the Columbia River will experience differential dilution and dispersion downstream. The effective concentrations of the wastewater constituents within the receiving waters will vary with time and will create an initial dilution zone which will expand and contract as a result of these processes.

The wastewater discharged by Celgar, at the time of sampling, was characterized by suspended solids (fibre and lime), colour, nutrients (nitrogen/phosphorus), BOD, resin/fatty acids, AOX (adsorbable organic halogens), chlorinated phenolic compounds, and chlorinated dioxins and furans. The wastewater discharged by Cominco was characterized by a variety of metals (particularly zinc, lead, copper, cadmium, arsenic, and mercury), as well as phosphorus, nitrates, ammonia, sulphates, AOX and PAH. Municipal outfalls add to nutrient enrichment within the river, as well as bacteriological contamination. These contaminants, depending on the loading, dilution and dispersion within the Columbia River, will elicit potential environmental responses in resident biological populations and/or communities.

Localized, non-point sources of contamination, including terrestrial run-off from industrial, urban and agricultural sites, lateral transfer of landfill leachate and septic field wastes, and aerial deposition may also represent a real environmental concern within the lower Columbia River. Many of these contaminant inputs, although not as localized as the industrial discharges, can contribute significantly to the overall quality of the receiving environment and to those waters eventually transported across the International Boundary.

Downstream Contaminant Transport

In addition to the localized environmental impacts associated with the discharge of various wastewater streams to the Columbia River, the potential for combined effects is also an environmental concern. Organic contaminants from Celgar and Castlegar are transported downstream, although considerably diluted before reaching the vicinity of the Cominco and Trail discharges. As a result of this mixing, the potential population and/or community impacts downstream of Trail may represent a more complex situation than is posed by individual outfall effects.

Transport of combined lower Columbia River contaminants across the International Boundary is also a primary environmental concern for the region. The Canadian contribution to the contamination of Roosevelt Reservoir sediments and fish with metals and chlorinated organics remains a concern, particularly with respect to the responsibility of the federal and provincial governments to prevent transboundary pollution.

Although almost all of the Pend d'Oreille River basin, which represents approximately 27% of the Columbia River input at the International Boundary, is within the states of Washington, Idaho and Montana, the contribution of potential contamination from this system is added to the Columbia River immediately prior to crossing the International Boundary upstream of the Roosevelt Reservoir. Appropriate control of contaminant sources on both sides of the border, including their respective composition and loadings, will ensure that the combined water quality of the Columbia River at the border will remain within acceptable limits.

The complexity of wastewater dilution, dispersion, mixing, and transboundary transport are important environmental processes which have been considered in the initial design of an integrated environmental monitoring program for the lower Columbia River (CRIEMP). The physical and chemical environmental concerns in the lower Columbia River, in terms of their magnitude and frequency, remain directly influenced by these processes.

SECTION B:

CRIEMP 1991-93 PROGRAM INTERPRETATION

SECTION B:

CRIEMP 1991-93 PROGRAM INTERPRETATION

Section B of this document provides an evaluation and interpretation of the information collected through the CRIEMP study implemented during 1991–1993.

B-1 STUDY DESIGN

The Columbia River Integrated Environmental Monitoring Program was designed to delineate the dispersion of contaminant inputs in the lower Columbia River receiving environment, and to estimate the impact of these inputs — either individually or in combination — on representative aquatic ecosystem components. The premise and implementation of this integrated approach was to support the primary CRIEMP objective to "collect and share environmental information on the lower Columbia River" (Baturin, 1993).

Following a thorough assessment of the stakeholder environmental requirements and concerns for the lower Columbia River, Sigma Engineering Ltd. (1990) provided detailed recommendations for a CRIEMP study design. The recommendations included implementing a preliminary reconnaissance program which could be used to provide information to further develop or refine the CRIEMP design. A broad geographic approach to sampling was suggested as a way to identify stations for long-term monitoring. A cross-section of taxonomic groups for bioaccumulation assessment would be employed to establish suitable species for a final monitoring program format.

Incorporation of a variety of the monitoring components recommended through the Sigma Engineering Ltd. (1990) design study resulted in the development of the 1991–1993 CRIEMP survey, which was designed to incorporate measurements of:

- water quality;
- sediment quality; and
- biological effects, through a bioreconnaissance component.

Design of the initial CRIEMP survey, recommended by McDonald (1991) and outlined by Baturin (1993), was subsequently approved by the CRIEMP Coordinating Committee. Included in this initial design were water and sediment quality assessments, as well as a number of biological approaches within the framework of a biological reconnaissance component. The 'bioreconnaissance' component included assessment of benthos and periphyton community structure, macroinvertebrate and macrophyte contaminant bioaccumulation, and macroalgal distribution.

The sampling methods and analytical techniques used in the water quality monitoring component of the program are presented in the summary report, *Columbia River Integrated Environmental Monitoring Program (CRIEMP 1991–1993) Data Report* (Baturin, 1993). Collection of the sediment and biological components of the CRIEMP survey data were performed by Norecol Environmental Consultants Ltd. A summary of this survey is presented in, *A 1992 Biological Reconnaissance and Sediment Sampling in the Columbia River Between the Hugh Keenleyside Dam and the International Boundary* (Norecol Ltd., 1992).

The basic sampling approach undertaken for each of the CRIEMP study components is briefly summarized below.

B-1.1 WATER

Eight stations were sampled for water quality from September 1991 through October 1992. As many as 152 variables were examined, including physical attributes (e.g., temperature, conductivity, pH, solids), a range of metals, chlorinated phenolic compounds, resin/fatty acids, dioxins/furans, nutrients, and bacteriological indicators. Frequency of sampling varied with variable or variable group, and ranged from 1 to 35 times.

BC Hydro has provided information collected October 1991 to June 1992 from two dissolved gas monitoring stations on the river. The instruments logged one-hour averages (five-minute sampling intervals) for barometric pressure, water temperature, total gas pressure, and dissolved oxygen partial pressure. One station monitored background dissolved gas levels in the water prior to discharge at Hugh Keenleyside Dam (in the forebay area above the dam); the second is located 5.4 km downstream of the dam, at Robson.

B-1.2 SEDIMENT

Eight stations on the Columbia River were sampled in September 1992 for analysis of sediment contaminant levels and toxicity. An additional station in Arrow Lake provided a reference site for this assessment. Sediments were taken using a combination of stainless steel Ekman dredge and/or hand scoop. Several samples were composited on-site to obtain single samples which were split for subsequent analyses of sediment metals, organics, particle size, and toxicity. Selected samples were split or subdivided in the field for analysis as quality assurance duplicates.

Analytical work was completed using standard techniques and quality control procedures; complete protocols have been reported previously (Norecol Ltd., 1992; Baturin, 1992). As many as 134 variables were measured within this study component, including a range of metals, acid volatile sulphides, organic carbon, chlorinated phenolic compounds, resin/fatty acids, dioxins/furans, nutrients, sediment particle size, and toxicity. Sediment toxicity tests used a combination of acute lethal (*Daphnia magna* survival), behavioural (amphipod reburial), and bacterial physiological (solid phase Microtox) responses.

B-1.3 BIORECONNAISSANCE

A recommendation made by Sigma Engineering Ltd. (1990) suggested that the choice of an appropriate complement of biological measures could be made once an initial, preliminary examination of biological effects was completed. A broad geographic approach to sampling was suggested as a way of identifying appropriate stations for long-term monitoring. Estimates of biological community structure and the use of a cross-section of taxonomic groups for bioaccumulation assessment could be employed to explore and subsequently establish suitable sentinel species for this portion of the Columbia River.

The Bioreconnaissance component of the 1991–1993 CRIEMP survey comprised the following biological measures:

- benthos community structure;
- periphyton/macrophyte community structure/distribution; and
- contaminant bioaccumulation by invertebrates and macrophytes.

Benthos Community Structure

Five shallow water benthos replicate samples were obtained from six stations using a combination of Waters-Knapp and modified Surber/Hess samplers. Six stations were sampled over two 1992 benthic surveys; the first was completed in April and the second during October. For the October survey, an additional pair of replicates were collected from larger boulder substrate.

For this study component a qualitative effort was made to select sites with similar substrate composition, water velocity, sampling depth, and general habitat conditions. Particle size analysis was completed on single samples taken for each station during the October survey. A single station located on the Kootenay River, immediately upstream of the Kootenay-Columbia confluence, was considered a reference station for this component.

Benthos samples retained on a 200 µm mesh screen were sorted and identified to the lowest taxon level possible, primarily to genus. However, Oligochaeta were identified only as low as the family level for the October benthos analysis. All identifications were verified by secondary taxonomists in the U.S.

Periphyton & macrophyte community structure

Periphyton

Periphyton community structure was estimated at five sampling stations along the Columbia River, with an additional reference site on the Kootenay River, during July 1992. Attempts were made to locate stations as close to the benthos sampling sites as possible. Sites characterized by large boulder substrate were selected to obtain adequate surface area and stability for sustained periphyton growth.

Periphyton samples were removed from 25 cm^2 of rock surface using a razor blade. The five replicates taken for each station were composited in a single sample jar. The resulting mixture was thoroughly homogenized and split into thirds for subsequent analysis of chlorophyll, biomass and taxonomy.

Macrophytes

A macrophyte survey of the lower Columbia River was completed during July 1992. Conducted from a boat, this survey delimited the major areas of macrophyte growth along either side of the river. Representative samples were collected for species identification.

Contaminant Bioaccumulation

Estimates of the bioaccumulation of available organics and metals were conducted on three groups of organisms: emergent caddisflies, Unionidae mussels, and aquatic macrophytes. Seven stations were sampled in July 1992 for the first two groups, while the bioaccumulation of contaminants in macrophytes were assessed for only five stations (also sampled in July). Three stations were sampled for all three groups.

Emergent caddisflies were collected by light-trapping methods over a period of four nights. Other insect taxa were removed from the samples, and the dominant caddisfly taxa were identified, weighed and enumerated to provide an estimate of species composition.

Unionidae mussels (*Anodonta oregonensis)* were obtained by divers. A minimum of five animals, selected for a common size category, were composited for organics and metals analyses.

Collection of the aquatic macrophyte, *Potomogeton perfoliatus,* consisted of tissue samples of approximately 2–5 grams. A single sample was obtained for each of the five stations surveyed.

B-2 DATA SOURCES & REVIEW

Water and sediment chemistry data, tissue bioaccumulation results, and benthic/algal community structural information collected as part of this program were acquired from the CRIEMP Coordinating Committee (J. Beatty Spence, Chair) at the outset of this project. The format of these data, and the subsequent standardization and analytical approach employed to assess these data, are presented below.

B-2.1 DATA FORMAT

Data from the 1991–1993 CRIEMP survey and from the BC Hydro dissolved gas monitoring were provided to Aquametrix as LOTUS spreadsheet files. Water quality data were supplied as independent station files, while the bioreconnaissance information was summarized (in table form) for each study component (i.e., sediment chemistry, benthos, periphyton, caddisfly tissue results, mussel tissue results, macrophyte tissue results, and sediment particle size analyses).

All data were imported to QUATTRO-PRO for WINDOWS which was used to remove all 'table formatting' characters from the files, as well as to prepare ASCII versions of the data appropriate for import to statistical and/or graphics programs.

Standardizing Sampling Station Designations

The 1991–1993 CRIEMP survey was implemented across four lower Columbia River reaches (I, II, III, and IV). To facilitate discussion and interpretation of the data in this document, the alphanumeric station designations (e.g., II-1, IV-3) used to report the component survey information are represented by descriptive station names (e.g., Birchbank, Waneta). The descriptive names are used throughout this report as a standard way of discussing station locations even though samples were acquired for study components (e.g., benthos or mussels) at slightly different sites near the station. A common station location is provided for the purposes of evaluating the data with respect to general location along the river system.

Locations of the survey reaches and individual sampling stations are shown in Figure B-1 and outlined in the following table.

CRIEMP 1991–1993 STANDARDIZED SAMPLING STATION DESIGNATIONS

STATION NO.	DESCRIPTIVE STATION NAME	LOCATION
I-1	Arrow Lake	Lower Arrow Lake; 1 km upstream of Syringa Creek
	Keenleyside	TDG Station at Hugh Keenleyside Dam Forebay
II-1	U/S Celgar	Upstream of Celgar, below Hugh Keenleyside Dam
II-2	D/S Celgar	Downstream of Celgar Pulp
II-3	Robson	Columbia River at Robson (includes TDG station)
II-4	U/S Castlegar	Upstream of Kootenay-Columbia confluence
III-1	China Creek	Columbia River at China Creek
III-2	Birchbank	Upper Birchbank (Federal/Provincial station)
III-3	Birchbank	Lower Birchbank
IV-1	D/S Cominco	Columbia River at Old Trail Bridge, downstream of Cominco, 1/3 of the way across the river from west side
IV-1A	Cominco West	Downstream of Cominco, west side of the river at the Old Trail Bridge
IV-1B	Cominco East	Downstream of Cominco, east side of the river at the Old Trail Bridge
	Ryan Creek	Columbia River at Ryan Creek
IV-2	Beaver Creek	Columbia River at Beaver Creek
IV-3	Waneta	Upstream of the Columbia River-Pend d'Oreille confluence
IV-3A	Waneta	Upstream of Station IV-3, across from gravel pit
IV-3B	Waneta	Upstream of Station IV-3 and Shepherd Flats
CS3	Kootenay	Kootenay River, below Brilliant Dam
Norns Creek	Norns Creek	Station at Norns (Pass) Creek
Glade	Glade	Kootenay River; upstream of Glade Ferry and sawmill
Grohman	Grohman	Fan at Grohman Narrows
Kootenay Lake	Kootenay Lake	West Arm, Kootenay Lake

B-2.2 DATA EDITING

To explore spatial and/or temporal changes in the parameters examined in CRIEMP, each component (water quality, sediment quality, bioaccumulation) matrix was developed to include all of the stations sampled. In an effort to reduce the size of the working matrices, further editing of the component data was performed using the minimum detectable concentration (MDC). For example, those parameters which reported less than the MDC at each of the stations (all samples) were removed from the working data matrix. Elimination of these parameters would not affect subsequent statistical analyses since all values reported (across samples) would have been reported as less than the MDC.

Dioxin/furan data were particularly variable with respect to MDC's, with the resulting data for any one parameter having as much as an order-of-magnitude (e.g., <0.5 and <5.6 ng/g) difference between samples. Given the situation where one sample revealed a *detectable* level of a parameter (e.g., 0.7 ng/g), but other samples all reported values *less than* a detection (MDC) which was greater than that level (e.g., <1.6 ng/g), then this particular parameter was excluded from the data matrix. It was assumed, under these conditions, that the difference between a sample with 0.7 ng/g cannot be differentiated from a sample having <1.6 ng/g. These samples, in fact, could have values ranging anywhere from 0.0 to 1.59 ng/g.

For sample parameters which had a fixed MDC, as was usually the case with trace metals in sediment or water, the detection limit was used as the 'absolute' level in subsequent analyses. Providing a conservative estimate of contaminant levels, a cadmium level reported as <0.005 μg/g, for example, was used in the statistical analyses as 0.005 μg/g. Although other acceptable approaches for dealing with MDC's in statistical tests include using half the detection level or simply assigning a zero in place of the value, use of the actual MDC as the reported level provides the conservative choice of the three. In potentially overestimating the level of a contaminant, the among-sample statistical comparisons or evaluations with existing criteria/objectives will err in favour of protecting the aquatic environment.

For subsequent statistical and/or descriptive analyses, QA/QC and sample audit information were excluded from the 'working' data matrix.

B-2.3 STATISTICAL APPROACH

Following an initial critique of the study design, data were analyzed by individual component and then an effort was made to provide an integrated assessment using two or more of the independent study components to jointly describe spatial differences in environmental integrity in the lower Columbia River.

Survey Design Evaluation

Initial examination of the program documented the degree of 'balance' of the study design, in a statistical sense, both within and between CRIEMP components. The degree to which elements of the program were concurrently sampled and replicated was discussed with respect to possible avenues for data analysis, interpretation and ultimately for program modification.

Single Component Assessment

Data analyses were initially performed for each of the CRIEMP components independently. This included a spatial and temporal assessment of the benthos community structure, a spatial examination of the periphyton community structure, differences in sediment chemistry between stations sampled, and the spatial differences in bioaccumulation of selected test organisms collected within the study area. Summary tables of the reduced (edited) 'working matrix' were provided as the basis of statistical tests, and results were presented graphically whenever possible.

Integrated Component Analysis

An integrated program component analysis was performed using benthos community structure as an example of the assessed biological effects measures. Anthropogenic changes in sediment and water quality were used to describe the fate of environmental chemical inputs (e.g., contaminants) and the disruptive influences of physical processes (e.g., water level changes as a result of hydroelectric facilities).

Ordination was used to graphically portray the multivariate (or multidimensional) benthos information in two-dimensions, the reduced space (axes) accounting for the maximum amount of variance within the original multivariate structure. To facilitate interpretation of the ordination, the individual benthos sample data (replicates) were treated independently and plotted within the ordination space to demonstrate the variability in the communities described at each station.

Ordination scores for each of the above analyses were correlated with water and sediment contaminant values in an effort to 'explain' the distribution of samples along each of the dominant Principal Component axes. This analysis was performed to provide an indication of which variables may influence, or contribute to differences noted among the benthos stations sampled on the lower Columbia River.

Rationale for Selected Method

Although CRIEMP did not design the initial sampling effort to conform with a rigorous, concurrent sampling program (primarily due to logistical constraints in the Columbia River system, and economic considerations), the multivariate approach presented in this report is an example of how future data collection might take advantage of such an approach in achieving the CRIEMP survey objectives. In particular, such techniques could be employed to document spatial and/or temporal changes in environmental conditions using the 'integrated' component possibilities inherent in the overall CRIEMP design.

The multivariate ordination performed in this study used a Principal Components Analysis (PCA) approach. As an indirect ordination method, Principal Components Analysis can be performed using a variety of analytical options available to an investigator. The selection and preference of these options are widely discussed in the literature, with each having similar advantages and disadvantages for subsequent interpretation of the data.

For the present study the following options were applied to the ordination performed:

- data matrix values transformed using $\log_{10}(x+1)$;
- non-centered adjustment of data; and
- ordination scores scaled from 0 to 100.

A great deal of controversy exists about the appropriate choice between centered and non-centered data for use in the ordination procedure. Mathematically and geometrically, centering involves specification of the origin, or the point of reference within the ordination. It is commonly achieved by expressing the variables in terms of their mean (and standard deviation - standardized data). Thus, this point represents the point of zero information and anything at it is of little concern, while deviation from it can be considered as 'information' (Noy-Meir, 1973). Centering effectively transfers the reference point to an 'average' sample which is defined by the mean. Consequently, a centered ordination will generally express inter-sample variation with respect to the mean sample processed.

When non-centered data are used the reference point is the true zero, i.e., a sample with the lowest possible contaminant level (< MDC). Thus, a resulting ordination using non-centered data expresses between-station similarities in absolute terms, which are directly dependent on initially recorded contaminant levels.

Using a non-centered ordination, if a data set consists of one or more disjunctions, a distinct bipolarity is introduced into the resultant ordinated data set, allowing an assessment of the number and sharpness of discontinuities in the samples. Since it is assumed that the CRIEMP stations selected in the lower Columbia River included areas contributing to elevated tissue contaminant levels or disturbed community structure, the resulting differences (comparing these areas with a suitable reference) would then appear as sample discontinuities in the data matrix. A non-centered ordination can therefore clearly differentiate these sites from those characteristic of normal environmental conditions.

Analytical Software

All data matrix manipulations and table generation were performed using QUATTRO-PRO for WINDOWS. Statistical summaries and tests were completed using SIGMA-STAT, with SIGMA-PLOT used to produce all of the graphical results. The Cornell Ecological Programs package (CEP-25B) ORDIFLEX was used for the PCA ordinations. SIGTREE (Nemec and Brinkhurst, 1989) and CLUSTER (an in-house program package) were employed for the community classification analyses.

B-3 CRIEMP 1991–1993 RESULTS & DISCUSSION

The following sections provide a summary of the numerical analyses and interpretation performed on the 1991–1993 CRIEMP survey information. The assessment includes an evaluation of the study design, analysis of independent program components, and an integrated analysis of a number of program components in delimiting spatial impacts in the lower Columbia River.

B-3.1 DATA QUALITY & RELIABILITY

The following data quality subsections provide: (i) an evaluation of the initial CRIEMP study design, primarily in terms of subsequent data analysis limitations; and (ii) a summary of analytical reliability (QA/QC) for the various study components comprising the 1991–1993 CRIEMP survey.

Study Design Evaluation & Analysis Limitations

The fundamental design of the Columbia River Integrated Environmental Monitoring Program is one which incorporates a variety of environmental indicators as the framework for a comprehensive monitoring design. Table B-1 summarizes the 1991–1993 CRIEMP monitoring program effort, and provides an indication of where each of the environmental components was sampled within the main-stem Columbia River and reference stations.

As a preliminary survey, CRIEMP did not attempt to sample all study components concurrently, but rather to select a range of appropriate sampling stations with which to 'test' each of the study components. Table B-1 clearly illustrates the problems associated with the allocation of sampling effort in the initial CRIEMP survey, although these problems are associated primarily with data analysis capabilities and not in the evaluation of component efficacy.

For example, only one station (Robson) of the six sampled for benthos (including the reference station) was actually sampled for sediment chemistry as well. Nearby sites, close to (but not at) Birchbank and Waneta, were selected for sediment samples due to lack of appropriate sediment structure at the stations used for the benthos sampling. Thus, direct comparison of sediment contaminant concentrations and the benthic community composition, which ideally should be an integral part of this program, can now only be done with an indeterminate amount of uncertainty. A subset of the sediment chemistry data, acquired close to those stations sampled for the benthos, were employed in our integrated component analysis primarily as an example of how future programs might use such an approach in a modified CRIEMP survey design.

Other program components, including bioaccumulation, should (where possible) also be conducted concurrently with benthic community sampling. A change in community composition and the levels of contaminants in resident community representatives are important associations to be able to make when assessing and interpreting data acquired through such a monitoring program. In this example, benthos and the two groups of test organisms used for bioaccumulation (mussels and caddisflies), were only sampled at common sites at the reference station (Kootenay River) and at the station farthest downstream (Waneta). This, unfortunately, leaves us with no possible associative test for these components for any station located immediately adjacent to any of the primary sources of contamination along the lower Columbia River.

In addition to the station location problems, sampling procedure problems have added to the uncertainty of the results in some program components. For example, benthos were sampled during both April and October, although sampling did not occur at similar elevations and water levels fluctuated significantly over this period. Sediment sampling, which took place in September 1992, was accomplished using a combination of dredge and scoop samplers. The dredge was used at some stations, sampling substrate from as deep as 25-30 metres, while other stations used the scoop, and obtained sediment at depths of 0.6 metres below the water surface (at that time). Again, given the significant changes in water levels from April, the reliability of comparisons between sediment samples taken from areas which probably were not submerged during some period of the year with those from deep water is questionable. In addition, the spatial comparability of such samples, given the inherent differences in hydrological influences (e.g., flow rates, sedimentation rates) between shallow and deep-water stations, will be in question given the probable differential accumulation of contaminants within these types of environments. Since the magnitude of these differences is unknown, the significance of observed differences between stations may be difficult to interpret, i.e., differentiating horizontal differences (downstream dilution effects) from those related to vertical, depth-related differences in contaminant accumulation (dispersion effects).

Many of the problems associated with sampling effort, both spatial and temporal, will have a direct bearing on the interpretive power for the present report. However, these problems do provide us with clear opportunity for program modification so that a truly integrated approach to environmental monitoring can be achieved for CRIEMP. Section C of this document provides detailed recommendations for CRIEMP modification based on the review and analysis of this initial program survey.

Analytical Reliability

Preparation of the CRIEMP Interpretive Report was based on monitoring information provided in a series of data files containing analytical results for each of the study components. Quality control measures reported in these data sets included procedural blanks, trip blanks, laboratory duplicate sample analyses, minimum detectable concentrations (MDC), and spiked water samples.

During the initial CRIEMP Reconnaissance Program, Environment Canada conducted a CRIEMP procedural audit which incorporated both field sampling and analytical components for the sediment, water and caddisfly portions of the monitoring program. Results of this audit have been provided, in detail, in an Environment Canada report (Tremblay and Moyle, 1995) and will not be reiterated in this document. The following subsections provide general comments and perceptions of data quality as determined from the QA/QC information contained within the component data files.

Water Chemistry

Trip blanks were included for every 10 to 20 water samples. Based on a review of these data, contamination problems were considered negligible and limited to the elements Al, Ba, Cd, Co, Fe, Mn, Ni, As, Cu, Hg and N. Given the very low levels at which these elements were reported, these problems were not considered significant in defining overall data quality or in the interpretation of these data in this document.

Duplicate sample analyses were carried out for chlorinated organics and most duplicates were in agreement. Differences in duplicate readings exhibited a log-normal distribution with most differences being zero or relatively small, and less than an order of magnitude in almost all cases. In most cases where larger differences occurred, a third replicate sample was reported to clarify the difference.

Some minor discrepancies existed for metal MDC's, but these do not reflect on the general data quality.

Sediment Chemistry - Metals

With respect to metals analyses, subsamples of composited sediment samples were reported for Arrow Lake (reference) and Waneta stations. Table B-2 presents a summary of these results; for each station the mean and sample standard deviation is presented adjacent to an estimate of the Coefficient of Variation (CV, as a percentage). Arrow Lake results were estimated using four subsamples, and Waneta were estimated using three.

As these station samples were homogenized (composited), the resulting subsamples should — theoretically — represent identical sediments and thus should produce comparable analytical results. The results in Table B-2, however, demonstrate a broad range of variability in the parameters measured. Lead varied, among subsamples, from 5 to 10%, cadmium ranged from 8 to 17%, and antimony from 20 to 116%. This within-sample variability may reflect analytical variance at different concentration levels (generally the higher variability was noted in samples with lower concentrations), but also may reflect the variable nature of the contaminants within the sediments themselves.

Despite the lack of field replication for the sediment component of this program, important implications regarding parameter variability can be realized from these composite sample data. Given the high variability associated with composite subsamples (Table B-2), the inherent variability among individual (untouched) field samples would question the power of spatial and/or temporal comparability of single samples acquired for sampling locations within the lower Columbia River.

Because of the lack of field sampling replication in various CRIEMP program components, the immeasurable reduction in statistical power has a profound effect on the interpretive capability for these program components. SECTION C of this document recommends the inclusion of field replicates in future monitoring efforts in order to include field variability into the spatial and/or temporal interpretation of contaminant stress and response in the lower Columbia River.

Sediment Chemistry - Organics

Duplicate sample analyses were performed on slightly more than 5% of all resin acids samples tested. All samples for duplicate analyses were taken from the Birchbank station. On average, duplicate samples for resin acids differed by 14%, based on the lower duplicate reading. Differences between duplicates were all less than one order of magnitude. Values reported for all samples ranged from the low ng/g to low µg/g range (i.e., three orders of magnitude) for all resin acids measured.

Duplicate analyses for dioxins and furans were performed on more than 15% of all samples. On average, duplicate samples for chlorinated dioxins differed by 5.2% and 28% for chlorinated furans. Differences between duplicates were less than one order of magnitude.

Fifteen percent of samples for chlorinated phenols, chlorinated guaiacols and chlorinated catechols were run in duplicate. Results of the duplicate sample analysis were consistent. For all but one set of duplicates tested, readings were below detection limits for both duplicates.

Procedural blanks for chlorinated phenols, guaiacols, catchalls, vanillins, syringol, dioxin and furan analysis were all below detection limits.

Caddisfly Tissue Chemistry

Procedural blanks (tissue blanks) for caddisfly were included for dioxin and furan and chlorinated phenols analyses. All of the tissue blanks analyzed were below the reported detection limits.

Mussel Tissue Chemistry

Procedural blanks were reported for the chlorinated phenolic compounds only; all blanks tested were below detection limits.

Duplicate samples were run for dioxin/furan analysis. Duplicates samples were very consistent, indicating a high degree of precision for the analyses. Concentrations were in the 1-3000 pg/g range, and duplicates differed by approximately 11%.

Overall data quality

Examination of the analytical results completed for the initial CRIEMP study indicates a good quality of information, with high recoveries and duplicate variability reported for specific analyses all within acceptable limits. The discussion relating to sediment chemistry composite analyses most likely reflects the variability inherent within the sampling environment, and suggests potential problems and limitations associated with a lack of field replication in the initial CRIEMP study design.

B-3.2 SEDIMENT QUALITY

Sediment quality information collected as part of the 1991–1993 CRIEMP survey is presented in the following sections by major group or parameter of concern: trace metals; total organic carbon; resin/fatty acids; chlorinated phenols, guaiacols, catechols; and dioxins/furans.

It was assumed that the CRIEMP reference stations represented 'normal' environmental conditions, and that both the levels of the constituents for which an analysis was completed and the Total Organic Carbon (TOC) of these sediments were that of background. Given this assumption, the sediment levels in Table B-7 (resins and fatty acids), Table B-8 (chlorinated phenolic compounds), and Table B-10 (chlorinated dioxins and furans) are presented as values standardized to reference station TOC, rather than to unit TOC (1.0 μg/g). This coding permits a direct comparison of the relative sediment concentrations of these parameters, given comparable TOC levels, with the actual values acquired for the reference stations. If further comparison is required using unit TOC, then each value in these tables should be divided by the reference TOC to provide values as 'μg constituent per g of TOC'. The relative difference among these data, however, will remain the same.

Trace Metals

Table B-3 presents a summary of the results of the sediment metals and acid volatile sulfide (AVS) analyses. Values listed in Table B-3 identify those parameters which were greater than those reported for the Arrow Lake reference station (upper table) and the Kootenay River reference station (lower table). Values in the light-shaded column, shows the actual values for each of these parameters at the reference stations sampled during this survey, and permits a comparison of these values with those levels reported at the stations sampled along the lower Columbia River in adjacent columns.

Sediment metals data are further summarized in Table B-4. This table indicates the factor by which each of these parameters exceed the levels reported at the respective reference stations. Since blank cells indicate parameters with levels equal to, or less than those observed at the reference sites, it is clear that trace metals are generally elevated at all sampling stations downstream of Cominco (Ryan Creek). The data presented in Tables B-4 and B-5 also illustrate that the majority of trace metal parameters were highest at the station immediately downstream of Beaver Creek, and that the Ryan Creek and Waneta stations revealed similar levels of most parameters.

In contrast, the Beaver Creek station is considered one of the few depositional sites downstream of Trail (Sigma Engineering Ltd., 1990). The substrate consists primarily of black sand, probably of slag origin. Comparatively high levels of most metals at this site most likely reflects the composition (industrial origin) of these substrates.

The elevation in metals at Beaver Creek was particularly evident in parameters such as silver, copper, molybdenum, and zinc, which occurred at levels 17 to 40 times higher than the Arrow Lake reference sediments, and12 to 65 times the Kootenay reference sediments. The difference in sediment quality of the two reference stations clearly reflects the degree to which elevated levels at Beaver Creek (and other Columbia River stations) can be interpreted. Table B-4 demonstrates these differences across a number of parameters.

Table B-5, which uses the Beaver Creek (worst case) station as an example, indicates that the two reference sites established for the initial CRIEMP survey differed as much as 300% for metals and 1000% for acid volatile sulfides (based on lower value). This suggests a significant discrepancy in parameters considered of interest in delimiting spatial impacts of industrial discharges such as Cominco (e.g., lead, zinc). It is not readily apparent that either of these stations would make the best reference station, since parameters such as lead and zinc at Arrow Lake were half that of the Kootenay station, while copper was approximately double at Arrow Lake.

One of the factors which can influence the bioavailability of trace metals in sediments, and the subsequent toxicity of these interstitial levels, is the concentration of acid volatile sulfides

(AVS). It has been suggested that the presence of AVS is associated with the binding of sediment metals into a solid phase sulfide under mild or moderately acidic conditions (Di Toro *et al.*, 1990). The FeS and MnS sediment sulfide compounds, which together are quantified as AVS, represent a reactive pool of solid phase sulfide that is available to bind with metals which have sulfide solubility parameters smaller than FeS, and include, for example, nickel, zinc, cadmium, lead, copper and mercury. Thus bound, the metals are less available for biological uptake and subsequent biological effects. Because AVS has been shown to have a direct influence on sediment toxicity, and thus on the biological impacts observed in the sediment environment, continued monitoring of this parameter should provide valuable insight into the distribution and availability of trace metal contamination in the lower Columbia River.

Figure B-2 illustrates spatial changes in AVS levels across the stations sampled in the lower Columbia River. The AVS data portrayed in this figure also demonstrate the variability between the reference sediment stations employed in the 1991–1993 CRIEMP survey. Where the Arrow Lake Reference site revealed low levels of AVS (< 6 μg/g), the Kootenay Reference site had ten times that level. The differences between these and the other sampling sites further illustrates the high variability in sediment structure in the lower Columbia River, and the problems which are inherent in evaluating the impacts of trace metals downstream of potential point sources. Increased level of effort (replication) in sediment sampling would provide the base upon which such variability could be quantified and employed in among-station statistical comparisons.

Total Organic Carbon (TOC)

The level of sediment organic carbon (% TOC) may directly influence the levels of complex organic compounds (e.g., phenols, resin acids, dioxins/furans) in a sediment sample by enhancing the adsorption capabilities in the sediment matrix. Figure B-3 provides a summary of the total organic carbon (TOC) information collected for each of the sediment sampling sites during the 1991–1993 CRIEMP survey, illustrating the spatial differences in TOC along this region of the Columbia River as compared with the selected sediment reference sites (Arrow Lake and Kootenay).

These data indicated that the reference areas contained 2.1-2.6% TOC. While these levels of organic carbon were the highest reported in this survey, the sediments collected between Robson and Birchbank (including China Creek) contained among the lowest (0.4-0.6% TOC). Organic carbon at the Celgar site (downstream) was reported at a level of 1.09%, Ryan Creek at 1.57%, and Waneta at 0.95%. The station sampled at Beaver Creek contained the lowest level of TOC at 0.2%.

Duplicate TOC analyses in the lab suggested a high degree of variability within the samples processed (Norecol Ltd., 1993; Tremblay and Moyle, 1995). Triplicate subsamples of sediments acquired from Arrow Lake indicated a coefficient of variation (CV) of 17.6%, while a duplicate set of samples for Waneta demonstrated variability in the order of 5.6% (Table B-2).

Stations between Robson and Birchbank contained approximately 43% TOC campared with other Columbia River sites (Figure B-3). The levels of organic carbon provide an indication of the relative deposition nature of each sampling station. Those stations between Robson and Birchbank are much less representative of a depositional environment than the other stations, which may in part explain spatial differences in contaminant levels among the stations sampled.

Resin and Fatty Acids

Table B-6 summarizes the sediment chemistry results for resin/fatty acids which were detected (above MDC) using the analytical procedures described previously. This table permits an independent comparison of the resin/fatty acid data with the values reported for the two reference stations (Arrow Lake = upper table; Kootenay = lower table). Data shown in this table represent those values which were in excess of those found in the respective reference area. Blank cells indicate parameters which were at levels less than (or equal to) those found at the reference sites. Table B-7 presents the resin and fatty acid levels standardized to reference station TOC.

Resin acids were detected in sediment samples at all stations. Abietic, dehydroabietic and isopimaric acids were consistently highest in sediments below Celgar.

The sediment levels of lauric, linoleic, myristic, oleic, palmitric, and stearic acids were all elevated at the Waneta station. Despite undetected levels of the majority of these compounds at the site immediately downstream of Celgar, the Waneta station, just upstream of the International Boundary, revealed significant concentrations.

It is probable that overall sediment levels of resin and fatty acids remain virtually undetectable between Celgar and Waneta as a result of sediment particle size distribution (see Norecol Ltd., 1992; Table 5-2). These data indicate that sediment structure in the Birchbank and Ryan Creek samples was considerably more coarse than in the samples from the site near Celgar and at Waneta, which may contribute to reduced adsorption properties of the sediment at Birchbank and Ryan Creek sites.

Chlorinated Phenols, Guaiacols, Catechols

Table B-8, which presents the data for chlorinated phenolic compounds (non-standardized and standardized to reference station TOC), indicates that the station immediately downstream of Celgar contained the highest levels of these compounds. The data also show that these organics were not detected in samples between the downstream mill site and the International Boundary (Waneta). Low concentrations of catechols and guaiacols were measured at Waneta, as were resin acids. It remains unclear, however, why many of these organic compounds are as much as an order of magnitude higher at the Waneta site compared with stations at Robson, Birchbank and Ryan Creek. It would be expected that the concentration of organic contaminants in sediments would be reduced as the distance from the Celgar source increased, since the sediments have similar physical characteristics. As indicated by Norecol Ltd. (1992), Table 5-2, the sediments at the Waneta site had finer particles than the Birchbank site. The Ryan Creek and Waneta sites had similar particle sizes in the sediments. Although Ryan Creek sediments were finer than those collected at Birchbank, the reduced levels of organics (including the chlorinated phenolics, guaiacols and catechols) may also be due to the origin of these sediment. It is suspected that bank erosion rather than upstream sources may be the source of these sediments.

Dioxins and Furans

The majority of sediment dioxin and furan congeners assessed were elevated at the station sampled downstream of Celgar (Table B-9). Total tetrachlorodibenzoparadioxin (T4CDF) and 2,3,7,8-T4CDF were consistently higher than the background levels (Kootenay and Arrow Lakes) at all stations downstream of Celgar. Levels reported in sediments below Celgar were 360 pg/g and 210 pg/g, respectively, with these being the highest levels of any furan or dioxin congener measured in the study area. These levels are two orders of magnitude higher than in the reference sediments sampled.

Table B-10 presents the above information standardized to the total organic carbon (TOC). These data support the above results in demonstrating a predominance of furans in the sediments sampled at all depositional sites in the lower Columbia River.

Figure B-4 provides an evaluation of the reported dioxin/furan information in terms of 2,3,7,8 TCDD oxic equivalents (TEQ's). The values presented in this figure, although not standardized to TOC, indicate that each of the stations sampled for this survey (with the exception of the Kootenay reference site) exceed present Sediment Quality Objectives recently established specifically for the lower Columbia River (maximum: 0.7 pg/g; Butcher, 1992). The Arrow Lake reference site also fails the sediment quality objective.

Table B-11 provides 2,3,7,8 TCDD TEQ's which are normalized to 1.0% total organic carbon, as recommended by Singleton (BC Environment, pers. comm.) in developing a new Interim Criterion for PCDD/Fs in sediments. Using TOC normalized TEQ's, this criterion level is set at 0.25 pg/g TEQ for 2,3,7,8 TCDD. As in the above analysis, all stations sampled during the 1991–1993 CRIEMP survey exceeded this criterion level with the exception of the Kootenay reference site.

B-3.3 WATER QUALITY

Water quality of the lower Columbia River was examined during the 1991–1993 CRIEMP at a number of sites. Records of water discharge data for Hugh Keenleyside Dam, Brilliant Dam, Birchbank and the International Boundary were available from Environment Canada. CRIEMP water quality sampling was conducted at eight stations. Total dissolved gases were recorded immediately above the Hugh Keenleyside Dam (forebay) and at the Robson monitoring station.

Data collected from this water quality survey are summarized and presented in the subsequent sections of this document.

Total Dissolved Gases

Figure B-5 presents the total dissolved gas (TDG) data obtained from monitoring stations established at the Hugh Keenleyside Dam forebay (June 4 through November 10, 1992) and at Robson (March 17 through November 10, 1992). Total dissolved gas levels in Lower Arrow Lake (Keenleyside forebay) were typically at or above saturation throughout most of the period, with levels as high as 111% recorded in late June and mid-August; after that time TDG declined, with levels dropping to below saturation during mid-October through early-November. Only a few of the 5382 observations acquired at the forebay location during the sampling period were above the B.C. Environment Working Criterion of 110% saturation for protection of aquatic life (Butcher, 1992).

The elevated TDG levels at the Hugh Keenleyside Dam forebay are likely due to thermal heating of the waters in Arrow Lakes over the spring and summer period. As the water temperatures begin to cool in the late summer and fall, the dissolved gas levels return to equilibrium or fall slightly below saturation, and remain at this level over the winter.

Total dissolved gas concentrations below the Hugh Keenleyside Dam (measured at the Robson site) showed considerable variation (Figure B-5); reported values fluctuated between 102% and 135% saturation. The majority of the recorded values at this site exceeded the B.C. Environment working criterion of 110% saturation. During periods of spillway discharge, the TDG levels generally were above 120% saturation. During periods of discharge through the low-level ports, dissolved gas levels were much lower (generally 105% to 115%), with the variation depending on the background TDG levels (i.e., forebay), the discharge volume, tailwater levels and location of the discharge ports. Recent data have indicated that under certain flow and tailwater conditions, the four south ports produce higher TDG concentrations than the four north ports, due to differences in the elevation of the energy dissipator for the two sets of ports (Klohn-Crippen Integ., 1993).

The high TDG levels in the Columbia River below the Hugh Keenleyside Dam (and below Brilliant and Waneta dams) affect aquatic organisms in shallow water throughout the CRIEMP study area. Fish held in shallow water subjected to high TDG levels are known to develop symptoms of gas bubble trauma, which involves the formation of gas bubbles internal and/or external to the animal (Fidler, 1988). The major symptoms of gas bubble trauma, which can cause death or lead to high levels of stress in fish, as identified by Fidler (1988) are as follows:

- bubble formation in the cardiovascular system, causing blockage of blood flow and death;
- over-inflation and possible rupture of the swimbladder in young fish leading to death or problems of over-buoyancy;
- extracorporeal bubble formation in gill lamellae, causing blockage of respiratory water flow and death by asphyxiation; and
- sub-dermal emphysema on body surfaces, including the lining of the mouth.

All symptoms of gas bubble trauma can weaken fish, especially in the younger life stages, thereby increasing their susceptibility to predation.

Although dissolved gas levels were very high in the CRIEMP study area during periods of spill at the dams, only a small number of fish captured in a study conducted for BC Hydro in 1990 exhibited external symptoms of gas bubble trauma (3% of catch for largescale and longnose sucker, 0.7% for rainbow trout, and 0.4% for mountain whitefish; Hildebrand, 1991). It appears that in the Columbia River, there is sufficient depth to allow most fish to use hydrostatic compensation to reduce or prevent the symptoms of gas bubble trauma. Each metre of water compensates for approximately 10% supersaturation, so fish that spend most of their time in water deeper than 3 to 4 metres during periods of high TDG would not experience symptoms of gas bubble trauma.

High TDG levels, however, can affect the biological productivity of the river by limiting the extent of fish-use of shallow water habitats, which are normally the most productive area in natural systems. High TDG levels can also affect benthic invertebrates in shallow water through the formation of gas bubbles under their carapaces, thus changing their buoyancy.

The magnitude and extent of impacts associated with TDG, although not measured in this monitoring program, may also have the potential to elicit synergistic responses in areas affected by other environmental stresses, such as chemical contaminant inputs.

Water Levels

In addition to the potential water quality (TDG) impacts associated with dam operations, the physical effects of discharge regulation, such as changes in water levels and water velocities, will have direct effects on biological communities and on local fisheries resources. For example, rapid fluctuations in water level during certain times of the year have been responsible for exposure of mountain whitefish eggs on gravel bars (G. Birch, pers. comm.).

Changes in water level will also have a direct effect on the development and maintenance of biological communities along the lower Columbia River. Periphyton species assemblages, determined in part by available light, will be directly influenced by water depth. Rapid changes in this parameter will thus affect the stability of these communities, which may indirectly affect macroinvertebrate populations along the river.

Figure B-6 summarizes the discharge rates measured below the Hugh Keenleyside Dam, the Brilliant Dam (on the lower Kootenay River), at Birchbank, and at the International Boundary over the two years (1991-1992) in which this study was conducted. Hydrographs demonstrate that discharges from the Hugh Keenleyside Dam are highly variable throughout the year.

The contributions of the Kootenay River, which are slightly lower than for the Hugh Keenleyside Dam, demonstrate a consistent discharge pattern over the year and between the two years. This relatively constant discharge (< 1000 cm) is interrupted in May-July when a period of maximum discharge corresponds to the release of water as the snow pack in the region melts. The hydrographs in this portion of the study area appear much more representative of an unregulated river system than those characterized by the discharges of the Hugh Keenleyside Dam.

The fluctuations in discharge in the remaining reaches of the lower Columbia River are strongly influenced by the release of water from the Hugh Keenleyside Dam. Discharge rates at both Birchbank and at the International Border reveal a high degree of variability within short periods of time. The International Border site shows slightly higher discharges and greater variability because of the regulated contributions of the Pend d'Oreille River through the Waneta Dam.

The fluctuations in discharge along the lower Columbia River contribute significantly to difficulties encountered in establishing comparable sampling stations for CRIEMP, and subsequently to the interpretation of environmental data collected spatially within this region. Discharge rate will determine the depositional characteristics of a sampling site, and will therefore determine the physical and chemical nature of the substrate, and subsequently the composition of biological communities at these sites. Changes in discharge rate represents an important covariable in assessing environmental impacts in the lower Columbia River, and must be considered in future monitoring efforts.

Contaminant Levels

Water quality conditions in the study area were evaluated relative to federal Water Quality Guidelines established by CCREM (1987), Provincial Water Quality Criteria (Pommen, 1991) and provincial Water Quality Objectives developed for the Columbia River from Hugh Keenleyside Dam to Birchbank (Butcher, 1992). Table B-12 lists these guidelines, criteria and objectives, and the use for which they were developed.

Water quality results that exceeded either the federal guideline or provincial criterion/objective are provided in Table B-13. This table lists the parameters which exceeded the criteria, the maximum levels reported, the number of observations (samples acquired), the number and frequency of observations above the MDC, and the percentage of observations exceeding the federal guideline (CCREM) and provincial criterion/objective.

Trace Metals

Water quality criteria were exceeded for metals including cadmium, chromium, mercury, lead, zinc, and copper (Table B-13). Given the variable hardness (50-75 mg/L), the appropriate criteria/objectives established by the provincial government (Pommen, 1991) were selected on the basis of an average hardness for the system (58.8 mg/L $CaCO_3$).

Levels of cadmium in the waters of the lower Columbia River did not, on average, exceed the provincial criterion of 0.0008 mg/L (maximum). At all stations, with the exception of Cominco West, values never exceeded this level. At Cominco West, despite an average level of 0.0006 mg/L, 2 of the 16 samples taken over the year (13%) were reported in excess of this criterion level. These elevated levels, 0.0011 mg/L and 0.0017 mg/L, did not occur during an extreme low-flow condition and thus could not be attributed to dilution affects.

With respect to total chromium levels, all stations upstream of Cominco reported levels in excess of the provincial criterion (0.002 mg/L maximum) on at least one of the sampling runs, while stations downstream of Cominco exceeded this level between 28 and 44% of the time. Despite fluctuating concentrations, average levels revealed at D/S Celgar, U/S Castlegar, and at Waneta were less than those of this maximum criterion value. As noted with the cadmium levels, no relationship between observed levels and water discharge conditions were apparent in these data.

The Provincial Water Quality criteria and the CCREM guidelines for mercury are established at a level of 0.0001 mg/L (Pommen, 1991). This value was exceeded at Waneta twice within the 11 samples analyzed by Zenon, twice within 12 samples analyzed by ASL, and once within the 49 samples analyzed by NLET (see Table B-13). The mercury criterion was exceeded only once at any other station — a single sample collected at Cominco West.

The levels of total zinc exceeded the Provincial Water Quality Criterion (0.03 mg/L) and the CCREM guidelines at four of the seven stations monitored along the lower Columbia River. Although average water column concentrations were less than the criterion level, a maximum concentration of 0.083 mg/L was reported just downstream of Cominco (Cominco West). This level was 2-3 times greater than reported at the other Columbia River stations, which generally revealed levels below or only slightly higher than the federal/provincial criterion value. The frequency of exceedances ranged from 0 to 10% at the majority of the Columbia River stations, with the Cominco West site exceeding the criterion limit approximately 44% of the time. The Cominco West station is located approximately 1 km downstream of Cominco's effluent, and is probably located within the effluent plume from Cominco.

No sample exceeded the maximum provincial lead criterion level, calculated using the equation supplied by Pommen (1991) to incorporate water hardness, $Pb = \exp(1.273 \ln[\text{hardness}] - 1.460)$, which resulted in a value of 0.0416 mg/L. The CCREM Criterion of 0.002 mg/L, which is considerably lower than that assigned by the province, was exceeded upstream and downstream of Celgar, at Cominco West and East, and at Waneta. The stations downstream of the smelter exceeded the lead criterion 25 to 88% of the time, whereas samples upstream of Cominco exceeded this lead criterion between 9 and 30% of the time. Maximum water column lead levels (0.031 mg/L) were reported at Cominco West, which represents an order-of-magnitude elevation over the CCREM maximum limit.

Copper levels did not exceed maximum provincial criteria (0.008 mg/L at hardness 65 mg/L). Maximum levels of 0.003 mg/L were reported for all stations with the exception of Cominco West, which revealed levels as high as 0.007 mg/L total copper.

Figure B-7 provides an example of the temporal changes in water quality in the lower Columbia River. Using the Cominco West station and total zinc as the example parameter, this figure illustrates the fluctuation in water column concentrations over time. The lower portion of the figure indicates the approximate river discharge conditions, established at Birchbank, for each of the sampling days. An obvious relationship between discharge rate and concentration is apparent for one of the sampling points (just after May 12), where extreme discharge (over 4,000 cm) is associated with water column concentrations of zinc of less than 0.01 mg/L. This relationship is not, however, capable of explaining the majority of fluctuations in these data. High concentrations with relatively high discharge would suggest a change in loadings to the river, possibly associated with changes in effluent composition and/or volume discharged.

The temporal changes in total zinc at Cominco West, illustrated in Figure B-7, reflect the trends apparent for each station and water quality parameter examined in this monitoring program. As with zinc, each demonstrates a high degree of within-station temporal variability which is only partially explained by the fluctuations in water flow.

In general, water column trace metal levels in the lower Columbia River remain below available water quality criteria/objectives levels when assessing annual average values. The data collected over an entire year, however, suggest a highly variable input of these metals, with the occurrence of levels in excess of these 'acceptable' limits. The frequency of sampling does not provide any insight into the duration of these trace metal spikes, and thus does not define the potential exposure periods to biological communities in the receiving environment.

Sampling frequency was, however, adequate for providing a good estimate of average water quality conditions over time. Average conditions in the receiving environment will provide some indication of the chronic exposure of resident biological communities to contaminant levels. In a rigorous, integrated study design in which water quality, discharge conditions and biological components are sampled concurrently, the long-term effects of such exposure may be accurately documented and subsequently related to the environmental (water quality) conditions.

Nutrients

Figure B-8 illustrates the spatial trends in dissolved phosphorus and sulfate along the lower Columbia River from the Hugh Keenleyside Dam (U/S Celgar) to just above the Pend d'Oreille River – Columbia River confluence. Phosphorus increased by more than one order of magnitude at the Cominco West station, likely reflecting the unmixed water conditions: the site is probably within the plume from Cominco effluents. Downstream of Cominco West (Waneta) the phosphorus level drops significantly, indicating dilution of Cominco effluents in the river.

The Cominco West sampling station, located just downstream of the Cominco Metals and Fertilizer plant, recorded levels of dissolved phosphorus in excess of 0.054 mg/L (54 µg/L), which is approximately 20 times higher than levels at other stations. The significant elevation in dissolved phosphorus at the Cominco West site may be responsible for the localized proliferation of a particular species of moss, occurring just at the water line, which has developed into extensive beds immediately downstream of Cominco (Cobban, pers. comm.). The species has not been reported, to any great extent, from any other areas of the lower Columbia River.

Bacteriological Indicators

Figure B-9 presents the results of bacteriological monitoring in terms of total fecal coliforms. The presence of coliform bacteria in water samples were well below limits (100/100 mL; 90th percentile) set by the provincial government for the protection of recreation and drinking water uses (Butcher, 1992). Given the present discharge volumes and effluent treatment technologies used by local communities, the bacteriological quality of the lower Columbia River was within acceptable limits (existing guidelines), and does not constitute a significant hazard to aquatic life within the system.

Organics

Chlorinated dioxins and furans were at less than detection limits in all water samples collected at all sites, and were thus eliminated from further analyses. These complex organic compounds tend to adsorb to sediment or to accumulate within tissue lipids of aquatic organisms. This adsorption and bioaccumulation process permits these compounds found at extremely low water column levels, to be retained. Results of this study component suggest that future monitoring efforts for dioxin/furan compounds concentrate on delimiting sediment and/or tissue burden levels, rather than attempting to identify and quantify the extremely low levels of these congeners in the water column.

Some chlorinated organics, other than dioxin and furans, were elevated at the station immediately downstream of Celgar, with levels becoming successively lower at stations farther downstream. Figures B-10 and B-11 illustrate the spatial trends in the average/maximum water quality conditions for selected resin/fatty acids and guaiacols, respectively. The water quality conditions in the lower Columbia River, with respect to resin acid concentrations, all fall below the Water Quality objectives recently established by BC Environment (Butcher, 1992). For dehydroabietic acid, all stations reported both average and maximum levels below the established criterion of 0.013 mg/L (at pH 8.0). Water quality objectives for chlorodehydroabietic acid were not met during one of the eight sampling periods at stations downstream of Celgar and at Castlegar.

B-3.4 BIORECONNAISSANCE COMPONENTS

The following sections summarize the results of the 1991–1993 CRIEMP bioreconnaissance study components. These components are benthos and periphyton community structure, bioaccumulation and sediment toxicity measures.

Benthos Community Structure

Benthos community structure was estimated for each of six stations during April and October 1992. The benthos data were analyzed using a combination of univariate descriptive measures, traditional classification (cluster analysis) methods and multivariate ordination techniques.

April Survey Results:

Analysis of the April benthos survey data was initiated following data matrix editing which omitted the non-benthic and meiofaunal organisms (Tardigrada, Rotifera, Ostracoda, Cladocera, Copepoda, Oribatei), and all organisms listed as 'unidentified'. Bryozoa were also omitted since numerical abundances were not provided with the data .

Figure B-12 indicates the number of taxa found in the five replicate samples taken at each of the six stations surveyed. The stations with the most diverse communities sampled in the spring were Kootenay, Robson and Birchbank (51-54 taxa). The station located upstream of Celgar reported the lowest species richness (a total of 27 taxa among the five replicates). The Ryan Creek and Waneta stations contained an intermediate diversity (35 and 37 taxa, respectively).

Figure B-12 also illustrates the proportion of EPT taxa (sum of Ephemeroptera, Plecoptera, and Trichoptera) at each site compared to the total taxa abundance. Ephemeroptera, Plecoptera, and Trichoptera represent a group of taxa which are generally sensitive to pollution and which are an important component of fish habitat. Generally, higher values for the number of EPT taxa are expected at the reference sites, and lower values at the downstream sites. The number of these taxa, although generally low across all stations, followed the spatial trends noted with the local taxa. In the case of EPT taxa, the highest numbers were reported for Kootenay and Birchbank (9 and 10 taxa, respectively), with intermediate numbers of taxa found at Ryan Creek and Waneta (7 and 8 taxa, respectively). The EPT taxa found upstream of Celgar and at Robson were approximately 25-50% of the those found at Kootenay and Birchbank.

Evaluation of the numbers of total sample taxa as well as the proportion of EPT taxa is provided as a preliminary examination of a multivariate information matrix on species abundance and composition. In terms of the April benthos survey, this assessment indicates a depression in the number of species found upstream of Celgar, with a correspondingly low proportion of EPT taxa. Given the general sensitivity of these taxon groups to water and sediment quality, as well as their importance as fish food, the status of these taxa within the benthos can provide valuable insight into community health in the lower Columbia River.

Cluster analysis of the April 1992 species composition and relative abundance data, using the Bray-Curtis Distance Coefficient (Figure B-13), indicated that the replicates from each station generally formed distinct groupings, suggesting that the sampling techniques were adequate and taxonomic analysis were consistent. The Waneta and Ryan Creek samples cluster together, while the remaining stations form a secondary group with approximately 20% similarity to these former sites.

Figure B-14 provides a SIGTREE (Nemec and Brinkhurst, 1989) analysis of these data. This classification, which supports the independent replicate analysis described above, indicates similar cluster linkages which are significant (P<0.01). The distinct clusters defined by this analysis confirm that the level of replication (five) selected for this survey was adequate for separating the stations. Lack of replicate clustering (single samples) in the Waneta and Ryan Creek samples supports the fact that these two stations form a group distinct from the other stations, and indicates a degree of overlap between the species assemblages found at each site.

October Survey Results

Comparable types of data analyses were run using the five replicate Waters-Knapp samples and the duplicate large-substrate samples taken during this survey. The dataset used in these analyses excluded those taxa which were not benthic.

Figure B-15 compares the total taxa with the EPT taxa for each of the six stations surveyed. This presentation employs data obtained from the analysis of the five-replicate small samples, thus making them directly comparable to the April benthos survey information. Unlike the benthos in the April survey, unclear spatial trends in taxon diversity (in terms of numbers of species) were apparent within the October data. The total number of taxa ranged from 30-42, with sites previously identified as the most diverse (Kootenay, Robson, Birchbank) represented by 65-80% of April's taxon diversity. Similar differences in EPT taxa numbers indicated as much as 90% reduction in these groups in the October sampling sites.

The low numbers of taxa (Figure B-15) suggest impaired quality at several sites, although the reason may be related more to the specific location where the samples were taken rather than the quality of the overall site itself. Most of the October sampling sites, for example, had been exposed at some time before sampling; in fact, sampling of the October benthos series took place approximately four weeks after the river levels had risen. This would also explain why there were fewer mayflies, stoneflies and caddisflies, although the timing of adult emergence is also a factor which could contribute to the observed differences.

Cluster and SIGTREE analyses support the results presented above for the taxon diversity. Although the results from the community classification (Figure B-16) indicate that the replicates from each site formed distinct groupings, the station clusters (Figures B-16 and B-17) are distinctly different from those provided in the analysis using April benthos data.

Comparison of the results from the two substrate sampling methodologies (Figures B-16 and B-18) completed in the October 1992 survey revealed different community assemblages. Results presented in these dendrograms reveal a distinct difference in linkage patterns, suggesting a difference in between-station similarities and thus the spatial distribution of similar benthos communities along the lower Columbia River.

Differences in this classification pattern may be attributable specifically to substrate composition (small versus large substrate), but most likely also reflect differences attributable to reduced sampling effort (number of replicates). The relatively high variation in sample composition (abundance/species) is reflected in the low similarities (high distance measures) calculated for the between-sample comparisons of large substrate collections portrayed in Figure B-18. With increased sampling effort (e.g., from two to five replicates), the reduced variability might provide considerably greater resolution of between-station similarities, thereby increasing the probability of estimating actual spatial differences in community structure.

Since the sampling locations, seasons (timing) and conditions were not similar for the April and October samples, no valid conclusions can be made regarding changes in the benthic fauna. The differences in benthos community structure apparent between the April and October survey results might be due to differences in water and sediment quality. Such correlations and conclusions cannot be drawn from these data, given the dramatic change in natural conditions which occurred at these sampling sites between survey periods. Comparisons between sediment samples taken in areas which were most likely not submerged during some period of the year with those from deep water reaches of the river is questionable. In addition, spatial comparability of such samples, given the inherent differences in hydrological influences (e.g., flow rates, sedimentation rates) between shallow and deep-water stations, will be in question given the probable differential accumulation of contaminant levels in these types of environments. Since the magnitude of these differences is unknown, the significance of observed differences between stations may be difficult to interpret.

Although these data are considered of limited value in associating aquatic and sediment quality with biological conditions, the monitoring effort has clearly demonstrated the need to design a program which will account for the dramatic fluctuations in water levels across this region of the Columbia River. Section C of this report addresses this aspect of sampling in a modified CRIEMP design for future sampling programs.

Periphyton Community Structure

Single composite samples for the periphyton community analysis were collected at each station, eliminating the possibility of evaluating these data with respect to site-specific variability (as performed for the benthos). Taxonomic identification, although completed to the lowest level possible, did not provide quantitative information for all taxa reported; some taxa were reported as number of cells per unit volume, while others were indicated only as being present or absent.

Table B-14 presents a basic summary of the periphyton information collected in the initial CRIEMP Reconnaissance survey. The table indicates the number of species found in each of the major periphyton taxonomic groups assessed by the analysis. This evaluation demonstrates that species richness (in this case, number of species) remains generally constant across all stations sampled, with the exception of the site downstream of Cominco (Ryan Creek). This station, with the lowest species richness (31) of all of the stations, indicates a significant reduction in the number of Pennales taxa (by approximately 50%).

A slight impact in periphyton community structure immediately below the Cominco discharges may be attributable to the metals associated with the effluent streams released by this industrial facility. Algae, and periphyton in particular, have been shown to be good indicators of trace metals impacts in aquatic systems.

Sampling periphyton once or twice a year will not provide enough information on the river system and its water and sediment quality to warrant inclusion in CRIEMP. If periphyton sampling was included, it would have to be sampled at least once a month to provide a representative picture of the algal community, since the composition and abundance can change rapidly. Also, as a photosynthetic group, many periphyton taxa are much more sensitive than invertebrates to subtle changes in turbidity, amount of sunlight, depth fluctuations, and other factors which do not relate specifically to contaminant inputs to the river. Many of these factors will be directly, and unpredictably influenced by the regulated flow of the Columbia River. Consideration of a sampling substrate which is suspended in the water column would eliminate the impacts of water level, although not necessarily of water velocity.

Bioaccumulation

Bioaccumulation information was acquired from tissue extracted from aquatic macrophytes, adult emergent caddisflies, and resident bivalves. The following subsections summarize the results of these analyses.

Macrophyte Chemistry

Results from measurements made in July 1992 indicate that levels of trace metals were consistently higher in macrophytes from the sample taken at Waneta (downstream of Trail) than the sample taken immediately downstream of Celgar (Table B-15). Specifically, 17 of the 25 trace metal parameters were higher in the macrophyte tissues sampled downstream of Trail (Waneta) than those sampled downstream of Celgar. With some parameters such as cadmium, copper, mercury, lead and zinc, the levels at Waneta were 2 to 10 times higher. Despite the few samples acquired for this bioreconnaissance component, higher levels of some metals at Waneta — downstream of Cominco which is the major source of metals to the system — demonstrate the potential for using this technique for monitoring metals in the system.

Unlike the trace metals, all organic parameters measured within the sampled macrophyte tissues, including chlorinated organics, were below the detection limits for samples acquired at each of the sites surveyed in July 1992. Employing aquatic vegetation as an indicator of contaminant bioavailability is useful in examining the fate of metals in the environment, but not of organics.

Emergent Caddisfly Chemistry

Table B-16 summarizes the caddisfly bioaccumulation data collected during July 1992. Samples were taken at Waneta, downstream of Celgar, and at two reference stations on the Kootenay River at Glade and at Grohman Narrows. Samples comprised a composite of species, with over 85% of the organisms represented by *Hydropsyche oslari*, *H. occidentalis*, *Cheumatopysche campyla* and *Psychomyia flavida* (Norecol Ltd., 1992). Table B-16 does not show those parameters which were less than detection across all of the sites sampled.

Metals, pentachlorophenol, and chlorinated dioxin/furan congeners were detected in emergent caddisflies at all sites tested during this period, including the reference stations. Table B-17 indicates those contaminants which had accumulated in the caddisfly tissues and the factor by which these levels differed from caddisfly tissues sampled at the reference sites. The upper table shows that six trace metal parameters were elevated in the caddisfly tissues at the station downstream of Celgar; the factor higher than the reference station ranged from 1.10 (for total zinc) to 3.07 (for total Sb). 2,4,6 trichlorophenol was shown to have slightly elevated tissue levels. Overall, for chlorinated phenolic compounds, the factor greater than the reference station ranged from 0 to 1.6.

The lower table identifies those chemical parameters which indicated elevated levels within the tissues of caddisflies collected at the Waneta station. At this site a suite of metals was found elevated within the processed tissues, with total lead at levels 4.29 that of background and total antimony above reference by a factor of 4.20. Other metal parameters were only slightly higher than background (factor greater than reference station ranged from 1.07 to 1.86).

The lower portion of Table B-17 also reveals the range of increased accumulation for pentachlorophenol, dioxin congeners, and furan congeners. The levels of these parameters in caddisflies tissues varies from 0.5 to a factor of 6.67. Elevated levels of T4CDD and the furan congener 2,3,7,8 T4CDF were greater than reference station by a factor of 5.20 and 6.67, respectively. Given the documented toxicity of 2,3,7,8-TCDF (Mehrle *et al.*, 1988), the elevated levels in tissues (although the absolute levels remain low) do illustrate the potential for bioavailability in this river system.

With minimal data collected between Celgar and the International Boundary, a comprehensive evaluation of the spatial impacts of these compounds on the bioavailability of contaminants discharged to the lower Columbia River system is not possible. Expansion in the numbers of bioaccumulation monitoring stations in this region of the river, and inclusion of sample replication for each site, would greatly enhance this component of CRIEMP.

Mussel Tissue Chemistry

Table B-18 provides the mussel (*Anodonta oregonensis*) tissue bioaccumulation data for each of the three stations sampled during the 1992 CRIEMP Reconnaissance survey. A single reference station (Kootenay River) was sampled in conjunction with the Columbia River mainstem station immediately downstream of Celgar as well as the station at Waneta (just above the International Boundary). As with the caddisfly tissue component of this survey, inadequate spatial sampling effort precludes the opportunity of properly assessing spatial changes in bioavailability in this region of the Columbia River.

Table B-19 summarizes the bioaccumulation results for the mussel tissue samples analyzed in this study component. The top table presents the factors by which Celgar samples are higher than the reference (Kootenay) for the parameters listed. At this site only trace metals were found to be higher than the assigned reference station. The metal factors greater than reference station ranged from 1.14 to 3.19.

The lower portion of Table B-19 indicates the factors by which the concentration differed from reference levels at the Waneta station. The factors range from 1.04 (selenium) to 62.75 (lead). The extremely high level of lead within the bivalve tissues is accompanied by a corresponding elevation in copper levels (factor greater than reference station of 10.52). Both of these results tend to correlate with the data presented in the sediment quality survey, which indicates that levels of many of these metals (including copper) are significantly higher than stations downstream of Beaver Creek.

The results of this CRIEMP survey component provide useful insight into the possible contaminant bioavailability and uptake. In the present survey, however, the spatial sampling effort is insufficient to address many of the questions relative to CRIEMP, and the choice of reference stations may be inappropriate for continued monitoring for this component. Data shown in Table B-20 suggest that levels of the listed metals are greater in the reference by a factor as high as 3.27 (greater than Celgar) or 1.26 (greater than Waneta). For the organic compounds, including 2,3,4,6 tetrachlorophenol and 19 dioxin/furan congeners, reference tissue levels exceed Celgar bivalve tissue levels by as much as 14 times and Waneta tissue levels by as much as 17.2 times.

Sediment Toxicity

The highest mortality in *Hyalella azteca* screening tests occurred in sediment samples from the downstream Celgar station and the station downstream of Cominco, with non-toxic responses noted for Arrow Lake, Kootenay, Robson, China Creek, Beaver Creek, and Waneta. Statistical significance of these results cannot be inferred due to the lack of replication in the experimental design. However, as results of preliminary tests, these data suggest the presence of a toxic sediment environment downstream of both the Cominco and Celgar facilities, and support the need for further investigation and quantification.

Figure B-19 summarizes the toxicological information produced by the sediment bioassays. The Microtox duplicate tests showed extreme variation and provided inconclusive results regarding sediment toxicity.

The amphipod bioassay results (Figure B-19), although not replicated, do provide some insight into the acute toxicity associated with sediment in the lower Columbia River. The amphipod survival, illustrated in the lower portion of this figure, suggests that sediment toxicity is greatest immediately downstream of both the Celgar and the Cominco industrial discharges. Results of these analyses have not been acquired through a rigorous sampling design, and thus should be considered preliminary at best. Logistical problems encountered during sample transport, which resulted in a processing delay, may also have contributed to the variable results in these analyses.

B-3.5 INTEGRATED COMPONENT ANALYSIS

In an effort to relate observed biological impacts to the physical and chemical parameters estimated in the lower Columbia River, an integrated component analysis was performed using the April 1992 benthos community structure data as the foundation for the analysis. As mentioned previously in this document, this integrated analysis is provided as an example of how the CRIEMP survey information could be employed to objectively assess spatial and/or temporal trends in the environmental quality of the lower Columbia River system. Although efforts have been made to use data which can legitimately be compared, the lack of concurrent sampling of physical/chemical parameters and the biological attributes during the 1991–1993 program give such comparisons a margin of uncertainty.

To provide an example of an integrated component analysis, the April 1992 benthos data set was selected over the October 1992 information, as it was considered more representative of a developed, more stable benthic community across the stations sampled. Figure B-6 gives hydrographs for 1991-1992 at stations along the lower Columbia River, thus indicating flow conditions before and during the period of this study. April sampling occurred when the river level was generally at its lowest point, and thus the specific areas (depths) sampled for benthos had always been submerged. In contrast, the October benthos survey was completed when the river levels had recently risen, and thus the communities sampled were representative of relatively 'young,' or immature species assemblages. In comparing the number of taxa identified between sampling periods, the October survey reported approximately 50% of the richness (number of taxa) indicated by the April survey results.

Figure B-20 summarizes the integrated component analysis performed using the April benthos data. The basis of this assessment is the Principal Components Analysis (PCA) portrayed in the centre of the figure. The PCA was run on the benthos species composition and relative abundance matrix with log(x+1) transformed data, and with station replicates treated independently. Results of the analysis revealed that 89.7% of the original multidimensional variability was accounted for in the first two Principal Component axes (labelled Axis I and Axis II).

Each of the station replicates is shown individually on Figure B-20. To facilitate the visual presentation of these results, the replicates for each of the six stations are enclosed within an ellipse, the centre of which represents the 'average' position for a particular sampling station, and the size of the ellipse an indication of the variability among replicates. The proximity of individual points (stations and replicates) within the ordination space is a function of between-sample similarity; the closer the points, the more similar the two samples in terms of the community species composition and relative abundance. Thus, in interpreting this particular PCA, three community 'types' can be differentiated from the dispersion of station replicates: one comprising Robson, Birchbank and Kootenay, a second represented only by the station upstream of Celgar (below Hugh Keenleyside Dam), and the third characterized by the stations at Ryan Creek (downstream of Cominco) and at Waneta.

The three community types shown in the PCA plot are supported by the cluster analyses presented in Section B-3.4. The community classification in the ordination is also supported by the number of taxa comprising these communities. Directly above the PCA plot is a bar graph showing the average species richness for each of the six benthos stations. Community Type I stations had 50-54 taxa, Community Type II was represented by only 20 taxa, and Community Type III stations reported 35-37 taxa.

Differences between the Community Types shown in Figure B-20 can be attributed to a variety of physical and/or chemical attributes. Using the principal component scores (coordinates) for each station, a correlation analysis with water and sediment quality data was performed. Of the variables included in this association test, the parameters listed in the table (Group 'A' Parameters) at the bottom of Figure B-20 demonstrated a statistically significant ($P<0.05$) relationship with Principal Components Axis II. These results suggest that differences in Community Types I and II (Robson, Kootenay, Birchbank and U/S Celgar) are different from Community Type III (Ryan Creek and Waneta), and that these differences may be attributable to differences in the levels of each of the parameters listed in this table.

The integrated component analysis also suggests that the distribution of stations along Principal Components Axis I is correlated with physical sample attributes, and that species compositional differences between each of the three Community Types may be associated with substrate composition. The bar graph immediately below the PCA shows the proportion of three major sediment particle sizes in samples taken from the three communities; these differences do indicate a variation between the communities which may also explain, or differentiate, the communities classified through this analysis and supported by the previous cluster analysis.

Current velocities at the sampling sites, although not correlated significantly with the distribution of stations along Principal Component Axis I, will also determine species composition and relative abundances. This physical attribute was substantially different at the U/S Celgar site (0.033 m/s) than at the Ryan Creek sampling site (0.56 m/s); other stations indicated intermediate velocities. Substrate composition, determined in part by water velocities, represent important physical attributes which will influence benthos community structure. Future sampling, designed to concurrently acquire information on physical, chemical and biological attributes of a site, will inevitably increase the capabilities of CRIEMP to identify the relationships between these primary monitoring components, and thereby address the overall objective of determining the 'health of the river.'

B-4 CONCLUSIONS

The 1991–1993 Columbia River Integrated Environmental Monitoring Program (CRIEMP) has provided some important insights into the present environmental conditions in the lower Columbia River system. Particular aspects of this program should be modified in order to improve the sensitivity of the integrated monitoring effort in defining spatial and/or temporal changes in environmental quality in the Columbia River from the Hugh Keenleyside Dam to the International Boundary downstream of Waneta.

The 1991–1993 CRIEMP survey incorporated a number of monitoring components which were considered appropriate to the examination of ecosystem conditions in the lower Columbia River. Conclusions that can be drawn from each of these primary program components are presented below.

WATER QUALITY CONDITIONS

- Water quality monitoring suggests that the entire lower Columbia River system is influenced by a variety of organic and inorganic contaminants, the *in situ* concentrations of which remain low and within water quality limits (criteria, guidelines and objectives) established for the protection of aquatic life. Maximum levels reported for trace metals exceeded these water quality limits more frequently at stations immediately downstream of Trail than at stations upstream. Trace metal parameters of concern include chromium, zinc, copper, and lead.

- Chlorinated dioxins and furans were not detected in the water column at any of the stations sampled, although levels of specific fatty/resin acid compounds such as arachidic acid were elevated immediately downstream of Celgar as compared with the other stations sampled. Averaged over an entire year of monitoring, these organic compounds all remained at levels below BC Environment criteria at all of the other stations sampled in the lower Columbia River. Maximum levels detected during this survey documented spikes in the receiving environment for some of these compounds, the magnitude of which did exceed criteria levels. The frequency of these spikes were typically in the order of 10-15%. It is anticipated that with the improvements recently initiated in the Celgar Pulp facility, loadings of these organic wastes will be substantially reduced and thereby potentially eliminate the occurrence of *in situ* levels in excess of Water Quality Criteria.

- The fluctuation in water quality was only partially related to river flow conditions. High levels of parameters were not associated with low flow conditions, suggesting that contaminant loadings changed frequently during the monitoring period. The 'spikes' noted in the water quality estimates may reflect a combination of water flow and effluent discharge characteristics, although an evaluation of the relative contribution of each was not possible given the data collected.

- In addition to the influence of chemical constituents of the water column, the initial CRIEMP survey has demonstrated the impacts associated with hydroelectric facilities operating over this portion of the lower Columbia River. Total dissolved gases (TDG) were generally reported at levels above that of the provincial criterion (110%) during all but the summer months at the Robson monitoring station.

Recent implementation of process changes to Celgar Pulp Mill and Cominco have resulted in dramatic improvements in the quality of effluent discharged to the Columbia River. Since these process changes have been initiated following the 1991–1993 CRIEMP study, it is anticipated that the improvements to the wastewater discharged will have had a direct influence on the present water, sediment and biota quality of the Columbia River.

SEDIMENT QUALITY CONDITIONS

- Elevated levels of trace metals in lower Columbia River sediments is restricted primarily to the region downstream of Trail, with no appreciable levels noted upstream of this point. The significance of these levels in terms of potential impacts to aquatic life, given the paucity of sediment quality criteria or objectives, is indeterminate at this time. Clearly, the persistence of metals in the sediments downstream of Cominco, and at the International Boundary, is of primary concern and importance for future monitoring efforts.

- Sediment data support anecdotal and survey information on the localized nature of depositional substrate in the lower Columbia River, and confirm the difficulties associated with sediment monitoring. The lack of depositional sites for sediment quality monitoring is further compounded by the differential sediment attributes of the few stations which could be assessed by the initial CRIEMP survey. Levels of acid volatile sulfide (AVS) were dramatically different between stations, suggesting a potential difference in the bioavailability of trace metals between these sites.

It is readily apparent that difficulties in establishing an adequate number of sediment sampling sites in the lower Columbia River significantly impedes the ability of CRIEMP to effectively define spatial impacts of contaminants accumulating in the sediment environment. However, the information collected from this initial survey does support the need to monitor temporal changes in the few sediment sites which have been established in this region of the Columbia River. Improvements to industrial discharges can be indirectly assessed by monitoring temporal changes to sediment levels at the existing stations.

BIORECONNAISSANCE

The biological impacts associated with physical and chemical perturbations in the lower Columbia River were documented using a combination of benthos and periphyton community structural analysis, bioaccumulation of contaminants in selected invertebrates and macrophytes, and by a limited number of sediment bioassays. This aspect of the 1991–1993 CRIEMP survey was considered a bioreconnaissance component, with the various methods 'field-tested' during this initial survey.

- The use of periphyton monitoring, macrophyte distributions, and the macrophyte bioaccumulations components of this initial CRIEMP survey were considered of limited value in monitoring the environmental condition of the river during this initial CRIEMP survey. Although the bioaccumulation of metals in macrophytes effectively demonstrated spatial differences, this indicator did not assess the impacts of organic contaminants. Continued use of this program component may not be completely suited to the overall goal of CRIEMP given the metals selectivity of macrophytes. Its use to monitor temporal changes in bioavailability in specific areas of the river may, however, warrant inclusion of the techniques in a revised program. The significance of the accumulation found in the tissue should be further investigated.

- The use of periphyton community structure on fixed, natural substrates is considered inappropriate as a biological monitoring tool given the regulated flow of the river. As a photosynthetic group, many of the periphyton taxa are much more sensitive to subtle changes in turbidity, amount of sunlight, depth fluctuations, and other factors which do not necessarily relate specifically to contaminant inputs to the river. With design modifications (use of artificial substrates), however, inclusion of this monitoring component in CRIEMP may permit standardization for many of these influencing parameters. The selection of glass slide trays, for example, would exclude inherent differences in natural substrates, while allowing structures to be anchored at selected sites in the river having comparable current velocities, depth control, etc. The use of such systems in the Columbia River, however, would necessarily require considerable effort in system design and installation logistics, given flow rates and fluctuations, and is not recommended.

- Documentation of macrobenthos community structure, in contrast, provided a useful tool for monitoring environmental response in the lower Columbia River. Replicate samples acquired in this study component suggested low within-station variability, thereby allowing considerable potential for quantitatively assessing spatial differences at appropriate sites along the river. The results of this initial CRIEMP survey, however, indicated a number of problems with the present design (e.g., number and location of sampling stations, timing of sampling, placement of sampler, and lack of substrate stratification). Despite these initial problems, the approach has considerable potential in documenting biological impacts within the receiving waters, providing it is initiated concurrently with other components of the program.

- Single, unreplicated sediment bioassay tests demonstrated that sediments immediately downstream of both Celgar and Cominco were toxic. Neither of the toxicity tests employed during this survey, however, supported any environmental effects at the sediment stations downstream of Beaver Creek or at Waneta, where levels of a number of trace metals and organic compounds were in excess of all other stations sampled. The explanation for this discrepancy is unclear, but does indicate that a more rigorous toxicity testing design would provide a better understanding of these results.

- Bioaccumulation data obtained from emergent caddisfly and freshwater bivalve (mussel) tissue analyses provided useful information on the uptake of contaminants. The extent of this sampling component was, however, limited with respect to spatial coverage within the study area. Only three stations, including the reference site, were assessed. The lack of sample replication precluded the opportunity of establishing the variability among such samples, or of estimating the statistical power of such biological indicator methods for future design considerations.

INTEGRATED COMPONENT ANALYSIS

- The nature of the initial CRIEMP design, particularly in employing a selection of physical, chemical and biological components within a monitoring framework, maintains the potential for providing an integrated analysis of ecosystem health in the lower Columbia River. However, lack of concurrent monitoring of these study components during the initial survey limits the capability of providing such an evaluation for the 1991–1993 data.

- As an example of integrated component analysis, the combination of multivariate methods (classification/ordination) employed in this report provided insight into community variability in the lower Columbia River, and presented a possible use of such methods in integrating the physical/chemical attributes of water/sediment quality with the inherent biological impacts. Within a modified program design, such methods would be capable of integrating information collected concurrently, i.e., benthos and sediment chemistry; bioaccumulation and water quality; or benthos with water quality. Such an integrated analysis approach may also be useful in relating (or eliminating) the effects of covariables such as water level (flow rates), or substrate composition.

In conclusion, the 1991–1993 CRIEMP survey has provided useful information regarding the possible spatial impacts in the lower Columbia River, and has 'field-tested' each program component such that an appropriate decision can be made regarding a revised CRIEMP survey design for future monitoring efforts. Considered as preliminary, this initial survey confirms the premise upon which the program was designed, i.e., to provide an **integrated** evaluation of the environmental conditions of the lower Columbia River. This monitoring effort has demonstrated that contaminant loads to the lower Columbia River are interacting with the biological components such that downstream bioavailability of these contaminants are affecting community structure, and are being ingested and possibly transferred among the biological system components. A revised program will differentiate near and far-field effects, and will provide a sound base upon which temporal changes (e.g., as a result of industrial discharge improvements) in environmental integrity can be documented.

SECTION C:

RECOMMENDED CRIEMP MODIFICATIONS

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RECOMMENDED CRIEMP MODIFICATIONS

C-1 PRESENT CRIEMP DESIGN LIMITATIONS

The 1991-1993 CRIEMP Reconnaissance program was designed to incorporate physical, chemical and biological components of an environmental situation audit. Proper integration of such components in a monitoring design can provide substantial spatial and temporal information on the dispersion and dilution of contaminants in the system, and concurrently on the combined impact these contaminants will have on the ecosystem integrity of the receiving environment.

The 1991-1993 CRIEMP survey was intended as an initial effort in monitoring using this multi-component approach. As a preliminary survey, results of this study were to serve two purposes; the first was to provide information on the 'state-of-the-environment' in the lower Columbia River, and the second was to provide the basis upon which a modified, integrated environmental monitoring program could be produced and recommended for implementation. In evaluating the information acquired by this initial survey in terms of this latter objective, a number of design limitations have been identified and have subsequently been considered in recommendations for a revised CRIEMP study design. These present monitoring program limitations include the following:

(i) Sampling Station Allocation

Although the original objectives of CRIEMP did not include the documentation of differences in near-field and far-field effects for each of the primary contaminant inputs to this river system, addition of stations located immediately downstream and upstream of each of the primary outfalls of concern would help define the environmental response of these inputs, and permit clear documentation of differences most likely attributable to further wastewater dilution and dispersion downstream of these inputs. It is realized that monitoring of certain program components (e.g., sediment quality) are constrained by the availability of appropriate substrate in the river. Where possible, however, each monitoring component should comprise stations in the areas specified above.

In addition to delimiting the localized effects of contaminant input to the Columbia River, the combined effects on river water quality at the International Boundary must remain a clear objective; it is thus imperative that appropriate sampling effort be maintained at a representative station (stratified by substrate type if required) located near the border (e.g., upstream of Waneta).

(ii) Concurrent Component Monitoring

CRIEMP did not concurrently sample all, or even a few, of the components included in the initial study design at the majority of stations presently included (see Table B-2). Without concurrent sampling and analysis (e.g., benthos community structure, tissue bioaccumulation, and sediment/water chemistry) interpretation of the information acquired from this monitoring program, particularly from an integrated perspective, is virtually impossible. Selection of stations must be made such that all (or the majority) of the program components can be sampled concurrently.

(iii) Appropriate Reference Areas:

Some of the present reference stations, characterized by slightly different substrate, sampled at different depths, and found to have higher levels of certain contaminants than stations sampled downstream of contaminant sources such as Celgar, must be replaced by appropriate reference stations. The number of reference stations will be defined by the degree to which sampling stratification is required of the program (e.g., a covariable such as substrate composition).

(iv) Sampling Positioning (Depths)

Water depths vary dramatically in the lower Columbia River as a direct result of the non-synchronized operation of the Brilliant and Hugh Keenleyside dams. Temporal sampling during the initial CRIEMP survey has resulted in sampling positions which were submerged during one period, exposed during a second sampling period (requiring allocation of sampling at a different location), or which have been exposed for variable amounts of time between periods. Discontinuous immersion of a sampling station does not represent worst-case exposure to potential contaminant effects. To ensure that temporal sampling is consistent and representative, consideration of sampling position at the lowest predictable water level must be incorporated into a modified design.

(v) Natural Substrate Variability

High variability in substrate composition has resulted in stations which differ considerably with respect to sediment particle size. This natural variability can have profound effects on community composition, and reflects the degree to which sedimentation processes may deposit contaminants at a particular site. It is apparent that sediment sites available for this region of the Columbia River are limited, and thus

CRIEMP OBJECTIVE AND COMPONENT HYPOTHESES

STUDY COMPONENT		HYPOTHESIS
OVERALL OBJECTIVE	H_0:	There is no difference, spatially or temporally, in ecosystem status (health) within the lower Columbia River.
I. WATER QUALITY COMPONENT	H_0:	There is no difference in water quality, spatially or temporally, within the lower Columbia River as compared with a normal, natural aquatic system having no anthropogenic influences.
	H_1:	Wastewater discharge from the Celgar Pulp facility has no impact (spatially) on water quality within the lower Columbia River, and improvements in wastewater characteristics from this operation will not change (temporally) water quality in the river.
	H_2:	Wastewater discharge from the Cominco Metals Smelter has no impact (spatially) on water quality within the lower Columbia River, and improvements in wastewater characteristics from this operation will not change (temporally) water quality in the river.
	H_3:	Discharge from dam operations have no impact (spatially) on water quality within the lower Columbia River, and changes (operationally or structurally) in these facilities will not change (temporally) water quality in the river.
II. SEDIMENT QUALITY COMPONENT	H_0:	There is no difference in sediment quality, spatially or temporally, within the lower Columbia River as compared with a normal, natural aquatic system having no anthropogenic influences.
	H_1:	Wastewater discharge from the Celgar Pulp facility has no impact (spatially) on sediment quality within the lower Columbia River; and improvements in wastewater characteristics from this operation will not change (temporally) sediment conditions within the river.
	H_2:	Wastewater discharge from the Cominco Metals Smelter has no impact (spatially) on sediment quality within the lower Columbia River, and improvements in wastewater characteristics from this operation will not change (temporally) sediment conditions in the river.
III. BIOLOGICAL EFFECTS COMPONENT	H_0:	There is no difference in the composition, structure or function of the biological populations or communities, spatially or temporally, within the lower Columbia River as compared with a normal, natural aquatic system having no anthropogenic influences.
	H_1:	Wastewater discharge from the Celgar Pulp facility has no impact (spatially) on the composition, structure or function of the biological populations or communities within the lower Columbia River, and improvements in wastewater characteristics from this operation will not change (temporally) these biological attributes within the river.
	H_2:	Wastewater discharge from the Cominco Metals Smelter has no impact (spatially) on the composition, structure or function of the biological populations or communities within the lower Columbia River, and improvements in wastewater characteristics from this operation will not change (temporally) these biological attributes within the river.

For the measurement of the (I) Water Quality; (II) Sediment Quality; and the (III) Biotic Component considerations, a set of three primary hypotheses can be formulated and tested within the scope of an appropriate study design. A general hypothesis for each of these CRIEMP components is that:

> *there is no difference in environmental quality (as determined by the appropriate component-specific measures), either spatially or temporally, within the lower Columbia River when compared with a normal, natural aquatic system having no anthropogenic influences.*

Failure to statistically reject this null hypothesis would thus conclude that there are no measurable environmental problems in the lower Columbia River system, as measured by the procedures employed in each of the CRIEMP components. In contrast, the alternate hypothesis (H_A), considered only should the null hypothesis be statistically rejected, would generally conclude that an environmental difference in the river system does exist. Furthermore, the magnitude and the spatial and/or temporal relationship of such a difference should be identifiable as a result of subsequent analysis of the quantitative information acquired through these CRIEMP components.

Three additional hypotheses have been presented in each of the CRIEMP components. Two of these secondary hypotheses will independently assess whether or not the primary contaminant inputs to the lower Columbia River (Celgar and Cominco) are contributing to a measurable, significant aquatic ecosystem impact, and whether or not independent improvements in wastewater quality and/or quantity are resulting in a measurable, significant improvement in ecosystem health. The final secondary hypothesis will assess the hydrological and water quality effects that the local dam operations (Hugh Keenleyside, Brilliant, and Waneta) will have on the aquatic system downstream of these facilities.

Inclusion of these secondary hypotheses has important implications to the sampling design for CRIEMP in that the division of monitoring effort (between CRIEMP participants) will reflect specific interests and concerns with regard to wastewater quality and the receiving environment. A coordinated effort in acquiring all of the information required of a rigorous monitoring program will also result in a reduction of cost and effort on the part of specific CRIEMP participants, while ensuring that redundancies in sampling effort are avoided.

C-2.2 PROPOSED MONITORING PROGRAM DESIGN

The proposed revisions to the Columbia River Integrated Environmental Monitoring Program (CRIEMP) do not apply to the basic design of the program, i.e., one that is based on the concurrent collection and integration of physical, chemical and biological measures. This basic design, initially implemented as a combination of routine water and sediment quality monitoring with a biological reconnaissance component during 1991-1993, is considered sound and appropriate for the lower Columbia River. The CRIEMP modifications recommended below are primarily of a design nature, reflecting the problems identified upon completion of this initial survey.

1. PROGRAM COMPONENTS

Comprehensive analytical work-up of sediment and water samples has been used in the present CRIEMP design to indicate the attributes associated with the variety of industrial and municipal discharges (contaminant inputs) potentially affecting the lower Columbia River. Biological community structure (benthos/periphyton and macrophyte distribution) has been employed to document a direct ecological response to contaminant input, while toxicity measures and bioaccumulation of contaminants in the tissues of organisms illustrate the availability of contaminants and the potential biomagnification of low concentrations of these contaminants through representative trophic levels in the system.

The following CRIEMP components are considered appropriate for a revised design. The rationale for exclusion or provisional inclusion in the program are provided for each of these monitoring components.

- **Water Quality**

The following points are recommended with respect to revisions to water quality monitoring in CRIEMP. To facilitate a balanced design for CRIEMP, and thus allow appropriate comparisons of water quality results with the other program components, sampling stations must be the same as those selected for all aspects of the biological sampling program.

For water quality monitoring it is recommended that the number of chemical parameters and the frequency of monitoring specific parameters for water in the receiving environment be reduced. It is suggested that CRIEMP omit sampling the water column for highly hydrophobic contaminants such as chlorinated dioxins/furans and resin acids. These compounds are virtually insoluble in water and tend to adsorb to suspended particulate matter, or in sediments and tissue. In the water these parameters will usually be present at extremely low levels, often below analytical detection limits. Given the improvements in effluent quality associated with the Celgar mill since this survey, it is anticipated that levels will remain well below detection in water.

It is also recommended that a revised CRIEMP monitoring design use stratified sampling over time to document changes in concentrations which may be directly related to water discharge. In addition to sampling concurrently with the other program components, we suggest that a stratified sampling of the water column at the selected monitoring stations be coordinated with extreme flow conditions (maximum, minimum) of the river. Of particular relevance are the low flow periods, in which loadings from the discharge sources will result in receiving water concentrations which will be at a maximum (worse case scenario). Similarly, planned sampling during a period of relatively stable flow may provide useful information on fluctuations in loadings to the river.

- **Sediment Quality**

The spatial evaluation of sediment quality is the most difficult monitoring component to achieve in the lower Columbia River given the paucity of depositional areas between the Hugh Keenleyside Dam and the International Boundary. However, sediment quality monitoring does represent an important monitoring component of CRIEMP, as contaminant levels deposited within sediment will directly affect the composition of resident biological communities as well as provide a source of available contaminants for uptake and accumulation by certain trophic levels within these communities.

Because of the restrictions in potential sediment sampling areas for this region of the Columbia River, delimitation of spatial impacts in sediment quality will prove impossible in terms of expanding the monitoring design of this component of the program. Given the few sediment stations available to the program, it may be prudent to monitor these sites for changes in sediment chemistry over time, thereby documenting changes (improvements) in environmental condition on a temporal rather than spatial scale.

The initial CRIEMP monitoring program included a comprehensive list of parameters which were quantified for the sediment samples collected. As many of these parameters are readily accumulated in sediments, the continued monitoring of the complete spectrum of contaminants is considered highly appropriate for the modified CRIEMP design. If future monitoring effort reveals a decline in levels within specific groups, then subsequent reduction in monitoring effort for these non-persistent groups might then lead to associated cost reductions to this aspect of the monitoring program.

- **Biological Components**

Benthos Community Structure

Quantitative descriptions of the benthos community structure provides an effective approach to monitoring spatial and temporal changes of both water and sediment quality of the lower Columbia River. Continued sampling of the benthos is recommended for CRIEMP, with proper consideration of replication, sampler position (water depths), substrate stratification, and sampling period.

An *in situ* (e.g., Hess) sampler should be used to collect all samples to obtain a representative list of benthos inhabiting the sediment. Proper selection of stations should, in addition to considering water depth (vertical position along the bank) and sampling period, require similar water velocities, which may also contribute to spatial differences in benthos. The collecting net mesh size should remain between 210 and 250 µm.

Substrates characteristic of erosional habitats (e.g., cobble) are the most common in this region of the Columbia River, and thus sampling in these environments would provide the ability to: (i) expand the monitoring effort to include near and far-field biological effects with respect to the major industrial discharges; and (ii) concurrently sample a number of CRIEMP components. Although sediment chemistry could not be acquired from such sites, concurrent sampling of water quality, as well as representative samples for bioaccumulation evaluations, would ensure that benthos community results be properly interpreted with respect to the objectives of CRIEMP.

Sampling of benthos should also be completed in the depositional environments, thus providing the opportunity of assessing biological community structure with respect to sediment contaminant levels.

Bioaccumulation in Invertebrate Tissues

The following recommendations are made with respect to monitoring contaminants in freshwater bivalves and in emergent caddisfly tissues. Sampling of invertebrates for tissue bioaccumulation should be implemented at each of the benthos community structure stations in order to relate the results of these program components as effectively as possible. The choice of specific test organisms should depend upon the availability of these invertebrates across all stations sampled, but would ideally comprise mussel bioaccumulation at depositional stations and caddisfly bioaccumulation at the erosional sites.

In addition to continued monitoring of the metals examined in the initial CRIEMP bioaccumulation survey, it is recommended that a revised program limit monitoring of organic compounds to contaminants with reasonable bioaccumulation potential (e.g., chlorinated dioxins and furans, tetrachlorophenols, pentachlorophenol). Analytical assessment of all bioaccumulated contaminants should be accompanied by a measure of lipid content to report organics on a lipid-corrected basis as well as a dry weight basis.

Bioaccumulation in Plant Tissues

The survey of macrophytes in the lower Columbia River, and the subsequent sampling of these plants for bioaccumulation, is considered to generate highly variable and unrepresentative results. Given that these macrophytes are fixed to the substrate, they are exposed to contaminant effects largely through water quality changes, and thus as a function of river level (which is highly variable). Additionally, uptake of contaminants in macrophyte tissues is restricted primarily to metals, and thus does not adequately document the environmental response to levels in organic compounds. It is recommended that the survey for macrophytes and the bioaccumulation of contaminants in their tissues be deleted from the revised CRIEMP monitoring program design.

Sediment Toxicity

Sediment toxicity can provide a useful estimate of sediment quality impacts. It is therefore recommended that toxicological information be acquired in support of the sediment quality survey, and that the revised CRIEMP continue to incorporate a set of standard sediment toxicity measures (e.g., amphipod behavioural/lethality tests).

Inclusion of toxicity as a CRIEMP component should require that such tests be conducted for sediments collected at each of the proposed sediment sampling stations; completion at only selected stations, like any of the integrated monitoring components, is not considered appropriate. Proper replication (minimum of three) should also be ensured for all stations (and reference) sampled. Three replicate samples will provide the minimal number of samples necessary to provide information on the distribution of values, and thus permit an objective estimate of optimum sample size and statistical power of these, and the other CRIEMP component tests.

Periphyton Community Analysis

The relatively rapid growth rates and sensitive shifts in species composition makes incidental monitoring of periphyton species assemblages highly variable, and therefore inappropriate as a tool for continued use in CRIEMP given the present procedural approach.

In a monitoring capacity, use of periphyton could be considered if the growing environment was stable, i.e., they were sampled from comparable substrates (composition, texture, orientation) at a depth which has remained constant over time (as in suspended, artificial substrates). Under these conditions, periphyton changes might reflect changes in water quality and thus would represent an appropriate tool for long-term monitoring efforts. The disadvantages associated with this approach include the logistical considerations of erecting physical structures which would be required at each station to support the artificial substrate apparatus. These structures, once in place, would then be susceptible to damage from drifting debris and/or as a result of vandalism.

The addition of this monitoring component is optional. If considered appropriate, it is recommended that such artificial substrate systems be installed at each of the water quality, benthos and bioaccumulation stations. This design would further strengthen the ability to assess information collected from subsequent CRIEMP surveys in a truly integrated manner.

2. SAMPLING STATION ALLOCATION

One of the primary problems associated with the initial CRIEMP design was the limited number and location of sampling stations in the study area (including appropriate reference stations), and the concurrent sampling of the various environmental components at each of these stations. It is thus recommended that the number of stations be increased in an effort to adequately define differences in near-field and far-field effects for each of the primary contaminant inputs to this river system. The addition of stations located immediately downstream and upstream of each of the primary outfalls of concern will help define the environmental response to these inputs, and permit clear documentation of differences most likely attributable to further wastewater dilution and dispersion downstream of these inputs.

In addition, selection of stations must be made such that the majority of the program components can be sampled concurrently. The difference in river conditions upstream of Tin Cup Rapids (above the Kootenay-Columbia confluence) and downstream of this point would suggest that station allocation, sampling effort and subsequent data analysis require that these two regions of the river be treated independently. Where the upper area is influenced solely by water level fluctuations of the Hugh Keenleyside Dam, and represents a deep basin with relatively slow-moving water, the much faster flow of the lower region of the Columbia is determined by the discharges of both the Hugh Keenleyside and the Brilliant dams.

A number of reference stations (minimum of two) will also be required to ensure that adequate background data can be acquired for each of the program components. The reference areas should be selected to represent appropriate comparisons for each of the river regions identified above. If substrate stratification is considered in a modified survey design, then each of these reference stations would require appropriate areas of depositional and erosional habitat as well.

The following station 'areas' are suggested for a revised CRIEMP design. The areas should represent the primary substrate (cobble) type in the system, and thus permit concurrent monitoring of benthos, water quality, bioaccumulation, and periphyton (optional). Sediment stations are to be sampled independently, at nearby locations, and are indicated by the asterisk. The two sample areas (I and II) represent the hydrological differences upstream and downstream of Tincup Rapids.

Sample Area		
I-1	Upstream of Celgar	
I-2	Immediately downstream of Celgar (within IDZ†)	
I-3	Downstream of Celgar (outside of IDZ)	*
	Robson	*
II-1	Downstream of Castlegar	
	Downstream of China Creek	*

II-2	Birchbank	*
II-3	Upstream of Cominco	
II-4	Immediately downstream of Cominco (within IDZ)	
II-5	Downstream of Cominco (outside of IDZ)	*
	Downstream of Beaver Creek	*
II-6	Waneta (upstream of Pend d'Oreille River)	*
I-R	Reference for Area I (other regional river system)	*
II-R	Reference for Area II (other regional river system)	*

* The exact locations of these station 'areas' are yet to be determined, although some are represented by existing stations.

† Initial Dilution Zone (IDZ) is defined as 100 m downstream from the point of discharge.

Baseline Reference Information

Acquiring and monitoring 'good' representative reference areas for the lower Columbia River has provided a significant problem in evaluating the comprehensive monitoring information obtained through CRIEMP. Although not specifically within the mandate of this integrated monitoring program, a need for adequate baseline reference data for this region of the province would provide a good background upon which expected water/sediment quality and biological community improvements in the lower Columbia River could be compared and contrasted. In pursuit of such a goal, effort from federal/provincial or other agencies/industries should be placed on establishing a baseline database for various stream/river measures routinely employed in regional monitoring programs. A number of reference areas, free from the influence of point-source and nonpoint source discharges, should be identified and appropriately sampled (e.g., stratified by substrate, depth, water velocity) to acquire background values for all of the parameters assessed by CRIEMP.

3. SAMPLING STRATIFICATION

The design modifications recommended for CRIEMP are based upon a division of sampling effort across two primary habitat types, that represented by the depositional substrate (fine sediments) and the other by the erosional substrate (cobble). Although the recommended sampling program covers the two primary habitat types in the lower Columbia River, this application of sampling effort does not strictly reflect a stratified design (in a statistical sense).

It is recommended that the modified program encompass two substrate environments, as summarized in the table below.

HABITAT TYPE	MONITORINGCOMPONENT
EROSIONAL (Cobble Substrate)	Water Quality Benthos Bioaccumulation (e.g., caddisfly) Periphyton (optional)
DEPOSITIONAL (Fine Sediments)	Water Quality Sediment Quality Bioaccumulation (e.g., mussel) Sediment Toxicity

4. SAMPLE REPLICATION AND POSITIONING

To ensure that an appropriate measure of variability is ascertained for all components of CRIEMP, it is recommended that field sample replication be included in the revised program. The lack of replication (other than for benthos) prohibits an objective estimate of optimum sample size for each of the CRIEMP components. It is therefore recommended that the next CRIEMP survey employ a minimum of three sample replicates for each of these monitoring components, and that these data be used at that time to statistically document the variability associated with the measures, and to subsequently determine the optimum sample size required for a specific statistical power for future program requirements.

For the benthos community structure, which presently uses five replicates, the sampling effort should be maintained at this level. The extraction of samples for each of the proposed sampling stations should be made at the lowest predicted level of water for the lower Columbia River. Sediment and benthos stations should, at all times, be inundated with water, and therefore be exposed to all potential contaminants passing across the site. Timing of sampling would thus require coordination with dam operations, but it is expected that an August sampling period may satisfy both the biological and the physical requirements of the recommended program.

5. ADDITIONAL SAMPLING INFORMATION

During sampling of concurrent CRIEMP components at each of the assigned sampling stations, the following (additional) information is recommended as an integral monitoring requirement: (i) substrate particle size; and (ii) habitat evaluations. As with the other CRIEMP components, particle size estimates should be properly replicated. Small differences in substrate composition can result in significant differences in benthos community composition, and can be employed to explain variability in sediment chemistry. Replication of substratum size analyses will enable statistical analysis of the results to be tested and used in interpreting differences in the benthos and/or sediment quality.

6. SAMPLING FREQUENCY AND TIMING

Two sampling periods have been suggested as an appropriate level of effort for a number of the program components, one during a low-flow period and the second within a period of stable flow. As the lower Columbia River is a regulated system, predictable flow rates cannot be anticipated and therefore relied upon for sampling schedules.

To facilitate the integrated analysis of all CRIEMP components, one of these sampling periods must be assigned for sampling the entire program, including benthos community structure, sediment/water quality estimates, bioaccumulation, and toxicity. It is recommended that the period in late summer (August) be employed to complete the concurrent sampling of all CRIEMP components; this period is typical of low water conditions for the lower Columbia River, and would thus facilitate sediment sampling at the suggested 'lowest water level' depth. Acquisition of caddisfly samples can only occur when the caddisflies emerge, and thus may have to be acquired during an earlier sampling survey.

The continued implementation of CRIEMP should ensure that all components, where possible, are sampled concurrently.

7. QUALITY ASSURANCE PROGRAM

Based on the review of the data provided for the initial CRIEMP survey, it is felt that the analytical precision and sensitivity of all measurements made is acceptable given the objectives of the CRIEMP design. Continued monitoring efforts, however, should require that a pre-determined QA/QC Program be presented to each analytical laboratory participating in the survey. In order to ensure data quality and allow an adequate assessment of the data generated we recommend that Specific Data Quality Objectives be developed and explicitly stated for each component of CRIEMP. These should include details on the required sensitivity, accuracy, precision and total uncertainty tolerable for all measurements.

The following items should be available and included as part of the quality assurance program and reporting requirements of the study to assure that data quality objectives have been met:

(i) Results of trip and laboratory blanks should be included with all data sets. Specific acceptance criteria should be defined and use of data should be dependent on meeting these criteria.

(ii) Field and laboratory replicates should be clearly identified in all data sets and frequency, variability, range and control limits should be calculated and reported as part of the quality assurance report. Specific acceptance criteria should be used to determine the need for further analysis (i.e., to re-run lab samples) and/or to determine the acceptable use of the data.

(iii) Measurements of standard reference materials should be reported. The quality assurance report should note the type, frequency and control limits for measurements of standard reference materials to provide assurance of accuracy in measurements.

(iv) Bench record sheets (dilutions, pre-concentrations, readings, calculations) should not be included in final data sets or the Quality Assurance report, but permanent records should be maintained and available for all samples to check data as required.

The QA/QC criteria and procedures should be followed for all aspects of the CRIEMP survey, including those for the benthos community structural component. If 10% error is determined to be the acceptable limit for sorting, then any samples sorted by an individual that do not meet this requirement should be re-sorted. The results from verifications of taxonomic identifications should be clearly stated.

A Quality Assurance Project Plan (QAPjP) should be in place before a CRIEMP survey is initiated. This should be followed throughout the program, with deviations noted and agreed upon by the concerned parties. The QAPjP should include Standard Operating Procedures (SOPs) which provide detailed information about all aspects of the sampling and analytical processes.

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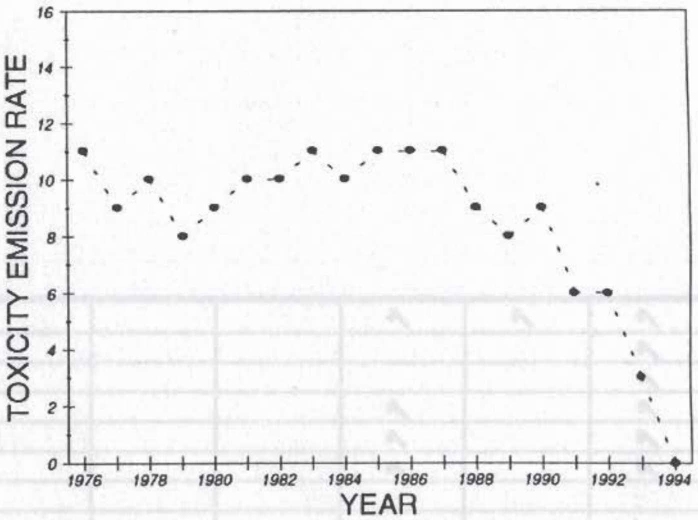
TABLES AND FIGURES

TABLE A-1. Celgar Pulp Company: Annual averages and trends of effluent parameters

	TSS	AOX	pH	TOXICITY	FLOW	TER	BOD
YEAR	T/DAY	(ppm)		LC50%**	M3/DAY	***	T/DAY
1974	15.46		5.60				
1975	18.70		6.25				
1976	18.77		5.74	14	127490	11	
1977	12.70		5.23	23	118210	9	
1978	12.15		4.85	12	112770	10	
1979	16.24		5.74	31	122110	8	
1980	13.57		5.33	24	121970	9	
1981	9.00		5.42	20	129250	10	
1982	8.82		5.29	12	117430	10	
1983	11.49		4.76	11	118500	11	22.93
1984	8.66		6.00	16	117090	10	17.56
1985	9.36		5.47	9	119250	11	18.84
1986	9.39		5.57	12	126830	11	22.99
1987	8.95		6.05	11	119250	11	22.86
1988	10.68		6.09	9	98000	9	22.40
1989	7.77		6.64	14	98000	8	19.31
1990	6.29		6.85	11	98000	9	21.87
1991	6.71	3.80	7.11	32	93000	6	19.35
1992	7.51	2.69	6.98	28	86000	6	17.92
1993	4.32	1.79	7.34	73	116000	3	6.09
1994	3.54	1.28	7.34	>100	116000	0	6.09



* Numbers taken from first quarter of 1994

** LC50 is the percent concentration of effluent at which 50% of the test rainbow trout survive during 96 hours of exposure.

*** TER is the Toxic Emission Rate; (100%-LC50%) * effluent flow in 100,000 cubic metres. A TER of 0 indicates a zero discharge of toxicity.

TABLE B-1: CRIEMP 1991-1993 survey design showing stations and components sampled

	MAINSTEM COLUMBIA RIVER STATIONS											
PHYSICAL-CHEMICAL COMPONENTS	**U/S Celgar**	**D/S Celgar**	**Robson**	**U/S Castlegar**	**China Creek**	**Birchbank**	**D/S Cominco**	**Cominco West**	**Cominco East**	**Ryan Creek**	**Beaver Creek**	**Waneta**
Water Quality	✔	✔		✔		✔	✔	✔	✔			✔
Sediment Quality		✔	✔		✔	✔				✔	✔	✔
Total Dissolved Gases			✔									
BIOLOGICAL COMPONENTS												
Benthos	✔		✔			✔				✔		✔
Periphyton	✔	✔				✔				✔		✔
Caddisfly Tissue		✔	✔			✔				✔		✔
Mussel Tissue	✔	✔	✔			✔						✔
Macrophyte Tissue	✔	✔	✔									✔
Sediment Toxicity		✔	✔		✔	✔				✔	✔	✔

	REFERENCE STATIONS					
PHYSICAL-CHEMICAL COMPONENTS	**Kootenay**	**Norns Creek**	**Grohman**	**Arrow Lake**	**Glade**	**Kootenay Lake**
Water Quality						
Sediment Quality		✔		✔		✔
Total Dissolved Gases				✔		
BIOLOGICAL COMPONENTS						
Benthos	✔					
Periphyton	✔					
Caddisfly Tissue			✔		✔	
Mussel Tissue	✔				✔	
Macrophyte Tissue	✔					
Sediment Toxicity				✔		

TABLE B-2. CRIEMP sediment contaminant data: Subsample variability in Arrow Lake (reference) and Waneta sediments

			ARROW LAKE SEDIMENT			WANETA SEDIMENT		
MDC	UNITS	PARAMETER	mean	std.dev.	CV	mean	std.dev.	CV
0.1	% (W/W)	Moisture	65.700	2.382	3.63	54.700	0.700	1.28
2	(ug/g)	Al_Total	37750.000	2242.766	5.94	13433.333	351.188	2.61
0.2	(ug/g)	As_Total	9.875	1.300	13.16	18.000	0.000	0.00
0.1	(ug/g)	Ba_Total	382.500	17.483	4.57	617.667	13.317	2.16
0.1	(ug/g)	Be_Total	1.450	0.058	3.98	0.700	0.000	0.00
1	(ug/g)	Ca_Total	7490.000	194.079	2.59	13800.000	200.000	1.45
0.1	(ug/g)	Cd_Total	1.100	0.183	16.60	9.833	0.850	8.65
0.3	(ug/g)	Co_Total	17.550	1.066	6.07	8.967	0.252	2.81
0.2	(ug/g)	Cr_Total	33.425	11.357	33.98	51.733	5.382	10.40
0.1	(ug/g)	Cu_Total	50.525	2.114	4.18	466.333	22.368	4.80
0.3	(ug/g)	Fe_Total	43800.000	3182.242	7.27	32233.333	907.377	2.82
0.05	(ug/g)	Hg_Total	0.063	0.013	20.13	1.477	0.150	10.17
40	(ug/g)	K_Total	10950.000	772.442	7.05	2956.667	80.208	2.71
2	(ug/g)	Mg_Total	11300.000	483.046	4.27	5343.333	151.767	2.84
0.2	(ug/g)	Mn_Total	801.500	110.123	13.74	395.667	9.074	2.29
0.4	(ug/g)	Mo_Total				1.933	0.058	2.99
1	(ug/g)	Na_Total	1092.500	91.059	8.33	565.333	0.577	0.10
0.8	(ug/g)	Ni_Total	50.600	3.389	6.70	18.800	0.656	3.49
4	(ug/g)	P_Total	1507.500	89.954	5.97	1383.333	68.069	4.92
2	(ug/g)	Pb_Total	74.250	7.411	9.98	535.333	29.143	5.44
3	(ug/g)	S_Total	404.750	20.023	4.95	3240.000	98.489	3.04
1.5	(ug/g)	Sb_Total	0.850	0.985	115.87	2.433	0.473	19.42
0.5	(ug/g)	Se_Total				1.000	0.000	0.00
2	(ug/g)	Sn_Total	6.500	5.066	77.94	3.666	1.531	41.75
0.1	(ug/g)	Sr_Total	89.425	3.529	3.95	84.967	1.823	2.15
0.3	(ug/g)	Ti_Total	2010.000	141.657	7.05	749.000	86.186	11.51
0.3	(ug/g)	Tl_Total				0.667	0.635	95.20
0.3	(ug/g)	V_Total	63.075	2.496	3.96	45.867	0.451	0.98
0.2	(ug/g)	Zn_Total	155.500	7.550	4.86	1990.000	90.000	4.52
0.3	(ug/g)	Zr_Total	6.000	1.726	28.77	5.667	0.751	13.25
1000	(ug/g)	C_Total	22875.000	3828.294	16.74	14733.333	896.289	6.08
300	(ug/g)	C_Total_Org	21350.000	3756.328	17.59	13366.667	757.188	5.66
500	(ug/g)	C_Total_Inorg	1525.000	287.228	18.83	1366.667	208.167	15.23
30	(ug/g)	N_Kjel_Tot	1292.500	58.523	4.53	777.000	498.898	64.21
2.5	(ug/g)	EOX				2.967	0.808	27.23
Wet Wt.	(ug/g)	Acid_Sol_S				93.333	28.868	30.93
		MEAN VARIATION AMONG REPLICATES:			15.59	MEAN VARIATION :		11.47

Note: CV = Coefficient of Variation; Blank = <MDC

TABLE B-3. CRIEMP sediment chemistry: Trace metal levels which exceed reference station values

MDC	UNITS	PARAMETER	SEDIMENT LEVELS OF TRACE METALS REFERENCE ARROW LAKE	D/S CELGAR	CHINA CR.	BIRCHBANK	RYAN CR.	BEAVER CR.	WANETA
1	(ug/g)	Ag_Total	<mdc				2	17	4
2	(ug/g)	Al_Total	46600						
0.2	(ug/g)	As_Total	10.2				30.75	44.2	18
0.1	(ug/g)	Ba_Total	382.5					1540	618
0.1	(ug/g)	Be_Total	1.45						
2	(ug/g)	Bi_Total	<mdc					15	
1	(ug/g)	Ca_Total	7490				11000	33000	13800
0.1	(ug/g)	Cd_Total	1.02				6.15	4.5	9.8
0.3	(ug/g)	Co_Total	17.55					32.9	
0.2	(ug/g)	Cr_Total	51.94	76.1			75.95	109.7	
0.1	(ug/g)	Cu_Total	53.82				427.5	1834	466
0.3	(ug/g)	Fe_Total	46060					47333	
0.05	(ug/g)	Hg_Total	0.06				0.68	0.49	1.48
40	(ug/g)	K_Total	10950						
2	(ug/g)	Mg_Total	11300						
0.2	(ug/g)	Mn_Total	875					1670	
0.4	(ug/g)	Mo_Total	<mdc				1.2	13.1	1.9
1	(ug/g)	Na_Total	1092					1280	
0.8	(ug/g)	Ni_Total	50.6						
4	(ug/g)	P_Total	1507				1880	2430	
2	(ug/g)	Pb_Total	76.6				643	520	535
3	(ug/g)	S_Total	405	763	438		2440	3030	3240
1.5	(ug/g)	Sb_Total	0.9				3	8.9	2.4
0.5	(ug/g)	Se_Total	<mdc				1		0.7
2	(ug/g)	Sn_Total	6.5						3
0.1	(ug/g)	Sr_Total	89.4				95.1	170	85
2	(ug/g)	Te_Total	<mdc						
0.3	(ug/g)	Ti_Total	2010						
0.3	(ug/g)	Tl_Total	<mdc						0.5
0.3	(ug/g)	V_Total	83.1						
0.2	(ug/g)	Zn_Total	164.6				2320	6730	1990
0.3	(ug/g)	Zr_Total	6				7.6	11.9	5.7
Wet Wt.	(ug/g)	Acid_Sol_S	<mdc	9	15	10.5	70	21	93

MDC	UNITS	PARAMETER	SEDIMENT LEVELS OF TRACE METALS REFERENCE KOOTENAY	D/S CELGAR	CHINA CR.	BIRCHBANK	RYAN CR.	BEAVER CR.	WANETA
1	(ug/g)	Ag_Total	1				2	17	4
2	(ug/g)	Al_Total	19600				39700	39100	13433
0.2	(ug/g)	As_Total	11				30.75	44.2	18
0.1	(ug/g)	Ba_Total	162				377	1540	618
0.1	(ug/g)	Be_Total	0.9						
2	(ug/g)	Bi_Total	<mdc					15	
1	(ug/g)	Ca_Total	7030				11000	33000	13800
0.1	(ug/g)	Cd_Total	4.5				6.15		9.8
0.3	(ug/g)	Co_Total	8.5				10.8	32.9	9
0.2	(ug/g)	Cr_Total	28.6	76.1		33	75.95	109.7	51.7
0.1	(ug/g)	Cu_Total	28.1				427.5	1834	466
0.3	(ug/g)	Fe_Total	21300				45900	47333	32233
0.05	(ug/g)	Hg_Total	0.06				0.68	0.49	1.48
40	(ug/g)	K_Total	4250						
2	(ug/g)	Mg_Total	7230				7710		
0.2	(ug/g)	Mn_Total	316	347			826	1670	396
0.4	(ug/g)	Mo_Total	<mdc				1.2	13.1	1.9
1	(ug/g)	Na_Total	424				574	1280	565
0.8	(ug/g)	Ni_Total	19.6				32.3	24.3	
4	(ug/g)	P_Total	1160				1880	2430	1383
2	(ug/g)	Pb_Total	176				643	520	535
3	(ug/g)	S_Total	2740					3030	3240
1.5	(ug/g)	Sb_Total	1.6				3	8.9	2.4
0.5	(ug/g)	Se_Total	<mdc				1		0.7
2	(ug/g)	Sn_Total	4					5	
0.1	(ug/g)	Sr_Total	54.8				95.1	170	85
2	(ug/g)	Te_Total	<mdc						
0.3	(ug/g)	Ti_Total	1190	1270			1500		
0.3	(ug/g)	Tl_Total	<mdc						0.5
0.3	(ug/g)	V_Total	34.2				52.9	50.4	45.9
0.2	(ug/g)	Zn_Total	539				2320	6730	1990
0.3	(ug/g)	Zr_Total	6.8				7.6	11.9	
Wet Wt.	(ug/g)	Acid_Sol_S	60				70		93

TABLE B-4. CRIEMP sediment chemistry: Factor by which trace metal levels exceed reference station levels, by sampling station

SEDIMENT LEVELS OF TRACE METALS: Factor Greater Than Reference

PARAMETER	REFERENCE ARROW LAKE	UNITS	D/S CELGAR	CHINA CR.	BIRCHBANK	RYAN CR.	BEAVER CR.	WANETA
Ag_Total	1	(ug/g)				2.0	17.0	4.0
Al_Total	46600	(ug/g)						
As_Total	10.2	(ug/g)				3.0	4.3	1.8
Ba_Total	382.5	(ug/g)					4.0	1.6
Be_Total	1.45	(ug/g)						
Bi_Total	2	(ug/g)					7.5	
Ca_Total	7490	(ug/g)				1.5	4.4	1.8
Cd_Total	1.02	(ug/g)				6.0	4.4	9.6
Co_Total	17.55	(ug/g)					1.9	
Cr_Total	51.94	(ug/g)	1.5			1.5	2.1	
Cu_Total	53.82	(ug/g)				7.9	34.1	8.7
Fe_Total	46060	(ug/g)						
Hg_Total	0.06	(ug/g)				11.3	8.2	24.7
K_Total	10950	(ug/g)						
Mg_Total	11300	(ug/g)						
Mn_Total	875	(ug/g)					1.9	
Mo_Total	0.4	(ug/g)				3.0	32.8	4.7
Na_Total	1092	(ug/g)					1.2	
Ni_Total	50.6	(ug/g)						
P_Total	1507	(ug/g)				1.2	1.6	
Pb_Total	76.6	(ug/g)				8.4	6.8	7.0
S_Total	405	(ug/g)	1.9	1.1		6.0	7.5	8.0
Sb_Total	0.9	(ug/g)				3.3	9.9	2.7
Se_Total	0.5	(ug/g)				2.0		1.4
Sn_Total	6.5	(ug/g)						
Sr_Total	89.4	(ug/g)				1.1	1.9	
Te_Total	2	(ug/g)						
Ti_Total	2010	(ug/g)						
Tl_Total	0.3	(ug/g)						1.7
V_Total	63.1	(ug/g)						
Zn_Total	164.6	(ug/g)				14.1	40.9	12.1
Zr_Total	6	(ug/g)				1.3	2.0	
Acid_Sol_S	6	(ug/g)	1.5	2.5	1.8	11.7	3.5	15.5

SEDIMENT LEVELS OF TRACE METALS: Factor Greater Than Reference

PARAMETER	REFERENCE KOOTENAY	UNITS	D/S CELGAR	CHINA CR.	BIRCHBANK	RYAN CR.	BEAVER CR.	WANETA
Ag_Total	1	(ug/g)				2.0	17.0	4.0
Al_Total	19600	(ug/g)				2.0	2.0	0.7
As_Total	11	(ug/g)				2.8	4.0	1.6
Ba_Total	162	(ug/g)				2.3	9.5	3.8
Be_Total	0.9	(ug/g)						
Bi_Total	2	(ug/g)					7.5	
Ca_Total	7030	(ug/g)				1.6	4.7	2.0
Cd_Total	4.5	(ug/g)				1.4		2.2
Co_Total	6.5	(ug/g)				1.3	3.9	1.1
Cr_Total	26.6	(ug/g)	2.7		1.2	2.7	3.8	1.8
Cu_Total	28.1	(ug/g)				15.2	65.3	16.6
Fe_Total	21300	(ug/g)				2.2	2.2	1.5
Hg_Total	0.06	(ug/g)				11.3	8.2	24.7
K_Total	4250	(ug/g)						
Mg_Total	7230	(ug/g)				1.1		
Mn_Total	316	(ug/g)	1.1			2.6	5.3	1.3
Mo_Total	0.4	(ug/g)				3.0	32.8	4.7
Na_Total	424	(ug/g)				1.4	3.0	1.3
Ni_Total	19.6	(ug/g)				1.6	1.2	
P_Total	1160	(ug/g)				1.6	2.1	1.2
Pb_Total	176	(ug/g)				3.7	3.0	3.0
S_Total	2740	(ug/g)					1.1	1.2
Sb_Total	1.6	(ug/g)				1.9	5.6	1.5
Se_Total	0.5	(ug/g)				2.0		1.4
Sn_Total	4	(ug/g)					1.3	
Sr_Total	54.6	(ug/g)				1.7	3.1	1.6
Te_Total	2	(ug/g)						
Ti_Total	1190	(ug/g)	1.1			1.3		
Tl_Total	0.3	(ug/g)						1.7
V_Total	34.2	(ug/g)				1.5	1.5	1.3
Zn_Total	539	(ug/g)				4.3	12.5	3.7
Zr_Total	6.6	(ug/g)				1.1	1.8	
Acid_Sol_S	60	(ug/g)				1.2		1.6

TABLE B-5. **CRIEMP Sediment Chemistry: Comparison of reference station metal concentrations to Columbia River maxima sampled at Beaver Creek**

SEDIMENT PARAMETER	ARROW LAKE REFERENCE (µg/g)	KOOTENAY REFERENCE (µg/g)	BEAVER CREEK (µg/g)	Factor greater than Arrow Reference	Factor greater than Kootenay Reference
Silver	<1	1	17	17	17
Cadmium	1.02	4.5	4.5	4.4	< ref
Copper	53.82	28.1	1,834	34.1	65.3
Lead	76.6	176.0	520	6.8	3.0
Molybdenum	0.4	0.4	13.1	32.8	32.8
Zinc	164.5	539.0	6,730	40.9	12.9
AVS	<6	60	21	3.5	< ref

TABLE B-6: CRIEMP sediment chemistry: Resin & fatty acid levels which exceeded reference station levels.

		SEDIMENT LEVELS OF RESIN & FATTY ACIDS					
UNITS	PARAMETER	REFERENCE ARROW LAKE	D/S CELGAR	ROBSON	BIRCHBANK	RYAN CR.	WANETA
(ng/g)	Abietic_Acid	31	2900			60	320
(ng/g)	Chlorodehydroabietic_Acid	<mdc	4				2.2
(ng/g)	Dehydroabietic_Acid	114	18000			130	310
(ng/g)	Dichlorodehydroabietic_Acid	<mdc					7.8
(ng/g)	Isopimaric_Acid	27	640			33	225
(ng/g)	Neoabietic_Acid	<mdc	390				6.3
(ng/g)	Pimaric_Acid	4	74				21
(ng/g)	Palustric_Acid	<mdc	490				122
(ng/g)	Sandaraco_Pim_Acid	36	630				
(ng/g)	Arachidic_Acid	765	2900	885		1000	1300
(ng/g)	Behenic_Acid	1565	13000	4600			3900
(ng/g)	Lauric_Acid	1750				1200	85000
(ng/g)	Lignoceric_Acid	750	11000	4100			3600
(ng/g)	Linolenic_Acid	<mdc		760			
(ng/g)	Linoleic_Acid	<mdc			3000	4200	34000
(ng/g)	Myristic_Acid	5350					35000
(ng/g)	Oleic_Acid	<mdc			3000	4200	34000
(ng/g)	Palmitric_Acid	12000	13000				43000
(ng/g)	Stearic_Acid	4800					21000

		SEDIMENT LEVELS OF RESIN & FATTY ACIDS					
UNITS	PARAMETER	REFERENCE KOOTENAY	D/S CELGAR	ROBSON	BIRCHBANK	RYAN CR.	WANETA
(ng/g)	Abietic_Acid	13	2900		14	60	320
(ng/g)	Chlorodehydroabietic_Acid	<mdc	4				2.2
(ng/g)	Dehydroabietic_Acid	49	18000		54	130	310
(ng/g)	Dichlorodehydroabietic_Acid	<mdc					7.8
(ng/g)	Isopimaric_Acid	<mdc	640		8.3	33	225
(ng/g)	Neoabietic_Acid	<mdc	390				6.3
(ng/g)	Pimaric_Acid	<mdc	74				21
(ng/g)	Palustric_Acid	<mdc	490				122
(ng/g)	Sandaraco_Pim_Acid	<mdc	630		32	13	
(ng/g)	Arachidic_Acid	1500	2900				
(ng/g)	Behenic_Acid	3200	13000	4600			3900
(ng/g)	Lauric_Acid	5800					85000
(ng/g)	Lignoceric_Acid	2100	11000	4100			3600
(ng/g)	Linolenic_Acid	<mdc		760			
(ng/g)	Linoleic_Acid	13000					34000
(ng/g)	Myristic_Acid	20000					35000
(ng/g)	Oleic_Acid	13000					34000
(ng/g)	Palmitric_Acid	51000					
(ng/g)	Stearic_Acid	6300					21000

TABLE B-7: CRIEMP sediment chemistry: Resin & fatty acid levels standardized to reference station TOC

SEDIMENT LEVELS OF RESIN & FATTY ACIDS

UNITS	PARAMETER	REFERENCE ARROW LAKE	Standardized to Arrow Lake Reference TOC D/S CELGAR	ROBSON	BIRCHBANK	RYAN CR.	WANETA
(ng/g)	Abietic_Acid	31	3683		73	71	582
(ng/g)	Chlorodehydroabietic_Acid	<mdc	5				4
(ng/g)	Dehydroabietic_Acid	114	22860		280	155	564
(ng/g)	Dichlorodehydroabietic_Acid	<mdc					14
(ng/g)	Isopimaric_Acid	27	813		43	39	410
(ng/g)	Neoabietic_Acid	<mdc	495				11
(ng/g)	Pimaric_Acid	4	94				38
(ng/g)	Palustric_Acid	<mdc	622				222
(ng/g)	Sandaraco_Pim_Acid	36	800		166		
(ng/g)	Arachidic_Acid	765	3683	3602	1453	1190	2366
(ng/g)	Behenic_Acid	1565	16510	18722	3322		7098
(ng/g)	Lauric_Acid	1750	2032	6512	4412		154700
(ng/g)	Lignoceric_Acid	750	13970	16687			6552
(ng/g)	Linolenic_Acid	<mdc		3093			
(ng/g)	Linoleic_Acid	<mdc			15570	4998	61880
(ng/g)	Myristic_Acid	5350	6604	19536	12456		63700
(ng/g)	Oleic_Acid	<mdc			15570	4998	61880
(ng/g)	Palmitric_Acid	12000	16510	45584	26469	14280	78260
(ng/g)	Stearic_Acid	4800		10175			38220

SEDIMENT LEVELS OF RESIN & FATTY ACIDS

UNITS	PARAMETER	REFERENCE KOOTENAY	Standardized to Kootenay Reference TOC D/S CELGAR	ROBSON	BIRCHBANK	RYAN CR.	WANETA
(ng/g)	Abietic_Acid	13	3915		79	76	621
(ng/g)	Chlorodehydroabietic_Acid	<mdc	5				4
(ng/g)	Dehydroabietic_Acid	49	24300		305	165	601
(ng/g)	Dichlorodehydroabietic_Acid	<mdc					15
(ng/g)	Isopimaric_Acid	<mdc	864		47	42	437
(ng/g)	Neoabietic_Acid	<mdc	527				12
(ng/g)	Pimaric_Acid	<mdc	100				41
(ng/g)	Palustric_Acid	<mdc	662				237
(ng/g)	Sandaraco_Pim_Acid	<mdc	851		181	17	
(ng/g)	Arachidic_Acid	1500	3915	3567	1582		2522
(ng/g)	Behenic_Acid	3200	17550	18538	3616		7566
(ng/g)	Lauric_Acid	5800		6448			164900
(ng/g)	Lignoceric_Acid	2100	14850	16523			6984
(ng/g)	Linolenic_Acid	<mdc		3063			
(ng/g)	Linoleic_Acid	13000			16950	5334	65960
(ng/g)	Myristic_Acid	20000	7020	19344	13560	3937	67900
(ng/g)	Oleic_Acid	13000			16950		65960
(ng/g)	Palmitric_Acid	51000					83420
(ng/g)	Stearic_Acid	6300		10075			40740

TABLE B-8: CRIEMP sediment chemistry: Chlorinated phenolic compound levels which exceed reference station levels, and standardized to reference station TOC

			SEDIMENT LEVELS OF ORGANICS					
			REFERENCE	REFERENCE				
MDC	UNITS	PARAMETER	ARROW LAKE	KOOTENAY	D/S CELGAR	BIRCHBANK	RYAN CR.	WANETA
0.3-3	(ng/g)	24/25_DCP	<mdc	<mdc	3			
0.2-4.6	(ng/g)	246_TCP	<mdc	<mdc	4.6			
0.2-1.3	(ng/g)	2346_TetraCP	<mdc	<mdc	1.3			
0.3-3.8	(ng/g)	45_DCguaiacol	<mdc	<mdc	3.8			
0.2-5.5	(ng/g)	345_TCguaiacol	<mdc	<mdc	5.5	0.4		0.5
0.1-0.9	(ng/g)	456_TCguaiacol	<mdc	<mdc	0.9			
0.2-3.4	(ng/g)	3456_TCguaiacol	<mdc	<mdc	3.4			
0.4-1.5	(ng/g)	36_DCcatechol	<mdc	<mdc	0.4			
0.3-1.8	(ng/g)	35_DCcatechol	<mdc	<mdc	1.8			0.9
0.4-2	(ng/g)	45_DCcatechol	<mdc	<mdc	1.4			1.1
0.6-13	(ng/g)	345_TCcatechol	<mdc	<mdc	13			8.4
1.2-29	(ng/g)	3456_TCcatechol	<mdc	<mdc	29			
0.1-1.4	(ng/g)	346_TCveratrole	<mdc	<mdc	0.6			
0.1-2.2	(ng/g)	345_TCveratrole	<mdc	<mdc	2.2			
0.1-2.2	(ng/g)	3456_TCveratrole	<mdc	<mdc	2.2			
1-7.6	(ng/g)	6_Chlorovanillin	<mdc	<mdc	3.5			
1-4.8	(ng/g)	56_DCvanillin	<mdc	<mdc	1.6			

			SEDIMENT LEVELS OF ORGANICS Standardized for Kootenay Reference TOC			
MDC	UNITS	PARAMETER	D/S CELGAR	BIRCHBANK	RYAN CR.	WANETA
0.3-3	(ng/g)	24/25_DCP	4.1			
0.2-4.6	(ng/g)	246_TCP	6.2			
0.2-1.3	(ng/g)	2346_TetraCP	1.8			
0.3-3.8	(ng/g)	45_DCguaiacol	5.1			
0.2-5.5	(ng/g)	345_TCguaiacol	7.4	2.3		1.0
0.1-0.9	(ng/g)	456_TCguaiacol	1.2			
0.2-3.4	(ng/g)	3456_TCguaiacol	4.6			
0.4-1.5	(ng/g)	36_DCcatechol	0.5			
0.3-1.8	(ng/g)	35_DCcatechol	2.4			1.7
0.4-2	(ng/g)	45_DCcatechol	1.9			2.1
0.6-13	(ng/g)	345_TCcatechol	17.6			16.3
1.2-29	(ng/g)	3456_TCcatechol	39.2			
0.1-1.4	(ng/g)	346_TCveratrole	0.8			
0.1-2.2	(ng/g)	345_TCveratrole	3.0			
0.1-2.2	(ng/g)	3456_TCveratrole	3.0			
1-7.6	(ng/g)	6_Chlorovanillin	4.7			
1-4.8	(ng/g)	56_DCvanillin	2.2			

			SEDIMENT LEVELS OF ORGANICS Standardized for Arrow Lake Reference TOC			
MDC	UNITS	PARAMETER	D/S CELGAR	BIRCHBANK	RYAN CR.	WANETA
0.3-3	(ng/g)	24/25_DCP	3.8			
0.2-4.6	(ng/g)	246_TCP	5.8			
0.2-1.3	(ng/g)	2346_TetraCP	1.7			
0.3-3.8	(ng/g)	45_DCguaiacol	4.8			
0.2-5.5	(ng/g)	345_TCguaiacol	7.0	2.1		0.9
0.1-0.9	(ng/g)	456_TCguaiacol	1.1			
0.2-3.4	(ng/g)	3456_TCguaiacol	4.3			
0.4-1.5	(ng/g)	36_DCcatechol	0.5			
0.3-1.8	(ng/g)	35_DCcatechol	2.3			1.6
0.4-2	(ng/g)	45_DCcatechol	1.8			2.0
0.6-13	(ng/g)	345_TCcatechol	16.5			15.3
1.2-29	(ng/g)	3456_TCcatechol	36.8			
0.1-1.4	(ng/g)	346_TCveratrole	0.8			
0.1-2.2	(ng/g)	345_TCveratrole	2.8			
0.1-2.2	(ng/g)	3456_TCveratrole	2.8			
1-7.6	(ng/g)	6_Chlorovanillin	4.4			
1-4.8	(ng/g)	56_DCvanillin	2.0			

TABLE B-9. CRIEMP sediment chemistry: Chlorinated dioxin and furan levels which exceed reference station levels

		SEDIMENT LEVELS OF DIOXIN/FURAN CONGENERS					
UNITS	PARAMETER	REFERENCE ARROW LAKE	D/S CELGAR	BIRCHBANK	RYAN CR.	BEAVER CR.	WANETA
(pg/g)	T4CDD	<mdc	2				0.7
(pg/g)	2378T4CDD	<mdc	1.8				0.7
(pg/g)	P5CDD	<mdc					
(pg/g)	12378P5CDD	<mdc					
(pg/g)	H6CDD	6.3	12				
(pg/g)	123478H6CDD	0.2					
(pg/g)	123678H6CDD	1	2.9				1.4
(pg/g)	123789H6CDD	0.7	1				
(pg/g)	H7CDD	28.5					
(pg/g)	1234678H7CDD	14					
(pg/g)	O8CDD	43					
(pg/g)	T4CDF	5.6	360	14	14	33	99
(pg/g)	2378T4CDF	0.9	210	8.3	5.3	22.3	61
(pg/g)	P5CDF	4	6.2		7.9		4.5
(pg/g)	12378P5CDF	<mdc	1.6		0.6		0.7
(pg/g)	23478P5CDF	<mdc	1.8		0.7		0.8
(pg/g)	H6CDF	10.5			22		
(pg/g)	123478H6CDF	1.4					
(pg/g)	123678H6CDF	0.4			1.4		
(pg/g)	234678H6CDF	0.4			0.7		
(pg/g)	123789H6CDF	<mdc					
(pg/g)	H7CDF	9.8			19		
(pg/g)	1234678H7CDF	4			11		
(pg/g)	1234789H7CDF	0.2	0.3		1.1		
(pg/g)	O8CDF	5.4			18		

		SEDIMENT LEVELS OF DIOXIN/FURAN CONGENERS					
UNITS	PARAMETER	REFERENCE KOOTENAY	D/S CELGAR	BIRCHBANK	RYAN CR.	BEAVER CR.	WANETA
(pg/g)	T4CDD	<mdc	2				0.7
(pg/g)	2378T4CDD	<mdc	1.8				0.7
(pg/g)	P5CDD	<mdc					
(pg/g)	12378P5CDD	<mdc					
(pg/g)	H6CDD	5.8	12				7.6
(pg/g)	123478H6CDD	<mdc			0.2		0.2
(pg/g)	123678H6CDD	0.8	2.9				1.4
(pg/g)	123789H6CDD	<mdc	1		0.3		0.6
(pg/g)	H7CDD	16					
(pg/g)	1234678H7CDD	7.5					
(pg/g)	O8CDD	45					
(pg/g)	T4CDF	4.7	360	14	14	33	99
(pg/g)	2378T4CDF	2.4	210	8.3	5.3	22.3	61
(pg/g)	P5CDF	<mdc	6.2		7.9		4.5
(pg/g)	12378P5CDF	<mdc	1.6		0.6		0.7
(pg/g)	23478P5CDF	<mdc	1.8		0.7		0.8
(pg/g)	H6CDF	2.7			22		
(pg/g)	123478H6CDF	<mdc	0.4		1.3		
(pg/g)	123678H6CDF	<mdc			1.4		0.3
(pg/g)	234678H6CDF	<mdc			0.7		0.3
(pg/g)	123789H6CDF	<mdc					
(pg/g)	H7CDF	3.1			19		4.4
(pg/g)	1234678H7CDF	1.4			11		2
(pg/g)	1234789H7CDF	<mdc	0.3		1.1		0.2
(pg/g)	O8CDF	2.2	1.5		18		3

TABLE B-10: CRIEMP sediment chemistry: Chlorinated dioxin and furan levels standardized to reference station TOC

UNITS	PARAMETER	REFERENCE ARROW LAKE	D/S CELGAR	BIRCHBANK	RYAN CR.	BEAVER CR.	WANETA
		SEDIMENT LEVELS OF DIOXIN/FURAN CONGENERS					
(pg/g)	T4CDD	<mdc	2.54				1.27
(pg/g)	2378T4CDD	<mdc	2.29				1.27
(pg/g)	P5CDD	<mdc					
(pg/g)	12378P5CDD	<mdc					
(pg/g)	H6CDD	6.3	15.24				13.83
(pg/g)	123478H6CDD	0.2			0.24		0.36
(pg/g)	123678H6CDD	1	3.68				2.55
(pg/g)	123789H6CDD	0.7	1.27				1.09
(pg/g)	H7CDD	28.5					
(pg/g)	1234678H7CDD	14					
(pg/g)	O8CDD	43			45.22		61.88
(pg/g)	T4CDF	5.6	457.20	72.66	16.66	84.81	180.18
(pg/g)	2378T4CDF	0.9	266.70	43.08	6.31	57.31	111.02
(pg/g)	P5CDF	4	7.87		9.40		8.19
(pg/g)	12378P5CDF	<mdc	2.03		0.71		1.27
(pg/g)	23478P5CDF	<mdc	2.29		0.83		1.46
(pg/g)	H6CDF	10.5			26.18		
(pg/g)	123478H6CDF	1.4			1.55		
(pg/g)	123678H6CDF	0.4			1.67		0.55
(pg/g)	234678H6CDF	0.4			0.83		0.55
(pg/g)	123789H6CDF	<mdc					
(pg/g)	H7CDF	9.8			22.61		
(pg/g)	1234678H7CDF	4			13.09		
(pg/g)	1234789H7CDF	0.2	0.38				0.36
(pg/g)	O8CDF	5.4			21.42		5.46

UNITS	PARAMETER	REFERENCE KOOTENAY	D/S CELGAR	BIRCHBANK	RYAN CR.	BEAVER CR.	WANETA
		SEDIMENT LEVELS OF DIOXIN/FURAN CONGENERS					
(pg/g)	T4CDD	<mdc	2.70				1.4
(pg/g)	2378T4CDD	<mdc	2.43				1.4
(pg/g)	P5CDD	<mdc					
(pg/g)	12378P5CDD	<mdc					
(pg/g)	H6CDD	5.8	16.20				14.7
(pg/g)	123478H6CDD	<mdc			0.3		0.4
(pg/g)	123678H6CDD	0.8	3.92				2.7
(pg/g)	123789H6CDD	<mdc	1.35		0.4		1.2
(pg/g)	H7CDD	16					
(pg/g)	1234678H7CDD	7.5					
(pg/g)	O8CDD	45					
(pg/g)	T4CDF	4.7	486.00	79.10	17.8	90.4	192.1
(pg/g)	2378T4CDF	2.4	283.50	46.90	6.7	61.1	118.3
(pg/g)	P5CDF	<mdc	8.37		10.0		8.7
(pg/g)	12378P5CDF	<mdc	2.16		0.8		1.4
(pg/g)	23478P5CDF	<mdc	2.43		0.9		1.6
(pg/g)	H6CDF	2.7	3.11		27.9		
(pg/g)	123478H6CDF	<mdc	0.54		1.7		
(pg/g)	123678H6CDF	<mdc			1.8		0.6
(pg/g)	234678H6CDF	<mdc			0.9		0.6
(pg/g)	123789H6CDF	<mdc					
(pg/g)	H7CDF	3.1	3.24		24.1		8.5
(pg/g)	1234678H7CDF	1.4	1.62		14.0		3.9
(pg/g)	1234789H7CDF	<mdc	0.41		1.4		0.4
(pg/g)	O8CDF	2.2			22.9		5.8

TABLE B-11. CRIEMP Sediment Chemistry: dioxins and furans 2,3,7,8 TCDD TEQ normalized to 1% TOC

SEDIMENT STATION	2,3,7,8 TCDD TEQ (Normalized to 1% TOC)
Arrow Lake Reference	0.337*
Kootenay Reference	0.214
D/S Celgar	12.54 *
Birchbank	2.20 *
Ryan Creek	0.790*
Beaver Creek	5.92 *
Waneta	5.64 *

* values exceed the proposed (draft, January 1995) CCME sediment quality guideline of 0.25 pg/g TCDD TEQ to protect aquatic life.

TABLE B-12 CRIEMP 1991-1993 survey: Federal and provincial freshwater guidelines, objectives and criteria used to assess water quality data.

		CCREM Water Quality Guidelines		B.C. Provincial Water Quality Criteria	
Parameter	Unit	Guideline	Use	Criteria	Use
water temp	°C	< 1°C over background levels		<1°C over background levels *	
diss. O_2	mg/L	9.5 (min.)	freshwater aquatic life	10 *	aquatic life
pH	pH units	6.5 - 9.0	freshwater aquatic life	6.5 - 8.5 *	freshwater aquatic life
colour	true colour unit	15	drinking water	15 *	drinking water
Res nonfilt	mg/L	10 over background	freshwater aquatic life	10 over background	freshwater aquatic life
Turbidity	NTU	1	drinking water	5 *	freshwater aquatic life
TDG	%			110% max saturation	freshwater aquatic life
Alk total	mg $CaCO_3$/L			10 - 20	freshwater aquatic life - mod. sensitive
Hardness total	mg $CaCO_3$/L	80 - 100	drinking water	80 - 100	drinking water
Sulfate diss.	mg/L	500	drinking water	100	freshwater aquatic life
Al diss.	mg/L	0.005 (pH <6.5) 0.1 (pH ≥6.5)	freshwater aquatic life	0.05 (30 d.av.) 0.1 (max.) for pH ≥6.5**	freshwater aquatic life
As total	mg/L	0.05	freshwater aquatic life	0.05	freshwater aquatic life
Ba total	mg/L	1.0	drinking water	1.0 (30 d. av.) 5.0 (max.)	freshwater aquatic life
Ca diss.	mg/L			4 - 8	freshwater aquatic life
Cd total	mg/L	0.0002 for hardness 0–60 mg $CaCO_3$/L*** 0.0018 for hardness >180 mg $CaCO_3$/L	freshwater aquatic life	0.0002 for hardness 0–60 mg $CaCO_3$/L*** 0.0018 for hardness >180 mg $CaCO_3$/L	freshwater aquatic life
Cr total	mg/L	0.002	freshwater aquatic life	0.002	aquatic life for phyto & zooplankton

TABLE B-12 continued

Parameter	Unit	Guideline	Use	Criteria	Use
Coliform count				≤200 (geom. mean) ≤100 (90th perc.) partial treatment	recreation primary contact drinking water
Cu total	mg/L	0.002 for hardn. 0 - 120 mg/L***	freshwater aquatic life	0.002 (30 d. av.) for hardn.<50mg/L***	freshwater aquatic life
Fe total	mg/L	0.3	freshwater aquatic life	0.3 (max.)	freshwater aquatic life
Mg total	mg/L			100	drinking water - taste threshold
Mn total	mg/L	0.05	drinking water	0.05 (max.)	drinking water
Hg total	mg/L	0.0001	freshwater aquatic life	0.00002 (30 d.av.) - 0.0001 (max.)	freshwater aquatic life
Pb total	mg/L	0.002 for hardn. 60-120mg/L*** 0.001 for hardn. < 60 mg/L	freshwater aquatic life	0.003 (max @ hardn. ≤8 mg/L)*** - 0.016 (30 d.av. @ hardn. 300 mg/L)	freshwater aquatic life
Tl total	mg/L			0.013	drinking water
Zn total	mg/L	0.03	freshwater aquatic life	0.03	freshwater aquatic life
NH_3	mg/L			e.g.: 30 d.av. = 1.59 as N if temp = 10°C**** & pH=7.8**	freshwater aquatic life
N NO_3, NO_2 diss	mg N/L			200 (NO_3); 0.06 (NO_2)	freshwater aquatic life
Na diss.	mg/L			20	drinking water
Resin Acid	mg/L			0.0001 - 0.062**	freshwater aquatic life
Phenols	mg/L	0.001	freshwater aquatic life	0.001	freshwater aquatic life
2346 TetraCP	ng/L	1000	freshwater aquatic life	40 - 300**	freshwater aquatic life
Pentachloro-phenol	ng/L	500	freshwater aquatic life	20 - 300	freshwater aquatic life
2,3,7,8,TCDD TEQ	pg/L	0.06 (proposed)		0.2*	freshwater aquatic life

* Water Quality Objectives for Lower Columbia River (Butcher 1992)
** pH dependent
*** Hardness dependent (Pommen 1991)
**** Temperature dependent

For more detailed criteria/guidelines, please refer to CCREM (1987) and Butcher (1992)

TABLE B-13 Summary of Water Quality Data for the 1991-93 CRIEMP Survey: Maximum levels and frequency of exceedance of the CCREM guidelines and the provincial water quality criteria for maximum values.

Station # and name	Analytical lab	Variable	Units	MDC	Maximum level	No. observations	No. above MDC	% above MDC	% above CCREM guideline	% above BCMOE criterion
II-1	Zenon *	Chromium	mg/L	0.002 - 0.005	0.004	11	2	18	9	9
U/S Celgar	Zenon	Lead	mg/L	0.001	0.003	11	4	36	9	0
	Zenon	Thallium	mg/L	0.003	0.014	11	2	18	no guideline	9
II-2	Zenon *	Chromium	mg/L	0.002 - 0.005	0.005	10	4	40	20	20
D/S Celgar	Zenon	Copper	mg/L	0.001	0.003	10	2	20	10	0
	Zenon	Lead	mg/L	0.001	0.003	10	3	30	30	0
	Zenon	Zinc	mg/L	0.002	0.038	10	8	80	10	10
II-4	Zenon *	Chromium	mg/L	0.002 - 0.005	0.005	11	3	27	27	27
U/S Castlegar	Zenon	Copper	mg/L	0.001	0.003	11	4	36	9	0
	Zenon	Zinc	mg/L	0.002	0.036	11	7	64	9	9
III-2	Zenon *	Chromium	mg/L	0.002 - 0.005	0.007	6	1	17	17	17
Birchbank	NLET	Chromium	mg/L	0.0002	0.0016	27	12	44	0	0
IV-1a	Zenon	Cadmium	mg/L	0.0005	0.0017	16	4	25	13	13
Cominco	Zenon *	Chromium	mg/L	0.002 - 0.005	0.011	16	7	44	44	44
West	Zenon	Copper	mg/L	0.001	0.007	16	13	81	50	0
	Zenon	Lead	mg/L	0.001	0.031	16	14	88	88	0
	Zenon	Mercury	mg/L	0.00005	0.00012	11	2	18	9	9
	Zenon	Zinc	mg/L	0.002	0.083	16	16	100	44	44
IV-1b	Zenon *	Chromium	mg/L	0.002 - 0.005	0.01	16	6	38	38	38
Cominco	Zenon	Copper	mg/L	0.001	0.003	16	5	31	6	0
East	Zenon	Lead	mg/L	0.001	0.005	16	6	38	25	0
IV-3	Zenon *	Chromium	mg/L	0.002 - 0.005	0.004	18	5	28	28	28
Waneta	NLET	Chromium	mg/L	0.0002	0.0042	50	20	40	6	6
	Zenon	Lead	mg/L	0.001	0.007	18	17	94	78	0
	NLET	Lead	mg/L	0.0002	0.0072	50	50	100	72	0
	Zenon	Mercury	mg/L	0.00005	0.00013	11	3	27	18	18
	ASL	Mercury	mg/L	0.000005	0.000012	12	2	17	17	17
	NLET *	Mercury	mg/L	0.00001 - 0.000005	0.000139	49	47	96	2	2
	Zenon	Zinc	mg/L	0.002	0.046	19	19	100	5	5
	NLET	Zinc	mg/L	0.0002	0.0312	49	49	100	2	2

* This detection limit changed during the program

TABLE B-14. CRIEMP periphyton community data: Number of species in major taxonomic groups

	CRIEMP PERIPHYTON SAMPLING STATION					
MAJOR TAXONOMIC GROUP	KOOTENAY	U/S CELGAR	D/S CELGAR	BIRCHBANK	RYAN CREEK	WANETA
Oscillatoriales	4	3	3	4	3	2
Chroococcales	1	5	2	3	1	2
Pennales	30	36	33	28	16	28
Chlorococcales	5	5	3	2	1	1
Zygnematales	3	4	3	3	3	3
Rhizochrysidales	0	0	1	0	0	0
Ulothricales	0	0	1	1	0	0
Tetrasporales	0	0	0	0	0	1
Oedogoniales	1	1	0	0	0	0
Nostocales	1	0	0	0	0	0
Ochromonadales	2	3	2	2	2	3
Dinokontae	2	1	1	1	1	2
Centrales	5	4	3	5	4	4
Euglenales	1	1	0	0	0	1
Cryptomonadales	0	1	0	0	0	1
Siphonocladales	1	0	0	0	0	1
Volvocales	0	0	0	0	0	1
Total Number of Species	57	64	52	49	31	50

TABLE B-15: Macrophyte tissue levels of trace metals, July 1992

PARAMETER	UNITS	CRIEMP 1992 SAMPLING STATIONS CELGAR Station II-2 (18 July 1992)	WANETA Station IV-3 (14 July 1992)
Moisture	% (W/W)	87	84.7
Al_Total	(ug/g)	543	417
As_Total	(ug/g)	0.2	1
Ba_Total	(ug/g)	45.7	110
Ca_Total	(ug/g)	24000	84700
Cd_Total	(ug/g)	1.1	6.3
Co_Total	(ug/g)	0.4	1.4
Cr_Total	(ug/g)	2.6	2.6
Cu_Total	(ug/g)	6.8	27.6
Fe_Total	(ug/g)	764	679
Hg_Total	(ug/g)	<0.05	0.11
K_Total	(ug/g)	16900	12000
Mg_Total	(ug/g)	2230	2290
Mn_Total	(ug/g)	78.3	381
Mo_Total	(ug/g)	<0.4	0.9
Na_Total	(ug/g)	424	583
Ni_Total	(ug/g)	4.9	1.9
P_Total	(ug/g)	1210	1610
Pb_Total	(ug/g)	3	38
S_Total	(ug/g)	2530	1850
Sb_Total	(ug/g)	<1.5	2
Se_Total	(ug/g)	<0.5	<0.5
Sr_Total	(ug/g)	111	241
Ti_Total	(ug/g)	56.7	25
Tl_Total	(ug/g)	<0.3	6.8
V_Total	(ug/g)	1.3	1.1
Zn_Total	(ug/g)	32.5	218
Zr_Total	(ug/g)	<0.3	0.4

TABLE B-16: Caddisfly tissue levels of trace metals, PCP and dioxin/furans, July 1992

			CRIEMP 1992 SAMPLING STATION			
			KOOTENAY (16 July 1992)	GROHMAN (19 July 1992)	D/S CELGAR (17 July 1992)	WANETA (16 July 1992)
MDC	UNITS	PARAMETER				
0.1	% (W/W)	Moisture	72.6	71.5	70.4	70.15
2	(ug/g)	Al_Total	14.5	16	18	11.5
0.2	(ug/g)	As_Total	2.8	2.1	2.1	1.95
0.1	(ug/g)	Ba_Total	4.25	4.8	2.7	2.1
1	(ug/g)	Ca_Total	764	922	1000	1125
0.1	(ug/g)	Cd_Total	0.3	0.4	0.3	0.65
0.2	(ug/g)	Cr_Total	0.9	1.2	1.3	1.25
0.1	(ug/g)	Cu_Total	23.4	27.7	20.7	37.25
0.3	(ug/g)	Fe_Total	102.5	124	102	113
40	(ug/g)	K_Total	6490	7310	6110	6955
2	(ug/g)	Mg_Total	697	848	705	896.5
0.2	(ug/g)	Mn_Total	17.7	19.4	13.4	13.15
0.4	(ug/g)	Mo_Total	1.15	1.2	1	1.95
1	(ug/g)	Na_Total	2170	2520	2050	2440
4	(ug/g)	P_Total	6805	8000	7180	8745
2	(ug/g)	Pb_Total	4.5	6	6	22.5
3	(ug/g)	S_Total	5530	5940	5590	6155
1.5	(ug/g)	Sb_Total	0	<1.5	2.3	3.15
0.5	(ug/g)	Se_Total	2.65	2.6	1.8	1.4
2	(ug/g)	Sn_Total	<2	2	<2	2.5
0.1	(ug/g)	Sr_Total	4.1	4.8	6.5	5.5
0.3	(ug/g)	Ti_Total	0.95	0.9	1.2	0.7
0.3	(ug/g)	Tl_Total	<0.3	1.2	<0.3	0.15
0.2	(ug/g)	Zn_Total	120	128	136	199
0.2-0.4	(ng/g)	246_TCP	<0.2	<0.3	0.4	<0.2
1.1-7.4	(ng/g)	Pentachlorophenol	2.5	4.2	1.1	7
0.07-1.5	(pg/g)	Total T4CDD	0.3	<0.2	<0.07	1.3
0.2-2.6	(pg/g)	Total P5CDD	<0.6	<0.6	<0.2	2.2
0.2-5.6	(pg/g)	Total H6CDD	2.9	2.9	<0.2	4.5
0.1-0.7	(pg/g)	123478H6CDD	0.4	<1.2	<0.2	<0.4
0.3-1.2	(pg/g)	123678H6CDD	0.5	<1.2	<0.2	<0.4
0.6-9.5	(pg/g)	Total H7CDD	8.4	11	<0.6	7.1
0.6-4.4	(pg/g)	1234678H7CDD	3.5	4.3	<0.6	2.4
0.7-30	(pg/g)	O8CDD	14	24	<2.7	14.3
0.3-6.3	(pg/g)	Total T4CDF	1.5	1.4	1.5	6.1
0.05-2.1	(pg/g)	2378T4CDF	<0.3	0.3	0.05	2
0.2-2.1	(pg/g)	Total P5CDF	0.9	<0.4	<0.4	2.1
0.3-1.5	(pg/g)	Total H6CDF	2.2	1.5	<0.4	0.9
0.3-3.4	(pg/g)	Total H7CDF	2.1	<1.4	<0.5	<0.8
0.3-1.4	(pg/g)	1234678H7CDF	1.4	<1.4	<0.5	<0.8
	(pg/g)	2378-T4CDD TEQ	0.38	0.72	0.36	0.66

TABLE B-17: CRIEMP Caddisfly Tissue Levels: Trace metals, PCP, and dioxins/furans compared with reference levels, July 1992

D/S Celgar samples compared to reference levels

CADDISFLY TISSUE RESULTS							
MDC	UNITS	PARAMETER	STATION D/S CELGAR	REFERENCE KOOTENAY	GROHMAN	MEAN	FACTOR HIGHER THAN REFERENCE LEVELS *
2	(μg/g)	Al Total	18	14.5	16	15.25	1.18
1	(μg/g)	Ca Total	1000	764	922	843	1.19
0.2	(μg/g)	Cr Total	1.3	0.9	1.2	1.05	1.24
1.5	(μg/g)	Sb Total	2.3	0	1.5	0.75	3.07
0.1	(μg/g)	Sr Total	6.5	4.1	4.8	4.45	1.46
0.2	(μg/g)	Zn Total	136	120	128	124	1.10
0.2-0.4	(μg/g)	246 TCP	0.4	0.2	0.3	0.25	1.60

Waneta samples compared to reference levels

CADDISFLY TISSUE RESULTS							
MDC	UNITS	PARAMETER	STATION WANETA	REFERENCE KOOTENAY	GROHMAN	MEAN	FACTOR HIGHER THAN REFERENCE LEVELS *
1	(μg/g)	Ca Total	1125	764	922	843	1.33
0.1	(μg/g)	Cd Total	0.65	0.3	0.4	0.35	1.86
0.2	(μg/g)	Cr Total	1.25	0.9	1.2	1.05	1.19
0.1	(μg/g)	Cu Total	37.25	23.4	27.7	25.55	1.46
2	(μg/g)	Mg Total	896.5	697	848	772.5	1.16
0.4	(μg/g)	Mo Total	1.95	1.15	1.2	1.175	1.66
4	(μg/g)	P Total	8745	6805	8000	7402.5	1.18
2	(μg/g)	Pb Total	22.5	4.5	6	5.25	4.29
3	(μg/g)	S Total	6155	5530	5940	5735	1.07
1.5	(μg/g)	Sb Total	3.15	0	1.5	0.75	4.20
2	(μg/g)	Sn Total	2.5	2	2	2	1.25
0.1	(μg/g)	Sr Total	5.5	4.1	4.8	4.45	1.24
0.2	(μg/g)	Zn Total	199	120	128	124	1.60
1.1-7.4	(μg/g)	Pentachlorophenol	7	2.5	4.2	3.35	2.09
0.07-1.5	(μg/g)	T4CDD	1.3	0.3	0.2	0.25	5.20
0.2-2.6	(μg/g)	P5CDD	2.2	1.6	0.6	1.1	2.00
0.2-5.6	(μg/g)	H6CDD	4.5	2.9	2.9	2.9	1.55
0.1-1.2	(μg/g)	123478H6CDD	0.4	0.4	1	0.7	0.57
0.3-1.2	(μg/g)	123678H6CDD	0.4	0.5	1	0.8	0.50
0.6-11	(μg/g)	H7CDD	7.1	8.4	11	9.7	0.73
0.6-4.4	(μg/g)	1234678H7CDD	2	3.8	4.3	3.9	0.51
2.7-30	(μg/g)	O8CDD	14.3	12	23.5	18.8	0.76
0.3-6.3	(μg/g)	T4CDF	6.1	1.5	1.4	1.45	4.21
0.05-2.1	(μg/g)	2378T4CDF	2	0.3	0.3	0.3	6.67
0.2-2.1	(μg/g)	P5CDF	2.1	0.9	0.4	0.65	3.23
0.3-1.5	(μg/g)	H6CDF	0.9	2.15	1.5	1.8	0.50
0.3-3.4	(μg/g)	H7CDF	0.8	1.7	1.4	1.6	0.50
0.3-1.4	(μg/g)	1234678H7CDF	0.8	1	1.4	1.2	0.67

* Calculated by dividing station tissue levels by mean of reference tissue levels

TABLE B-18: Mussel tissue levels of trace metals, PCP and dioxin/furan, July 1992

			CRIEMP 1992 SAMPLING STATIONS		
			KOOTENAY R.	CELGAR (II-2)	WANETA (IV-3)
MDC	UNITS	PARAMETER	(17 July 1992)	(18 July 1992)	(14 July 1992)
2	(ug/g)	Al_Total	183	429	388
0.2	(ug/g)	As_Total	2.8	0.9	2.8
0.1	(ug/g)	Ba_Total	1030	669	859
1	(ug/g)	Ca_Total	33100	29400	44700
0.1	(ug/g)	Cd_Total	3.6	1.1	13.3
0.3	(ug/g)	Co_Total	1.1	1.1	1
0.2	(ug/g)	Cr_Total	5.3	14.6	7.1
0.1	(ug/g)	Cu_Total	6.1	14.8	64.2
0.3	(ug/g)	Fe_Total	2610	3760	4590
0.05	(ug/g)	Hg_Total	<0.05	<0.05	0.08
40	(ug/g)	K_Total	1120	1280	989
2	(ug/g)	Mg_Total	1190	1250	1360
0.2	(ug/g)	Mn_Total	4770	4780	5330
0.4	(ug/g)	Mo_Total	0.9	<0.4	0.8
1	(ug/g)	Na_Total	2710	2090	2150
0.8	(ug/g)	Ni_Total	1	3	1.6
4	(ug/g)	P_Total	27800	24900	30900
2	(ug/g)	Pb_Total	4	2	251
3	(ug/g)	S_Total	6560	6480	6070
0.5	(ug/g)	Se_Total	2.7	2.2	2.8
0.1	(ug/g)	Sr_Total	138	250	229
0.3	(ug/g)	Ti_Total	6.8	21.7	19.5
0.3	(ug/g)	V_Total	<0.3	0.5	0.6
0.2	(ug/g)	Zn_Total	214	256	962
0.3	(ug/g)	Zr_Total	1.8	1.6	1.9
0.2-0.3	(ng/g)	pentachlorophenol	0.3	<0.2	<0.2
0.4-0.7	(ng/g)	2346_TetraCP	0.7	<0.4	<0.4
0.2-2.7	(pg/g)	P5CDD	2.7	<0.2	<0.3
70-270	(pg/g)	H6CDD	255	78	70
4.3-22	(pg/g)	123678H6CDD	22	4.3	5.2
0.3-3	(pg/g)	123789H6CDD	2.9	0.9	<0.3
440-1500	(pg/g)	H7CDD	1350	470	440
120-370	(pg/g)	1234678H7CDD	355	130	120
1100-340	(pg/g)	O8CDD	3100	1100	1100
2-12	(pg/g)	T4CDF	10.9	3.8	2
0.9-2.6	(pg/g)	2378T4CDF	2.5	2.3	0.9
2.5-53	(pg/g)	P5CDF	43	3.4	2.5
0.1-0.6	(pg/g)	12378P5CDF	0.6	<0.1	<0.2
0.1-0.9	(pg/g)	23478P5CDF	0.9	<0.1	<0.2
26-180	(pg/g)	H6CDF	180	26	38
0.1-1.7	(pg/g)	123478H6CDF	1.4	<0.1	<0.3
0.1-1.3	(pg/g)	234678H6CDF	1.2	<0.1	<0.3
34-180	(pg/g)	H7CDF	175	34	42
12-60	(pg/g)	1234678H7CDF	60	12	15
7.4-24	(pg/g)	O8CDF	22	7.4	8.5
	(pg/g)	2378-T4CDD TEQ	10.6	3.5	3.4

TABLE B-19: CRIEMP Mussel Tissue Levels: Trace metals, PCP, and dioxins/furans compared with reference levels, July 1992

Celgar samples higher than Kootenay reference

MDC	UNITS	PARAMETER	MUSSEL TISSUE RESULTS		
			D/S CELGAR	REFERENCE	FACTOR HIGHER THAN REFERENCE LEVELS *
2	(μg/g)	Al Total	429	183	2.34
0.2	(μg/g)	Cr Total	14.6	5.3	2.75
0.1	(μg/g)	Cu Total	14.8	6.1	2.43
0.3	(μg/g)	Fe Total	3760	2610	1.44
40	(μg/g)	K Total	1280	1120	1.14
2	(μg/g)	Mg Total	1250	1190	1.05
0.8	(μg/g)	Ni Total	3	1	3.00
0.1	(μg/g)	Sr Total	250	138	1.81
0.3	(μg/g)	Ti Total	21.7	6.8	3.19
0.3	(μg/g)	V Total	0.5	0.3	1.67
0.2	(μg/g)	Zn Total	256	214	1.20

Waneta samples higher than Kootenay reference

MDC	UNITS	PARAMETER	MUSSEL TISSUE RESULTS		
			WANETA	REFERENCE	FACTOR HIGHER THAN REFERENCE LEVELS *
2	(μg/g)	Al Total	388	183	2.12
1	(μg/g)	Ca Total	44700	33100	1.35
0.1	(μg/g)	Cd Total	13.3	3.6	3.69
0.2	(μg/g)	Cr Total	7.1	5.3	1.34
0.1	(μg/g)	Cu Total	64.2	6.1	10.52
0.3	(μg/g)	Fe Total	4590	2610	1.76
0.05	(μg/g)	Hg Total	0.08	0.05	1.60
2	(μg/g)	Mg Total	1360	1190	1.14
0.2	(μg/g)	Mn Total	5330	4770	1.12
0.8	(μg/g)	Ni Total	1.6	1	1.60
4	(μg/g)	P Total	30900	27800	1.11
2	(μg/g)	Pb Total	251	4	62.75
0.5	(μg/g)	Se Total	2.8	2.7	1.04
0.1	(μg/g)	Sr Total	229	138	1.66
0.3	(μg/g)	Ti Total	19.5	6.8	2.87
0.3	(μg/g)	V Total	0.6	0.3	2.00
0.2	(μg/g)	Zn Total	962	214	4.50
0.3	(μg/g)	Zr Total	1.9	1.8	1.06

* Calculated by dividing station tissue levels by mean of reference tissue levels

TABLE B-20: CRIEMP Mussel Tissue Levels: Factor by which Kootenay reference station levels exceed Waneta and D/S Celgar levels

			MUSSEL TISSUE RESULTS				
MDC	UNITS	PARAMETER	KOOTENAY REFERENCE	WANETA	D/S CELGAR	FACTOR KOOTENAY HIGHER THAN WANETA *	FACTOR KOOTENAY HIGHER THAN D/S CELGAR *
0.2	(µg/g)	As Total	2.8	2.8	0.9	-	3.11
0.1	(µg/g)	Ba Total	1030	859	669	1.20	1.54
1	(µg/g)	Ca Total	33100	44700	29400	-	1.13
0.1	(µg/g)	Cd Total	3.6	13.3	1.1	-	3.27
0.3	(µg/g)	Co Total	1.1	1	1.1	1.10	-
40	(µg/g)	K Total	1120	989	1280	1.13	-
0.4	(µg/g)	Mo Total	0.9	0.8	0.4	1.13	2.25
1	(µg/g)	Na Total	2710	2150	2090	1.26	1.30
4	(µg/g)	P Total	27800	30900	24900	-	1.12
2	(µg/g)	Pb Total	4	251	2	-	2.00
0.5	(µg/g)	Se Total	2.7	2.8	2.2	-	1.23
0.3	(µg/g)	Zr Total	1.8	1.9	1.6	-	1.13
0.4-0.7	(µg/g)	2346 TetraCP	0.7	0.3	0.4	2.33	1.75
0.2-2.7	(µg/g)	P5CDD	2.7	0.3	0.2	9.00	13.50
70-270	(µg/g)	H6CDD	255	70	78	3.64	3.27
4.3-22	(µg/g)	123678H6CDD	22	5.2	4.3	4.23	5.12
0.3-3	(µg/g)	123789H6CDD	2.9	0.3	0.9	9.67	3.22
440-1500	(µg/g)	H7CDD	1350	440	470	3.07	2.87
120-370	(µg/g)	1234678H7CDD	355	120	130	2.96	2.73
1100-340	(µg/g)	O8CDD	3100	1100	1100	2.82	2.82
2-12.	(µg/g)	T4CDF	10.9	2	3.8	5.45	2.87
0.9-2.6	(µg/g)	2378T4CDF	2.5	0.9	2.3	2.78	1.09
2.5-53	(µg/g)	P5CDF	43	2.5	3.4	17.20	12.65
0.1-0.6	(µg/g)	12378P5CDF	0.6	0.2	0.1	3.00	6.00
0.1-0.9	(µg/g)	23478P5CDF	0.9	0.2	0.1	4.50	9.00
26-180	(µg/g)	H6CDF	180	38	26	4.74	6.92
0.1-1.7	(µg/g)	123478H6CDF	1.4	0.3	0.1	4.67	14.00
0.1-1.3	(µg/g)	234678H6CDF	1.2	0.3	0.1	4.00	12.00
34-180	(µg/g)	H7CDF	175	42	34	4.17	5.15
12-60.	(µg/g)	1234678H7CDF	60	15	12	4.00	5.00
7.4-24	(µg/g)	O8CDF	22	8.5	7.4	2.59	2.97
		TOTAL METALS			**RANGE:**	**1.10-1.26**	**1.12-3.27**
					AVERAGE:	**1.16**	**1.81**
		ORGANIC COMPOUNDS			**RANGE:**	**2.33-17.20**	**1.09-14.00**
					AVERAGE:	**4.99**	**5.94**

* Calculated by dividing Kootenay reference levels by Waneta or D/S Celgar levels.

.- = Kootenay reference levels not exceeded

Figure A-1. Columbia River Study Area

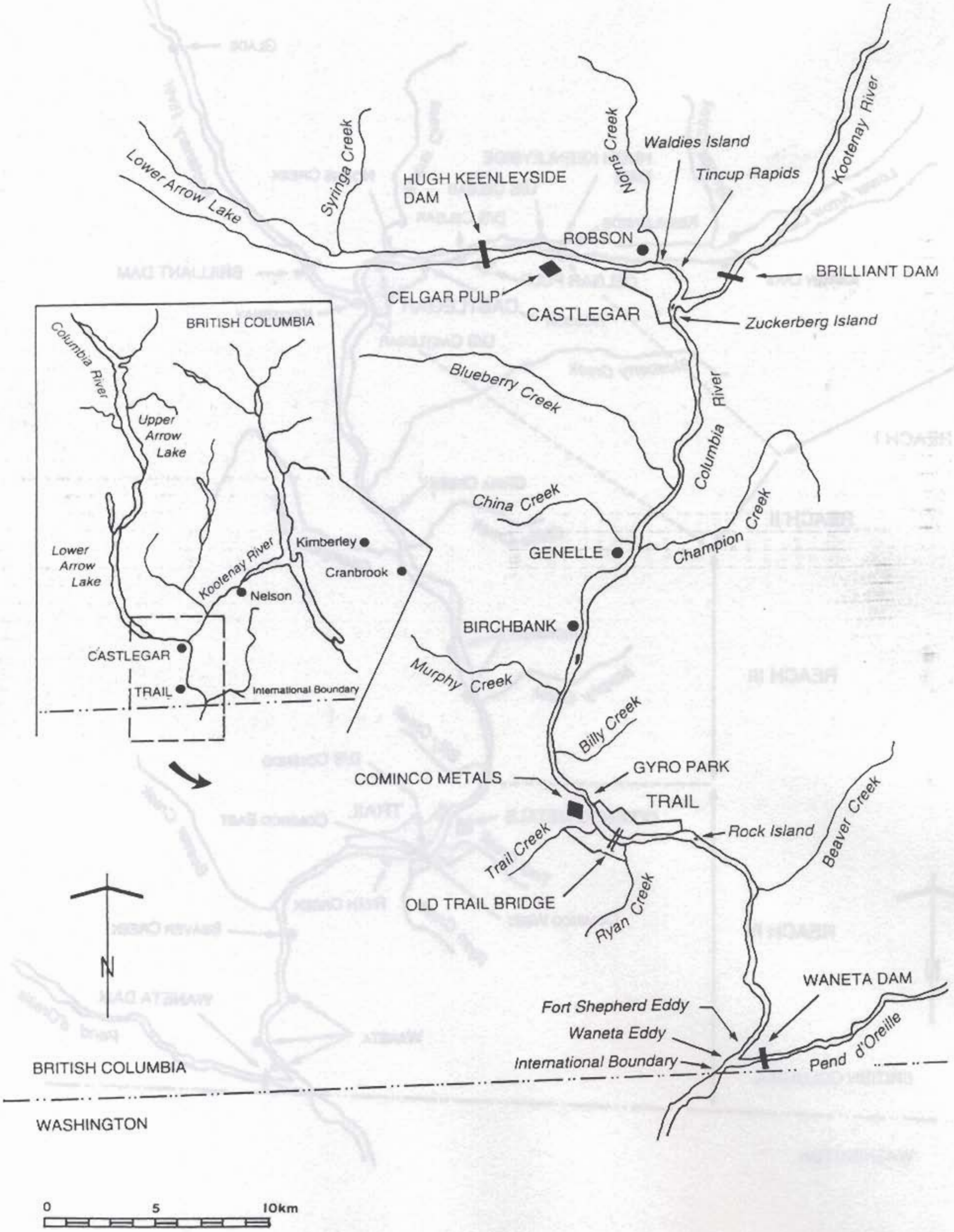


Figure B-1. Location of CRIEMP Survey Stations and Reaches

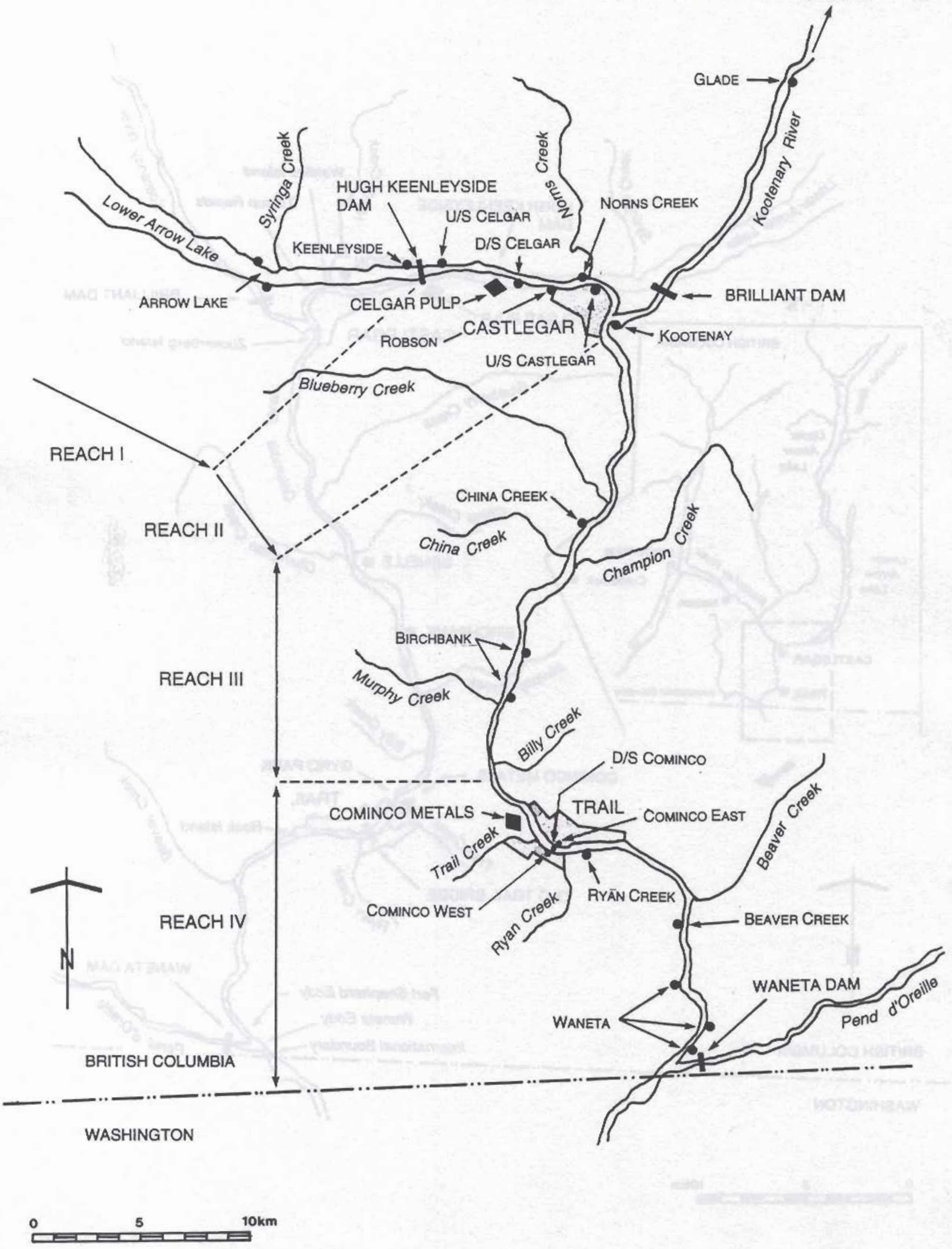


FIGURE B-2: CRIEMP sediment chemistry: Levels of Acid Volatile Sulfides (AVS).

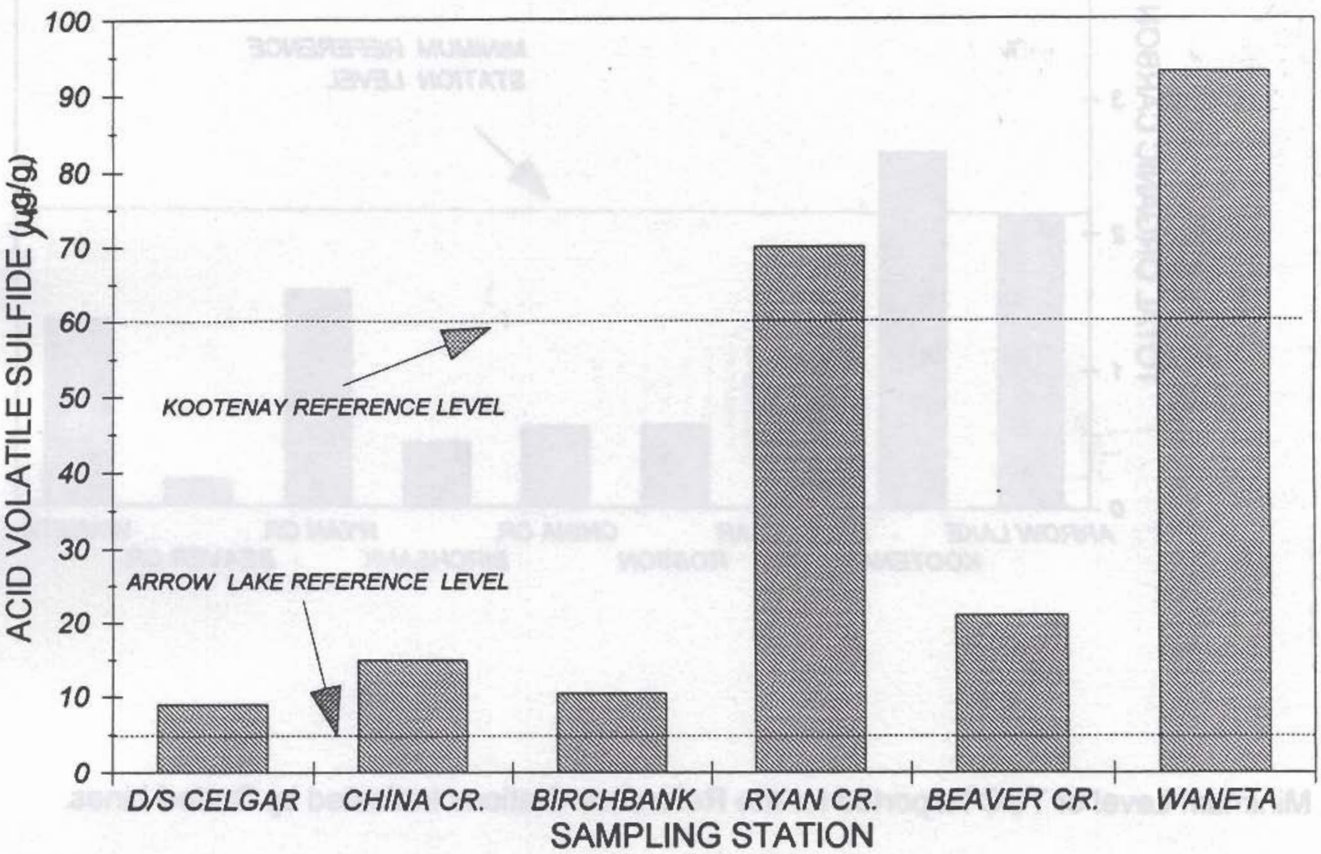
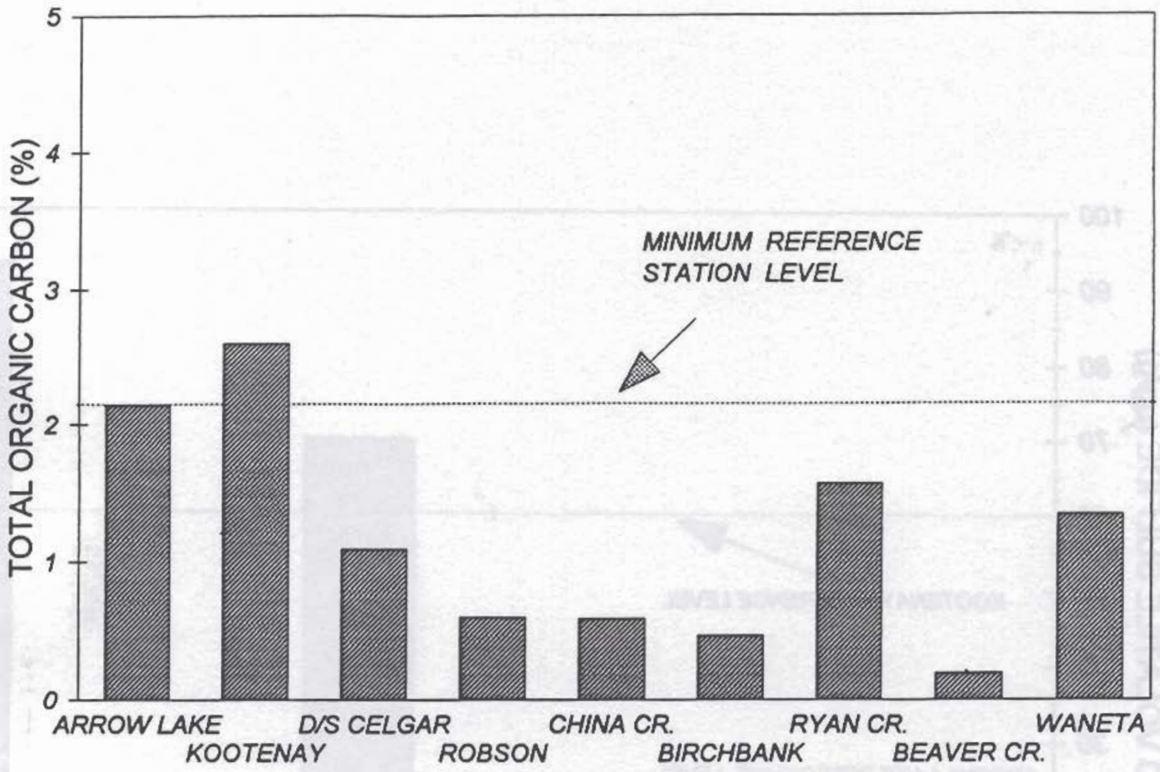


FIGURE B-3: CRIEMP sediment chemistry: Levels of Total Organic Carbons (TOC).



Minimum Level of TOC Reported for the Reference Stations Indicated by Dotted Lines.

FIGURE B-4: CRIEMP sediment chemistry: Dioxin and furans as 2,3,7,8 TCDD Toxic Equivalents.

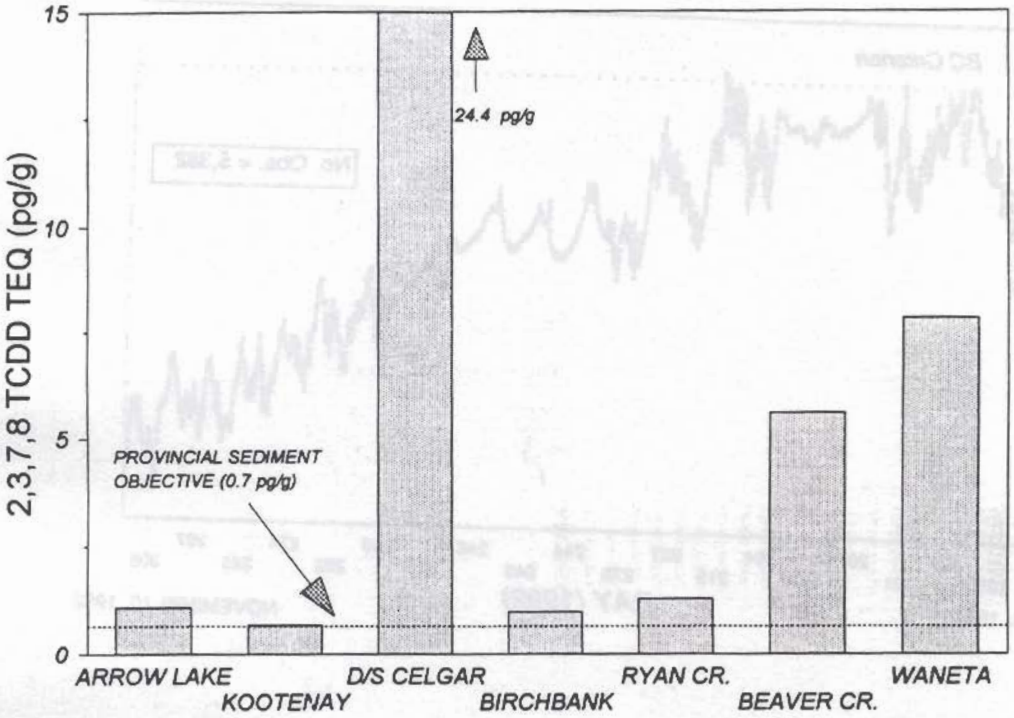
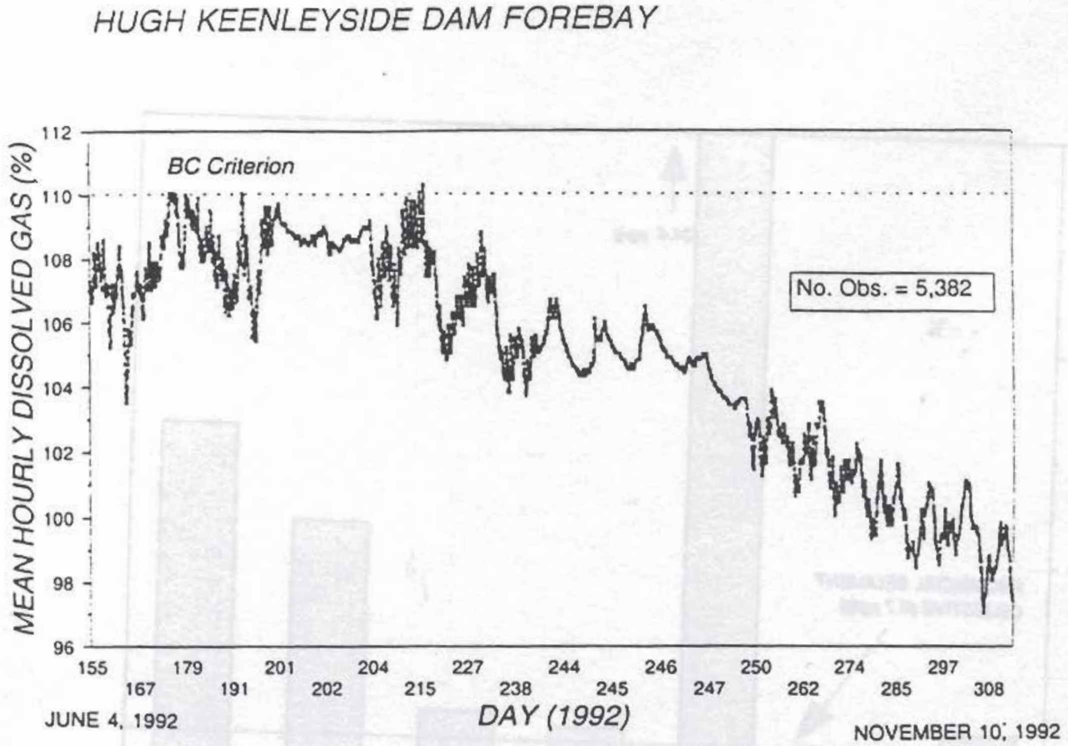


FIGURE B-5: CRIEMP water quality data: Total Dissolved Gas (TDG) levels measured at Hugh Keenleyside Dam and at Robson, 1992.



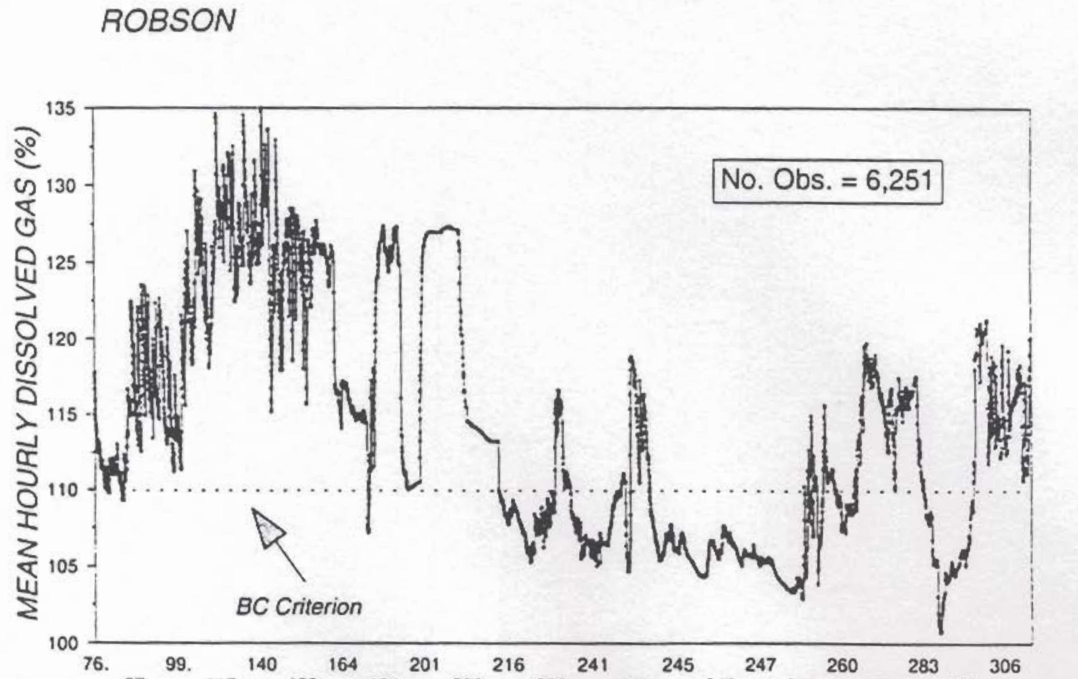


FIGURE B-6. CRIEMP water quality data: Flow rates at Hugh Keenleyside Dam, Brilliant Dam, Birchbank, and at the International Border, 1991-1992

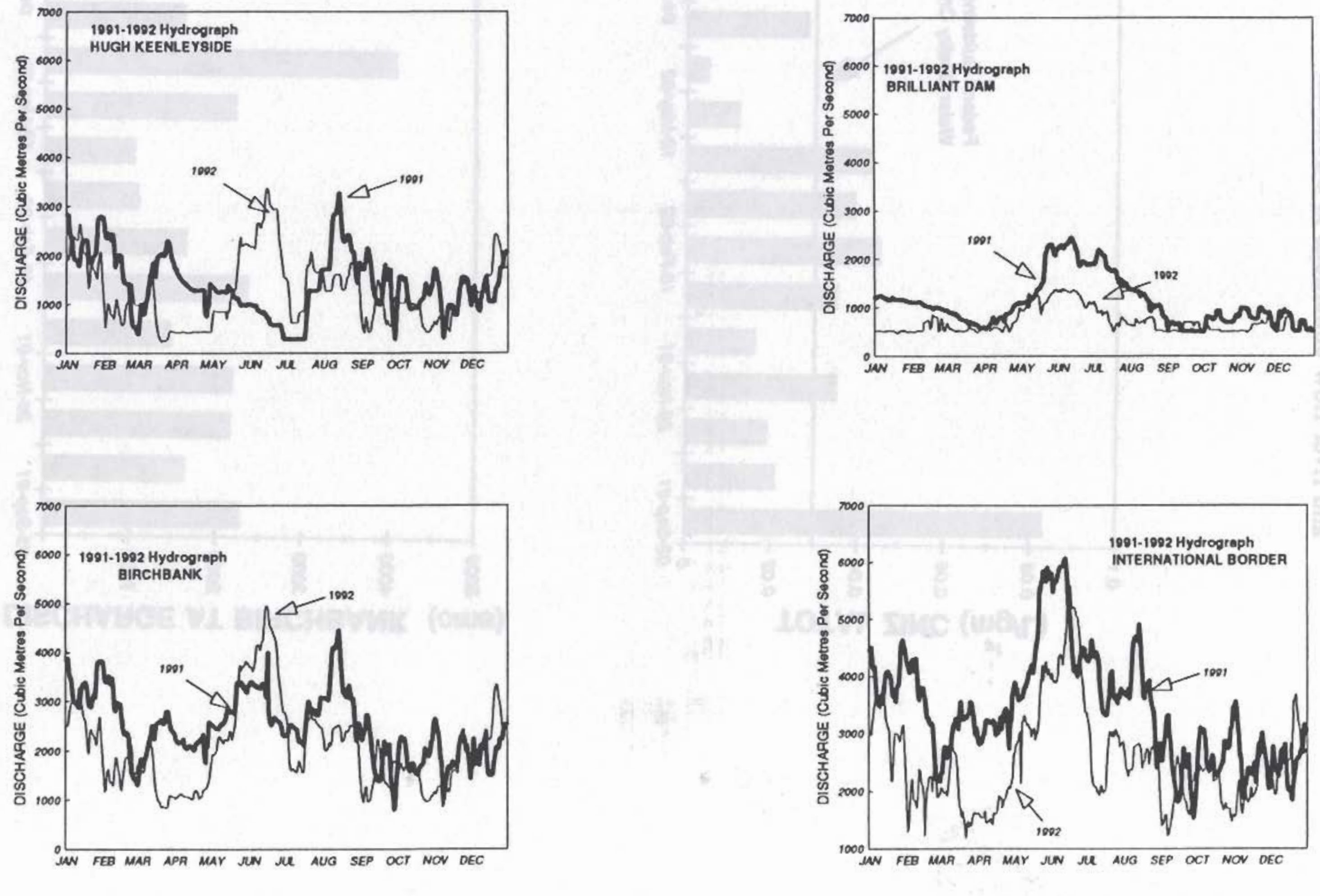
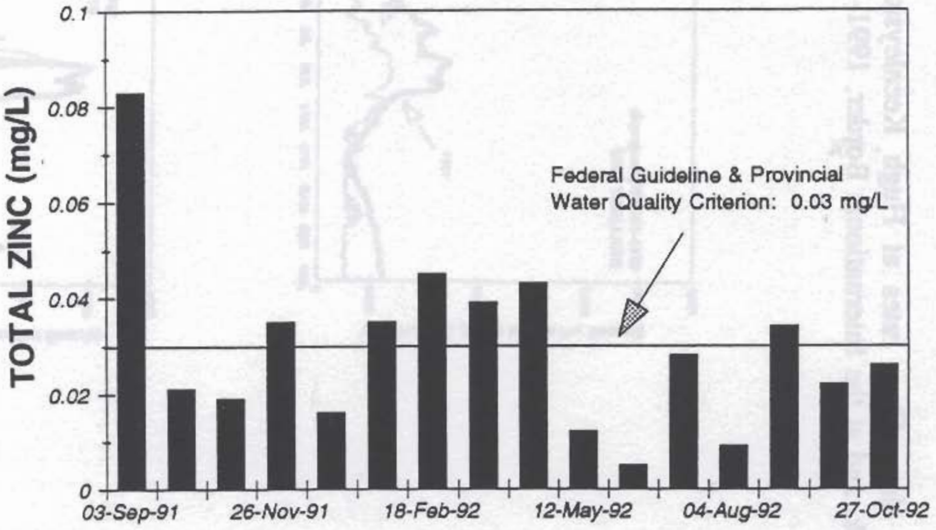


FIGURE B-7. CRIEMP water quality data: Levels of total zinc at Cominco West station and river flow conditions at Birchbank



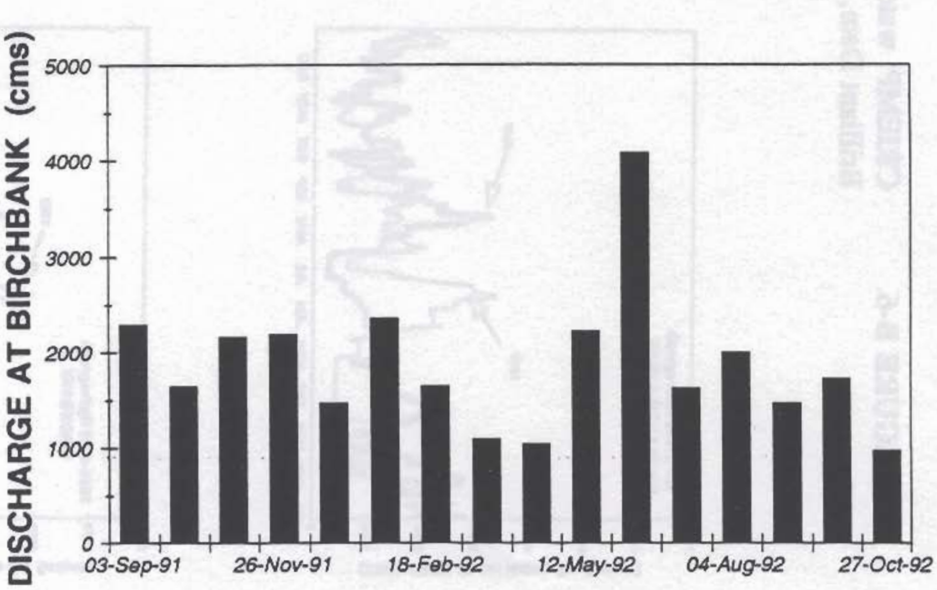


FIGURE B-8. CRIEMP water quality data: Mean levels of dissolved phosphorus and sulphate by station

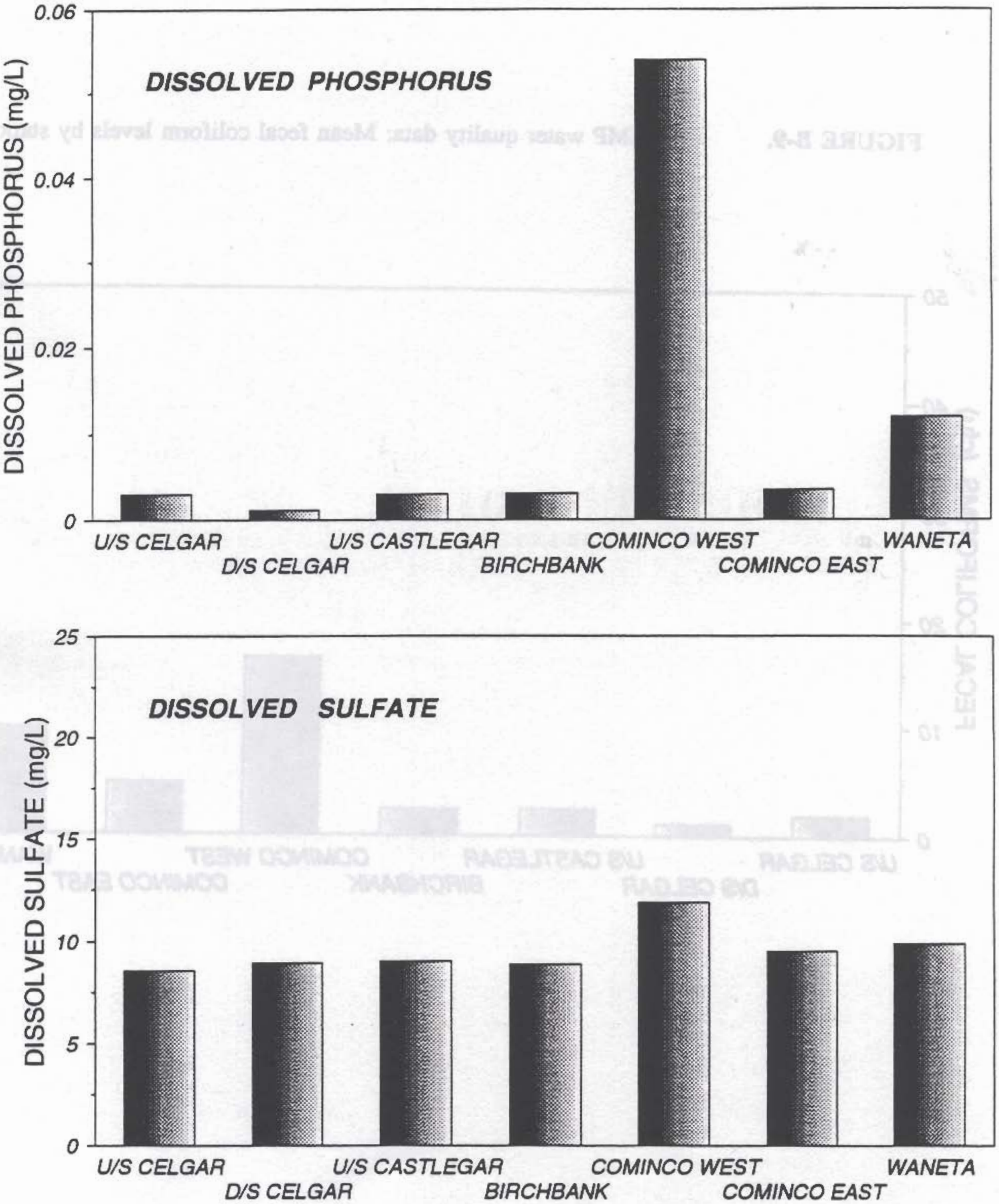


FIGURE B-9. CRIEMP water quality data: Mean fecal coliform levels by station

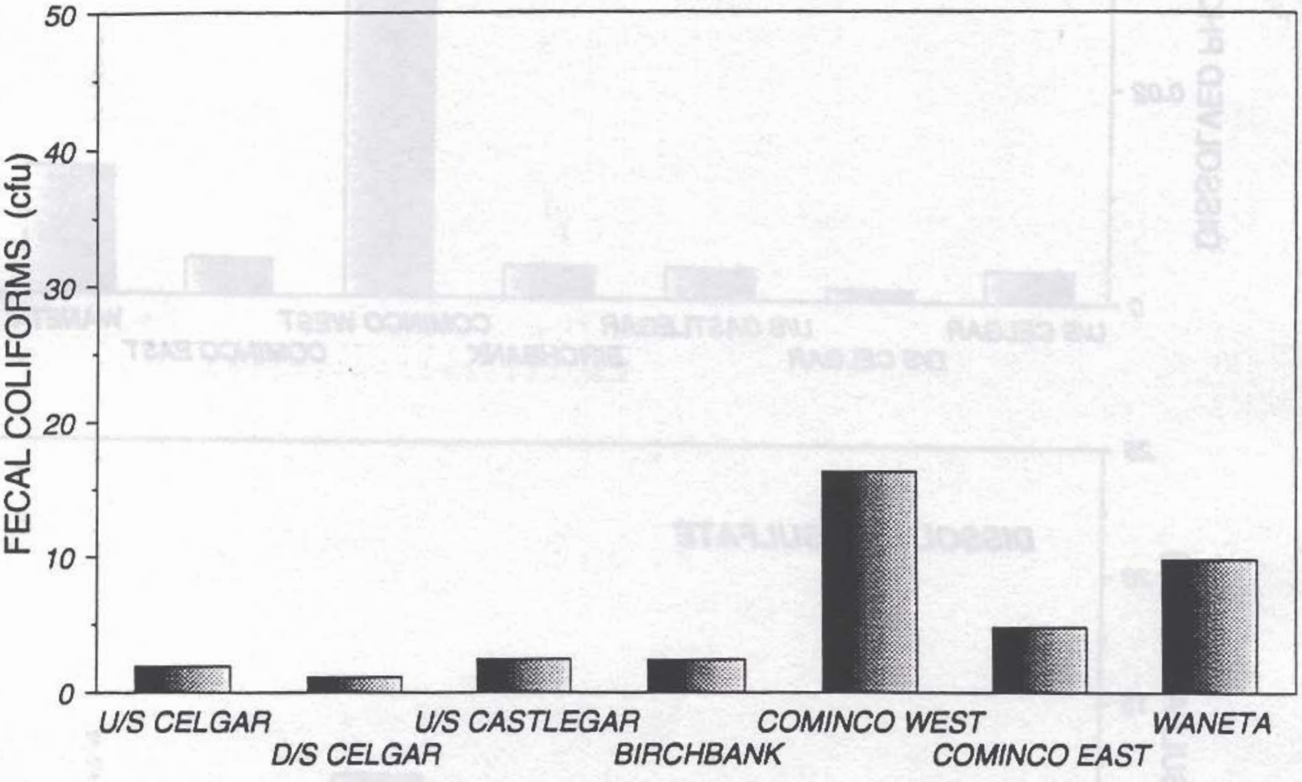
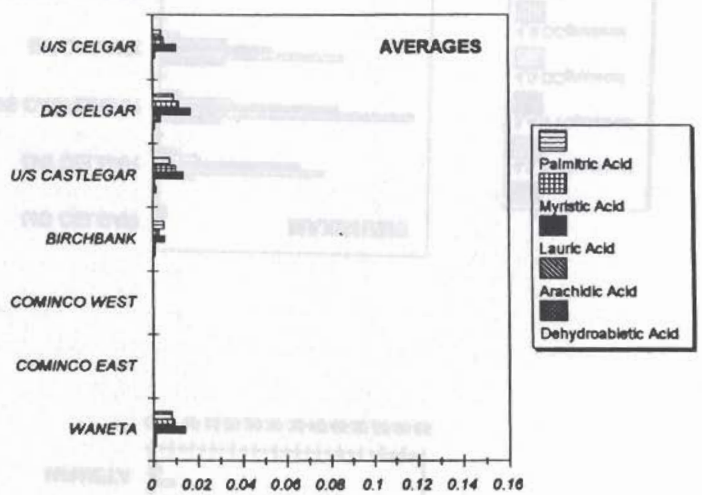


FIGURE B-10: CRIEMP water quality data: Average and maximum levels of selected resin/fatty acids.

		PARAMETER	AVERAGE	MAXIMUM	n
U/S CELGAR					
	(mg/L)	Dehydroabietic_Acid	0.001	0.01	16
	(mg/L)	Arachidic_Acid	0.001	0.007	15
	(mg/L)	Lauric_Acid	0.010	0.043	16
	(mg/L)	Myristic_Acid	0.005	0.019	15
	(mg/L)	Palmitric_Acid	0.004	0.019	16
D/S CELGAR					
	(mg/L)	Dehydroabietic_Acid	0.001	0.003	15
	(mg/L)	Arachidic_Acid	0.003	0.026	14
	(mg/L)	Lauric_Acid	0.016	0.14	14
	(mg/L)	Myristic_Acid	0.011	0.088	14
	(mg/L)	Palmitric_Acid	0.009	0.057	13
U/S CASTLEGAR					
	(mg/L)	Dehydroabietic_Acid	0.001	0.006	15
	(mg/L)	Arachidic_Acid	0.001	0.001	15
	(mg/L)	Lauric_Acid	0.013	0.071	15
	(mg/L)	Myristic_Acid	0.010	0.048	14
	(mg/L)	Palmitric_Acid	0.007	0.038	15
BIRCHBANK					
	(mg/L)	Dehydroabietic_Acid	0.001	0.004	17
	(mg/L)	Arachidic_Acid	0.001	0.002	15
	(mg/L)	Lauric_Acid	0.005	0.021	17
	(mg/L)	Myristic_Acid	0.003	0.009	16
	(mg/L)	Palmitric_Acid	0.005	0.013	17
COMINCO WEST					
	No Data				
COMINCO EAST					
	No Data				
WANETA					
	(mg/L)	Dehydroabietic_Acid	0.001	0.001	29
	(mg/L)	Arachidic_Acid	0.001	0.001	28
	(mg/L)	Lauric_Acid	0.009	0.11	28
	(mg/L)	Myristic_Acid	0.006	0.088	27
	(mg/L)	Palmitric_Acid	0.008	0.05	29



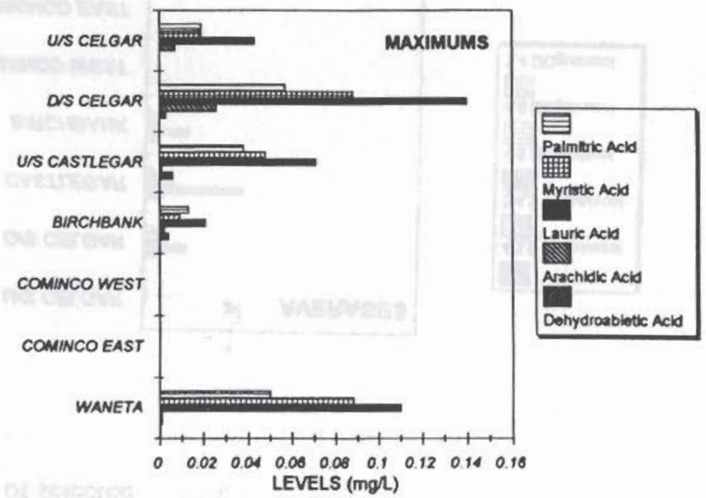
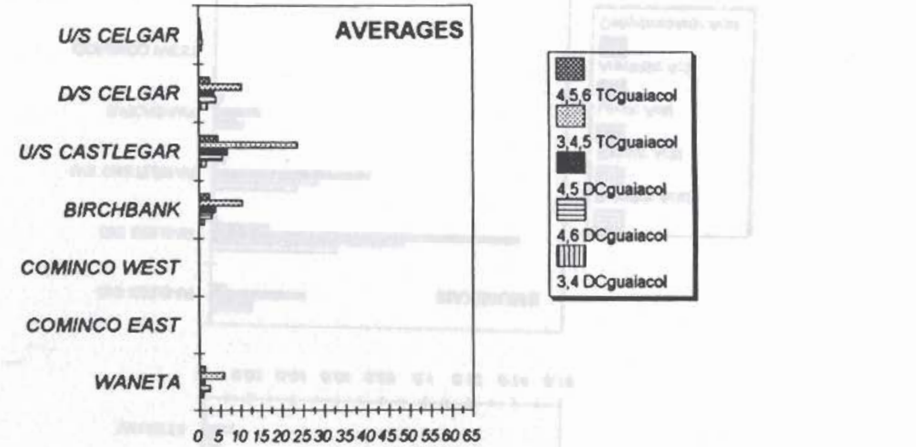


FIGURE B-11: CRIEMP water quality data: Average and maximum levels of selected guaiacols.

		PARAMETER	AVERAGE	MAXIMUM	n
U/S CELGAR					
	(ng/L)	34_DCguaiacol	0.85	1.8	17
	(ng/L)	46_DCguaiacol	0.81	2.4	17
	(ng/L)	45_DCguaiacol	0.66	1.6	17
	(ng/L)	345_TCguaiacol	0.38	0.9	17
	(ng/L)	456_TCguaiacol	0.35	0.8	17
D/S CELGAR					
	(ng/L)	34_DCguaiacol	2.07	4.5	18
	(ng/L)	46_DCguaiacol	4.02	10	18
	(ng/L)	45_DCguaiacol	3.63	34	18
	(ng/L)	345_TCguaiacol	10.19	40	18
	(ng/L)	456_TCguaiacol	2.58	8.9	18
U/S CASTLEGAR					
	(ng/L)	34_DCguaiacol	1.73	5.2	18
	(ng/L)	46_DCguaiacol	5.57	18	18
	(ng/L)	45_DCguaiacol	6.85	43	18
	(ng/L)	345_TCguaiacol	23.75	61	18
	(ng/L)	456_TCguaiacol	4.49	15	18
BIRCHBANK					
	(ng/L)	34_DCguaiacol	1.25	4.1	18
	(ng/L)	46_DCguaiacol	2.99	16	18
	(ng/L)	45_DCguaiacol	3.83	27	18
	(ng/L)	345_TCguaiacol	10.41	44	18
	(ng/L)	456_TCguaiacol	2.31	15	18
COMINCO WEST					
		No Data			
COMINCO EAST					
		No Data			
WANETA					
	(ng/L)	34_DCguaiacol	0.81	1.8	16
	(ng/L)	46_DCguaiacol	2.37	8	16
	(ng/L)	45_DCguaiacol	1.14	3.3	16
	(ng/L)	345_TCguaiacol	5.85	24	16
	(ng/L)	456_TCguaiacol	1.28	4.4	16



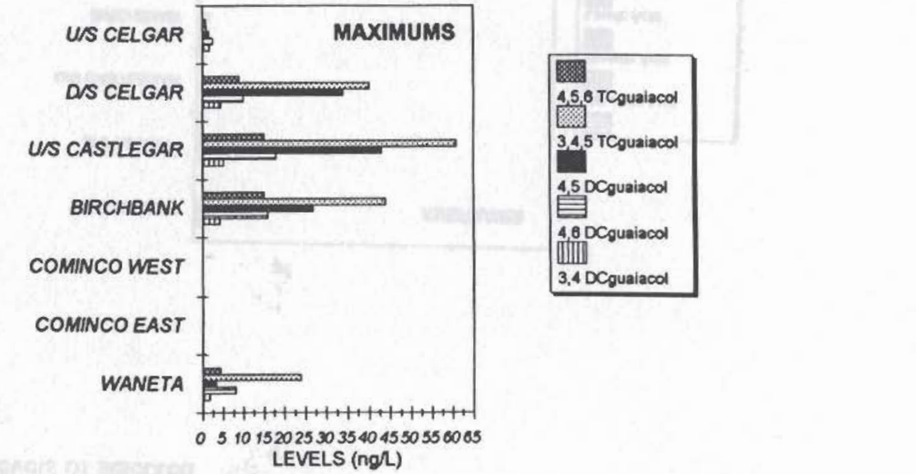


FIGURE B-12. CRIEMP benthos community data: Total taxa present, number of EPT taxa and total sample abundance, April 1992 survey

	NUMBER TAXA	EPT TAXA	TOTAL ABUNDANCE
APRIL	Mean	Mean	Mean
KOOTENAY	54	9	2683
U/S CELGAR	27	2	211
ROBSON	51	4	2097
BIRCHBANK	53	10	984
RYAN CR.	35	7	271
WANETA	37	8	213

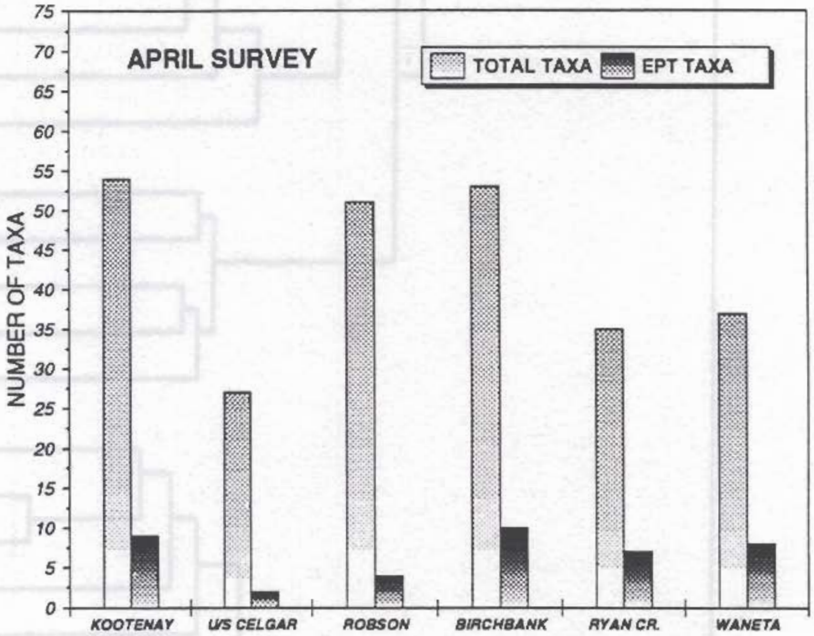


FIGURE B-13. CRIEMP benthos community data: Q-type cluster analysis, composition and relative abundance, April 1992 survey

No. of Stations = 30 (replicates treated independently)
No. of Taxa = 90

Cluster Analysis Options:

- Coefficient = Bray-Curtis Coefficient
- Linkage = UPGMA
- Linkage scale = Distance

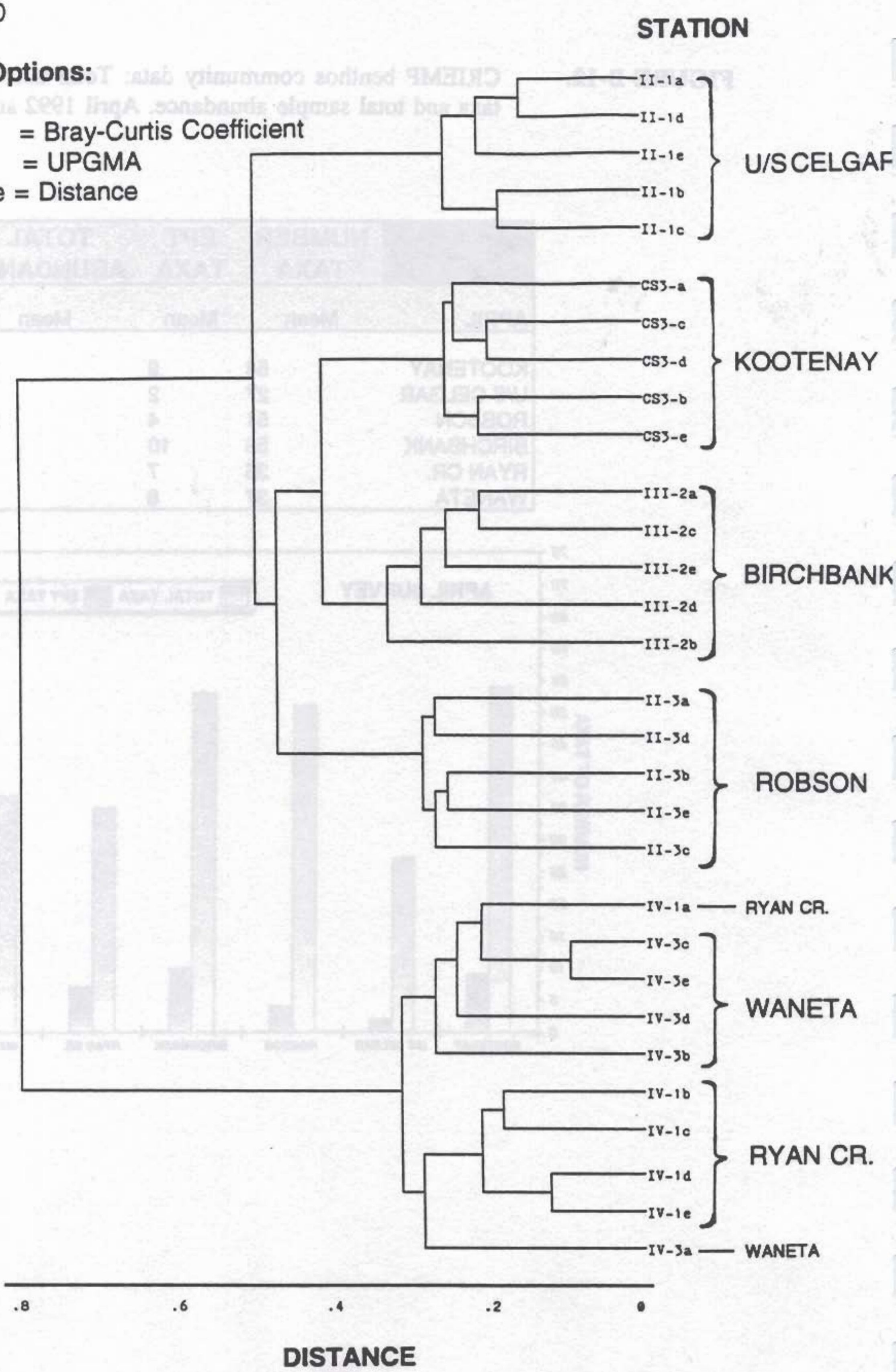
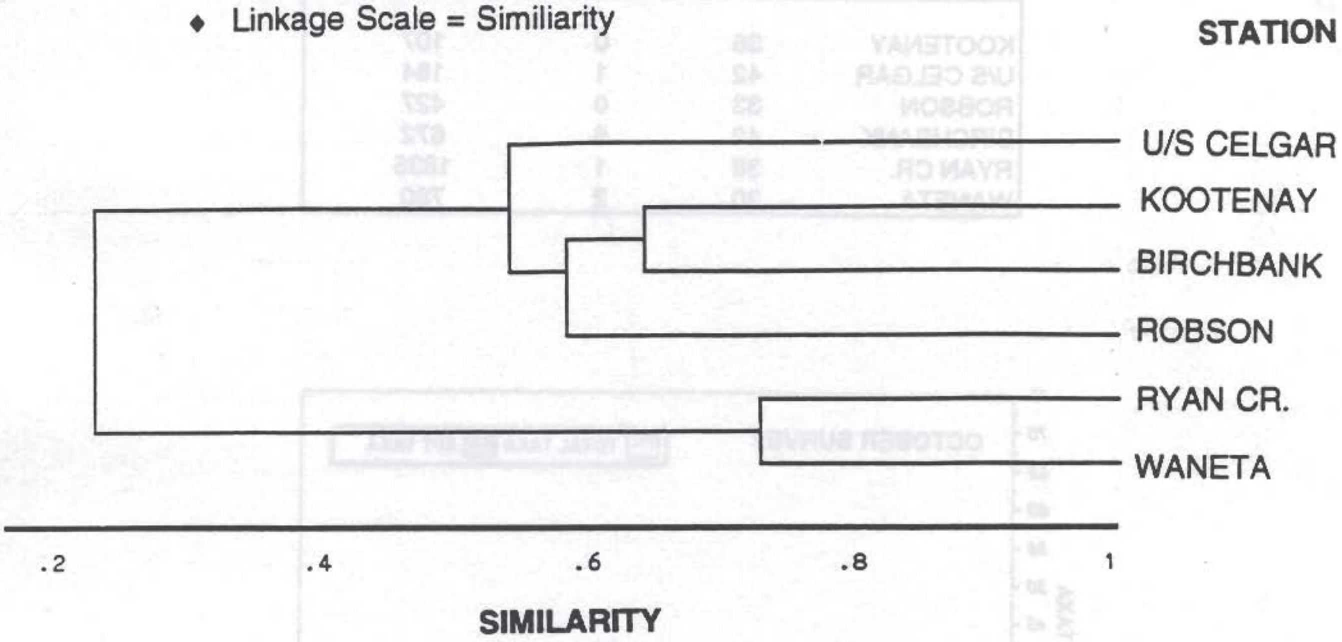


FIGURE B-14. CRIEMP benthos community data: Q-type cluster/significance analysis, composition and relative abundance, April 1992 survey

No. of Stations = 6
No. of Replicates = 5
No. of Taxa = 90

SIGTREE Options:

- Coefficient = Bray-Curtis Coefficient
- Linkage = UPGMA
- No. of simulations = 500
- Linkage Scale = Similiarity



LINKAGE	CLUSTERS LINKED	SIMILARITY	PROBABILITY
1	Ryan Cr. - Waneta	0.7522	P = 0.006
2	Kootenay - Birchbank	0.6548	P = 0.004
3	Kootenay - Robson	0.5865	P < 0.001
4	Kootenay - U/S Celgar	0.5462	P < 0.001
5	U/S Celgar - Ryan Cr.	0.2346	P < 0.001

FIGURE B-15. CRIEMP benthos community data: Total taxa present, number of EPT taxa and total sample abundance, October 1992 survey

	NUMBER TAXA	EPT TAXA	TOTAL ABUNDANCE
OCTOBER	Mean	Mean	Mean
KOOTENAY	36	0	107
U/S CELGAR	42	1	184
ROBSON	33	0	427
BIRCHBANK	42	6	672
RYAN CR.	38	1	1835
WANETA	30	2	780

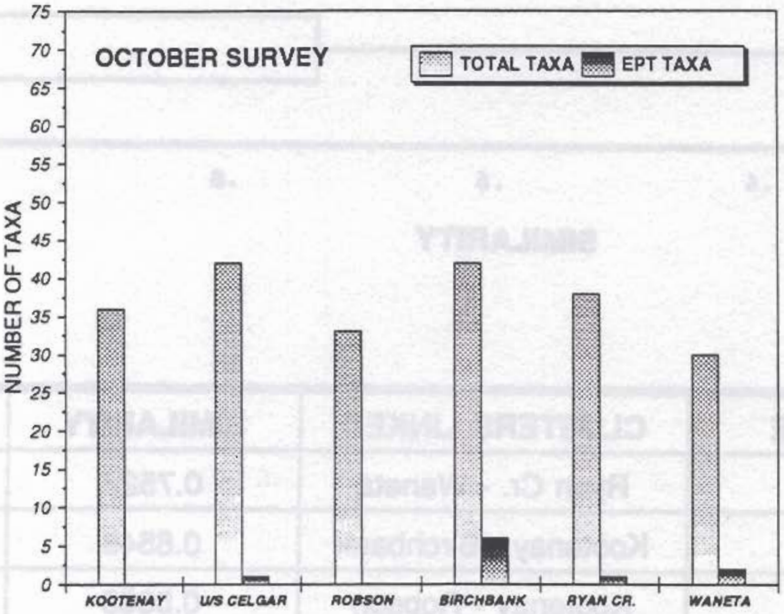


FIGURE B-16. CRIEMP benthos community data: Q-type cluster analysis, composition and relative abundance, October 1992 survey

No. Stations = 6 (small substrate)
No. of Replicates = 5
No. of Taxa = 73

Cluster Analysis Options:

- Coefficient = Bray-Curtis
- Linkage = UPGMA
- Linkage Scale = distance

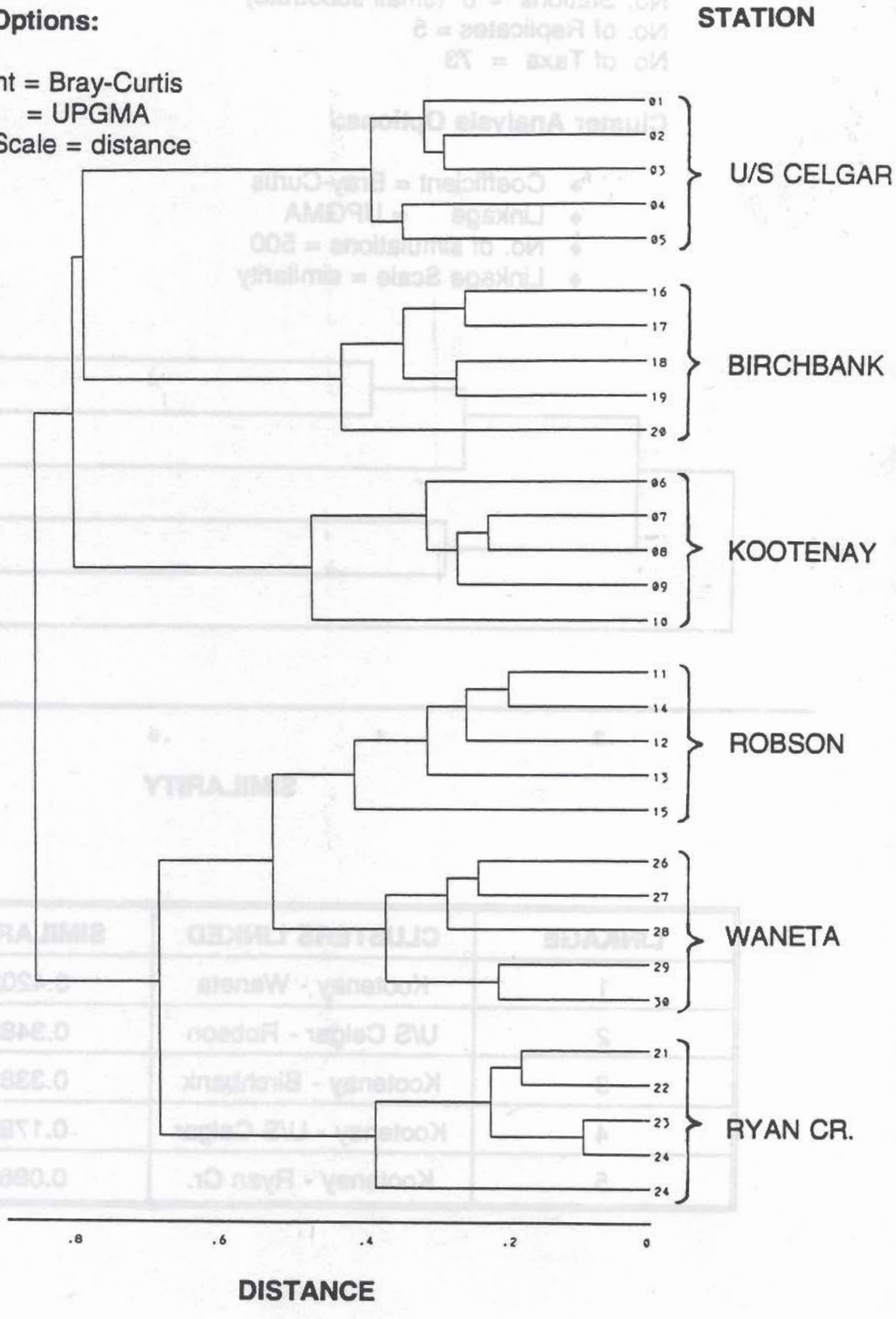
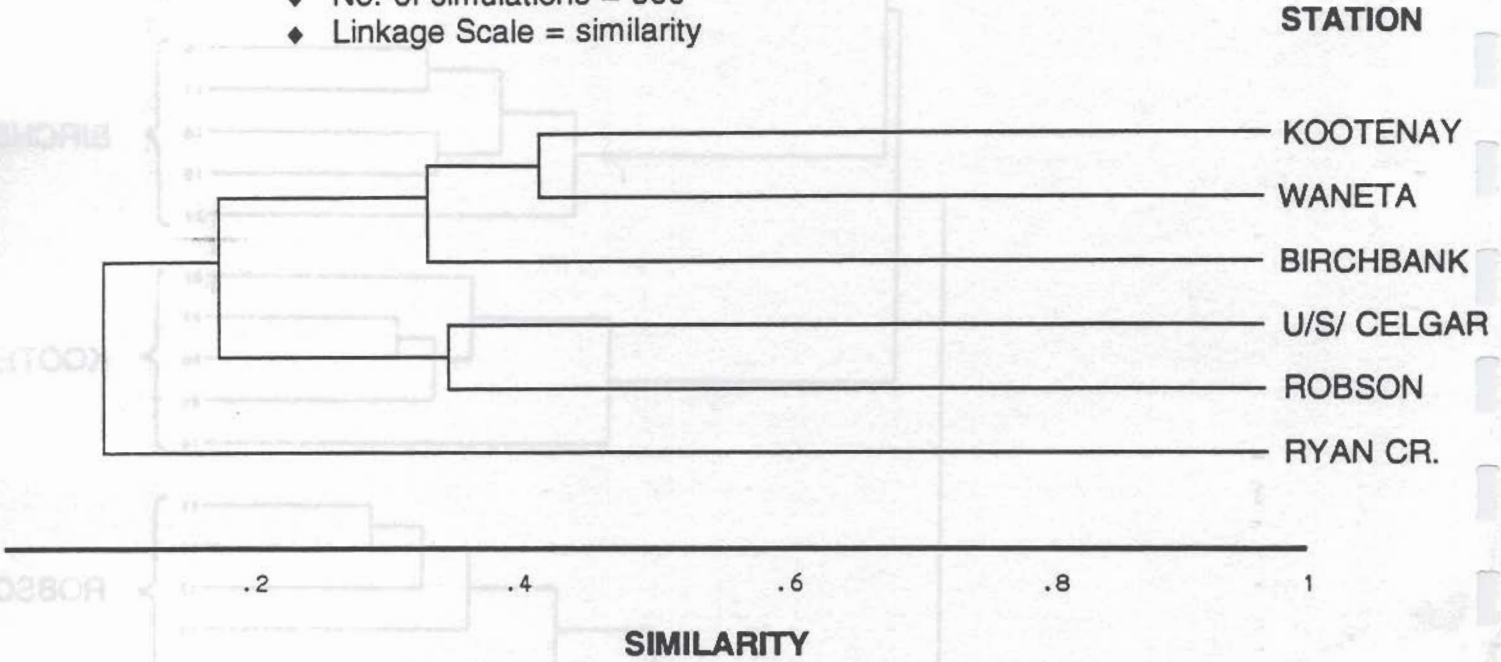


FIGURE B-17. CRIEMP benthos community data: Q-type cluster/significance analysis, composition and relative abundance, October 1992 survey

No. Stations = 6 (small substrate)
No. of Replicates = 5
No. of Taxa = 73

Cluster Analysis Options:

- Coefficient = Bray-Curtis
- Linkage = UPGMA
- No. of simulations = 500
- Linkage Scale = similarity



LINKAGE	CLUSTERS LINKED	SIMILARITY	PROBABILITY
1	Kootenay - Waneta	0.4202	P < 0.001
2	U/S Celgar - Robson	0.3489	P = 0.002
3	Kootenay - Birchbank	0.3385	P = 0.010
4	Kootenay - U/S Celgar	0.1789	P < 0.001
5	Kootenay - Ryan Cr.	0.0865	P < 0.001

FIGURE B-18. CRIEMP benthos community data: Q-type cluster analysis, composition and relative abundance (large substrate), October 1992 survey

No. Stations = 6 (large substrate)
No. of Replicates = 2
No. of Taxa = 57

Cluster Analysis Options:

- Coefficient = Bray-Curtis
- Linkage = UPGMA
- Linkage Scale = similarity

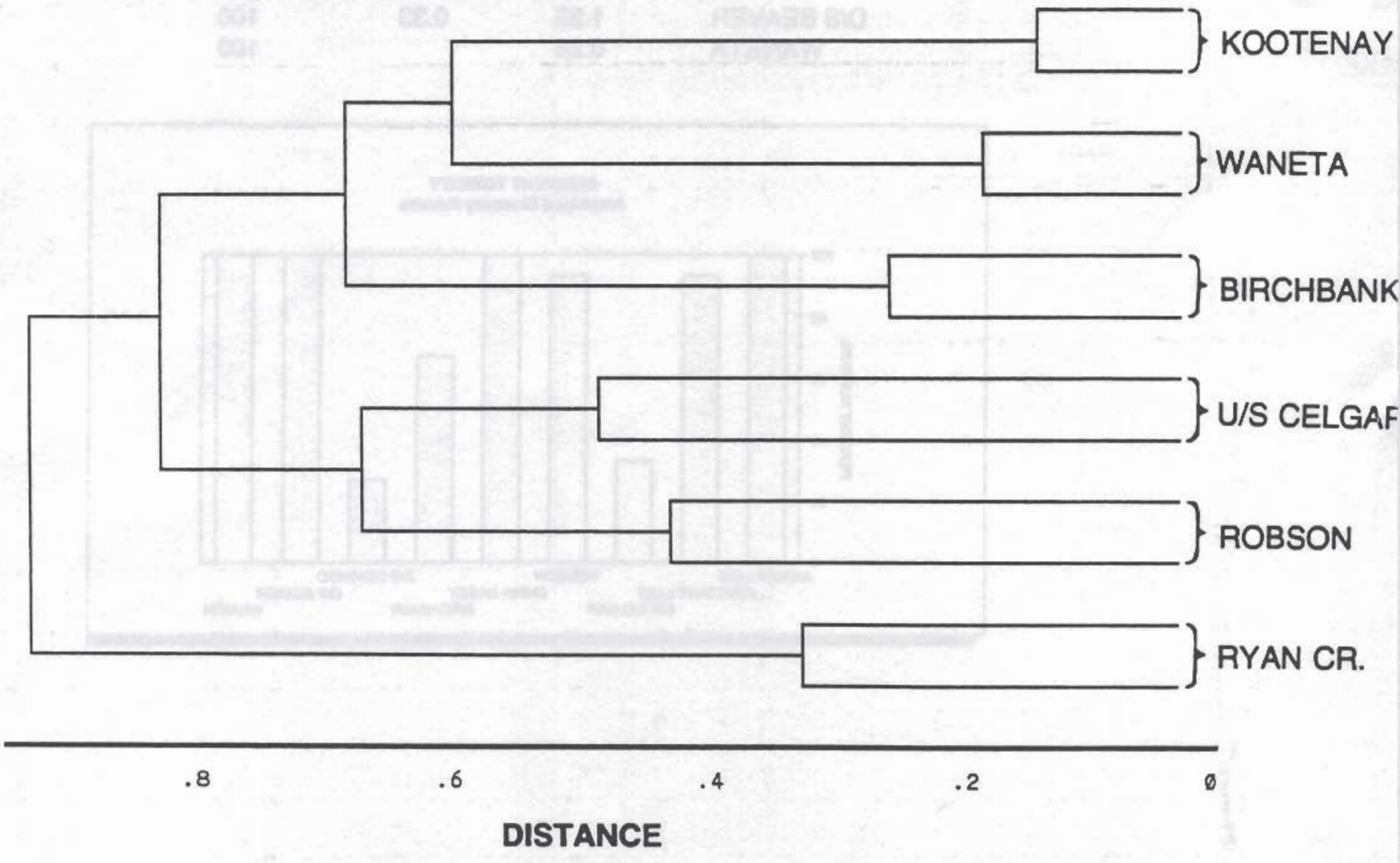


FIGURE B-19. CRIEMP sediment toxicity data: Microtox and amphipod survival bioassays

	MICROTOX TEST		AMPHIPOD BIOASSAY
CRIEMP SEDIMENT SAMPLING STATION	EC50 (% by wt.)	EC50 (% by wt.)	*Hyella azteca* (% survival)
ARROW LAKE	0.44	1.15	100
KOOTENAY LAKE	0.15		93
D/S CELGAR	2.34		33
ROBSON	8.13	5.1	93
CHINA CREEK	1.26		100
BIRCHBANK	1.28		67
D/S COMINCO	0.39		27
D/S BEAVER	1.25	0.33	100
WANETA	0.28		100

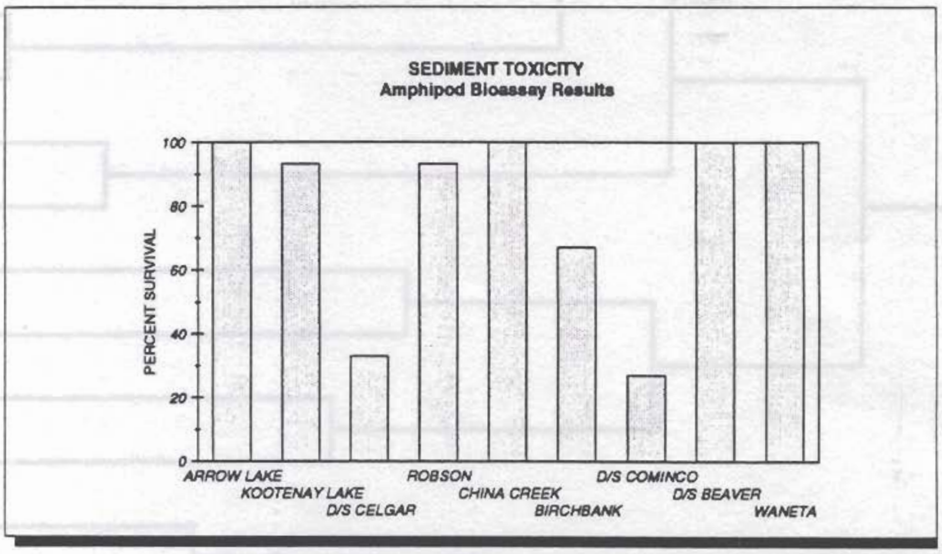
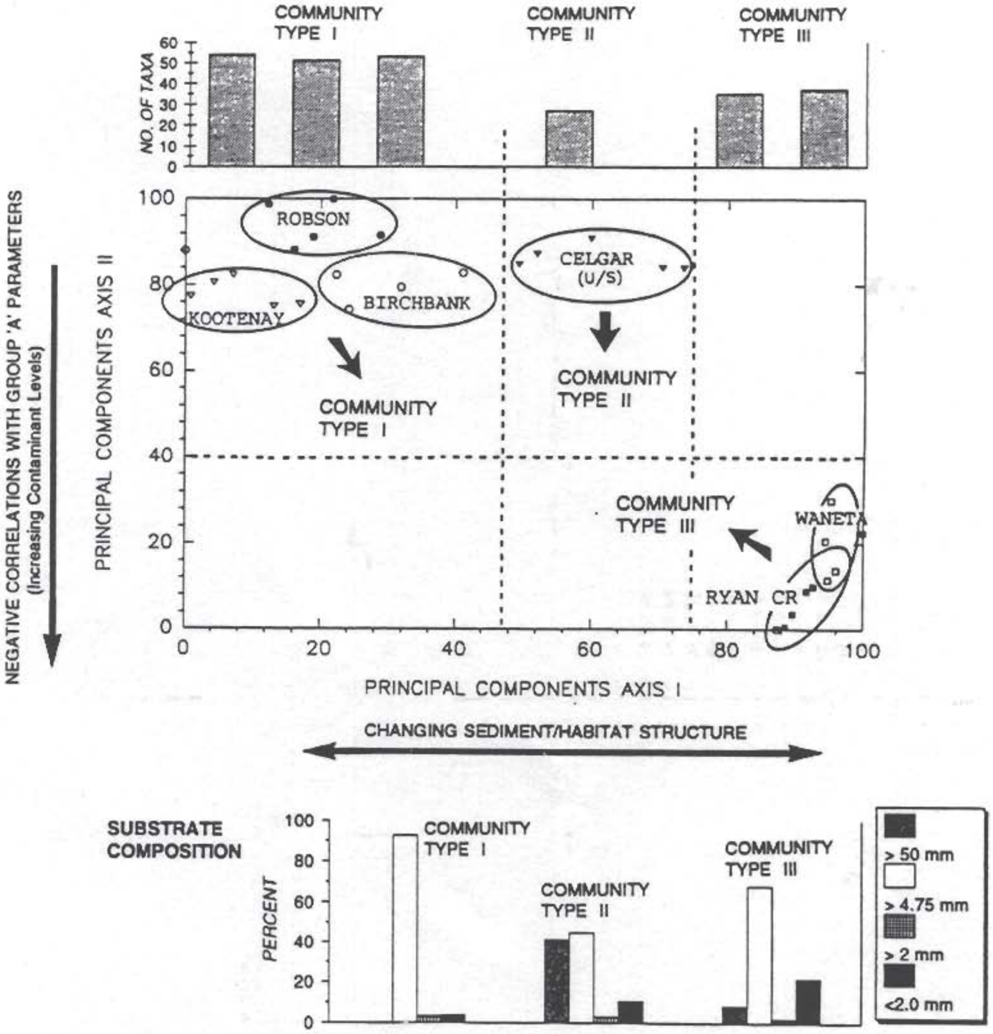


FIGURE B-20 CRIEMP benthos community data: Principal components analysis and correlations with physical/chemical attributes, April 1992 survey



GROUP 'A' PARAMETERS

SEDIMENT PARAMETER	Correlation (r); Prob.	WATER PARAMETER	Correlation (r); Prob.
Total Copper (Cu)	-0.992; P = 0.008	Hardness	-0.950; P = 0.13
Total Sodium (Na)	-0.980; P = 0.020	Fecal coliforms	-0.945; P = 0.015
Total Lead (Pb)	-0.998; P = 0.004	E.coli	-0.958; P = 0.010
Total Antimony (Sb)	-0.985; P = 0.035	Enterococcus	-0.988; P = 0.001
Total Strontium (Sr)	-0.988; P = 0.032	Fluoride	-0.985; P = 0.002
Total Zinc (Zn)	-0.998; P = 0.002	Abietic acid	-0.942; P = 0.017
Total Zirconium (Zr)	-0.978; P = 0.020	Dehydroabietic acid	-0.926; P = 0.024
Acid Soluble Sulfide	-0.959; P = 0.041	Total copper (Cu)	-0.893; P = 0.042
(SEE NOTE)		Total magnesium (Mg)	-0.895; P = 0.040
NOTE: other sediment metals show similar, although not a statistically significant relationship.			