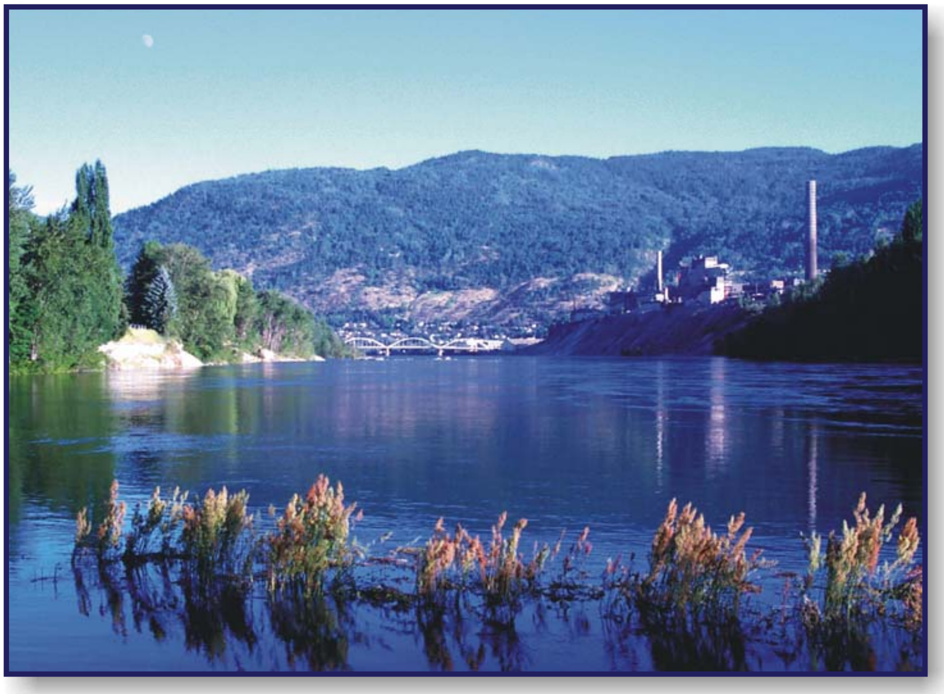
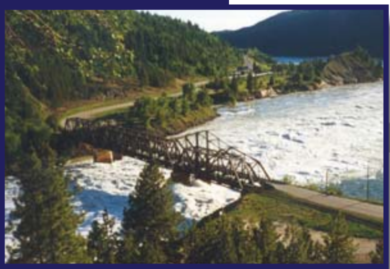
teckcominco

SUMMARY REPORT

TECK COMINCO METALS LTD. AQUATIC ECOLOGICAL RISK ASSESSMENT





Issue Date: December 2010

Golder Associates

Prepared by: Stella Swanson
Golder Associates, Calgary, (now
Swanson Environmental Strategies Ltd.)

Prepared for: Teck Cominco Metals Ltd. (now Teck Metals Ltd.)
Trail, British Columbia

The Past: Cominco smelter

The Present: Teck Cominco smelter

The Columbia River valley

Waneta 1891

Waneta 2001

Up close and personal with a prickly sculpin

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INTRODUCTION

This report presents the final results of the aquatic component of the Teck Cominco Metals Ltd. (now Teck Metals Ltd.) Ecological Risk Assessment (ERA). Teck Metals Ltd. is referred to as Teck Cominco in this report because the ERA was completed prior to the name change. The ERA was conducted under the British Columbia Contaminated Sites Regulation (CSR). Teck Cominco elected to conduct a landscape-scale risk assessment as the basis for a Wide Area Remediation Plan, as provided for under the CSR.

The Teck Cominco Metals Ltd. Smelter, Trail, B.C. (Photo taken in 2003)

The ERA was conducted over a period of five years and consisted of a series of stages and components. Consequently, there have been many reports produced as part of the documentation of the ERA. All of these reports may be found in the libraries at Selkirk College in Castlegar, the Trail and District Public Library in Trail and on the Teck web site (www.teck.com).

Two final ERA reports, one on the terrestrial component and one on the aquatic component, were released in 2010 after revisions in response to regulatory review. These two reports, in turn, are being used as the basis for the wide area risk management plan (which includes, but is not limited to, remediation). This summary report summarizes the aquatic ERA final report produced in April 2010.

Background to the Risk Assessment

The Columbia River valley north of Genelle

Trail, British Columbia (B.C.) has been the site of a major lead and zinc smelting facility for over 100 years. In 1990, the Trail Community Lead Task Force initiated studies on human health exposure and risk. Following these studies, Teck Cominco initiated an ERA.

The goal of Teck Cominco is that there will be no significant ecological impacts or constraints on desired land and water uses, in the Area Of Interest (AOI), related to past and present Teck Cominco smelter operations at Trail, B.C. Thus, the ERA determined how past, present or future emissions from the smelter have impacted, or might potentially impact, animals (birds, fish, mammals, insects, amphibians), plants, sediment, soil and water in the area. The term “emissions” is used to include releases to the air via stack and fugitive emissions, and releases to the Columbia River via permitted discharge of treated effluent and historic discharge of slag.

Study Area Description

Figure S-1 Teck Cominco Smelter Site, Trail, British Columbia

The Teck Cominco smelter is located in the City of Trail, which is situated in the West Kootenay region of south-eastern British Columbia. The smelter facility is in the Columbia River valley, approximately 15 km north of the boundary with Washington State (Figure S-1).

The aquatic ERA Area of Interest (AOI) encompassed the 56-km section of the Columbia River and its tributaries from downstream of the Hugh Keenleyside Dam, and Brilliant Dam on the Kootenay River and Waneta Dam on the Pend d'Oreille River, to the International Boundary (Figure S-2). The Hugh Keenleyside, Brilliant and Waneta dams are physical barriers to fish migration, providing natural up-stream endpoints for the study. Numerous tributaries ranging from small intermittent first-order streams to fourth-order streams containing important fish habitat occur within the AOI. The initial dilution zone immediately downstream of the smelter was considered to be part of the AOI; e.g., there was a sampling station for algae within a few metres of the effluent diffuser. Therefore, risk assessment findings relative to the risk management goals include this zone.

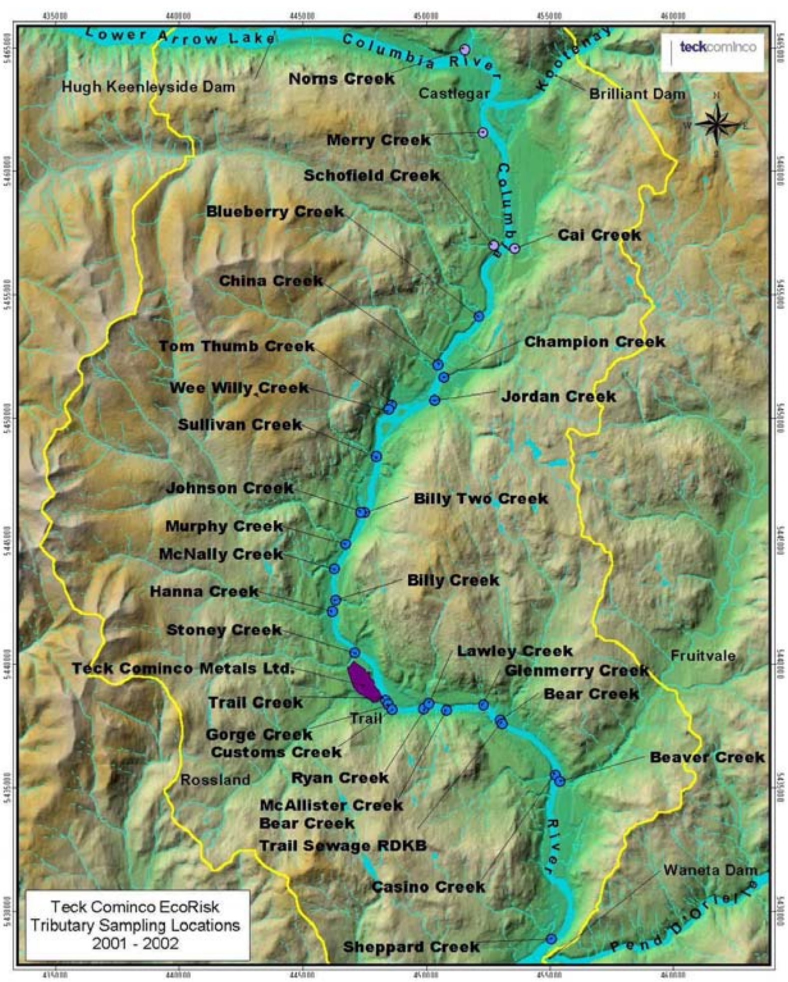


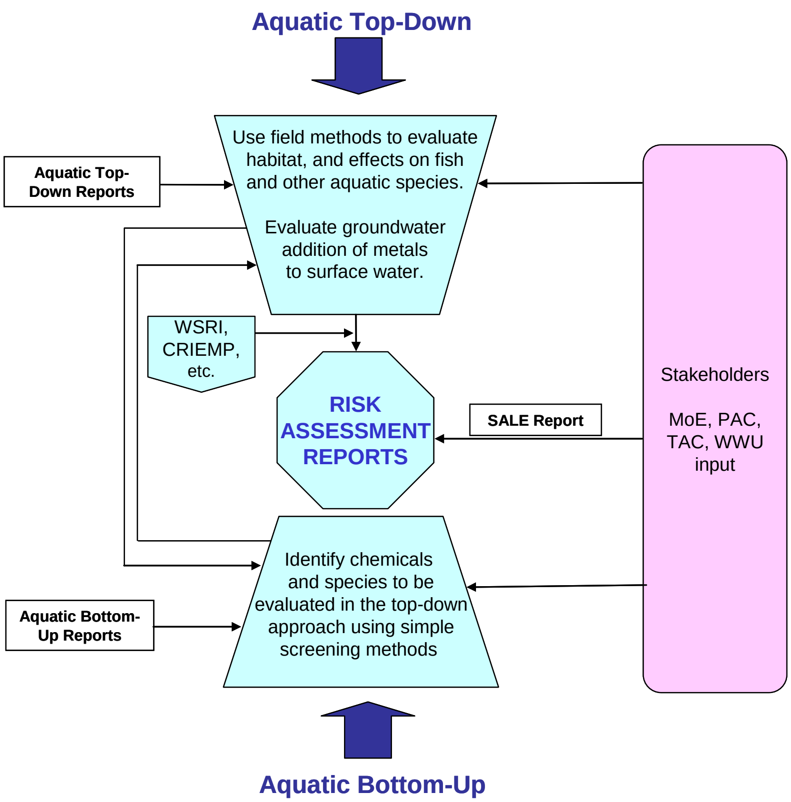
Figure S-2 The AOI for the Aquatic Component of the ERA Showing the Portion of the Columbia River and Its Tributaries Included in the Study Area.

Tributary water sampling locations used in 2002 and 2003 are also shown.

OVERALL APPROACH USED FOR THE ERA

Bottom-Up and Top-Down Perspectives

An ecological risk assessment that covers an area the size of the AOI (80,000 ha) cannot depend upon the traditional chemical-by-chemical risk modelling methods developed for smaller sites. Therefore, the study team decided to use a weight-of-evidence (WOE) approach that incorporated both top-down and bottom-up lines of evidence (Figure S-3).



(WSRI = White Sturgeon Recovery Initiative; CRIEMP = Columbia River Integrated Environmental Monitoring Program; MoE = B.C. Ministry of Environment; PAC = Public Advisory Committee; TAC = Technical Advisory Committee; WWU = Western Washington University).

Figure S-3 The "Top-Down" and "Bottom-Up" Approaches

The bottom-up approach started with examining individual metal concentrations measured over a number of years by Teck Cominco, government agencies and other industries in water, sediment and fish tissue, and then comparing these concentrations with water quality objectives, sediment quality guidelines and any available guidelines for metal concentrations in fish.

The bottom-up perspective continued with comparisons between metal concentrations and published thresholds for effects. The published effects thresholds were for chronic, long-term exposure and sub-lethal effects such as reductions in growth or reproduction. The lowest available published effects thresholds were chosen, providing these thresholds were for species that were relevant to the AOI (i.e., test results for tropical species were not used).

The bottom-up approach compared water, sediment and fish tissue data with water quality objectives, sediment quality guidelines, available guidelines for metal concentrations in fish tissue, and the lowest available published effects levels.

In screening-level risk assessments, comparisons with objectives, guidelines and effects thresholds are often the limit of what is done to estimate risk.

The top-down approach started with field and laboratory studies of effects on aquatic plants, animals or their habitats, and then evaluated whether these effects were linked with smelter emissions. The top-down approach included the use of a gradient study design; that is, a design that followed the responses of aquatic life as metal concentrations changed from upstream of the smelter to immediately below the smelter,

The top-down approach used a combination of laboratory and field studies. Any significant responses were examined for links with smelter emissions. Sampling focused on following the gradient of metal concentrations in water from upstream of the smelter to downstream. Sampling also focused on the areas in the river where sediments settle out and accumulate.

to increasing distances downstream. The gradient approach also assisted with distinguishing responses to other non-smelter stressors in the river. Non-smelter stressors are present throughout the AOI (e.g., flow regulation due to operation of dams which would create responses in aquatic life across the metal gradient). Stressors expected to occur in the same gradient as smelter-related stressors include those associated with treated sewage effluent and storm-water discharge from the City of Trail, as well as stressors present in tributary flow immediately upstream and downstream of the smelter (e.g., metals or nutrients originating from historic landfill areas and past operations of the Teck Cominco fertilizer plant).

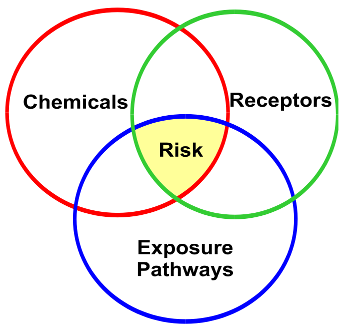
The gradient design in the tributaries to the Columbia River followed metal concentrations from upstream headwater conditions (with lower dilution, but also sometimes lower smelter-related atmospheric deposition) to downstream close to the Columbia River (with greater dilution but higher smelter-related atmospheric deposition). The top-down approach also included a regional groundwater study to determine the relative role of groundwater as a pathway for transport of metals into surface water. Data useful for the top-down approach were obtained from other programs conducted in the AOI including the Upper Columbia White Sturgeon Recovery Initiative (UCWSRI) and the Columbia River Integrated Environmental Monitoring Program (CRIEMP).

Information from bottom-up and top-down approaches formed a set of lines of evidence that were combined into an overall weight-of-evidence.

A separate series of studies on groundwater was initiated in response to questions specific to the smelter site. The results of these studies to date show that groundwater pathways originating on site may contribute to localized aquatic ecological risks off-site. These studies will further define loads and area of potential local effects to biota. Future groundwater data will be used as input to remediation planning as and if appropriate. The information provided by both bottom-up and top-down approaches formed the various lines of evidence that were then combined into an overall weight-of-evidence for the amount of smelter-related risk to aquatic life in the AOI.

Problem Formulation: The First Step in Risk Assessment

Before proceeding into the full assembly of the WOE for risk, the study team conducted a Problem Formulation. Problem Formulation is the first stage of any risk assessment. The purpose of Problem Formulation is to develop a focused understanding of the sources of risk (e.g., sources of chemicals), the pathways that link the stressors to aquatic plants or animals (called "receptors"), and the expected responses in aquatic plants or animals.

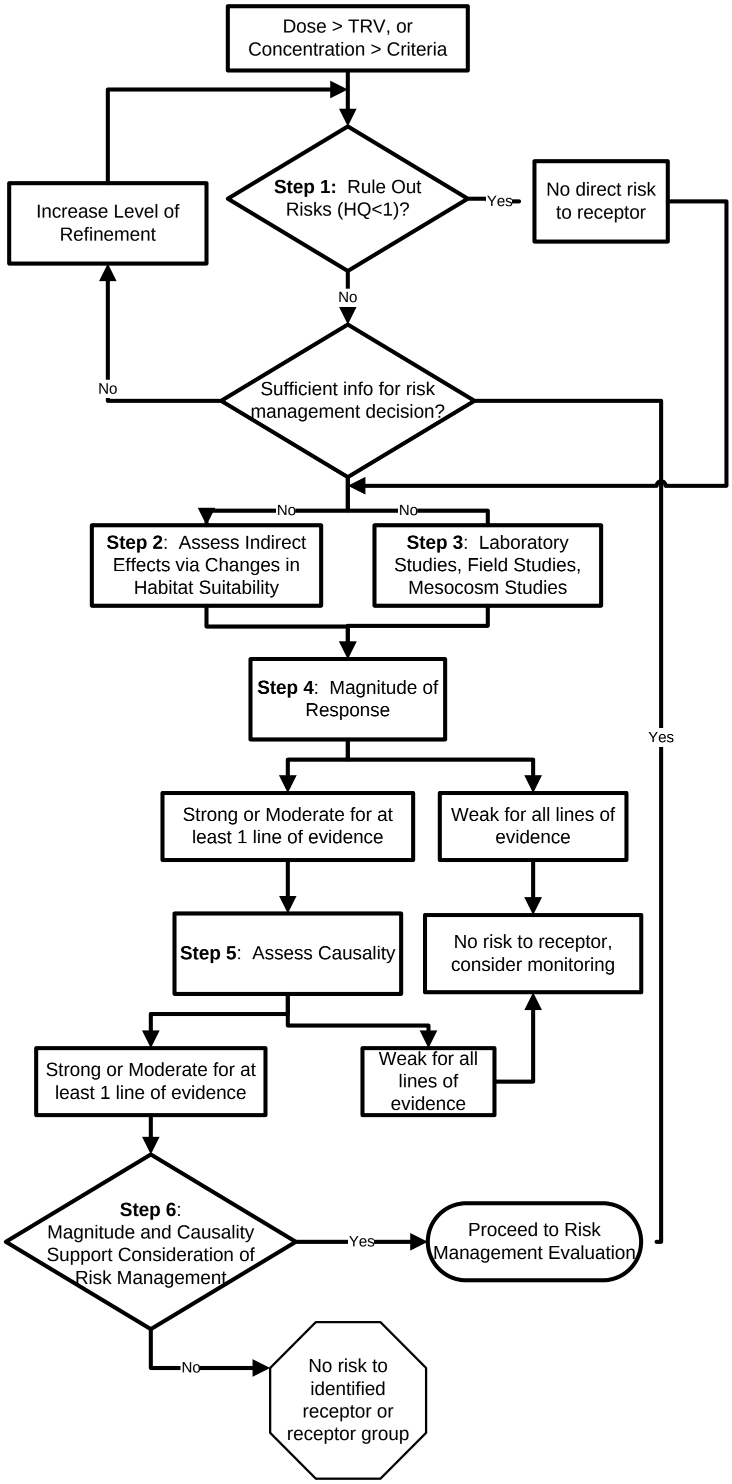


The three required components for risk

"Focus" is the operative word in Problem Formulation. First, we have to understand why we are doing the risk assessment. Therefore, Problem Formulation includes setting risk management goals, objectives, assessment endpoints and measures. These terms are explained in more detail below; however, the main purpose of establishing goals, objectives, endpoints and measures is to allow risk management decisions to be made in the context of a pre-established understanding of what is being protected and how much protection is required. Second, Problem Formulation includes focusing on specific stressors, species, and routes of exposure. This is necessary because it is impractical to assess risk to every possible combination of stressor and receptor. At the end of the Problem Formulation stage, we have developed an initial understanding of what could cause stress to which species, how this could occur, and what the response of those species might be. After we have narrowed down the assessment, we can proceed with assembling a WOE for risk.

Sequential Analysis of Lines of Evidence (SALE): a New Method for Assembling a Weight-of-Evidence for Risk

A new method was developed by the study team to assemble all of the lines of evidence into an overall WOE. This method is called the Sequential Analysis of Lines of Evidence (SALE) (Hull and Swanson 2006). The SALE approach uses lines of evidence in sequence, starting with the bottom-up evidence (which is best used for screening purposes) and then proceeding to the top-down, field-based lines of evidence (Figure S-4).



(TRV = Toxicity Reference Value; HQ = Hazard Quotient.)

Figure S-4 The Sequential Analysis of Lines of Evidence Process

Description of the SALE Process

The sequential aspect of the SALE process is based upon two primary ideas. First, risks can be ruled out using certain lines of evidence, including comparisons of water or sediment quality with conservatively-derived effects benchmarks. In Step 1, the SALE process recognizes that comparison with effects benchmarks is most useful in ruling out risk rather than predicting risk to ecological populations or communities. Second, the SALE process requires that each line of evidence where risks are not ruled out is assessed for three things: (1) the magnitude of effect; (2) the strength of the cause/effect link with the smelter; and, (3) the uncertainty caused by natural variability plus our lack of knowledge about ecological processes. These three criteria are evaluated together to characterize the degree of risk from smelter emissions (Steps 2-5). The magnitude of effects must be greater than negligible for the SALE to proceed beyond Step 4 into an analysis of cause/effect. The exception to this rule is if there is high uncertainty attached to the magnitude rating. It is only when the combination of magnitude and evidence for a cause/effect link with the smelter are strong enough that risk management is considered (Step 6).

The SALE approach explicitly includes interaction between risk assessors and risk managers. It illustrates to risk managers how risk management can go beyond the simple derivation of risk-based concentrations of chemicals of concern in water or sediment to risk management goals based on ecological objectives (e.g., species diversity or fish health). It also can be used to stimulate discussion of the limitations of the science of ecological risk assessment, and how scientists deal with uncertainty. It can assist risk managers by allowing their decisions to be based on a sequential, flexible and transparent process that includes direct toxicity risks, indirect risks (via changes in habitat suitability and food web interactions), and the spatial and temporal factors that may influence the risk assessment.

External Review of the ERA Approach

The overall approach used for the ERA, as well as interim reports, were reviewed by a Technical Advisory Committee (TAC), a Public Advisory Committee (PAC), and other external reviewers, including Dr. Wayne Landis of Western Washington University. The TAC included representatives of federal and provincial regulatory agencies.

RESULTS OF THE PROBLEM FORMULATION: THE FIRST STAGE OF THE RISK ASSESSMENT

Risk Management Goal and Objectives


The Columbia River valley

Risk management objectives were developed in accordance with the risk management goal of **"no significant ecological impacts or constraints on desired land and water uses, in the Area Of Interest (AOI), related to past and present Teck Cominco smelter operations"** The management objectives translate the more general management goal into statements about what must occur in order for the goal to be achieved. The TAC and the PAC were asked to provide review and input to the risk management objectives for aquatic life. The aquatic risk management objectives are:

- **Minimize, now and in the future, smelter operation-related direct and indirect effects within the AOI on the diversity of aquatic plant and animal communities in the Columbia River and its tributaries.**
- **Minimize, now and in the future, smelter operation-related direct and indirect effects within the AOI on fish populations in the Columbia River and its tributaries.**
- **Prevent, now and in the future, smelter operation-related direct and indirect effects on threatened and endangered aquatic species in the AOI.**

Meeting the Risk Management Objectives

We know that risk is minimized or prevented when we are sufficiently confident that the magnitude of effects shown to have a cause-effect link with smelter emissions is minimal.

In order to meet the risk management objectives, risk must be minimized or prevented. The question is "how do we know when risk is minimized or prevented?" The SALE approach is designed to answer this question by evaluating three important considerations: (1) the **magnitude** of effects (i.e., how large a change in aquatic life abundance, diversity, or other measurements was observed?); (2) the **strength of the cause/effect link** with smelter emissions (i.e., is it likely that the observed changes were caused by the smelter?); and, (3) **uncertainty** (i.e., how sure are we about the accuracy and precision of our measurements, our understanding of how smelter emissions would cause effects, and our ability to detect these effects?).

Is there a response downstream of the smelter and is that response large enough to be ecologically significant?

Magnitude is judged in several ways. First, the amount of the measured response can be compared with statistical definitions of "critical effect size". The "critical effect size" is the required degree of statistical difference between reference and exposed aquatic populations or communities to qualify as an ecologically significant difference. The critical effect size is designed to distinguish between natural variation and a response to a stressor. For example, there can be very high natural variation in abundance of bottom-dwelling invertebrates from reference site to reference site, or from year-to-year. In order for a statistically significant difference in abundance to be regarded as an ecologically significant response to a stressor (such as metals from the smelter), the change in abundance at sites exposed to smelter emissions would have to be greater than the range of natural variation at reference sites. Of course, this means that we must have done enough sampling to be confident that (a) we have a good understanding of the range of natural variability, and (b) that we have enough sampling power in our study design to distinguish the "signal" of an effect from the "noise" of natural variability.

The second method for judging magnitude is to evaluate the strength of the statistical correlation between measurements (such as species diversity) and concentrations of smelter-related metals in water or sediment. Very low correlations indicate that factors other than smelter-related metals are likely to be controlling the abundance and diversity of aquatic life. Moderate or high correlations indicate that smelter-related metals are likely to be influencing abundance and diversity of aquatic life.

The third method for judging magnitude is to use general scientific knowledge about which species are sensitive to metals and which species are tolerant of metals and examine the presence of metal-sensitive and metal-tolerant species in exposed sites. In some cases, there is a relatively good scientific understanding of the response of aquatic communities to metals. For example, the response of attached algae (periphyton) to metals has been studied for many years, and we know which groups of attached algae tend to disappear when metal concentrations are elevated. Thus, if these groups of metal-sensitive attached algae are absent, we have an indication that smelter-related metals are affecting the attached algae community.

How strong is the evidence for a cause/effect link between the measured response and the smelter?

Causation is judged using formal causation criteria originally designed for use with studies of the causes of human disease. These criteria have been modified for this study and include:

- spatial correlation (the responses correspond with where metal concentrations are elevated)
- temporal correlation (the responses occurred after the release of smelter-related metals occurred)
- gradient of response (the response increased as metal concentrations increased)

- plausibility of a connection to smelter-related metals (there is a known mechanism for metal effects on the aquatic community and the response was of the expected magnitude)
- consistency of response (there were repeated observations of metal effects in the AOI, and there is existing knowledge from other regions where similar metal concentrations have caused similar effects)
- experimental verification (metal effects were observed under controlled conditions and there was concordance of these experimental results with field data)
- specificity (the effect is specific to metals).

Each line of evidence is examined against these causal criteria and an overall score is produced that reflects the strength of the evidence for a cause/effect link between smelter emissions and the measured responses in aquatic plant or animal life. It is very rare that a line of evidence meets all causal criteria; therefore, even if some of the evidence for causality is weak, a line of evidence can still be valid.

How sure are we about our ability to distinguish a response from natural variability? How well do we understand the ecology of the river and the possible effects of the smelter on the river ecosystem?

Uncertainty is evaluated by examining three things: (1) how well the field sampling captured natural variability; (2) the adequacy of information on other factors (apart from the smelter) that could also be responsible for the measured characteristics of the aquatic life; and, (3) our general level of knowledge about the ecology of large river ecosystems and what level and type of effect would cause overall changes in ecosystem structure (e.g., diversity of plant or animal species) or function (e.g., yearly production of fish).

The combination of magnitude, causation and uncertainty scores was used to determine whether risks were minimal. For example:

- if the magnitude of the response observed in the field or during toxicity tests does not exceed the critical effect size, and the strength of causation link with the smelter is weak and uncertainty is low, then risk is minimal; or
- if the magnitude of the response exceeds the critical effect size but the causation link is weak and uncertainty is low then the risk is minimal; or
- if the magnitude of the response exceeds the critical effect size and the causation link is strong and the uncertainty is low-to-moderate, then some action may be required to minimize the risk.

Assessment Endpoints and Measures: Specific Aquatic Ecosystem Components and Characteristics to be Protected

In order to assess whether each risk management objective is met, "assessment endpoints" are selected. Assessment endpoints specify what is to be protected in the aquatic ecosystem. For example, an important component of the Columbia River ecosystem is the attached algae (periphyton) community and one of the characteristics of this community to be protected is the species diversity (also called community composition). Therefore, the assessment endpoint is attached algae community composition.

Each assessment endpoint has associated measures used to determine if the assessment endpoint (and thus the risk management objective) is being met. For example, if the assessment endpoint is white sturgeon spawning, the spawning success of white sturgeon can be measured by the use of egg incubation trays placed at the spawning grounds.

Each line of evidence used in this ERA is made up of measures of assessment endpoints. The assessment endpoints and associated measures for each risk management objective are presented below.

Risk Management Objective #1:

Minimize, now and in the future, smelter operation-related direct and indirect effects within the AOI on the diversity of aquatic plant and animal communities in the Columbia River and its tributaries.

Assessment Endpoints

- attached algae community composition; and,
- benthic (bottom dwelling) invertebrate community composition.

Measures

The measures for the attached algae and benthic invertebrate communities are listed below for the mainstem Columbia River as well as the tributaries (see parentheses after each line of evidence).

Attached algae growth on cobble

Stonefly nymph – an example of a benthic invertebrate

Attached Algae Community

- metal concentrations in water compared to effects benchmarks derived from the literature (Columbia River and tributaries);
- attached algae community composition along a gradient from upstream to downstream (Columbia River);
- total abundance (numbers/m^2) and total biomass (chlorophyll *a* + dry weight) along the upstream to downstream gradient (Columbia River and tributaries); and,
- presence of metal-sensitive attached algae species (Columbia River).

Periphyton biomass (chlorophyll *a* and dry weight) supplements information on community composition by providing an indication of the amount of energy stored by periphyton that is available for consumption. It is important to measure effects on biomass because of the importance of periphyton as a food source. Reduced biomass of algae means less food for herbivorous invertebrates and fish.

Benthic (Bottom-Dwelling) Invertebrate Community

- metal concentrations in water and sediment compared to effects benchmarks derived from the literature (Columbia River and tributaries);
- toxicity to *Chironomus tentans* (a midge species) in laboratory sediment toxicity tests (Columbia River);
- various measures of species diversity along the upstream to downstream gradient (Columbia River and tributaries, though tributary data are qualitative because of the sampling method used);
- abundance along the upstream to downstream gradient (Columbia River and tributaries, though tributary data are qualitative because of the sampling method used); and,
- presence of metal-sensitive benthic invertebrate species (Columbia River).

Information on natural factors that influence attached algae and benthic invertebrates was gathered at the same time as the above measures; e.g., water temperature, dissolved oxygen, pH and sediment characteristics (such as visual observation of % slag content and measurement of % clay, silt, sand and gravel).

Risk Management Objective #2:

Minimize, now and in the future, smelter operation-related direct and indirect effects within the AOI on fish populations in the Columbia River and its tributaries.


Prickly sculpin


Mountain whitefish

Assessment Endpoints

- growth, condition and reproductive capability of selected representative fish species in the Columbia River (mountain whitefish, prickly sculpin);
- fish habitat quality in the Columbia River; and,
- fish habitat quality in the tributaries.

Measures (Lines of Evidence)


Electrofishing for fish upstream of the smelter

- metal concentrations in water and fish tissue compared to effects benchmarks derived from the literature (Columbia River);
- measures of health in mountain whitefish and prickly sculpin (Columbia River);
- laboratory fish toxicity test results (e.g., LC50s, EC50s) required under Teck Cominco's provincial licence to operate (Columbia River); and,
- fish habitat quality for spawning, rearing, feeding and over-wintering (Columbia River and tributaries).

Risk Management Objective #3:

Prevent, now and in the future, smelter operation-related direct and indirect effects on threatened and endangered wildlife and aquatic species in the AOI.


White sturgeon

Assessment Endpoints

- presence, survival, and reproductive success of white sturgeon in the AOI; and,
- habitat quality for white sturgeon in the AOI.

Measures

- white sturgeon presence and use of habitats in the AOI;
- mapped habitat suitability for white sturgeon;
- White Sturgeon Recovery Initiative information (including data on spawning success and recruitment of young sturgeon into the population, metal concentrations in sturgeon tissue, incidence of

deformities in young sturgeon in the AOI and laboratory toxicity tests on young sturgeon).

Potential Chemicals of Concern and Pathways of Exposure

Potential Chemicals of Concern (PCOC) were identified by screening maximum observed concentrations in water and sediment against the lowest available water and sediment quality guidelines or objectives.

Potential Chemicals of Concern (PCOC) were identified by screening maximum observed concentrations in water and sediment against the lowest available water and sediment quality guidelines or objectives. PCOC common to water and sediment in the mainstem of the Columbia River and its tributaries were: arsenic, cadmium, chromium, copper, lead, thallium, and zinc. Mercury was identified as an additional PCOC for water; cobalt, iron, and selenium were included as PCOC for tributaries; nickel and silver were included as PCOC for sediments.

Aquatic life in the AOI can be exposed to the PCOC through several routes, or exposure pathways. The sources of the PCOC are the discharges of treated smelter wastewater into the Columbia River, release into the air via the stack emissions, groundwater originating at the smelter site and migrating off-site, and historic discharge of slag into the river (which ended in 1995). The primary exposure pathways are water, sediment, and food items.

It was assumed that stressors released on the smelter site would be confined and mitigated on site; however, groundwater pathways from the site to the river were investigated and considered. Nutrients from the former Cominco fertilizer operations were also considered but were not formal PCOC.

The ERA considered risks associated with stressors originating from the smelter that migrate outside the Teck Cominco site. It was assumed that effects due to localized stressors (e.g., fuel tank leakage) would be confined to the site and mitigated, thereby preventing effects at a larger spatial scale. Nutrients from the former fertilizer operation were considered and discussed as part of the periphyton assessment but were not PCOC.

Selected Representative Species or Communities

It is not practical to assess risk to each aquatic species present in the AOI; therefore, it is standard practice to select species or communities that are important components of the food web, and are sensitive and/or prone to be the most highly-exposed to the PCOC because of their food preference or their habitat. Some of the representative species should be highly valued by people. In addition, there should be sufficient knowledge about the chosen representative species or communities to allow interpretation of the results.


Attached algae along the shoreline


Benthic invertebrates in a sorting tray


White sturgeon


White sturgeon


Mountain whitefish


Prickly sculpin

The attached algae community and the benthic invertebrate community were chosen because they are important components of the aquatic food web. The attached algae community contains species known to be sensitive to metals and can be highly exposed via water at locations where PCOC concentrations in water are elevated. The benthic invertebrate community also contains species known to be sensitive to metals and can be highly exposed to metals via sediments; e.g., at locations where historic slag deposits remain. There have been studies of attached algae and benthic invertebrates in the past (e.g., before and after the installation of the Kivcet smelter which greatly reduced emissions of metals).

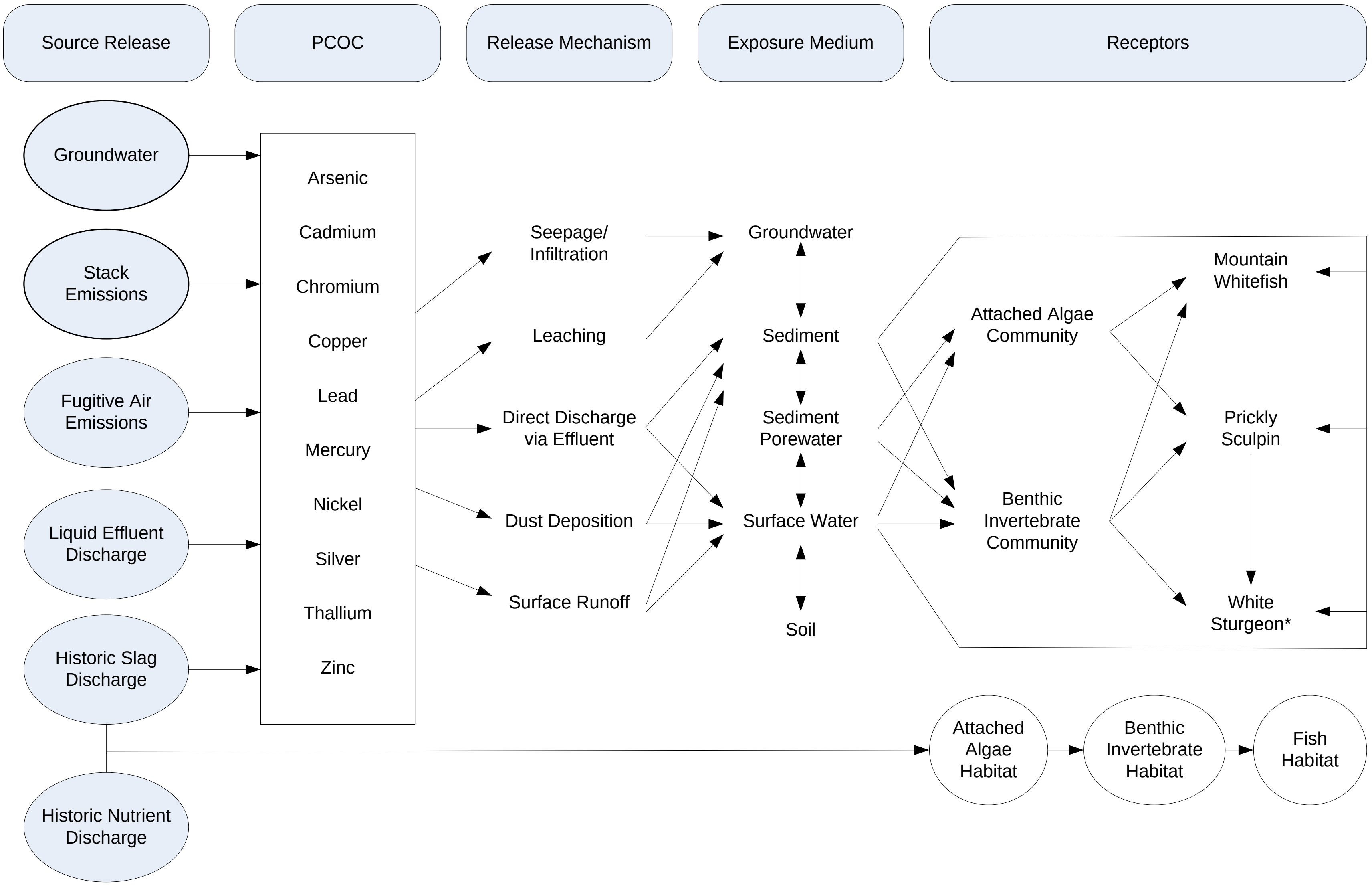
Representative species or communities of organisms were selected on the basis of their position and importance in the food web, their sensitivity to metals, their relative exposure to metals due to their habitat and food habits, their relative abundance, and their importance to people.

Mountain whitefish, white sturgeon, and prickly sculpin were chosen as representative fish species. Mountain whitefish was chosen on the basis of the availability of historic and current data on fish health, the degree of exposure of this bottom-feeding species to metals, and its relative abundance (and thus ease of capture along the gradient of exposure). White sturgeon was chosen because it is a red-listed species in British Columbia, and is now listed under the federal Species At Risk Act (SARA). Prickly sculpin was chosen from among several candidate small-bodied fish species after a preliminary field program in the spring of 2004, which indicated that prickly sculpin were present in sufficient numbers to obtain the required sample size for valid statistical analysis along the gradient of exposure. Prickly sculpin live in a relatively small area of the river their whole lives; therefore, they are a good choice for studying more localized effects. Furthermore, they are part of the food chain leading to predator fish.

Conceptual Models of Risk to Aquatic Life in the AOI

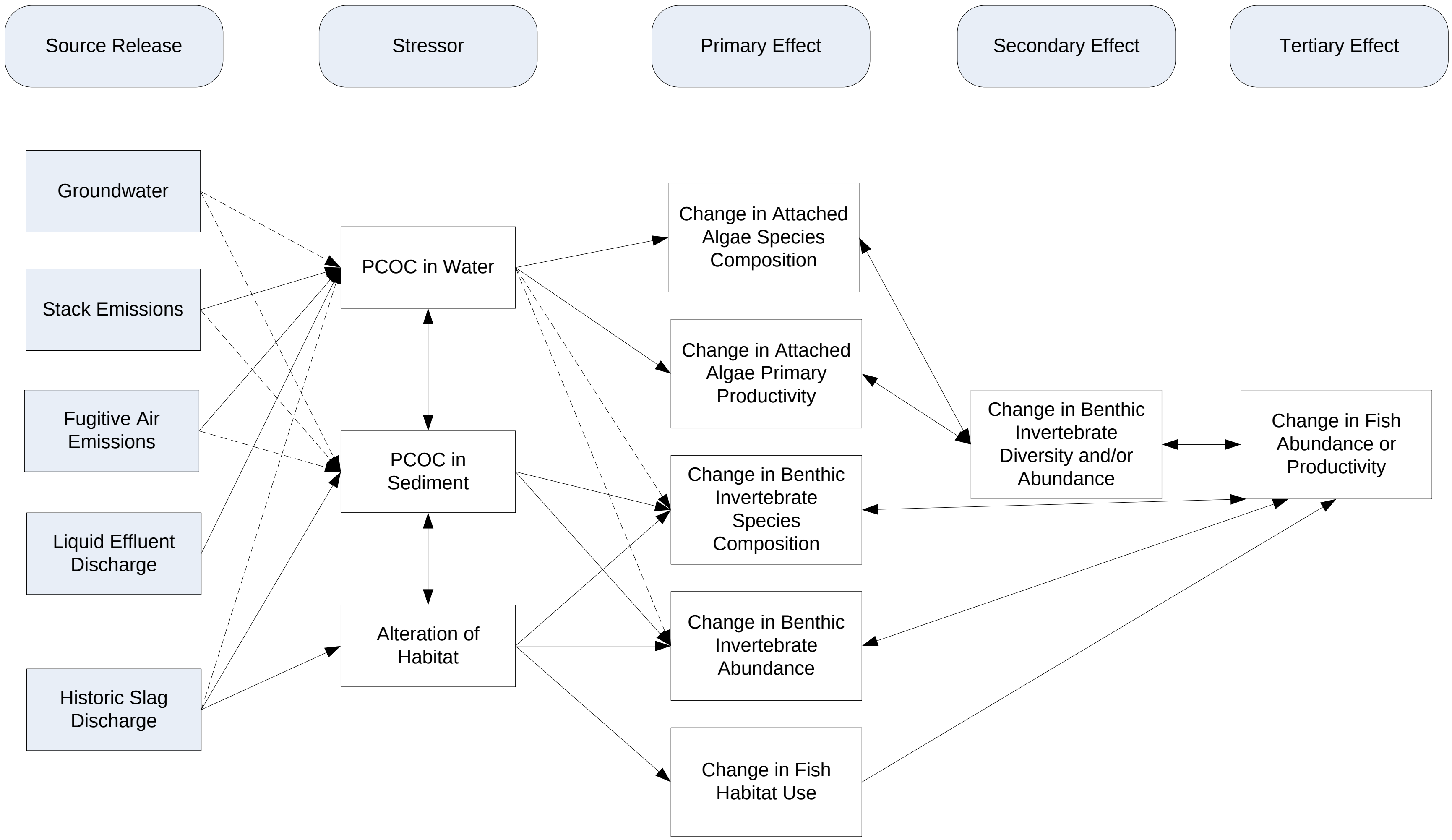
Risks to aquatic life from exposure to PCOC can occur in two ways: (1) direct effects via the toxic action of PCOC on aquatic plants or animals; and, (2) indirect effects via changes in the quantity or quality of food items, changes in the species composition within the food chain (e.g., a decrease in metal-sensitive invertebrates that graze on algae), behavioural effects (e.g., avoidance of burrowing in sediment with elevated metals), or via physical changes in the habitat. Two conceptual models were produced to represent these two risk mechanisms.

Conceptual Model 1 of Direct Risks from Smelter Emissions



* Sturgeon are opportunistic feeders and eat live and dead fish, invertebrates and plants.

Conceptual Model 2 of Indirect Risks from Smelter Emissions



Note:
Dotted lines identify minor contributors to exposure or effects.

Other Sources of Risk to Aquatic Life in the AOI

Brilliant Dam

Looking upstream toward Zellstoff Celgar pulp mill

The Teck Cominco smelter is not the only source of risk to aquatic life in the AOI. Other sources include agricultural and urban runoff, emissions from the Zellstoff Celgar pulp mill, flow regulation by the Hugh Keenleyside, Brilliant and Waneta dams, and input of sediments to the Columbia River or its tributaries via erosion caused by transmission corridors, roads and railroads. Direct impacts on fish result from recreational fishing and various fish management programs, including introduction of species such as walleye in the U.S.

This risk assessment accounted for the effects of other sources by using information from other studies, such as the Columbia River Integrated Environmental Monitoring Program (CRIEMP), Environmental Effects Monitoring (EEM) conducted by Zellstoff Celgar, studies by B.C. Hydro on fish distribution and abundance and total dissolved gas effects, and data collected in support of the White Sturgeon Recovery Initiative (WSRI).

ASSESSMENT OF RISK TO AQUATIC BIOTA IN THE TRIBUTARIES OF THE COLUMBIA RIVER

Smelter-related risk to aquatic biota living in the tributaries of the Columbia River was evaluated in a screening-level assessment. The screening-level assessment consisted of Step 1 of the SALE process (comparison with water and sediment quality guidelines and benchmarks for effects) and a qualitative approach to the other SALE steps. A “qualitative” approach means that the assessment was done using observations about the habitat made by the field crews, as well as data from sampling that did not meet all of the requirements of a fully-quantitative statistical study design. If the screening-level assessment had shown that there were moderate or high risks in any of the tributaries, then a more detailed, fully quantitative assessment would have been conducted. However, moderate or high risks were not identified. Therefore, the assessment of risks to tributaries was limited to the screening-level assessment.

Pathways Linking Smelter Emissions to Tributaries

The key linkage between the smelter and tributaries is deposition from smelter air emissions to soils and then either surface runoff or seepage from soil to groundwater.

The key linkage between smelter emissions to the air and tributaries was deposition of PCOC to the soil of tributary watersheds followed by either:

- surface runoff during rainfall or snow-melt transporting PCOC to tributary water and sediment; or,
- seepage of PCOC down through the soil to the groundwater which then discharges to the tributaries.

A regional groundwater investigation by Klohn Crippen (2006) showed that the majority of water flow in the tributaries originates from areas above 800 m elevation, and that these flows provide substantial dilution flow for areas below 800 m. A regional model of water cycling from air-to-surface water-to-groundwater showed that on an average annual basis, 48% to 66% of precipitation input to the tributaries is lost back to the atmosphere via evapotranspiration and 1% to 8% seeps into the groundwater. The remaining 30% to 44% of the precipitation input becomes surface runoff to the creeks; however, most of this occurs during spring melt and high rainfall events. During low-flow periods, groundwater makes up much of tributary flow. Therefore, data on the surface water quality in tributaries during low-flow periods provides information regarding the relative amount of PCOC carried by groundwater to the tributaries.

A regional groundwater study showed that most of the water flow in tributaries originates above 800 m elevation and that during low-flow periods, groundwater makes up much of the flow.

Tributaries Selected for the Screening-Level Assessment

Ryan Creek

China Creek

Five creeks within the AOI were selected to represent tributaries that may be affected by smelter emissions: Murphy, China, Ryan, Sullivan and Bear creeks. These systems were selected based on their presence within the AOI, their similar size, the presence of elevated metals in past samples, and the use of the tributaries by both resident and migratory fish stocks (e.g., for spawning in their lower reaches by Columbia River-based fish species).

Blueberry Creek

Three reference creeks were selected to provide information for comparison: Blueberry, Norns and Deer creeks. These systems were selected because they showed no sign of effects on water or sediment quality from smelter emissions but were still within the Columbia River watershed, and thus were representative of the watershed's natural metal concentrations. However, the reference creeks are not pristine; there are other activities such as roads, transmission corridors, logging and historic mining in the reference watersheds.

Results of Step 1 of SALE for the Tributary Assessment

Although PCOC concentrations exceeded water quality objectives or sediment quality guidelines at least once in all of the tributaries studied, risks were judged to be low.

Risks were judged to be low because some PCOC exceeded water quality objectives in both reference and exposure creeks, and because there was no consistent pattern in PCOC concentrations relative to the

All of the study creeks have at least two other human activities in their watershed that could contribute PCOC.

Fine sediments where PCOC can accumulate are very rare in the

Risk to aquatic life in tributaries due to PCOC concentrations in water and sediment was not ruled out in Step 1 because all of the five "exposure creeks" had at least one instance of PCOC concentrations in water exceeding water quality objectives or sediment quality guidelines.

Although risk from PCOC in water and sediment was not ruled out, the available information showed that risk is very low. There were several reasons for this conclusion:

- First, concentrations of some PCOC exceeded water quality objectives in both reference and exposure creeks, indicating the presence of natural concentrations that also exceed objectives (this also illustrates how conservative the objectives are).
- Second, there was no consistent pattern in PCOC concentrations in water at upper, middle or lower tributary sites. If smelter emissions were the dominant source of PCOC, concentrations in water (during low flow with no confounding effect of dilution from runoff) would be expected to be higher at lower elevations where most of the deposition of smelter-related PCOC occurs.
- Third, all of the study creeks have at least two anthropogenic activities in their watersheds that could contribute PCOC to the tributaries, including rights-of-way, logging and residential agricultural use.
- Fourth, PCOC concentrations in the five exposure creeks were much lower than in exposure locations at the Teck Cominco Kimberley site (where extensive toxicity testing took place); the Trail area exposure tributaries had concentrations that were similar to Kimberley area reference sites.
- Fifth, toxicity test data from the Kimberley area identified zinc as the greatest potential risk to aquatic life; however, the risks were described as "low". The Trail area zinc concentrations were an order of magnitude lower than at Kimberley. Therefore, it is unlikely that toxicity tests conducted on water or sediment from the Trail area tributaries would show effects.
- Finally, fine sediments where PCOC would accumulate are very rare in the tributaries to the Columbia River because of the steep gradient of these systems. There were only three locations where fine sediments were found and two of these locations were in reference creeks.

A wetland area of Ryan Creek was the only location where risk from PCOC was judged to be sufficient to warrant follow-up work.

The only exception to the conclusion that risk to aquatic life in tributaries is low was in a wetland area of Ryan Creek. In the wetland, PCOC concentrations in fine sediments were substantially higher than guidelines. The wetland was the only location in any of the exposure creeks containing fine sediments. Therefore, follow-up on sediment-related risk is focussing on wetlands areas. This follow-up work is being conducted outside of the scope of this ERA.

Ryan Creek wetland

Results of Steps 2-4 of SALE for the Tributary Assessment

Attached algae:

View of attached algae along shoreline

Data collected in 2005 from the five exposure creeks and three reference creeks were examined for evidence of direct effects from PCOC (Conceptual Model 1) or indirect effects via changes in habitat or changes in food quantity or quality (Conceptual Model 2). Data collected in other studies were also included in the evaluation. Three groups of aquatic organisms were examined: attached algae, benthic invertebrates, and fish.

The amount of attached algae growth was low at both reference and exposure sites, and was typical of mountain streams with very low nutrient content. There was a high degree of variability from creek-to-creek and also between different locations within a creek.

The 2005 data do not show strong evidence for risk to attached algae from metal concentrations. However, there may have been effects in the past in Bear, McNally, McAllister, and Glenmerry creeks.

Concentrations of PCOC in 2005 did not exceed effects thresholds for attached algae. Effects thresholds were derived from the scientific literature and were based on the lowest concentrations reported to have caused effects in any algal species. Previous data from earlier years show some risk from cadmium and zinc in Bear Creek, McNally Creek, McAllister Creek, and Glenmerry Creek because concentrations of these two metals exceeded effects thresholds.

Benthic Invertebrates:

Tributary sampling for invertebrates– Blueberry Creek

Water quality variables, including PCOC, were not strong determinants of the benthic communities in the study streams: rather, communities largely reflected habitat variation.

No dramatic or consistent differences were found in benthic invertebrate community composition between reference and exposure sites in 2005. There were similar numbers of taxa (species, genera or families, depending upon the level of identification) and the distribution of individuals across the taxa present was also similar. The exception was upper Bear Creek, where larval blackflies were exceptionally abundant, likely because of very good habitat for larval blackflies at that location (i.e., not because of any smelter-related effect).

There were no consistent correlations between concentrations of metals, nutrients or other water quality variables and benthic invertebrate community variables. This suggests that water quality variables were not strong determinants of the benthic communities in the study streams: rather, communities largely reflected habitat variation.

Concentrations of PCOC measured in 2005 did not exceed effects thresholds for benthic invertebrates. However, concentrations of cadmium and zinc were above effects thresholds during previous studies in several creeks, including Hanna, Ryan, and Bear creeks.

Fish and Fish Habitat:

Rainbow trout, a species present in some tributaries

Typical tributary habitat (Deer Creek)

Fish use of the tributaries is limited by natural or anthropogenic barriers to upstream movements. The steepness of the creek channels and large bed material sizes (boulders and cobble) limit spawning opportunities for salmonid species such as rainbow trout. The lower reaches of some of the tributaries are used by fish species that reside in the mainstem Columbia River; these reaches provide important spawning and rearing habitat for mainstem populations of salmonids.

Six of the study tributaries are known to support resident fish populations (Deer Creek, Norns Creek, Blueberry Creek, China Creek, Hanna Creek, and Murphy Creek). Species diversity is higher in the three reference streams (Deer, Norns, and Blueberry creeks). Bull trout and rainbow trout are common to all tributaries that support resident fish populations.

The three reference tributaries are known to support seven to nine species; whereas, the exposure streams are known to support one or two species. The difference is likely a result of habitat availability and quality in the reference streams versus that of the exposure streams, rather than exposure to PCOC. The three reference streams tend to be large (stream lengths of 17 to 31 km and third-order watersheds) and have more complex stream networks, which is typical of larger streams with greater drainage areas. Therefore, it is likely that more habitat is available in the reference streams. The lower reaches of the three reference streams also appear to have lower gradients, as there are suitable gravel deposits for salmonid spawning (which provide important spawning habitat for Columbia River mainstem populations). In addition, the majority of the exposure streams had very short sections of channel


Lower Ryan Creek showing typical steep gradient and boulder substrate

There is little evidence to indicate that PCOC concentrations would be a driving factor in determining fish community composition or fish abundance in the tributaries.

that were accessible from the Columbia River (80 to 200 m), due to the presence of anthropogenic or natural barriers. This would also serve to limit the available habitat that could support fish.

Given the difference in watershed characteristics between the reference and exposure streams and the limited fisheries information, it is not possible to determine if there have been direct or indirect effects on fish resulting from metal deposition in the watersheds. However, water quality data indicate that only silver and zinc concentrations exceed effects thresholds, and zinc concentrations in reference streams also exceed these benchmarks. Furthermore, the evidence for low metal-related risk to the attached algae or benthic invertebrate communities shows that risks to fish via indirect effects on food supply would also be low. Therefore, there is little evidence to indicate that PCOC concentrations would be a driving factor in determining fish community composition or fish abundance in the tributaries.

Risk Characterization for the Tributary Assessment: Should We Proceed to Consideration of Risk Management?

None of the lines of evidence for the tributaries provide strong evidence for smelter-related risks to tributary systems.

None of the lines of evidence for the tributaries provide strong evidence for smelter-related risks to tributary systems. Because each of these lines indicated similar evidence of low risk from metals, there is confidence in the overall assessment of low risk from smelter emissions to tributary systems. Natural habitat variables are likely to be the primary determinant of attached algae and benthic invertebrate communities. Natural habitat features and anthropogenic barriers to fish movement appear to be primary factors influencing fish presence in the tributaries.

The available information indicates that any follow-up investigations done to address uncertainty should focus on wetland-type habitats within the tributary systems because these habitats are where water and sediment metal concentrations are usually the most elevated.

Because of the lack of evidence for smelter-related risks to aquatic life in tributary systems, it is not necessary to proceed to consideration of risk management. However, there are several sources of uncertainty in the assessment. The available information indicates that any follow-up investigations done to address uncertainty should focus on wetland-type habitats within the tributary systems because these habitats are where water and sediment metal concentrations are usually the most elevated. The fish habitat quality of erosional areas in the remainder of the tributary systems does not demonstrate any pattern of metal-related effects.

ASSESSMENT OF RISK TO AQUATIC BIOTA IN THE MAINSTEM COLUMBIA RIVER

The assessment of risks to aquatic life in the mainstem Columbia River used the full SALE process for a formal evaluation of magnitude of effect, strength of evidence for causation and rating of uncertainty.

Results of Step 1 of the SALE Process

Step 1 of the SALE process is illustrated in Figure S-5.

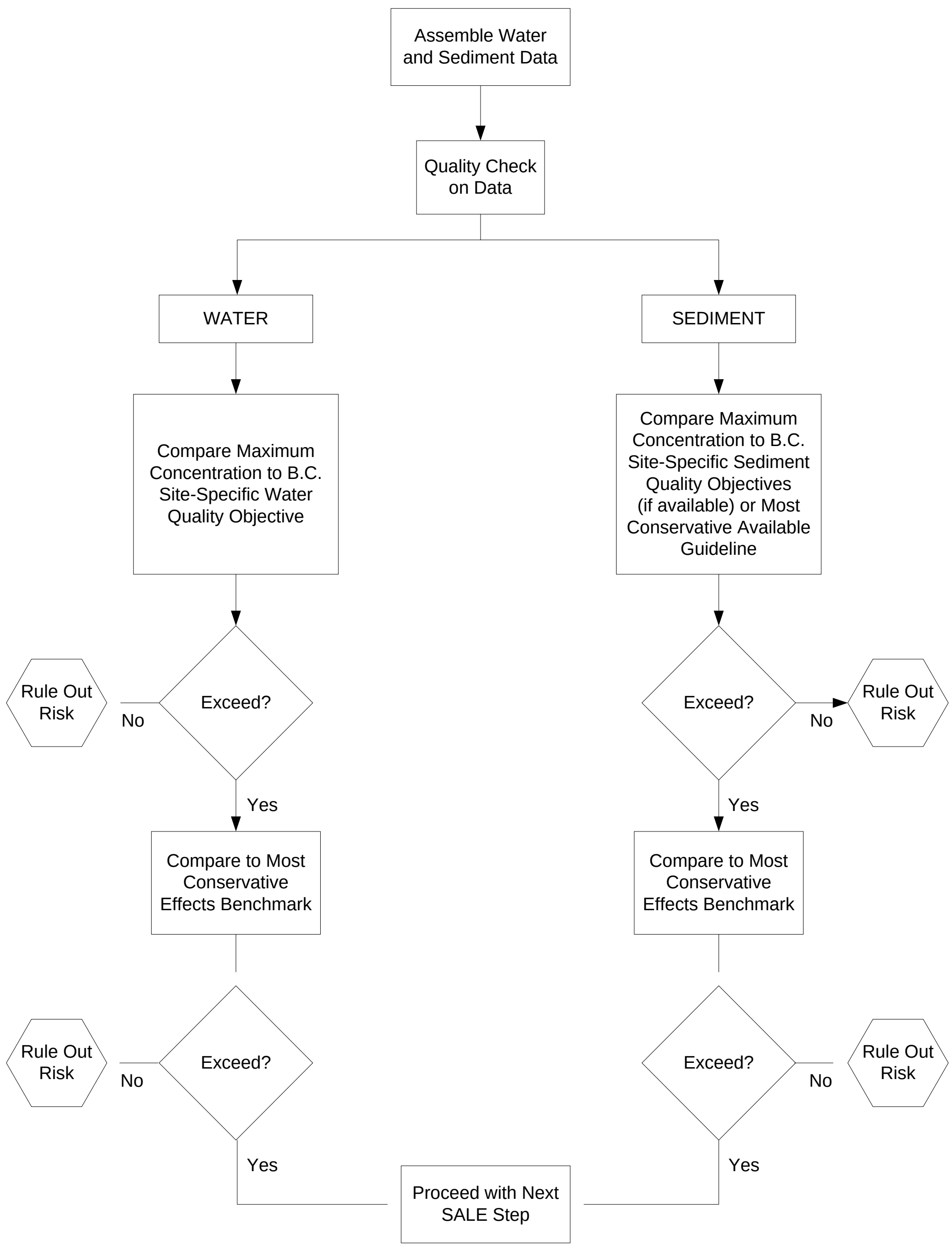


Figure S-5 Step 1 of the SALE Process

The comparison with water quality objectives and sediment quality guidelines was completed during the Problem Formulation. Of the total original list of chemicals, 8 metals in water and 9 metals in sediment in the area of interest were identified as potential chemicals of concern (PCOC) (Table S-1).

Table S-1 PCOC in the Mainstem of Columbia River

	Water	Sediment
1	Arsenic	Arsenic
2	Cadmium	Cadmium
3	Chromium	Chromium
4	Copper	Copper
5	Lead	Lead
6	Mercury	Nickel
7	Thallium	Thallium
8	Zinc	Silver
9		Zinc

Water quality objectives are not effects benchmarks. They are set to be deliberately protective. Therefore, if PCOC concentrations are less than water quality objectives, risks can be ruled out with confidence.

Water quality objectives are not effects benchmarks. Water quality objectives in Canada are based upon the principle of no effect on any aquatic species anywhere; therefore, they incorporate so-called safety factors. These safety factors are applied to effects benchmarks found in the scientific literature. For example, if the lowest benchmark for effect on any aquatic test species in the literature is 10 mg/L, a safety factor of 10 is applied to produce the water quality objective of 1 mg/L. Because of the built-in safety factors, exceedance of water quality objectives does not mean that there will be effects on aquatic organisms. Therefore, as a secondary screening stage in Step 1, maximum water and sediment concentrations measured from 1995 to 2001 were compared to effects benchmarks for each group of aquatic receptors (attached algae, benthic invertebrates and fish). These effects benchmarks were derived from the literature. The selected benchmarks were conservative to ensure that risks could be ruled out with confidence.

Details on the selection of effects benchmarks, the literature sources of the benchmarks and comparisons with data from the study area were presented in the Aquatic Problem Formulation report (Golder 2003).

The results of Step 1 may over-estimate the potential for risk to aquatic life because water and sediment quality data collected since 2001 that show further declines in the concentrations of some of the PCOC were not screened against effects benchmarks. This was because the risk assessment had proceeded to the next steps in the process; i.e., field studies. As a consequence, some of the PCOC carried forward to subsequent steps in the assessment may not have been necessary and should have been ruled out; e.g., arsenic. However, the study team is confident that the remainder of the SALE process deals with the potential for over-estimation of risk through the use of field-based lines of evidence and a formal cause/effect evaluation.

The results of Step 1 may over-estimate the potential for risk to aquatic life because water and sediment quality data collected since 2001 that show further declines in the concentrations of some of the PCOC were not screened. This is because the risk assessment had proceeded to the next steps in the process.

Risks to attached algae from concentrations of PCOC in water could be ruled out for arsenic, chromium, mercury and thallium because maximum concentrations observed from 1995 to 2001 did not exceed conservative effects benchmarks. Risks to attached algae from concentrations of cadmium, copper, lead and zinc could not be ruled out because maximum concentrations exceeded effects benchmarks on at least one occasion. However, many of the concentrations that exceeded the effects benchmarks occurred in earlier years of the period 1995-2001.

Risks to benthic invertebrates from concentrations of PCOC in water were ruled out for chromium, mercury and thallium. Risks from the remaining PCOC could not be ruled out.

Concentrations of all PCOC in sediments exceeded effects ranges on at least one occasion at the Waneta sampling station. Therefore, no risks could be ruled out.

Cadmium, copper, and zinc concentrations in water exceeded chronic effects benchmarks for fish at least once; however, all of these exceedances occurred in earlier sampling periods (1995 or 1999). Risks to fish from concentrations of the other PCOC in water were ruled out.

Risks to fish from tissue concentrations of arsenic, chromium, copper, mercury, nickel, lead, selenium, thallium and zinc were ruled out. Copper concentrations in fish muscle were above the concentration reported to have an effect on survival.

In summary, the PCOC retained for further assessment are:

Water:
- arsenic, cadmium, chromium, copper, lead, zinc

Sediment:
- arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, zinc

Fish Tissue:
- copper

Attached Algae: Results of SALE Steps 2-6


Attached algae sampler in place at the Stoney Creek sampling site

The attached algae community was evaluated using field studies of attached algae colonization of artificial substrates consisting of a tray of glass slides (see adjacent photos) placed in the Columbia River in a gradient from upstream to downstream (Figure S-6).


Artificial substrates used to study attached algae

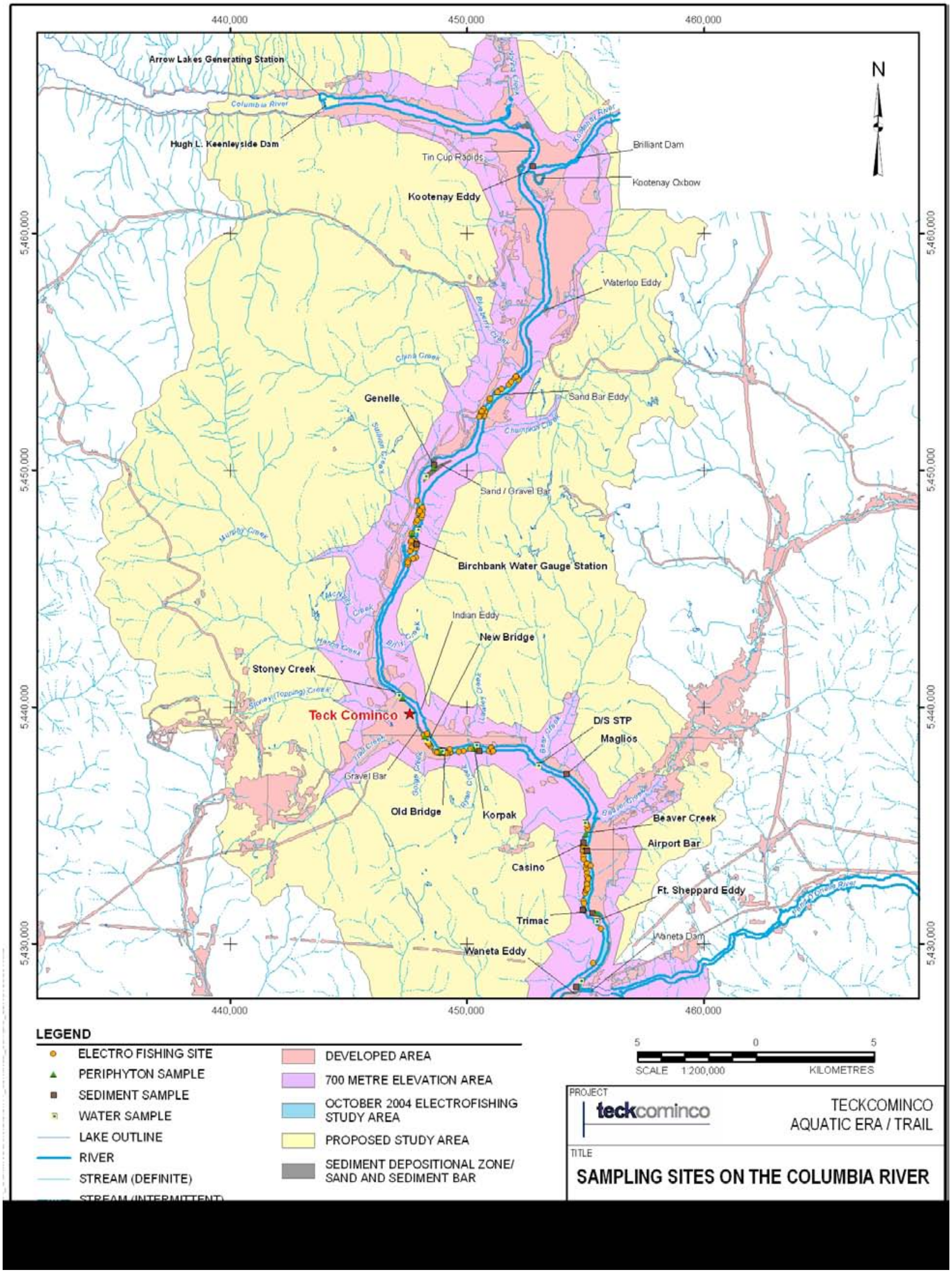


Figure S-6 Sampling Sites on the Columbia River.

Step 2: Effects on Habitat

Heavy *Fontinalis* (a type of attached alga) growth on cobble during period of discharge from Teck Cominco phosphate fertilizer plant (pre-1994)

Current effects of slag on the physical habitat for attached algae in the AOI are minimal. Since the cessation of slag discharge in 1995, most historic slag deposits in shallower water habitats where periphyton occur have been scoured and moved downstream. Remaining slag in shallow-water zones is limited to small amounts trapped in gaps between the cobble or interspersed with the gravel and sand.

Current condition of shoreline area near the west side of Trail; note the lack of any heavy attached algae growth

Current effects of slag on the physical habitat for algae within the AOI are minimal.

Nutrient concentrations are low, with no evidence of effects on algae growth except perhaps in areas adjacent to storm-water discharges and Trail Creek and Ryan Creek mouths

Groundwater may affect localized areas of algae habitat near Stoney Creek and near the southeastern margin of the smelter site.

Flow regulation is the most important confounding variable affect the physical habitat for attached algae.

Nutrient concentrations in the river are low, with no evidence of effects on algal growth or species composition within the AOI, with the possible exception of areas adjacent to storm-water discharges from the City of Trail, as well as inputs from Trail Creek and Ryan Creek. Nutrient conditions were historically higher downstream of Trail because of the discharge from the Teck Cominco fertilizer plant. These discharges resulted in a luxuriant growth of periphyton in some areas of the river. Since the cessation of phosphate-rich discharges from the phosphate portion of the Teck Cominco fertilizer plant in 1994, the growth of periphyton and aquatic plants such as cattail and sedge along the shoreline downstream of Trail has dramatically decreased.

Storm-water discharges from Trail occur within the initial dilution zone of the smelter. Stressors within storm-water discharge can include nutrients. Trail Creek is affected by urban runoff from Rossland and Warfield and by input from Haley Creek, which is influenced by drainage from legacy waste materials adjacent to the Teck Cominco Fertilizer Operations. In addition, during the timeframe of the periphyton studies, a small number of direct household sewer connections to Trail Creek were still in use (subsequently eliminated by the City of Trail). A groundwater investigation conducted on the Teck Cominco smelter site revealed two areas of groundwater contamination that may affect water quality in localized areas of algae habitat, one on the northern boundary of the site in the vicinity of Stoney Creek and one on the southeastern margin of the site. The area near Stoney Creek is affected by seepage recharge from Stoney Creek and by the Regal Landfill. The groundwater plume at the southeastern margin of the smelter site has the potential to affect the physical habitat of periphyton by creating localized impacts on water temperature. Furthermore, this plume may cause localized exceedances of water quality objectives in the immediate vicinity of discharge into the riverbed.

The most substantial confounding variable is flow regulation due to operation of dams in the AOI. Periphyton in shallower shoreline areas of the river are regularly exposed to desiccation during flow reductions related to river regulation for power production and flood control.

Steps 3 and 4: Assessment of the Response of the Attached Algae Community in the Columbia River

Magnitude of the Response

The magnitude of response in measures of algal biomass was evaluated according to the degree of upstream-to-downstream difference, as well as whether there was evidence of a gradient with distance from the smelter. Consistency between this study and a previous study was also examined.

The magnitude of response in the three measures of biomass (chlorophyll *a*, ash free dry weight and cell density) was evaluated using three criteria: (1) whether there was any change downstream versus upstream of the smelter in 2003; (2) whether there was an indication of a gradient in the response; i.e., changes in biomass decreased with increasing distance from the smelter in 2003; and, (3) the degree of consistency in responses downstream of the smelter observed in the 1999 post-Kivcet study and the 2003 study.

The magnitude of response in algae community composition was evaluated based on the degree of upstream-to-downstream difference, correlations between community composition and PCOC concentrations, and similarity among sites.

The magnitude of response in measures of community composition was evaluated by examining: (1) statistically significant differences in community metrics upstream versus downstream of the smelter; (2) statistically significant correlations between community metrics and concentrations of PCOC; and, (3) the degree of similarity among sites as determined by comparisons using the Bray-Curtis index. The magnitude criterion for the qualitative measure of "presence of sensitive or tolerant species" is a narrative based upon a conservative interpretation of the relative occurrence of sensitive or tolerant species; i.e., all it takes is a difference in one species to push the magnitude from low to moderate.

Attached algae responses were greatest at the New Bridge site, which is about 25 metres from the smelter effluent discharge.

Attached algae responses were greatest at the New Bridge site (approximately 25 metres from the effluent discharge) within the permitted "initial dilution zone: The New Bridge site had one high-magnitude response, based upon several significant correlations between lead and thallium concentrations and some algae species. This site had a moderate-magnitude decrease in algal abundance (as measured by chlorophyll content and cell numbers) and another moderate-magnitude decrease in the presence of metal-tolerant algae species at the New Bridge, which was not expected and which indicates the presence of non-smelter factors that affect species composition (e.g., water flow velocity).

Near the New Bridge site

The shoreline adjacent to the Korpak site

The Korpak site had one moderate and one high magnitude response. There were significant negative correlations between the proportion of specific taxa and cadmium and zinc concentrations at this site. The Korpak site was also dissimilar to other sites when examined using the Bray-Curtis similarity index.

All other sites except the Genelle site had at least one significant negative correlation between the proportion of specific taxa and the concentration of arsenic, cadmium, lead, thallium and zinc. These findings were given a moderate magnitude ranking.

Correlations between algal species composition and cadmium and zinc concentrations were observed at the Korpak site.

Table S-2 Criteria Used to Assign a Score for the Magnitude of Effect on Attached Algae

Line of Evidence	Method of Assessment of the Line of Evidence	Evidence of Negligible to Low Magnitude ○	Evidence of Moderate Magnitude ⦿	Evidence of High Magnitude ●
Periphyton Community Biomass	Qualitative analysis of trends in chlorophyll *a*, ash free dry weight and cell density upstream-to-downstream of the smelter. Statistical analysis was not conducted because of the loss of 1 of 3 replicates at the New Bridge and Old Bridge sites.	No decline in chlorophyll *a*, ash free dry weight or cell density downstream of the smelter.	Some decline in chlorophyll *a*, ash free dry weight and/or cell density downstream of the smelter relative to upstream, but no evidence of a gradient in the response; i.e., decreasing response with increasing distance downstream.	Definite decline in chlorophyll *a*, ash free dry weight and cell density downstream of the smelter relative to upstream and evidence of a gradient in the response; i.e., responses decrease with increasing distance downstream.
Periphyton Community Composition	Statistical analysis community metrics versus PCOC concentrations of upstream-to-downstream sites; narrative description of presence of metal-sensitive taxa and metal-tolerant taxa.	No significant difference ($p < 0.05$) in community composition metrics at the site vs. other sites; no significant correlation between community metrics and PCOC concentration; Bray-Curtis analysis shows site is similar to all others; no difference in presence of metal-sensitive or metal-tolerant species.	A significant difference ($p < 0.05$) in community metrics at the site vs. other sites; at least one statistically significant ($p < 0.05$) correlation between community composition metrics and PCOC concentration; Bray-Curtis index comparison shows the site is dissimilar to at least one other site; a difference in presence of at least one metal-sensitive or metal-tolerant species.	A significant difference ($p < 0.05$) in community metrics at the site vs. most or all other sites; most or all community metrics have a significant correlation with PCOC concentration; Bray-Curtis index comparison shows site is dissimilar to most or all other sites, especially sites with lower PCOC concentrations; differences in presence of several metal-sensitive or metal-tolerant species.

Criteria Used to Evaluate the Amount of Uncertainty

There are two major sources of uncertainty: natural variability and the level of our understanding of how smelter emissions may cause effects.

As explained above, there are two major sources of uncertainty: natural variability, and our understanding of how smelter emissions may cause effects, either directly, or indirectly (which is portrayed in the two conceptual models). Uncertainty in the assessment of the magnitude of response was evaluated according to how well natural variability was addressed and how well the data supported the conceptual models of smelter-related effects (Table S-3).

The same criteria for judging the amount of uncertainty were used for all lines of evidence.

The criteria for judging the amount of uncertainty presented in Table S-3 were used for all of the lines of evidence (for attached algae, benthic invertebrates and fish). The following discussion presents the reasoning behind the criteria. This reasoning was applied to all lines of evidence.

Recording velocity of the water at the Korpak site – an example of a factor contributing to natural variability

Uncertainty is judged by the ability of the sampling design to distinguish a response from natural variability. Natural variability is the result of the response of aquatic plants and animals to factors such as water depth, flow, substrate characteristics, temperature, and the amount of light that enters the water column. Natural variability can be very large, which creates difficulties when we try to tell the difference between sampling sites or between one sampling year and another. For example, the difference in attached algae abundance between a site upstream of the smelter and another site downstream of the smelter may be due to differences in water velocity at the two sites and not PCOC discharged by the smelter. There are statistical methods that can be used to determine the number of samples required to produce a certain level of confidence that we can tell the difference between natural variability and the response to human activities. These methods help us understand the amount of so-called "statistical power" in our sampling design. Therefore, one of the ways that we can judge our uncertainty when evaluating a particular line of evidence is to examine the statistical power of our sampling.

Cobble substrate: substrate type is an important factor contributing to natural variability

Uncertainty is also judged by how well we understand the relative role of natural variables in determining the characteristics of aquatic populations and communities (the second row of bullets under "natural variability" in Table S-3). Observational field studies (such as those conducted for this assessment) should include measurement of all important natural variables that could contribute to the measured response in aquatic life. If measurement is not practical, then a narrative description of the variables should be produced (e.g., a description of the relative amount of growth of rooted aquatic plants).

We are more confident that natural variability is accounted for in the study design if all measurements of the response to the smelter show a consistent direction (i.e., increase or decrease) as well as a consistent magnitude. Responses within sites closer to the smelter (where PCOC concentrations are higher) should be similar, and responses should decrease with decreasing PCOC concentration. Therefore, another criterion used to judge uncertainty is consistency in the measured response (the third row of bullets under "natural variability" in Table S-3).

Sandy substrate: there will be differences in aquatic life at this site compared to the site with cobble substrate shown above

We have confidence that our two conceptual models are not in error if the data support the models (Table S-4). Model error is a reflection of our ignorance about how stressors affect aquatic populations and communities. The two conceptual models developed for this assessment put forward the ideas that: (1) the PCOC emitted from the smelter directly affect aquatic life through exposure via water, sediments or in food items; and, (2) smelter emissions indirectly affect aquatic life through physical changes in habitat quality or through changes in the abundance or distribution of prey and predators. One or both of these conceptual models could be in error.

Table S-3 Criteria Used to Assign a Score for Uncertainty Related to Our Understanding of Natural Variability and the Role of Natural Variables

Uncertainty Score		
Low (?)	**Moderate (??)**	**High (???)**
- there are enough samples to be confident that we can tell the difference between a response and natural variability (this is called statistical power)	- there are not enough samples to be confident that we can tell the difference between a response and natural variability (statistical power is less than standard requirements)	- there are very few samples and we are sure that we cannot tell the difference between a response and natural variability
- all important natural variables that could affect the attached algae response are measured and are part of the statistical analysis	- most important natural variables that affect the attached algae response are measured, and others that are not measured are at least described	- most important natural variables that affect the response are not measured, and narrative descriptions are not always available for those that are not measured
- all measurements of the response (e.g., abundance and diversity) show a consistent direction (increase or decrease) and magnitude	- most measurements of the response show consistent direction and magnitude	- measurements of the response do not show consistent direction and magnitude

Table S-4 Criteria Used to Evaluate a Score for Support for the Two Conceptual Models

Source of Uncertainty	Strong Support (?)	Moderate Support (??)	Weak or No Support (???)
Conceptual Model 1 (Direct Effects)	**Several Lines of Evidence Are Available *and* They Indicate Direct Effects** - several lines of evidence from the laboratory and the field indicate the presence of direct effects	**At Least Two Lines of Evidence Are Available *and* At Least One Indicates Direct Effects** - at least two lines of evidence indicate the presence of direct effects	**Only One Line of Evidence is Available *or* Most or All Lines of Evidence Do Not Indicate Direct Effects** - only one line of evidence is available and it indicates direct effects, *or* there is more than one line of evidence but most or all show that there are no direct effects
	All Important Confounding Variables Are Quantified *and* They Do Not Account for All of the Observed Responses - all important confounding anthropogenic variables that affect the attached algae response are quantified *and* their contribution to the observed biological response is well-understood *and* the responses to the other stressors do not account for all observed responses; therefore, the conceptual model can still be valid	**Most Confounding Variables Are Quantified *and* They Do Not Account for All of the Observed Responses** - most of the important confounding anthropogenic variables that affect the biological response are quantified and others that are not quantified are described with a narrative *and* the contribution to the observed biological response is understood for at least some of the stressors *and* the responses to the other stressors may account for most of the observed responses; therefore, the validity of the conceptual model is in question	**Confounding Variables Are Not Quantified *or* They Do Account for Most or All of the Observed Responses** - most of the important confounding anthropogenic variables that affect the response are not quantified or described, *or* the confounding variables are quantified and the responses to these variables account for all of the observed responses; therefore, the conceptual model does not apply

Table S-4 Criteria Used to Assign a Score for Support for the Two Conceptual Models (continued)

Source of Uncertainty	Strong Support (?)	Moderate Support (??)	Weak or No Support (???)
Conceptual Model 2 (Indirect Effects)	**Data Available *and* They Strongly Support Hypotheses of Indirect Effects** - data are available from laboratory and/or field experiments designed to test the hypothesis of indirect effects at environmentally realistic PCOC concentrations, *and* the data show that indirect effects are occurring - responses measured in field observational studies (these are not experimental studies) are greater than would be expected at the observed PCOC concentrations, *and* the pattern of response cannot be explained on the basis of direct effects of PCOC concentrations alone, *and* there are data collected at the same time for all major links in the food chain that indicate effects due to changes in food chain interactions	**Limited Data Available *and* Some Data Support Hypotheses of Indirect Effects** - some data are available from laboratory and/or field experiments, *and* indirect effects are one of the plausible explanations for the results of the experiments - responses measured in field observational studies are greater than expected at the observed PCOC concentrations, *or* data collected at the same time for all major links in the food chain indicate that there may be effects due to changes in food chain interactions	**No Data Available *or* the Data Do Not Support Hypotheses of Indirect Effects** - no experimental data are available, *or* indirect effects are not a plausible explanation for the results of the experiments - responses measured in field observational studies are expected at the observed PCOC concentrations, *or* the pattern of response can be explained on the basis of direct effects of PCOC concentrations alone, *or* data collected at the same time for all major links in the food chain indicate that there are no effects due to changes in food chain interactions
	Sufficient Knowledge to Develop Hypotheses of Multiple Stressor Effects *and* Data Support these Hypotheses - multiple stressor effects in the receiving environment are well-understood because of relevant experimental data for that environment and/or comprehensive field data that show responses that are explained best by indirect mechanisms *and* the observed responses are in accordance with the understanding of multiple stressor effects in the study area	**Limited Knowledge with Tentative Hypotheses of Multiple Stressor Effects *and* Data are in Partial Accordance with These Hypotheses** - multiple stressor effects in the receiving environment are somewhat understood because of some relevant experimental data for that environment and/or limited field data that show responses that are explained best by indirect mechanisms *and* the observed responses are at least partly in accordance with the understanding of multiple stressor effects in the study area	**Insufficient Knowledge to Develop Hypotheses of Multiple Stressor Effects *or* Data are not in Accordance with Multiple Stressor Hypotheses** - multiple stressor effects in the receiving environment are not understood because of the lack of any relevant experimental data for that environment and/or the lack of any field data that show responses that are explained best by indirect mechanisms, *or* multiple stressor effects are well understood or somewhat understood and the observed responses are not in accordance with this understanding

If the Conceptual Model 1 for direct effects is valid, the data will show toxicity from the PCOC. Confounding stressors (such as flow regulation) will not account for the observed responses.

The criteria for judging support for Conceptual Model 1 (direct effects) address how well the information from laboratory and field studies support the hypothesis of direct toxicity. The criteria also address our understanding of the role that confounding anthropogenic stressors (such as flow regulation) could play in producing the observed responses (Table S-3). If the data show toxicity and if other stressors do not account for the responses, then we have confidence that our conceptual model for direct effects is valid. However, if data do not show toxicity, or the responses could be caused by stressors other than those produced by the smelter, then our conceptual model for direct effects may be invalid.

If the Conceptual Model 2 for indirect effects is valid, the data will show effects of habitat change or food chain interactions that produce responses over and above those caused by direct toxicity of the PCOC.

The criteria for judging support for Conceptual Model 2 (indirect effects) address whether laboratory or field data are consistent with the hypothesis of indirect effects via habitat change or food chain interactions and whether we understand how several stressors (called multiple stressors) would interact. For example, if the responses observed are greater than would be expected given the PCOC concentrations *and* the pattern of response cannot be explained on the basis of direct effects of PCOC concentrations alone, *and* there are data collected at the same time for all major links in the food chain that indicate effects due to changes in food chain interactions, then we have confidence that the Conceptual Model is valid. However, if data show that there are no changes in food chain interactions, or that the responses can be explained on the basis of the direct toxicity of the PCOC alone, then the conceptual model may be invalid.

Our knowledge of how multiple stressors interact in the environment is very limited. Therefore, the uncertainty related to multiple stressor effects will always be high.

Our general state of knowledge about how multiple stressors interact is very limited. A rigorous, theoretical basis for the prediction of multiple stressor effects is not available in the scientific literature. Despite the wealth of published observational data, and the existence of several useful tools for interpretation of cause/effect relationships, there are no tools that allow a confident prediction of ecosystem response to multiple stressors (Swanson *et al*. 2004). Therefore, although the criterion regarding multiple stressors is included in Table S-3 for completeness, in reality, the uncertainty related to multiple stressor effects will always be high and the validity of the conceptual model for indirect effects due to multiple stressor interactions will be unknown.

Uncertainty in the Attached Algae Lines of Evidence

There is a moderate level of uncertainty in the ability to tell the difference between natural variability and a possible response of attached algae to the smelter.

The uncertainty due to variability is moderate because: the study design did not have a high level of statistical power; several variables known to affect attached algae communities were not accounted for in the sampling design; confounding anthropogenic stressors were present near at least one of the downstream sampling sites; there was a lack of correspondence between statistical correlations with PCOC and exceedances of water quality objectives; and, there was a disparity between cell density and algal biomass in 2003.

Insufficient data were available before the implementation of the attached algae study to calculate the required number of replicates per site to achieve the desired statistical power. Notwithstanding the lower-than-ideal statistical power, responses that were distinguishable from natural variability were detected in response to the gradient in PCOC concentrations. However, the magnitude of the response may be underestimated.

There are many natural factors that affect the abundance and diversity of attached algae.

The development of attached algae communities is determined by several natural factors. These factors are: physical habitat characteristics; the relative competitive advantage of various algal taxa under the current habitat conditions; and, the changes created by the attached algae on habitat conditions (which can give a competitive advantage to new species). The sampling design did not account for all of these variables. For example, frequency of high flow events is an important factor that determines attached algae community structure. Therefore, it is difficult to compare attached algae community assemblages between years in the Columbia River (which has a highly variable hydrological regime) even if samples were collected on the same day.

Other sources of stressors to the attached algae community include flow regulation due to operation of dams and localized sources such as storm sewer outfalls.

There are other anthropogenic sources of stressors in the AOI that may also affect the attached algae community. The regulation of river flow due to the operation of dams can leave the attached algae community either "high and dry" or at water depths where light penetration is low. Storm-water discharges from Trail occur within the initial dilution zone of the smelter, directly confounding the interpretation of data from the New Bridge and Old Bridge sites. Stressors within storm-water discharges can include nutrients, metals, and organic compounds. During the timeframe of the attached algae studies, a small number of direct household sewer connections to Trail Creek were still in use (these have since been eliminated). Trail Creek discharge is most likely to confound the interpretation of data from the Old Bridge and Korpak sites. Ryan Creek contains elevated PCOC concentrations, possibly related to a combination of natural ore bodies in the watershed and historic mining activity. Ryan Creek discharge is most likely to confound the interpretation of data from the Korpak site.

There is low-to-moderate support for Conceptual Model 1, which predicts direct effects from the smelter.

The evidence provides a low-to-moderate level of support for Conceptual Model 1. Although there were some high and moderate-magnitude responses at the New Bridge and Korpak sites, confounding natural and anthropogenic stressors are present at these sites. In particular, the high-velocity conditions at the New Bridge site may have limited colonization on the samplers while confounding stressors originating from storm-water discharges and Trail and Ryan Creeks may have influenced the results.

There is weak support for Conceptual Model 2, which predicts indirect effects from the smelter.

The evidence provides weak support for Conceptual Model 2. There are no experimental data regarding indirect effects using environmentally realistic concentrations of PCOC for the study area. The pattern of response in the field is not strongly indicative of indirect effects because the response can be explained by a combination of natural variability, direct effects of PCOC immediately downstream of the smelter and effects of non-smelter stressors such as storm-water discharge.

The ability to assess future risks to attached algae is limited by the extent to which the operation of the smelter can be predicted. This assessment assumes that the smelter outputs can reasonably be predicted for 10-20 years.

The level of confidence in the ability to assess future risks is limited by the extent to which the operation of the smelter can be predicted. This assessment assumes that the smelter outputs can reasonably be predicted for 10-20 years. During this period, climate change will not affect the mainstem Columbia River as much as in other areas because of the storage capacity in the Columbia River system due to impoundments. Furthermore, the terms of the Columbia River Treaty govern how river flow is managed. This assessment assumes no change in the terms of the Treaty. Therefore, a change in river flows and volumes sufficient to affect PCOC concentrations is not anticipated for the 10-20 year time period identified for this assessment.

Step 5: Assessment of Causation for Attached Algae Lines of Evidence

The evidence for a cause/effect relationship between smelter-related emissions and attached algae responses is weak.

The responses observed in the AOI did not present strong, consistent evidence of a link to smelter emissions as per Conceptual Model 1. In no case did all lines of evidence at a site indicate strong causative links. The probable confounding influence of non-smelter related stressors was illustrated by the low magnitude of response, the lack of a strong or consistent gradient upstream-to-downstream, and the lack of consistency in response.

The potential for indirect effects as per Conceptual Model 2 via changes in grazing pressure or alterations in competitive interactions appears to be low; however, the uncertainty associated with Conceptual Model 2 is high, partly because of the lack of experimental data that test hypotheses related to indirect effects. The pattern of response along the upstream-to-downstream gradient does not appear to be consistent with the hypothesis of indirect effects.

Step 6: Attached Algae Risk Characterization

The risk management objective for attached algae is:

> *"Minimize, now and in the future, smelter operation-related direct and indirect effects within the AOI on the diversity of aquatic plant and animal communities in the Columbia River and its tributaries."*

The New Bridge site

The combination of magnitude, causation, and uncertainty scores was used to produce a recommendation regarding the need for management of risks to the attached algae community (Table S-5). Physical effects on attached algae habitat are not included in this table because there were no physical effects with a magnitude greater than "low". Table S-5 does not include a score for the level of support for the two conceptual models; the uncertainty score in this table is for uncertainty related to natural variability and our understanding of the role of natural variables. As noted above, there is little support for the direct effects hypothesized in Conceptual Model 1 or the indirect effects hypothesized in Conceptual Model 2.

Table S-5 Summary of Magnitude, Uncertainty and Causation Scores for the Lines of Evidence for Attached Algae

Site	Periphyton																		Presence of Sensitive Taxa			Proceed to Consideration of Risk Management Options?
	Total Cell Density			Chlorophyll *a*			Ash Free Dry Weight			Statistical Difference in Community Metrics Among Sites			Correlation Between Community Metrics and PCOC Concentra-tions			Bray-Curtis Similarity						
	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	
Stoney Creek	⊙	O	??	⊙	⊙	??	O	O	??	O	O	??	⊙	⊙	??	O	O	??	O	O	??	Dealt with in separate risk management program
New Bridge	⊙	O	??	⊙	⊙	??	O	O	??	O	O	??	●	◉	??	O	O	??	⊙	◉	??	Yes
Old Bridge	O	O	??	O	O	??	O	O	??	O	O	??	◉	◉	??	O	O	??	O	O	??	No
Korpak	●	O	??	O	O	??	O	O	??	O	O	??	◉	⊙	??	◉	O	??	O	O	??	Yes
Beaver Creek	O	O	??	O	O	??	O	O	??	O	O	??	⊙	⊙	??	O	O	??	O	O	??	No
Fort Sheppard	O	O	??	O	O	??	O	O	??	O	O	??	◉	⊙	??	O	O	??	O	O	??	No

Notes:

Magnitude:

- ● strong response.
- ⊙ moderate response.
- O weak response.

Causation:

- ● strong overall strength of causal evidence.
- ⊙ moderate overall strength of causal evidence.
- O weak overall strength of causal evidence.

Uncertainty:

- ? low uncertainty (high statistical power, full gradient design, all important natural variables accounted for).
- ?? moderate uncertainty (moderate statistical power, control/impact rather than full gradient design; most natural variables accounted for).
- ?? high uncertainty (low statistical power, important natural variables not accounted for).

The results of the SALE process indicate that the risk management objective is being met at all sites for the periphyton assessment endpoint except Stoney Creek, New Bridge and Korpak.

The results of the SALE process indicate that the risk management objective is being met at all sites for the periphyton assessment endpoint except Stoney Creek, New Bridge and Korpak. The Stoney Creek site is being dealt with under a separate risk management program. The New Bridge site lies within the initial dilution zone authorized by the current B.C. Ministry of Environment (MOE) license. Nevertheless, risk management options at the New Bridge site will be considered within the context of the risk management goals for the wider ecological risk assessment but addressed through permitting.

There is moderate confidence in the risk characterization because:

- several lines of evidence examined not only for magnitude, but also for causation and uncertainty, indicate that the risk management objective is currently being met at all sites except Stoney Creek, New Bridge and Korpak;

- the uncertainty associated with the individual lines of evidence contributing to the risk characterization is moderate;
- sampling was conducted along a gradient of exposure, including areas of maximum exposure to PCOC from the smelter in the near-field;
- the response of periphyton to metals is well known; therefore, absence of the expected response is important and convincing information;
- natural variability in periphyton was addressed satisfactorily via the sampling design; and,
- no future increases in smelter-related stressors are expected (within the next 10-20 years).

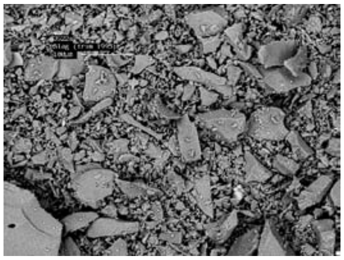
Benthic Invertebrates: Results of SALE Steps 2-6

Taking a Ponar grab sample of sediment

The response of benthic invertebrates to smelter-related stressors (PCOC and slag) was studied using laboratory toxicity testing of sediments as well as field sampling of the benthic invertebrate community in the limited areas of the river where sediments (and slag) tend to settle out. The focus was on sediments because PCOC concentrations in water rapidly fall below effects thresholds outside of the initial dilution zone of the smelter. Samples for toxicity testing and for characterizing the benthic community were taken from sites along an upstream-to-downstream gradient from Kootenay Eddy to the farthest downstream site at Waneta (Figure S-6). The sites upstream of the smelter were Kootenay Eddy, Genelle and Birchbank. The sites downstream of the smelter were Korpak, Maglios, Casino, Airport Bar, Trimac, Fort Sheppard and Waneta.

Emptying a Ponar grab sample of sediment

Step 2: Physical Effects on Habitat



Slag particles

There were historic effects on benthic habitat because of the discharge of slag to the river by the smelter. Since the cessation of slag discharge in 1995, historic slag deposits have been re-distributed and transported downstream. Long-term settling areas (depositional habitat) where suspended sediments are deposited on the river bottom are rare within the AOI; therefore, there are few areas with significant slag deposits remaining in the AOI. Because of their physical nature, slag particles may create a lower-quality habitat than natural substrates, including sand substrates.

Significant slag deposits within the AOI are limited to long-term depositional areas such as the Waneta Eddy. The total area affected by slag is only 0.1% or less of the total bottom habitat in the AOI.

Based upon the observed slag content, effects on benthic invertebrates from physical alteration of the habitat due to slag deposition would be expected to be greatest at the Maglios and Waneta sites.

The area of depositional habitat in the AOI is estimated to be 0.1% (or less) of the total sediment habitat. Therefore, the spatial extent of physical effects on habitat is small relative to the area of the entire AOI.

Several other natural habitat characteristics influence the benthic invertebrate community within the AOI. These include water depth, current velocity, the degree of algae and aquatic plant growth and the size distribution of bottom materials (boulder, cobble, gravel, sand, silt or clay). These factors were measured at all sampling stations and their influence was examined via statistical analysis.

Steps 3 and 4: Evaluation of Magnitude and Uncertainty in Benthic Invertebrate Field and Laboratory Data

The criteria used to define the magnitude of response for the three benthic invertebrate lines of evidence are presented in Table S-6.

The magnitude of response in laboratory toxicity tests and in field samples of the invertebrate community was determined by statistical comparisons between reference (upstream of the smelter) and exposure (downstream of the smelter) sites.

The magnitude of response in laboratory toxicity tests was determined by the degree of toxicity observed as well as by the statistical difference between samples taken at reference (upstream of the smelter) sites versus exposed sites (downstream of the smelter). The magnitude of response observed in field samples of the benthic invertebrate community was determined by the statistical difference between upstream reference and downstream exposed sites. Several different statistical tests were used, including a type of analysis called multivariate analysis (the third row in Table S-6). In multivariate analysis, the entire dataset is analyzed at once, and the sampling sites are placed on plots (called ordination plots) where the axes represent variables that explain much of the variation in the data. The arrangement of the sites on these plots helps distinguish “clusters” of sites; e.g., some sites may cluster according to an axis correlated with depth while others may cluster according to an axis correlated with PCOC concentrations.

Table S-6 Magnitude Criteria for the Benthic Invertebrate Lines of Evidence

Line of Evidence	Method of Assessment of the Line of Evidence	Evidence of Negligible to Low Magnitude ○	Evidence of Moderate Magnitude ◉	Evidence of High Magnitude ●
Sediment toxicity	Statistical comparisons of toxicity endpoints between reference and exposure sites	Less than 20% reduction in each toxicological endpoint	Statistically significant ($p < 0.05$) more than 20% but less than 50% reduction in one or more toxicity endpoints relative to reference sites	Statistically significant ($p < 0.05$) more than 50% reduction in one or more toxicity endpoint relative to reference sites
Benthic invertebrate community	Statistical comparisons of benthic community variables between reference and exposure sites	No statistically significant differences in benthic community variables between reference and exposure sites	Statistically significant reduction ($p < 0.05$) in one or more benthic community variables relative to reference sites and that reduction is >2 standard deviations from the reference mean	Statistically significant reduction ($p < 0.05$) in most or all benthic community variables relative to reference sites and those differences are >3 standard deviations from the reference mean
Benthic invertebrate community	Multivariate analysis	Reference and exposure sites cluster together on ordination plot	Reference and exposure sites form clusters that partially overlap on ordination plot	Reference and exposure sites cluster separately on ordination plot


Shoreline immediately downstream of Maglios site along east bank


Waneta Eddy sampling area with Waneta Dam and confluence of Pend d'Oreille in background


Fort Sheppard Eddy area near west shoreline


Looking upstream from the Trimac sampling site


Sediment taken at Kootenay Eddy (upstream reference site)

The Maglios and Waneta sediments produced high-magnitude responses in sediment toxicity tests. All of the other sites had low magnitude responses except for responses that were in opposite directions in Trimac sediments (positive in the 10-day test; negative with a moderate magnitude in the 20-day test). There is no obvious explanation for the results from the Trimac site, although declining water quality in the laboratory test container over time is a possibility because the tests were run without renewal of overlying water.

The Waneta site had high-magnitude responses in benthic invertebrate community characteristics. The Maglios site also had high-magnitude responses, although there were fewer statistical comparisons done for this site because of fewer replicate samples taken. The Fort Sheppard site showed moderate response in one set of statistical analyses (site-by-site comparisons) but not in another set (multivariate analysis). All of the other sites had responses that were rated as low to negligible.

Natural habitat characteristics were important variables influencing the benthic invertebrate community. The sampling sites could be separated into two groups based on habitat characteristics. Sites at Kootenay Eddy and Fort Sheppard Eddy had greater amounts of aquatic plant cover and were located in deeper water than most other sites. Sites at Genelle Eddy, Birchbank Eddy, Korpak, Maglios, Casino, and Airport Bar were in shallower waters and had low aquatic plant cover. Sites at Trimac and Waneta Eddy did not easily fit into these groups. The site at Trimac was in shallower water; however, it had greater aquatic plant cover than most of the other sites. Waneta Eddy had no aquatic plant growth and was considerably deeper than all other sites.

All sites were similar in terms of field-measured water quality parameters such as dissolved oxygen, pH, water temperature and total dissolved solids (a measure of the concentration of different types of salts in the water).

Sediment particle size and carbon content were similar at most sites. There were measurable total organic carbon concentrations only at Kootenay Eddy and Trimac. Sediment characteristics at Trimac were distinct from those at other sites, having the largest proportion of clay and the highest carbon content.

Sediments were analyzed using a method called "sequential extraction", which provides an indication of the potential for metals to be released from the sediment matrix and taken up by aquatic organisms. Metals must be released and taken up by organisms before effects can occur. The sequential extraction results showed that the overall potential for release of copper, lead and zinc from sediments was higher at Maglios and Fort Sheppard than at other sites. Total copper concentrations and zinc were higher at Waneta than at other sites; however, the potential for release of these metals was lower than at Maglios and Fort Sheppard.

In summary, all lines of evidence indicate that the benthic invertebrate communities at the Maglios and Waneta sites had a response of high magnitude. These two sites had the highest observed slag content in the

All lines of evidence indicate that the benthic invertebrate communities at the Maglios and Waneta sites had high magnitude responses. These sites had the highest observed slag content in the sediments. The Waneta site had among the highest concentrations of PCOC, and the Maglios site had a higher potential for release of PCOC for uptake by aquatic life.

sediments. The Waneta site had among the highest concentrations of PCOC, and the Maglios site had a higher potential for release of PCOC for uptake by aquatic life. The benthic community at the Fort Sheppard site had a moderate response in one measure compared to upstream sites; but not in the other measures. The benthic invertebrate communities at all other sites downstream of the smelter had low magnitude responses.

Uncertainty

The uncertainty associated with the toxicity test line of evidence is moderate because of concerns with some of the laboratory controls. Mean survival and weight of the midge larvae used as test organisms in laboratory controls were sometimes lower that the required level. Compared to the laboratory controls, higher survival and biomass were achieved in most reference site sediments. The lower survival and growth in the laboratory controls may have been due to the physical nature of the silica sand used as the control sediment.

There is moderate uncertainty in the toxicity test line of evidence, because of some concerns with the laboratory controls.

The uncertainty associated with natural variability of the measures of the benthic invertebrate community is low because the sampling design was in accordance with criteria for statistical power (Table S-3). Furthermore, the design produced an adequate representation of a gradient in PCOC concentrations and habitat features.

There is low uncertainty in the field data on the benthic invertebrate community.

There is a moderate level of support for Conceptual Model 1, which predicts direct effects from the smelter.

The support for Conceptual Model 1 is moderate because at least two lines of evidence indicate direct effects (at Waneta and Maglios), most potential confounding variables are quantified and they do not account for all of the observed responses (Table S-4). The use of laboratory and field-based evidence for response of benthic invertebrates in concert with concurrent chemistry data provided a wider basis for interpretation of the potential for effects from exposure to PCOC. Furthermore, several natural habitat variables that can account for the observed benthic invertebrate community characteristics were measured and included in the statistical analysis. However, confounding anthropogenic stressors such as flow regulation were not included in the analysis.

There is moderate-to-weak support for Conceptual Model 2, which predicts indirect effects caused by the smelter.

The data provided moderate-to-weak support for Conceptual Model 2. There was moderate support for the presence of physical effects on habitat due to historic slag discharge based upon significant changes in the benthic invertebrate community at sites with higher slag content (Maglios and Waneta). There was weak support for the predicted indirect effects via changes in other levels of the food chain, although support could not be assessed at all sampling sites because sites were not always the same for attached algae and benthic invertebrates. The Korpak and Fort Sheppard sites had both periphyton and benthic invertebrate samples taken. The Korpak site had low periphyton abundance relative to upstream reference sites; however, this site

The combination of the lack of evidence for combined effects of multiple stressors and the difficulty in distinguishing among potential causes led to the conclusion that there was weak support for the multiple stressor effects predicted by Conceptual Model 2.

clustered together with upstream reference sites when benthic invertebrate community data were assessed. There was some (albeit inconsistent) evidence for responses in the benthic invertebrate community at Fort Sheppard; however, the periphyton community at this site was not significantly different than upstream reference sites.

The combination of the lack of evidence for combined effects of multiple stressors and the difficulty in distinguishing among potential causes led to the conclusion that there was weak support for the multiple stressor effects predicted by Conceptual Model 2. There is insufficient scientific understanding to develop hypotheses of multiple stressor effects in the study area (e.g., the combined effect of PCOC, flow regulation and nutrient addition). However, the gradient sampling design assisted with distinguishing responses to some of the other stressors in the AOI. For example, upstream reference sampling sites were within the expected gradient of response to the Zellstoff Celgar pulp mill discharge. Therefore, if there was a distinct spatial pattern of responses of benthic invertebrates to the pulp mill discharge, one or all of the upstream sampling stations would be expected to be statistically distinct. This was not the case; the reference sites were clustered with all of the exposure sites except Maglios and Waneta.

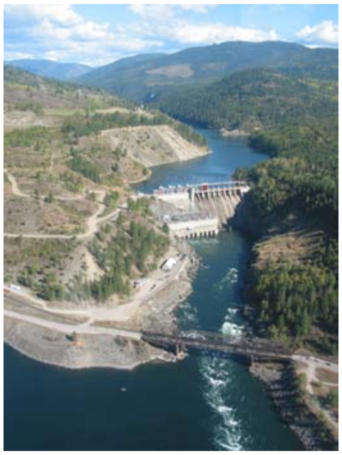
The assessment of future risks to benthic invertebrates is limited to the period for which operation of the existing smelter can reasonably be predicted; i.e., 10-20 years. Changes in PCOC concentrations or distribution of slag caused by changes in flow beyond those currently observed are not predicted for the next 10-20 years.

Responses to stressors that overlap with the smelter-related gradient of PCOC concentrations were more difficult to distinguish. For example, the near-field exposure sites within the smelter-related gradient (Maglios and Korpak) were also within the zone of influence of storm-water discharges from the City of Trail and input from tributaries such as Trail Creek, which is affected by the former Teck Cominco fertilizer plant.

Some of the significant differences in the benthic invertebrate community observed at Maglios may be due to these other stressors, or to combined effects of multiple stressors. However, if combined effects were occurring, significant differences would be expected at the Korpak site as well; however, this site was not distinguishable from reference sites.

The assessment of future risks to benthic invertebrates is limited to the period for which operation of the existing smelter can reasonably be predicted; i.e., 10-20 years. Climate change will not affect the mainstem Columbia River as much as in other areas over the next 10-20 years because of the storage capacity in the Columbia River system due to impoundments. In addition, the terms of the Columbia River Treaty govern how river flow is managed. This assessment assumes no change in the terms of the Treaty. Therefore, changes in river flows and volumes beyond currently observed hydrograph variations are not anticipated for the10-20 year time period identified for this assessment. Furthermore, changes in PCOC concentrations or distribution of slag caused by changes in flow beyond those currently observed are not predicted.

Step 5: Assessment of Causation for Benthic Invertebrate Lines of Evidence



The Waneta Eddy area showing the Waneta Dam and confluence with the Pend d'Oreille River

Looking upstream from the Maglios sampling site; east bank

The strongest evidence for a causal link between slag deposits and/or PCOC and benthic invertebrate responses occurred at the Waneta site, followed by the Maglios site. Evidence for a causal link with the smelter at other sites was much weaker.

Indirect effects on the benthic invertebrate community via changes in food web structure are not indicated by the data.

Toxicity test results provided moderate evidence of a causal link to smelter emissions; this rating was driven by results at the Waneta and Maglios sites. The strongest links are at the Waneta site, where sediment chemistry and observed percentage slag are concordant with the toxicity test results. The Maglios site also had high percentage slag and elevated PCOC concentrations; however, there were other sources of PCOC and the potential for other chemical stressors (such as pesticides) in the immediate vicinity of this site.

Analysis of field data showed that there was low-to-moderate evidence of a causal link between PCOC concentrations and responses and moderate evidence of a causal link with physical habitat effects due to slag deposition. Sites with the highest concentrations of particular PCOC did not always have significant differences. However, significant differences greater than the critical effect size were detected at the two sites with higher observed slag content (Fort Sheppard and Waneta). Multivariate analysis showed moderate evidence of a causal link with PCOC concentrations and slag content at the Maglios and Waneta sites. These two sites were in a very distinct cluster.

The analysis of benthic invertebrate community data showed that natural variables strongly influenced the benthic invertebrate community. This finding contributed to lower scores assigned for spatial correlation, biological gradient, consistency of association and specificity.

In summary, the strongest evidence for a causal link with the smelter occurred at the Waneta site, followed by the Maglios site. Evidence for a causal link with the smelter at other sites was much weaker. Therefore, Conceptual Model 1 appears to apply to a limited extent within the AOI.

Indirect effects on the benthic invertebrate community as per Conceptual Model 2 are not indicated in the available data. The attached algae community was altered in the immediate vicinity of the Teck Cominco smelter effluent discharge; however, there were no benthic invertebrate data available from this site because the very swift current and deep water made sampling extremely difficult. The nearest site to the near-field attached algae sites (at Maglios) may have a combination of direct and indirect effects; however, the PCOC concentrations in the sediments and the percentage slag composition at Maglios are high enough that direct effects may dominate. Indirect effects via changes in fish populations (thus changing feeding rates on benthic invertebrates) are unlikely given the lack of moderate or high-magnitude responses in the fish receptor species.

Step 6: Risk Characterization for Benthic Invertebrates

The risk management objective for benthic invertebrates is:

> *"Minimize, now and in the future, smelter operation-related direct and indirect effects within the AOI on the diversity of aquatic plant and animal communities in the Columbia River and its tributaries."*

The risk management objective for benthic invertebrates is not being met at the Waneta and Maglios sites.

The combination of magnitude, causation, and uncertainty scores was used to produce a recommendation regarding the need for management of risks to the benthic invertebrate community (Table S-7). Risk from direct physical effects on benthic invertebrate habitat via slag deposition was also considered.

Risk management options can include monitoring, not only of the benthic invertebrate community but also of the connections between benthic invertebrates and the fish community. Further investigation of causation is also required, especially at Maglios.

The risk management objective is not being met at the Maglios and Waneta sites. A recommendation to proceed to risk management does not imply that active remediation is required at these sites; rather, it indicates that consideration of risk management options should proceed. Options can include monitoring, not only of the benthic invertebrate community but also of the connection between the benthic invertebrate community and the fish community. This would provide additional information regarding the relative importance of addressing the issue of elevated slag content and elevated PCOC concentrations. Furthermore, risk management options may include further investigation of causation, particularly at the Maglios site, where sources of non-smelter stressors are known to exist.

There is conflicting evidence from the Fort Sheppard site; therefore, further investigation is required at this site.

The Fort Sheppard site produced conflicting evidence, leading to the "yes, but confirm with more data" answer regarding the need to proceed to evaluation of risk management options. Although sediment toxicity tests and multivariate analysis showed low-magnitude responses with either low or moderate uncertainty, site comparisons between Fort Sheppard and Airport Bar (which had much lower PCOC concentrations in the sediments) indicated moderate-magnitude responses with low uncertainty. There was also moderate evidence of direct effects on habitat caused by slag deposition at Fort Sheppard.

The evidence for indirect effects on benthic invertebrates is not strong enough to lead to a recommendation for risk management. However, uncertainty with respect to indirect effects is high, particularly at the Maglios and Waneta sites. Therefore, the examination of risk management options should include consideration of both direct and indirect effects at these sites.

There is moderate confidence in the risk characterization and the recommendation that evaluation of risk management options is required at Maglios and Waneta and perhaps required at Fort Sheppard because:

- several lines of evidence were examined not only for magnitude but also for causation and uncertainty;

No future increases in smelter-related stressors are expected within the 10-20 year time-frame used in this assessment; therefore, consideration of risk management options should focus on confirmation of results at Maglios, Waneta and Fort Sheppard.

- sampling was conducted along a gradient of exposure to PCOC and slag, including areas of highest expected exposure in well-known, longer-term depositional areas;
- all of the depositional areas with the finer sediments expected to be associated with higher concentrations of PCOC that were identified during exploratory surveys of the AOI were sampled during the formal sampling program; and,
- natural variability in benthic invertebrate measures was addressed satisfactorily via the sampling design; but,
- there were conflicting lines of evidence at the Fort Sheppard site;
- there were other, uncharacterized sources of stressors at Maglios; and,
- uncertainty was moderate for the toxicity test lines of evidence.

No future increases in smelter-related stressors are expected within the 10-20 year time-frame used in this assessment; therefore, consideration of risk management options should focus on confirmation of results at Maglios and Waneta, further characterization of the risk at Fort Sheppard, and further investigation of causation at Maglios and, if necessary, at Fort Sheppard.

Table S-7 SALE Summary Table for Benthic Invertebrates

Site (Downstream of Smelter)	Sediment Toxicity						Benthic Invertebrate Community Similarity to Reference						Direct Effects on Habitat Caused by Slag Deposition			Proceed to Evaluation of Risk Management Options?
	Survival			Growth			Site Comparisons			Multivariate Analysis						
	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	
Korpak	○	○	??	○	○	??		-		○	○	?	○	○	??	**No**
Maglios	●	⊙	??	●	⊙	??		-		●	⊙	?	●	⊙	??	**Yes**
Casino	○	○	??	○	○	??		-		○	○	?	○	○	??	**No**
Airport Bar	○	○	??	○	○	??	○	○	?	○	○	?	○	○	??	**No**
Trimac	○	○	??	⊙	○	??				○	○	?	○	○	??	**No**
Fort Sheppard Eddy	○	○	??	○	○	??	⊙	○	?	○	⊙	?	⊙	○	??	**Yes, but confirm with more data**
Waneta Eddy	●	⊙	??	●	⊙	??	●	⊙	?	●	⊙	?	●	⊙	??	**Yes**

Notes:

Magnitude:

- ● strong response.
- ⊙ moderate response.
- ○ weak response.

Causation:

- ● strong overall strength of causal evidence.
- ⊙ moderate overall strength of causal evidence.
- ○ weak overall strength of causal evidence.

Uncertainty:

- ? low uncertainty (high statistical power, full gradient design, all important natural variables accounted for).
- ?? moderate uncertainty (moderate statistical power, control/impact rather than full gradient design; most natural variables accounted for).
- ??? high uncertainty (low statistical power, important natural variables not accounted for).

Fish: Results of SALE Steps 2-6

Fish were sampled in four study areas on the lower Columbia River: two exposure areas (downstream of the smelter effluent outfalls in the near-field immediately downstream of the smelter and in the far-field in the Fort Sheppard-to-Waneta area) and two reference areas (upstream of the smelter) (Figure S-6). The reference areas were:

Boat electrofishing

- **Reference Area A**: between Kinnaird Bridge and the mouth of Champion Creek; and,
- **Reference Area B**: from just upstream of Sullivan Creek to just upstream of Murphy Creek, including the Birchbank Eddy.

Indicators of fish health were measured in fish from all four sampling areas. These indicators are the same as those used in the national EEM program, in order to provide consistency with other fish health data collected in the AOI under programs such as CRIEMP and EEM studies conducted by Zellstoff Celgar.

Step 2: Effects Due to Smelter-Related Change in Physical Habitat (All Fish Species)

Historic discharge of slag to the Columbia River (pre-1995 and installation of Kivcet Smelter)

The historic discharges of slag from the Teck Cominco lead smelter and nutrient-enriched effluent from the Teck Cominco phosphate fertilizer plant affected the physical habitat of fish in the Columbia River by changing the nature of the substrate and by stimulating the growth of attached algae and aquatic plants. Slag along the river edges, in backwater areas and in depositional areas affected spawning, rearing and feeding habitats both directly and via changes in the food supply provided by the benthic invertebrate community.

There is still sufficient slag to alter physical habitat at Waneta and Fort Sheppard eddy, and scattered smaller areas; however, affected habitats represent a very small proportion (<0.1%) of total bottom habitat in the AOI.

Since cessation of slag discharge, the slag deposits have been scoured and redistributed, occurring primarily at the Fort Sheppard and Waneta eddies, plus scattered smaller areas such as the Maglios benthic invertebrate sampling site. The percentage composition of slag is still sufficient to alter directly the nature of the physical habitat in these areas; however, affected habitats represent a very small proportion (<0.1%) of total bottom habitat in the AOI.

Shoreline at smelter site after cessation of slag discharge (photo taken 2004)

Summary of Direct Effects on Fish Habitat

- The remnant pockets of slag deposition in the AOI directly affect fish habitat quality, and these changes in habitat occur in areas that are used by a variety of fish species. The relative amount of habitat affected by slag deposition is very small (<0.1% of the total habitat in the AOI).
- There is no longer any evidence of wide-spread nutrient enrichment effects on fish habitat (via stimulation of attached algae and aquatic plant growth) in the AOI.
- The operation of dams in the AOI is an important source of direct effects on fish habitat. Dam operators have successfully reduced some effects (e.g., decreased total gas pressure or TGP). However, other flow-related issues remain problematic.
- Historic discharges from the Zellstoff Celgar pulp mill created a localized fibre mat area and current discharges may still be affecting benthic invertebrate density (and hence fish food supply) in the immediate vicinity of the mill discharge.
- The relatively high number of human activities in the AOI can create many localized habitat disturbances; however, the relative significance of these disturbances cannot be assessed with the current data.
- Yearly monitoring of fish populations (such as the fish indexing program) is an important tool for evaluating the status of fish populations as they respond to overall fish habitat effects in the AOI.

Brilliant Dam

Sullivan Creek showing effect of road and culvert on habitat

Steps 3 and 4: Evaluation of Magnitude and Uncertainty in Field and Laboratory Data for Fish

Criteria for judging magnitude of effects on fish health were derived from the literature and professional judgement.

The criteria for judging the magnitude of effects on fish health (Table S-8) were based on Environment Canada guidelines for relative gonad size (gonad somatic index or GSI), relative liver size (liver somatic index or LSI) and condition factor (a measure of the girth of a fish relative to length). The magnitude of response for other fish health measurements, including the Pathology Index (a summary index describing the incidence of parasites, infections, malformations and other abnormalities) and population characteristics was determined using a combination of guidance from the literature and professional judgement.

Table S-8 Magnitude Criteria for the Fish Health Lines of Evidence

Line of Evidence	Method of Assessment of the Line of Evidence	Evidence of Negligible to Low Magnitude ○	Evidence of Moderate Magnitude ◉	Evidence of High Magnitude ●
Fish Health Parameter	Statistical comparison of fish health parameters between reference and exposed fish.	Statistical difference ($p < 0.05$), but magnitude of any statistical difference is less than: 25% for GSI and LSI, 10% for condition; 20% for age, length and weight.	Statistical difference ($p < 0.05$), and magnitude of any statistical difference is greater than 25% but less than 40% for GSI and LSI; greater than 10% but less than 30% for condition; greater than 20% but less than 40% for age, length and weight.	Statistical difference ($p < 0.05$) and magnitude is greater than 40% for GSI, LSI, age, length and weight and greater than 30% for condition.
Pathology Index (PI)	Comparison of mean PI between reference and exposed fish.	PI of exposed fish less than or equal to PI for reference fish.	PI for exposed fish at least 20% greater but less than 40% greater than PI for reference fish.	PI for exposed fish at least 40% greater than PI for reference fish.
Fish Population Characteristics	Qualitative comparison of upstream versus downstream of the smelter, plus comparison of 2001-2005 sampling period (post-Kivcet smelter) with 1990-1994 period (pre-Kivcet smelter).	No difference or no consistent trend in percent composition, catch-rates, size-distribution, or population estimates between upstream and downstream sampling sections or over time.	Some, but inconsistent evidence for: shifts in percent composition and size distribution over time and/or upstream versus downstream; declines in catch-rate upstream versus downstream of the smelter and/or over time; declines in population estimates over time.	Definite and consistent shift in percent composition and/or size distribution with time and/or upstream versus downstream of the smelter; definite and consistent decline in catch-rate upstream versus downstream of the smelter and over time; definite decline in population estimates over time.

The magnitude of all responses was low except for condition and liver size in female sculpin

Spatial trends were evaluated by comparing the Kootenay, Upper and Middle sampling sections (upstream of the smelter) with the Lower section (downstream of the smelter). Temporal trends were evaluated by comparing the 2001-2005 data with data from the early 1990s (prior to installation of the Kivcet smelter with accompanying decreases in metal discharge plus the cessation of discharge of slag to the river).

Catch rate of mountain whitefish was higher upstream of the smelter and there was a moderate-magnitude shift to larger fish in more recent sampling years.

The magnitude of all responses in prickly sculpin and mountain whitefish was low except for LSI and condition factor in near-field female sculpin. The near-field sampling area was from the New Bridge to just downstream of Korpak. Relative liver size was 36% lower in near-field female sculpin than in reference sculpin; this exceeded the critical effect benchmark of 25%. The percent decrease in LSI fell in the moderate magnitude category. The condition factor of near-field female sculpin was 78% higher than reference. This percent difference fell in the high magnitude category.

Fish population characteristics showed few relationships upstream versus downstream of the smelter or over time. There was a moderate magnitude difference in catch-rate of mountain whitefish, with higher catch-rates upstream of the smelter. There was a moderate magnitude shift to larger fish in the more recent sampling years for mountain whitefish and rainbow trout; however, this shift did not occur in all of the years from 2001-2005.


Dissection of a mountain whitefish


Female mountain whitefish with gonads removed


Prickly sculpin specimen with internal parasites (part of the Pathology Index measurement)


Starting the dissection of a slimy sculpin

There is a low-to-moderate amount of uncertainty in the field data on fish health and fish populations.

There is a low-to-moderate level of support for Conceptual Model 1, which predicts direct effects caused by the smelter.

Uncertainty in Lines of Evidence for Prickly Sculpin and Mountain Whitefish

The uncertainty associated with natural variability of fish health measurements is low-to-moderate. The sampling design had adequate statistical power; thus, there is reasonable confidence that the data were sufficient to distinguish a response from natural variability. However, the control/impact design does not address the presence of gradients in potentially confounding natural or anthropogenic variables, apart from the use of one near-field and one far-field sampling area. It is unlikely that these two downstream sites, plus the two upstream reference sites fully represented gradients in habitat features (e.g., water depth and velocity, substrate characteristics, bankform characteristics, instream cover, and abundance of attached algae and benthic invertebrate food sources) that may influence fish health. Also, these four stations did not represent the full extent of gradients in non-smelter stressors, such as temperature and dissolved gas conditions due to dam operation, or nutrient enrichment due to pulp mill discharge.

The lack of full coverage of gradients is of some concern regarding interpretation of mountain whitefish data because of the mobility of this species during spawning. Mountain whitefish can be expected to be exposed to the full range of variables in the AOI during their life cycle. The lack of a gradient design is of less concern for prickly sculpin, since sculpin remain within a localized area for their entire life cycle.

The evidence provides a low-to-moderate level of support for Conceptual Model 1. Two fish health measures indicated direct effects (for prickly sculpin, on relative liver size and weight). There were higher catch-rates of mountain whitefish upstream of the smelter and there has been a shift to larger mountain whitefish and rainbow trout in more recent sampling years. The observed responses in prickly sculpin at the near-field site could be due to some of the other variables (e.g., storm-water discharges from the City of Trail); therefore, the validity of the conceptual model is in question. However, the full range of confounding natural and anthropogenic stressors was not included in the analysis. Furthermore, the interaction between direct physical effects on habitat caused by slag and responses to the PCOC could not be assessed statistically.

There is weak support for Conceptual Model 2, which predicts indirect effects caused by the smelter.

The evidence provides weak support for the indirect effects via food chain interactions predicted by Conceptual Model 2. The observed differences in weight and liver size in near-field sculpin may, in part, reflect an indirect effect from smelter emissions because near-field periphyton biomass at the Old Bridge was elevated (providing a larger food supply and thus faster growth). However, benthic invertebrate abundance was not uniformly elevated relative to upstream in the near-field fish sampling area (although the invertebrate data are for depositional habitats whereas sculpin feed primarily in erosional habitats). Another possible indirect mechanism for the larger sculpin in the near-field is reduced intra-specific competition because of metal-related reduced survivorship of young sculpin. The reduced competition would result in compensatory increases in growth and condition in the young fish that survive. Indirect effects of this kind have been reported for moderately acidified lakes with elevated metals; however, metal concentrations were considerably higher than in the Columbia River. The fact that sculpin at the far-field area had larger LSIs than fish from the reference areas suggests that food (e.g., benthic invertebrates) may be more abundant in the far-field area. Interestingly, the highest abundance of benthic invertebrates was observed at Ft. Sheppard Eddy (>150,000 organisms/m^2), which is located immediately downstream of the fish sampling stations.

The use of prickly sculpin assisted with distinguishing responses to some of the other stressors in the AOI because they remain within a relatively small area and thus reflect exposure to local sources.

The use of prickly sculpin assisted with distinguishing responses to some of the other stressors in the AOI because they remain within a relatively small area and thus reflect exposure to local sources. Hence, the fish health indicators measured in sculpin from the upstream reference sampling sites would reflect exposure to upstream stressors such as the Zellstoff Celgar pulp mill discharge, whereas fish health indicators measured in sculpin from the near-field site would reflect exposure to the smelter discharges plus storm-water discharges from the City of Trail and other sources such as Trail Creek (affected by the Teck Cominco fertilizer plant). Sculpin at the far-field site were exposed to lower smelter-related metal concentrations, as demonstrated by the lower body

Risks to fish health and fish populations over the next 10-20 years are not expected to increase, because smelter emissions are not predicted to increase. Furthermore, effects of climate change on river flows (and thus PCOC concentrations and slag distribution) will be mitigated by river flow management according to the terms of the Columbia River Treaty.

burdens of metals measured in sculpin collected from this site. The spatial pattern of responses of sculpin appear to correspond most with Conceptual Model 1 (direct effects of exposure to near-field metal concentrations) rather than indirect effects or effects of multiple stressors. However, this result is highly uncertain.

The assessment of future risks to fish health and fish populations is limited to the period for which operation of the existing smelter can reasonably be predicted; i.e., 10-20 years. As discussed for periphyton and benthic invertebrates, climate change will not affect the mainstem Columbia River as much as in other areas over the next 10-20 years because of the storage capacity in the Columbia River system due to impoundments. In addition, the terms of the Columbia River Treaty govern how river flow is managed. This assessment assumes no change in the terms of the Treaty. Therefore, changes in river flows and volumes beyond currently observed hydrograph variations are not anticipated for the 10-20 year time period identified for this assessment. Furthermore, changes in PCOC concentrations or distribution of slag caused by changes in flow beyond those currently observed are not predicted.

Step 5: Assessment of Causation for Prickly Sculpin and Mountain Whitefish Lines of Evidence

There is weak evidence for a cause/effect link between prickly sculpin health and smelter emissions.

On balance, there is weak evidence for a cause/effect link between the higher condition factor and smaller livers in female sculpin from the near-field sampling and smelter emissions. The evidence was judged as weak because responses were observed only in females, there were no effects on sculpin distribution and habitat use downstream of the smelter, there is a questionable mechanism for effects on condition factor (because abundance of food organisms did not uniformly increase in the near-field), and effects of metals on liver size occur at much higher concentrations than those observed downstream of the smelter. Furthermore, there was no consistency with any of the observed or postulated patterns of response to metals published in the scientific literature.

There is no evidence for a cause/effect link between mountain whitefish health and smelter emissions.

Evaluation of a cause/effect link for mountain whitefish health was not required because all responses were low in magnitude.

Evaluation of a cause/effect link for mountain whitefish populations was conducted despite the lack of evidence for effects on mountain whitefish health parameters because of the potential interaction between smelter-related habitat changes and exposure to PCOC and the uncertainty associated with indirect effects.

Examination for causation showed that there was no evidence of smelter-related effects on the mountain whitefish population in the AOI.

There was no evidence of a consistent spatial or temporal trend in mountain whitefish population parameters relative to the smelter. Mountain whitefish have continued to have the highest percent composition within the fish community of the AOI throughout the period for which data are available (1990-1994; 2001-2005). This is true both upstream and downstream of the smelter. The change in catch-rate with time occurred in all sampling sections, not just downstream of the smelter and may be due to a change in sampling methods. The shift in size distribution of mountain whitefish back to a predominance of larger fish occurred within the overall population, both upstream and downstream of the smelter. Fluctuations in size distribution from 1990-1994 and 2001-2005 do not coincide with reductions in exposure to PCOC or to the cessation of slag discharge. Population estimates provided no evidence of a stressor-response relationship between PCOC concentrations and measures of population size. There was no consistency of association between population estimates and exposure to the smelter-related stressors.

Step 6: Risk Characterization for Prickly Sculpin and Mountain Whitefish

The risk management objective for mountain whitefish and prickly sculpin is:

> *"Minimize, now and in the future, smelter operation-related direct and indirect effects within the AOI on fish populations in the Columbia River and its tributaries."*

Prickly sculpin and mountain whitefish are reliable indicators for other fish species.

It is assumed that if the risk management objective is met for prickly sculpin and mountain whitefish, then it will also be met for all other fish species in the AOI. This assumption is supported by the fact that mountain whitefish have been shown to have higher concentrations of PCOC in their tissues than walleye or rainbow trout and similar concentrations to largescale sucker; therefore, it is unlikely than any other large-bodied species would have greater exposure to the PCOC in the AOI. Furthermore, mountain whitefish have historically been demonstrated to be the most sensitive large-bodied fish species to the stressors present in the AOI and historically have exhibited a number of responses to these stressors (which included, but were not limited to smelter-related PCOC and slag) in the early 1990s. Prickly sculpin, because of their fidelity to relatively small home ranges and their food habits, would be expected to have exposures to PCOC that are as high as (or higher) than other small-bodied fish species in the AOI.

The weight of evidence for effects on fish health and fish populations show that the risk management objective is being met.

The weight of evidence indicates that the risk management objectives are being met for mountain whitefish and prickly sculpin (Table S-9). Therefore, an evaluation of risk management options is not required for these receptors. However, because there was no sampling reach for prickly sculpin that directly overlapped the Maglios benthic invertebrate site and because there may be direct or indirect effects on prickly sculpin at this site, further fish health work focussing on the Maglios site may be warranted. This would be true only if benthic invertebrate impacts are confirmed and are shown to be causally related to the smelter, and if the zone of smelter-related impact is large enough to encompass the home range of a sub-population of prickly sculpin. There is no compelling argument for further monitoring or evaluation of large-bodied fish species in the AOI relative to direct risks from smelter-related stressors. (Table S-9).

Table S-9 SALE Summary Table for Prickly Sculpin and Mountain Whitefish

Receptor Species	Fish Health			Fish Population Characteristics			Direct Effects of Slag on Habitat			Proceed to Evaluation of Risk Management Options?
	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	Magnitude	Causation	Uncertainty	
Prickly Sculpin	○→⊙	○	?	○	○	??	○	○	??	No
Mountain Whitefish	○	○	?	○	○	?	○	○	?	No

Notes:

Magnitude:

● strong response.
⊙ moderate response.
○ weak response.

Causation:

● strong overall strength of causal evidence.
⊙ moderate overall strength of causal evidence.
○ weak overall strength of causal evidence.

Uncertainty:

? low uncertainty (high statistical power, full gradient design, all important natural variables accounted for).
?? moderate uncertainty (moderate statistical power, control/impact rather than full gradient design; most natural variables accounted for).
?? high uncertainty (low statistical power, important natural variables not accounted for).

Some additional data on the Maglios site and on slag-related effects on sculpin habitat would reduce uncertainty regarding smelter-related risks to sculpin populations.

The largest uncertainty associated with the prickly sculpin risk characterization is with respect to the direct effects of slag deposition on prickly sculpin habitat as well as population characteristics. Observations of slag content of sediments were limited to depositional habitats. Prickly sculpin primarily use erosional habitats. It is assumed that slag will not be present in large amounts in erosional habitats; however, there is a potential for small pockets of slag to accumulate around the coarser substrates favoured by sculpin.

Additional data on the relative occurrence of slag in erosional areas of the AOI have been collected subsequent to the completion of this ERA. These data are still in the process of being assembled and interpreted. Once this interpretation is complete, the potential for effects of any slag deposition in erosional habitat on habitat quality (e.g., via changes in food organism abundance or diversity) can be evaluated.

Uncertainty for the mountain whitefish risk characterization is low and additional data are not required.

The uncertainty associated with the mountain whitefish risk characterization is less than for prickly sculpin because of the presence of several years of population-level data as well as fish health data that demonstrate improvement since the discharge of PCOC decreased and the discharge of slag ceased. It is unlikely that other large-bodied fish species have been at greater risk than mountain whitefish. Therefore, there is no compelling argument for further monitoring or evaluation of large-bodied fish species in the AOI relative to direct risks from smelter-related stressors.

Monitoring in anticipation of possible future increases in discharge of PCOC is not required because there are currently no plans for major production capacity increases in Trail.

There is also no compelling argument for monitoring in anticipation of possible future increases in discharge of PCOC. Discharge of PCOC in the treated effluent continues to decline; this decline is reflected in water quality data. In the foreseeable future, releases of PCOC to air and water from the Teck Cominco metallurgical plants may generally be expected to remain at their current low levels, or to decline somewhat further. Of course, there will be fluctuations in the amounts of various PCOC released, as the primary smelter feed sources (zinc and lead concentrates from various mines) change, but these variances will be maintained within the limits specified in current permits under the B.C. Environmental Management Act. Key metallurgical plants at Trail (zinc electrolytic and melting, silver refinery and lead smelter) have all undergone expansion and updating in the past several decades. These plants currently operate at or near full capacity and there are currently no plans for major production capacity increases in Trail. However, changes in available feeds, changes in technology, and changes in the suite of products made at Trail are likely to occur in the future, just as they do for other major industrial facilities. Any such changes will be only be made upon consideration of potential environmental risks and in consultation with key stakeholders.

There is considerable confidence in the risk characterization for fish in the AOI.

There is considerable confidence in the risk characterization and the recommendation that consideration of active risk management options is not required because several lines of evidence examined not only for magnitude but also for causation and uncertainty indicate that the risk management objective is currently being met and the uncertainty associated with the risk characterization is low for mountain whitefish. The uncertainty associated with the risk characterization for prickly sculpin can be addressed by some additional evaluation of slag effects in erosional habitats plus confirmatory monitoring of fish health measures.

The lack of any direct response of the fish receptors to the smelter-related stressors reduces, but does not eliminate the likelihood of indirect effects as per Conceptual Model 2. The effects on benthic invertebrates at Maglios and Waneta may reduce the local food supply, especially for small-bodied fish. However, there is no evidence of effects on fish populations; therefore, effects via changes in competition or predator-prey interactions are highly unlikely.

The data on fish distribution, abundance and fish health do not indicate the need for management of risks from indirect effects. Uncertainty is not as great for indirect effects on fish as it is for the other receptors because of the extensive monitoring that has been conducted in the AOI on fish habitats, distribution and abundance. Effects of stressors from other anthropogenic sources such as pulp mills and dams are being addressed by mitigation and monitoring programs conducted by the operators.

White Sturgeon: Magnitude of Response According to Evidence from Other Studies

The white sturgeon is a red-listed and SARA-listed species. The White Sturgeon Recovery Initiative is striving to prevent the extinction of this species in the Upper Columbia River.

The white sturgeon is a red-listed and SARA-listed species that is the subject of considerable effort aimed towards understanding its current status, the contributing factors for its current status, and recovery. The White Sturgeon Recovery Initiative (WSRI) began in 2000 with an agreement signed by Fisheries and Oceans Canada, B.C. MOE and B.C. Hydro. The WSRI brings together the interests of over 25 partners, including government, First Nations and American tribes, industry, environmental groups and others to the challenge of preventing the extinction of this species in the Upper Columbia River (WSRI 2004).

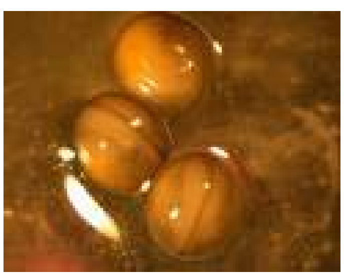
Area at Pend d'Oreille River confluence with the Columbia River at Waneta near where sturgeon spawning takes place

The present study relied upon the WSRI and others (such as B.C. Hydro and B.C. MOE publications) for data on white sturgeon health and population status in the AOI. Lines of evidence available from these sources were:

- habitat characteristics and smelter-related effects on habitat;
- distribution and habitat use;
- population dynamics; size and age distribution; and, recruitment;
- spawning activity;
- contaminant concentration in sturgeon tissue;
- incidence of external anomalies in adults and juveniles;
- toxicity tests using juvenile sturgeon; and,
- genomics studies.

This study relied upon the WSRI and other studies for data on white sturgeon health and population status in the AOI.

The low recruitment of juveniles into the white sturgeon population creates the greatest risk to the sustainability of this species in the AOI. It has been estimated that the population in the AOI would decline from 1,100-1,300 fish to less than 100 individuals within about 15-40 years, depending upon assumed rates of mortality (Hildebrand *et al.* 1999). These estimates do not account for potential compensatory changes in growth and recruitment as the population changes.



Sturgeon eggs

The low recruitment of juveniles into the white sturgeon population creates the greatest risk to the sustainability of this species in the AOI. Information obtained in 2007 from a State of Washington sampling program indicates that recruitment of wild juveniles has been occurring in the portion of the population that resides on the U.S. side of the border. According to these recent data, there have been at least some successful spawning events resulting in recruitment of juveniles in most if not all years since 1995. The current level of recruitment is unlikely to be sufficient to maintain the population; however, earlier estimates of population decline may no longer be valid.

Dam operations have eliminated historic habitats, leaving four primary areas within the AOI for use by white sturgeon.

Another major response in white sturgeon in the AOI is the restricted use of habitat because of the presence of dams. Historic habitats are no longer available to the remnant population residing in the AOI. The population primarily uses four areas within the AOI; therefore,

Mysid shrimp

Juvenile white sturgeon grow rapidly in the AOI because of a ready food supply provided by introduced mysid shrimp.

Information on tissue concentrations of PCOC in white sturgeon is too limited to allow confident conclusions to be made regarding direct effects of PCOC.

Comparison of concentrations of cadmium, copper and zinc in water in the AOI with recently-derived effects thresholds for juvenile white sturgeon indicates that concentrations have been well below effects thresholds since 2003 at all sampling stations and have always been at least an order of magnitude lower than effects thresholds at Waneta.

maintenance of favourable habitat conditions in these four habitats is vital. This includes favourable depth and flow conditions, temperature within the tolerance range (especially during pre-spawning, spawning and development of eggs), Total Gas Pressure (TGP) within acceptable limits, availability of velocity refugia (i.e., places to escape from fast-flowing water), fine substrates, and the availability of food suitable for all life stages.

Juvenile white sturgeon grow rapidly in the AOI because of a ready food supply provided by mysid shrimp, which are introduced to the system upstream of dams to support kokanee, become entrained in the dam discharge and are swept downstream to the juvenile sturgeon feeding areas. Investigation of stomach contents of juvenile sturgeon shows that other invertebrates in the AOI, such as water scuds (often called freshwater shrimp) are also important food sources.

Sample sizes for PCOC concentrations in white sturgeon tissue are too low to allow confident interpretation and are far less than required for adequate statistical power. Furthermore, effects thresholds in the literature are for concentrations in the tissues of teleost (bony) fish and may not be applicable to sturgeon. Given the limited information and uncertainty, it is impossible to either confirm or invalidate Conceptual Model 1 (direct effects of PCOC) for sturgeon based on tissue concentrations.

Very recent information regarding the toxicity of cadmium, copper and zinc to early life-stage white sturgeon has provided another line of evidence regarding the potential risk to the white sturgeon population from PCOC exposure (see Addendum Table to the Aquatic SALE report). Vardy et al. (2010) have found that the early juvenile life-stage (40 days post-hatch) of white sturgeon is more sensitive to copper compared to earlier and later life stages, and that the early life-stages of white sturgeon have comparable sensitivity to copper, cadmium and zinc as relatively sensitive salmonid species, such as Chinook salmon. Concentrations of cadmium, copper and zinc in water at the New Bridge site in 1995 were slightly greater than the Vardy et al. (2010) thresholds for cadmium, copper and zinc. Cadmium concentration at the New Bridge site was slightly greater than the effects threshold in 2003. Concentrations have been below the Vardy et al. (2010) thresholds since 2003 at all sampling stations in the AOI, including the New Bridge site. Concentrations at Waneta (which is one of the four remaining habitats for white sturgeon in the AOI) have been at least an order of magnitude below the Vardy et al. (2010) effects thresholds during the entire period of record for this assessment.

Although there has been a high incidence of deformities in hatchery-reared juvenile sturgeon in the AOI in the past, these deformities do not appear to have caused effects on condition or growth and recent data show that the incidence of deformities has dramatically declined. The incidence of deformities in wild adult sturgeon in the AOI varies widely from study to study; this variation may have more to do with differences in

Earlier high incidence of deformities in hatchery-reared sturgeon has decreased dramatically and current levels are low. Incidence of deformities in wild adult sturgeon in the AOI varies widely from study to study.

Laboratory toxicity tests and tests on gene expression on smelter effluent used full-strength or half-strength effluent, which is not a relevant representation of exposure in the river. Further testing at realistic concentrations would reduce uncertainty regarding the actual level of toxicity expected in the river.

deformity classification methods than a true variation in the population. The effect of observed deformities on growth and survival is unknown.

Responses of early life-stage sturgeon in laboratory toxicity tests to undiluted or 50% smelter effluent were of a high magnitude (100% mortality). However, there was no toxicity at 1% effluent and environmentally relevant concentrations have not been tested. There is at least a 1:1000 dilution factor in the immediate area of effluent discharge. Dilution would be even greater in the area at Waneta where sturgeon spawn. Therefore, the relevance of the toxicity test results is questionable. Furthermore, the tests were conducted on effluents obtained during a maintenance shut-down of the smelter. Therefore, it is very difficult to determine whether the responses observed in the toxicity tests are indicative of what could be expected during normal operation of the smelter and at environmentally relevant concentrations. Additional testing of effluent produced during normal operations and at environmentally realistic concentrations would reduce this uncertainty.

Laboratory toxicity tests and tests on gene expression on smelter effluent used full-strength or half-strength effluent, which is not a relevant representation of exposure in the river. Further testing at realistic concentrations would reduce uncertainty regarding the actual level of toxicity expected in the river.

There was a distinct response in gene expression in early-life stage white sturgeon to exposure to undiluted and 50% smelter effluent, but no response to 1% effluent. The relevance of the observed response in gene expression (which is an expected response to a stressor) to whole-organism or population-level responses under environmentally relevant concentrations is unknown.

Sturgeon hatchery

Hatchery-reared juvenile

Uncertainty in White Sturgeon Lines of Evidence

There is a low degree of uncertainty regarding our understanding of the current status of the white sturgeon population in the AOI.

There is adequate information to support the current understanding of the status of the white sturgeon population in the AOI. There is an extensive database on white sturgeon distribution, habitat use and spawning in the AOI that has been assembled over more than 10 years of monitoring. Monitoring of the distribution, condition and growth of hatchery-reared juvenile sturgeon has contributed additional data.

Though we know that wild young white sturgeon are not surviving to join the population, we do not know why.

Although the status of the population is reasonably well-understood, the causes of the low recruitment are not. There are many candidate causes. These causes almost certainly interact.

There is weak support for Conceptual Model 1, which predicts direct effects from PCOC on white sturgeon.

The applicability of Conceptual Model 1 to white sturgeon is uncertain. The information on PCOC concentrations in sturgeon tissue cannot be interpreted with confidence because of the very small sample size and the lack of tissue-based effects benchmarks. Concentrations in water in the AOI from 1995-2006 have been well below thresholds for cadmium, copper and zinc effects on juvenile white sturgeon (with the exception of the New Bridge site prior to the Kivcet smelter in 1995, and once in 2003). Slag is scoured from the spawning beds by flushing flows from the Pend d'Oreille River; therefore, direct physical effects of slag on developing eggs are unlikely. Experimental data that test the hypothesis of direct effects from whole smelter effluent were obtained using concentrations that were not environmentally relevant.

There is also weak support for Conceptual Model 2, which predicts indirect effects caused by PCOC.

The applicability of Conceptual Model 2 to white sturgeon is also uncertain. There is little supporting evidence for indirect effects on sturgeon via PCOC effects on food items or via competitive or predator-prey interactions. Juvenile white sturgeon grow rapidly in the AOI, largely because they have a ready food supply in the form of mysids introduced to the system to enhance kokanee production. Physical (via slag) or chemical effects on alternative food items (such as amphipods) may be important for larger juveniles that are switching from mysids to larger prey; however, this is unknown.

The major problem for the white sturgeon population in the AOI appears to be survival of young. There are no apparent indirect links between smelter emissions and survival of young; however, the lack of data produces a high uncertainty with respect to the role that PCOC may play in combination with other stressors.

Step 5: Assessment of Causation for White Sturgeon Lines of Evidence

White sturgeon at shoreline

Juvenile white sturgeon

White Sturgeon

Evidence of a cause/effect link with the smelter for white sturgeon responses in the AOI is weak for the following reasons:

- Data on white sturgeon distribution and habitat use do not support the assumption of a spatial or temporal correlation with PCOC concentrations or effects of slag on habitat. There is no evidence of avoidance of the area by sturgeon; in fact, quite the opposite appears to be the case.
- There is no evidence of a gradient in response to PCOC concentrations with respect to white sturgeon distribution and habitat use. The primary causes of white sturgeon distribution are the sturgeon's preference for deeper water, lower current velocity, and substrates that consist at least partially of sand.
- Recruitment failure was first noticed in the early 1990s and began in the 1960s and 1970s, long after the smelter began operations. The population had recruitment prior to the 1960s, during a period of much higher PCOC concentrations. This lack of any correlation in time between PCOC concentrations and effects on recruitment weakens the argument for a cause/effect link with the smelter.
- There is no consistency of association between effects on juvenile growth or survival in the AOI and exposure to PCOC or slag. Juvenile sturgeon grow rapidly in the AOI because of a ready food supply provided by mysid shrimp and other invertebrates in the system.
- White sturgeon spawning activity occurs every year at Waneta in habitats that are not affected by slag (because they are scoured by high flows from the Pend d'Oreille River). Exposure to PCOC may be one of the stressors affecting sexual maturation and development of the eggs; however, there are no data to support or refute this hypothesis.
- Spawning has no temporal correlation with the smelter; spawning has continued to occur throughout the life of the smelter with no indication of temporal trends in response to reductions in PCOC concentrations after installation of the Kivcet smelter in 1997.
- There is no consistency of association between spawning activity and exposure to PCOC or slag.
- There is a potential for effects on larval sturgeon after they hatch and then drift downstream, across the U.S. border and out of the AOI, because of the presence of slag in areas where larvae may be feeding; however, there are no data to support or refute this possibility.
- There is very weak evidence of temporal and spatial correlation between concentrations in water and recruitment failures from 1995-2006 because concentrations have not exceeded effects thresholds for juvenile white sturgeon except at the New Bridge site in 1995 and once for cadmium in 2003.

- Full and half-strength effluent from the Teck Cominco smelter (during a maintenance period) was clearly toxic to early-life stage white sturgeon. However, no tests were conducted at environmentally relevant concentrations, which would be at least a 1000-fold lower than full-strength effluent; therefore, the applicability of this line of evidence to white sturgeon growth and survival in the AOI is highly uncertain.
- Effects on gene expression also received a moderate score for causality because of the clear increase in gene expression after exposure to full and half-strength Teck Cominco effluent. However, as with the toxicity test data, the data on gene expression are of highly uncertain applicability to wild fish in the AOI that are exposed to much lower effluent concentrations.

There is weak evidence for a cause/effect link between the smelter and the white sturgeon lines of evidence.

In summary, the strength of the evidence for a cause/effect link between the smelter and white sturgeon lines of evidence in the AOI is weak. This is because of the lack of spatial correlations between white sturgeon use of the habitat, spawning, egg hatch, or juvenile growth and slag or PCOC concentrations. Furthermore, there is very little evidence of any temporal correlation between the critical effect – lack of recruitment of young white sturgeon into the population – and PCOC or slag concentrations. Recruitment was successfully occurring during the period when discharges were much higher than they are today.

There are many candidate causes of the low recruitment of young sturgeon into the population.

There are many candidate causes of the low recruitment of young into the population and these causes almost certainly interact. The problem with recruitment has been narrowed down to the period between egg hatch (which occurs successfully at Waneta) and the stage where larval sturgeon are recruited into the population as “young-of-the-year”. Therefore, there appears to be a problem with survival of the larvae as they drift downstream and then start to feed.

The strongest link between low recruitment and human activities is with dam-related flow regulation.

The strongest link between low recruitment and anthropogenic factors is with flow regulation, which has reduced peak flows during the spawning period by more than 50%. This means that potentially critical larval feeding habitat can be left “high and dry”, greatly reducing the area available for the larvae to feed and possibly forcing them into areas where they are more vulnerable to predation by species such as introduced walleye.

The potential effect of historic deposits of slag in larval sturgeon feeding areas cannot be discounted.

Slag (and PCOC concentrations associated with it) may also play a role in reducing larval survival in areas outside of the AOI as the larvae drift across the U.S. border. The hypothesis is that PCOC uptake via food or water affects survival either via direct toxicity or via reduction in food quantity or quality. However, if this were true, recruitment failure should have occurred when PCOC and slag discharges were much higher historically. Nonetheless, the potential effect of the historic deposits of slag in larval feeding grounds cannot be discounted.

Another hypothesis that links the smelter with white sturgeon is that river flow regulation has reduced the spring freshet and the natural scouring of the substrates and slag has compounded this effect. However, the known spawning areas at Waneta (and North Port across the U.S. border) are not prone to deposition of slag because they are high velocity areas.

Evidence for indirect effects via changes in the food chain caused by PCOC is weak.

Evidence for indirect effects on white sturgeon (Conceptual Model 2) via changes in food organisms, competition, or predator-prey interactions in the AOI is weak. The only potential link may be the effect of slag on the composition of the benthic invertebrate community at locations such as Waneta; slag may affect the abundance of a preferred food item – water scuds (amphipods). However, juvenile white sturgeon have been shown to grow rapidly in the AOI, including at Waneta. Adult sturgeon exist in a nutrient-limited system and no longer have access to salmon as a prey item. Neither of these factors is related to the smelter. There is no evidence that the smelter is affecting other fish species; therefore, the likelihood of indirect effects via changes in competition or predator-prey interaction is negligible.

Evidence for multiple stressor/cumulative effects on white sturgeon where PCOC form part of the cause of observed responses is non-existent; therefore, the applicability of Conceptual Model 2 regarding multiple stressor effects is highly uncertain. Dam operations appear to have had a strong influence on the physical habitat for all life stages of white sturgeon. The deliberate introduction of walleye and bass into the system also increased the abundance of predators that could potentially feed on early life stages of white sturgeon. A recent study has shown that juvenile white sturgeon have similar sensitivity to cadmium, copper and zinc as salmonid species. Cadmium, copper and zinc concentrations in the AOI since 2003 have not exceeded the effects thresholds for juvenile white sturgeon.

Step 6: Risk Characterization for White Sturgeon

The risk management objective for white sturgeon is:

> *"Prevent, now and in the future, smelter operation-related direct and indirect effects on threatened and endangered aquatic species in the AOI."*

The white sturgeon population in the AOI exists in a very limited habitat (due to dams) and is showing very low recruitment of young into the population. There are many potential causes for the low recruitment. The evidence for a link between the smelter and the recruitment failure is weak because of the lack of correlation between the onset of low recruitment and the concentration of PCOC and slag in the AOI.

Given the current difficulties with maintenance of the white sturgeon population, risk management obviously needs to continue.

Indirect effects on white sturgeon caused by the Teck Cominco smelter are unlikely, with the possible exception of a reduction in food supply in larval feeding areas due to the presence of slag or PCOC in sediments. However, juvenile white sturgeon using the Waneta and Fort Sheppard areas grow rapidly, indicating that the food source in the AOI is sufficient.

Given the current difficulties with maintenance of the white sturgeon population, risk management obviously needs to continue. Continued involvement of Teck Cominco in the White Sturgeon Recovery Initiative research program is recommended, in order that uncertainties regarding the relative risks from PCOC and slag deposits can be defined with more confidence.

CONCLUSIONS

None of the lines of evidence for the tributaries provide strong evidence for smelter-related risks to tributary systems. Because of the lack of evidence for smelter-related risks to aquatic life in tributary systems, it is not necessary to proceed to consideration of risk management. The available information indicates that any follow-up investigations done to address uncertainty should focus on wetland-type habitats within the tributary systems because these habitats are where water and sediment metal concentrations are usually the most elevated.

The risk management objective for attached algae is not being met at the Stoney Creek, New Bridge and Korpak sites. The Stoney Creek site is being dealt with under a separate risk management program. The New Bridge site lies within the initial dilution zone authorized by the current MOE license. Nevertheless, risk management options at the New Bridge site would be considered within the context of the risk management goals for the wider ecological risk assessment but addressed through permitting.

The risk management objective for benthic invertebrates is not being met at the Waneta and Maglios sites. Risk management options can include monitoring, not only of the benthic invertebrate community but also of the connections between benthic invertebrates and the fish community. Further investigation of causation is also required, especially at Maglios.

It is possible that the risk management objective for benthic invertebrates is not being met at the Fort Sheppard site; however, the evidence was inconsistent. Confirmatory studies would reduce the uncertainty regarding smelter-related risk to benthic invertebrates at this site.

There are non smelter-related stressors in the vicinity of the New Bridge, Maglios, Korpak and Fort Sheppard sites. Additional data would help increase the understanding of the role of the non-smelter stressors. The role of slag in the sediment as a physical stressor versus the role of PCOC as chemical stressors may also require clarification at these sites in order to refine risk management options. The additional data could be obtained both from laboratory tests and field investigations. The temporal framework would be better understood with a quantitative evaluation of sediment transport and deposition mechanisms in the AOI; this evaluation would assist in the prediction of the length of time for the current slag deposits to be further transported and/or buried with natural sediment materials.

The SALE analysis indicated that the risk management objectives are being met for mountain whitefish and prickly sculpin in the AOI. Therefore, an evaluation of risk management options is not required for these receptors. However, follow-up work at the Maglios site and interpretation of recent additional studies on slag distribution in sculpin habitat will add confidence to the assessment of risk to sculpin populations in the AOI. There is no compelling argument for further monitoring or evaluation of large-bodied fish species in the AOI relative to direct risks from smelter-related stressors.

The risk management objective for white sturgeon is not being met; however, the causes are not strongly linked to the Teck Cominco smelter. Rather, the current status of the white sturgeon in the AOI is likely to be due to cumulative effects from multiple stressors. The relative role of PCOC and slag deposition appears to be minor; however, there is high uncertainty regarding this conclusion because of limited data. Continuing participation by Teck Cominco in the White Sturgeon Recovery Initiative appears to be the appropriate response to the current understanding of the situation.

Just south of Trail looking north towards the Teck Cominco smelter

The assessment of future smelter-related risks is limited to the period for which operation of the existing smelter can reasonably be predicted; i.e., 10-20 years. Climate change will not affect the mainstem Columbia River as much as in other areas over the next 10-20 years because of the storage capacity in the Columbia River system due to impoundments. In addition, the terms of the Columbia River Treaty govern how river flow is managed. This assessment assumes no change in the terms of the Treaty. Therefore, changes in river flows and volumes beyond currently observed hydrograph variations are not anticipated for the 10-20 year time period identified for this assessment. Furthermore, changes in PCOC concentrations or distribution of slag caused by changes in flow beyond those currently observed are not predicted.

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