Terrestrial Ecological Risk Assessment for the Teck Metals Ltd. Smelter at Trail, BC.

MAIN REPORT

Revised

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TERRESTRIAL ECOLOGICAL RISK ASSESSMENT FOR THE TECK METALS LTD SMELTER AT TRAIL, BC.

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EXECUTIVE SUMMARY

The Teck Metals Ltd. (Teck) Ecological Risk Assessment (ERA) was produced under the British Columbia Contaminated Sites Regulation (CSR). Teck elected to use a landscape perspective and to use the information to develop a risk-based Wide Area Remediation Plan. The terrestrial risk assessment component of the ERA used a combination of risk modelling and field-based studies. Interpretation of the findings was guided by a Sequential Analysis of Lines of Evidence (SALE) approach to characterize the degree of risk from smelter-related emissions. The overall approach, individual study plans, and interim reports were reviewed by a Technical Advisory Committee (TAC), a Public Advisory Committee (PAC), and other external reviewers.

The ERA was guided by the agreed management goal that there will be “no unacceptable residual ecological risk from past or current smelter-related emissions”. Risk management objectives for the terrestrial ERA were stated as:

1. Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on the maintenance of dynamic self-sustaining vegetation communities in natural “wildland” areas;

2. Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on the maintenance of desired native and introduced plant species in “urban” areas;

3. Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on forage crops, pastureland, vegetable, and fruit production in “agricultural” areas;

4. Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on populations of wildlife in natural “wildland” areas, including resident and migratory birds, small and large mammals, valued charismatic species (*e.g*., raptors, bears), predators (*e.g*., coyotes), and hunted and harvested species (*e.g.,* deer), and lower trophic level food resources (*i.e*., insects and soil dwelling organisms);

5. Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on wildlife populations in “urban” areas, including resident and migratory birds, small and large mammals, and lower trophic level food sources (*i.e*., insects and soil dwelling organisms);

6. Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on wildlife populations in “agricultural” areas, including resident and migratory birds, small and large mammals, and lower trophic level food sources (*i.e*., insects and soil dwelling organisms);

7. Prevent, now and in the future, smelter operation-related direct and indirect effects on individual organisms of threatened and endangered wildlife species in the Area of Interest; and,

8. Prevent, now and in the future, smelter operation-related direct and indirect effects on individual agricultural animals in the Area of Interest.

The initial Area of Interest (AOI) for the terrestrial ERA extended along the Columbia River valley from the International Boundary north to Castlegar, and was approximately defined by the

2,100 m contour at the west boundary, and the 1,200 m contour at the east boundary (*i.e.,* the "height of land" on both sides of the river valley). The AOI was redefined by considering the concentrations of arsenic, cadmium, lead and zinc in soil, relative to BC CSR soil standards. This decreased the size of the AOI to approximately 40,000 ha, which was about half the original size.

A total of 31 elements were considered to identify Potential Chemicals of Concern (PCOCs): aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, fluoride, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, phosphorus, potassium, selenium, silver, sodium, strontium, sulphur, thallium, tin, titanium, vanadium, zinc. After screening these elements, antimony, arsenic, cadmium, copper, lead, mercury, and zinc were PCOCs for all objectives.

Ecological receptors were selected to evaluate the objectives, and be representative of the various habitats and land uses in the AOI. The receptors were: terrestrial plant communities; avian communities; mammalian communities; wildlife species selected as representatives of food webs/habitats (American crow, American robin, belted kingfisher, black bear, black-capped chickadee, Columbian ground squirrel, coyote, deer mouse, dusky shrew, mallard, osprey, red-backed vole; red squirrel, red-tailed hawk, river otter, white-tailed deer); agricultural species (chicken, cow, horse, crops); and, Listed species (bobolink, canyon wren, great blue heron, Lewis's woodpecker, Townsend's big-eared bat, white-throated swift).

Conceptual models were developed to address direct and indirect effects of PCOCs on the receptors. Direct effects included toxicity related reductions in survival, growth or reproduction of the different receptors; indirect effects pertained to changes in habitat quality either through loss of or changes in the relative abundance of predators or food resources, or changes in the physical environment.

The Teck smelter is not the only source of stress to the terrestrial environment in the AOI. A variety of land uses in the AOI produce point and non-point sources of chemical stressors. In addition, physical stressors caused by habitat alteration or destruction occur as part of some land uses (*e.g*., urban development; agricultural land use; linear developments such as transmission corridors, roads and railroads; logging), as well as from natural events such as fire.

Assessment of Risk to Plant Communities

<u>Wildland Plant Communities</u>

The total area with metal concentrations in soil that exceeded CSR standards for plants and soil invertebrates is approximately 6,120 ha, which is 14% of the total 42,666 ha within the AOI. However, factors other than PCOC concentrations in soil, such as climate, soil texture and depth, previous air pollution injury, logging and fire have influenced the plant communities in the AOI. Therefore, the ERA was not restricted to areas of elevated metal concentrations in soil. Instead, the ERA focussed on those locations within the AOI that had evidence of persisting, smelter-related effects on plant communities. A four-step screening process eliminated areas with non-relevant land uses such as roads, airports and gravel pits; areas where the plant communities were in advancing structural stages; units with logging impacts IF metal concentrations in soil were less than CSR standards AND units were not previously impacted by SO_2; and, units in early structural stages IF metal concentrations in soil were less than CSR standards AND the area was not previously impacted by SO_2. This screening process eliminated 34,349 ha or 80% of the AOI. The remaining 8,317 ha (20% of the AOI) were evaluated in greater detail using other effects data.

The evaluation of wildland plant communities was completed using four Lines of Evidence (LOE): forest productivity; plant community statistics (species richness and diversity, presence of sulphur dioxide sensitive or tolerant plant species, percentage of tree, shrub and herb cover); changes in soil physical and chemical characteristics; and, changes to avian and mammalian herbivore populations/communities. Based on these LOE, there is evidence that metals and previous air pollution injury may continue to influence plant communities in up to 18.4% of the AOI (7,863 ha).

The plant communities within the AOI have continued to develop since the time period used to develop the biophysical habitat map (aerial photograph taken in 1999) and the field data were collected for statistical analysis of plant community characteristics (2001). Therefore, consideration of risk management options should be based on an updated assessment of the status of plant community structure.

Urban Plants

Urban plants were assessed in a Problem Formulation, using anecdotal information on plant growth, and presence and condition of native, introduced and sensitive species grown in the area. Representatives from the Trail Parks Department, the Horticultural Society and Communities in Bloom indicate that native and introduced plants in urban areas are growing well. However, organic matter and fertilizer have been added to city vegetable and flower gardens.

Based on the available evidence, consideration of risk management for urban plants is not indicated at this time. If property-specific issues arise in the future, site-specific data on PCOC concentrations in soil may be required.

Agricultural Crops

Agricultural plants were assessed in a Problem Formulation using anecdotal information regarding condition and yield of forage crops and grapes. The two farms in Columbia Gardens were contacted (a dairy farm and a vineyard). No adverse effects on forage crops or grapevines were reported that could be attributed to smelter emissions. Fruit and forage crops in agricultural areas are growing well. However, the dairy farmer amends the soil.

Based on the available evidence, consideration of risk management for agricultural plants is not indicated at this time. If property-specific issues arise in the future, site-specific data on PCOC concentrations in soil may be required.

Assessment of Risk to Wildlife

American robins were evaluated specifically because risks could not be ruled out using modelling. The results of the SALE evaluation for robins support the conclusions that: American robin populations persist in the AOI; habitat is being utilized by American robins; and, there is suitable habitat for American robins in the AOI.

The results for the avian community support the conclusions that: avian wildlife populations persist in the AOI; available habitat is being utilized to a similar extent as in reference habitat areas; and, the habitat (including areas that are in early to mid-seral stages) is suitable for a wide range of avian species (although in different proportions than would have been present prior to historical, smelter-related effects).

No unacceptable direct toxicity risks were predicted for mammals. The results support the conclusions that: mammalian wildlife populations persist in the AOI; available habitat is being utilized; and, the habitat is suitable for a wide range of mammalian species. Similar to birds, it can be expected that mammalian populations and communities are influenced by the habitats present in the AOI. A formal habitat evaluation was conducted only for white-tailed deer and river otter.

The SALE evaluation related to risks to American robin, the avian community and the mammalian community indicated that the risk management objectives are being met in the AOI. Stakeholder consultation will be required to discuss and evaluate trade-offs associated with risk management of vegetation communities where smelter-related effects on vegetation persist because some of these areas provide habitat for valued species.

Assessment of Risk to Threatened and Endangered Wildlife

Threatened and endangered species, known as Listed Species, are ranked according to their status in B.C. Species become Listed for many reasons, including: occurrence at the limit of their range; habitat loss or fragmentation; *etc*.

Evidence used to assess Listed Species included prey diversity and abundance, records of Red and Blue Listed Species presence in the AOI and knowledge of the presence of suitable habitat in the AOI. Both direct and indirect toxicity was evaluated for: bobolink, canyon wren, great blue heron, Lewis's woodpecker, white-throated swift and Townsend's big-eared bat. The evidence indicates that risk management objectives for most of the Listed wildlife species are being met, with the possible exception of Lewis' woodpecker:

- Canyon wren and white-throated swift have abundant suitable habitat near the smelter, and their foraging habits (on rocky talus at the base of cliffs for wren and aerially on small insects near vertical cliffs for swift) minimize the potential for exposure to PCOCs in soil or soil-based food chains;
- Most of the Townsend's big-eared bat habitat is located farther away from the smelter (*e.g.*, in the Pend d'Oreille) and is not influenced by smelter emissions;
- Direct toxicity modelling ruled out risks to great blue heron. The number of great blue heron is increasing in the AOI as habitat improves. Risks from wetland areas within the AOI are likely to be low, and wetlands are not used as much as other areas for foraging.
- Impacts on bobolink habitat suitability are not related to smelter emissions, but more due to agricultural land management, urban development, *etc*.
- Lewis' woodpecker may be limited due to the lack of old growth forest availability in the AOI.

The priority for risk management relates to availability of suitable nesting habitat for Lewis's woodpecker. There are areas within the AOI where habitat maintenance or enhancement could be conducted for this species.

Assessment of Risk to Livestock

Three types of animals were selected as representatives of domestic livestock: chickens, cattle and horses. Risks were ruled out for chickens and cattle, based on direct toxicity modelling which considered the full distribution of metal concentrations in soils, site-specific data for uptake of PCOCs into forage, and the assumption that all forage and feed was from the area (*i.e.*, no supplementation with feed from outside the AOI). A local dairy farmer also was contacted and he did not have any concerns about smelter emissions related to his cows.

Therefore, the risk management objective is being met for chickens and cattle; consideration of risk management is not indicated by these results.

Risks to survival, growth, development and reproduction of individual horses, due to smelter emissions, could not be ruled out *via* LOR3 risk modelling. The predicted 90^{th} percentile Exposure Ratio (ER) = 2 for lead. Comparisons of recent soil and forage data to older data (when impacts on foals were observed) suggest risks are up to 16-fold lower now than in the early 1970s, when smelter emissions were much higher. No additional data or information is available regarding horses and thus no additional SALE analysis could be conducted. Therefore, the risk management objective for horses may not be met under very specific scenarios; however, the uncertainty regarding this statement is high. Raising foals is prevented on Teck-sold lands through a restrictive covenant on title. In addition, there is an advisory against raising foals in the area; notification was given to veterinarians in the area. It is recommended that the restrictive covenant on title for lands currently holding such a covenant be maintained, as well as any future Teck lands that are sold.

Conclusions

The SALE analysis indicated that risk management objectives were being met for urban plants, agricultural crops, avian and mammalian wildlife, most Listed Species, and most livestock. Therefore, an evaluation of risk management options is not required for these receptors.

Risk management objectives may not be met for up to 7,900 ha of the AOI for wildland plant communities. However, the plant communities within the AOI have continued to develop since the time period used to develop the biophysical habitat map (aerial photograph taken in 1999) and the field data were collected for statistical analysis of plant community characteristics (2001). Therefore, consideration of risk management options should be based on an updated assessment of the status of plant community structure.

Risk management should be considered for the Lewis' woodpecker (a Listed Species) related to availability of suitable nesting habitat. In addition, it is recommended that the restrictive covenant on title for lands currently holding such a covenant be maintained, as well as for any future Teck lands that are sold, due to the potential risks to young horses.

Prior to any risk management activity, a field survey for presence of individuals of Listed Species, as well as an evaluation of habitat suitability for Listed Species, should be conducted at an appropriate scale within the area subject to remediation.

1.0 INTRODUCTION

This introduction includes a summary of the purpose of the Final Terrestrial ERA report (Section 1.1), provides an overview of the approach used in the ERA (Section 1.2), lists the groups who provided consultation and external review of the ERA (Section 1.3), lists the management goals and objectives for the terrestrial ERA (Section 1.4), and describes the report organization (Section 1.5).

1.1 Purpose

Trail, British Columbia has been the site of a major lead and zinc smelting facility operated by Teck Metals Ltd. (Teck) for over 100 years. Metal concentrations in environmental media (*e.g.,* soil, sediment, water) surrounding the Trail smelter operations often exceed British Columbia Contaminated Sites Regulation (CSR) standards (Cantox Environmental *et al*., 2001; Cantox Environmenal, 2003; Golder, 2007c; Intrinsik, 2007). Teck has chosen to use a risk-based approach to develop a Wide Area Remediation Plan. The Trail wide-area assessment process requires that both a human health risk assessment and an ecological risk assessment be conducted. In 1990, the Trail Community Lead Task Force initiated studies on human health exposure and risk, and Teck is currently concluding a human health risk assessment update which incorporates recent data and several exposure scenarios not previously modelled. In 2000, Teck initiated an Ecological Risk Assessment (ERA). The ERA will help determine whether there are or could be ecological effects attributable to Teck's smelter operations, the significance of those effects, and the factors influencing those effects. The assessment can then be used to help evaluate options for remediation.

This document comprises the Final Terrestrial ERA Report. It integrates all relevant data and analyses completed over the course of the ERA. It is not meant to be a stand-alone compilation of all data and previous reports. Rather, it summarizes the key data and identifies the sources from which these data were obtained. The specific sources of information used for the assessment of each objective are listed in the relevant section of this report.

There have been a large number of documents produced as part of this risk assessment. To aid in understanding how this document fits in with the other reports, a "document map" has been produced (Figure 1-1). The map highlights this report and where it contributes to the risk assessment process. Note that wetlands are being assessed in a separate process.

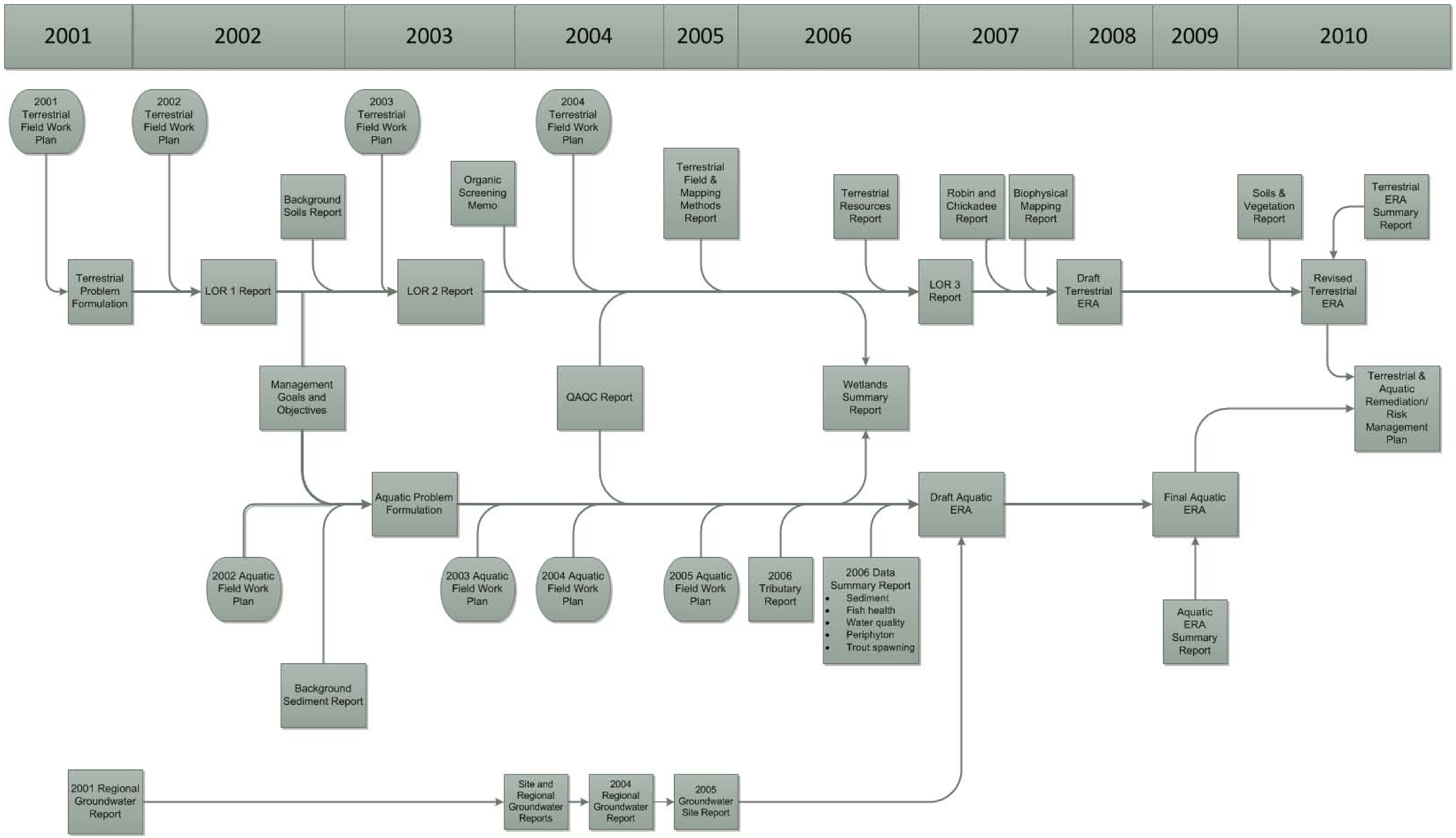


Figure 1-1 Reports Produced during the ERA and where this Report fits into the Process

1.2 Overview of Approach

There is no guidance available from any jurisdiction on completing wide-area ERAs. Therefore, the project team used the best available ERA techniques and resources, and developed new techniques and approaches for completing this ERA.

Wide-area ERA must consider large spatial and temporal scales. Traditional ecological risk modelling methods were often used without regard for the relevant ecological scales. Furthermore, there are very few examples of landscape-scale risk assessments that combine modelling with field-based approaches. Therefore, for this ERA, the study team used a weight-of-evidence (WOE) approach and incorporated both field-based measurements of exposure and effect, and modelling of direct toxicity lines of evidence (Figure 1-2). The terrestrial risk assessment used a combination of risk modelling, biophysical habitat mapping and field studies of soil chemistry, vegetation and wildlife. The details of these studies are presented in supporting documents, notably the terrestrial wildlife risk modelling reports (Cantox Environmental, 2003a; Intrinsik, 2007), and various terrestrial field study reports (*e.g.*, the terrestrial resources report (Golder, 2007a), the mapping methods report (Enns and Enns, 2007b; Appendix C) and the soils and vegetation report (Enns and Enns, 2010; Appendix F)).

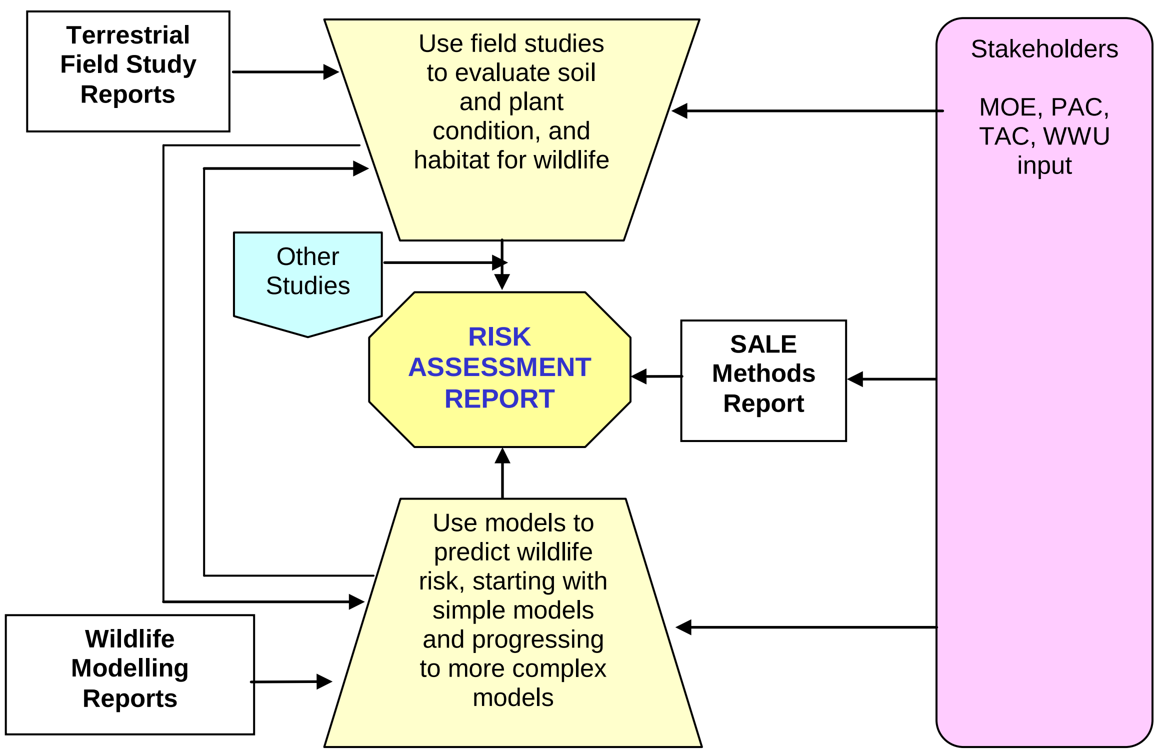


Figure 1-2 Overall Approach to the Terrestrial ERA

[MOE = Ministry of Environment, PAC = Public Advisory Committee, TAC = Technical Advisory Committee, WWU = Western Washington University, SALE = Sequential Analysis of Lines of Evidence]

The terrestrial ERA addressed spatial issues by using geo-spatial analysis to define the areas within the area of interest (AOI) where soil metal concentrations exceeded the CSR (Golder, 2007a), and by devoting a considerable effort to the development of a comprehensive biophysical habitat map (Appendix C). Temporal issues were addressed by examining historic evidence for smelter-related effects and comparing past effects with the current condition of the vegetation communities in the AOI relative to the record of emissions reductions. The evaluation of structural stages of the vegetation communities in the AOI also provided temporal information, for example, early structural stages may be indicators of continuing smelter-related effects while later structural stages illustrate the pattern of re-establishment of plant communities in previously disturbed areas.

The study team developed a sequential approach (Figure 1-3) to assembling the WOE for terrestrial risk (called SALE for Sequential Analysis of Lines of Evidence) (Teck Cominco *et al*., 2005; Hull and Swanson, 2006). SALE recognizes that direct toxicity modelling (or a comparison of site media concentrations to criteria/benchmarks) is more effective in ruling out risk than in providing a quantitative estimate of risk. This applies even when direct toxicity modelling proceeds through various tiers of complexity, termed levels of refinement (LORs).

Field-based lines of evidence are used to evaluate the magnitude of response and then, if the magnitude is sufficient, to evaluate causation. A recommendation to proceed to a risk management evaluation is made only when the sequential analysis has shown sufficient magnitude and causation. The SALE approach includes consideration of indirect effects on habitat suitability as well as direct toxicity (impacts caused by the direct toxic action of the chemical). This is an important advancement, because indirect effects may be greater than direct toxicity effects.

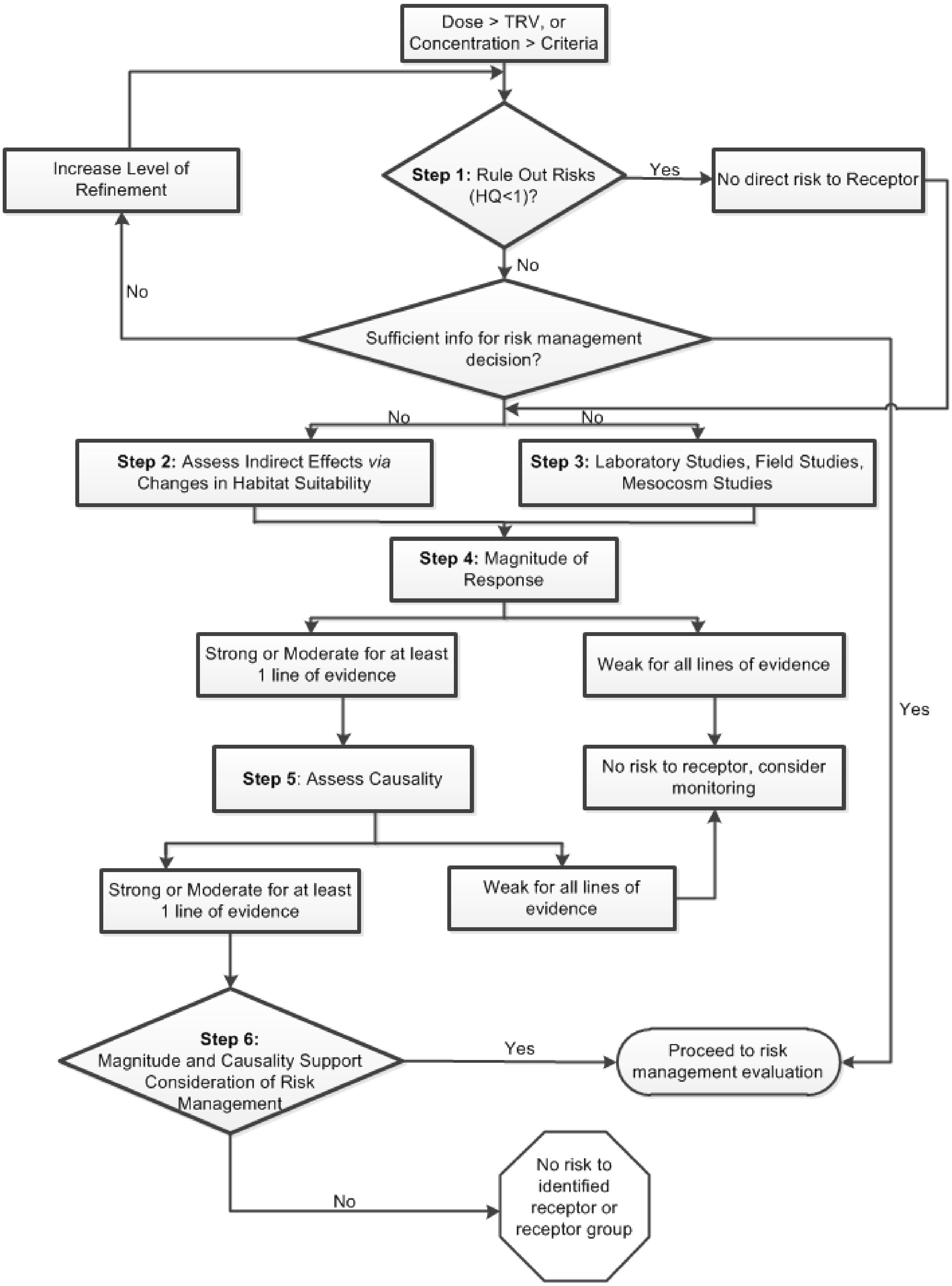


Figure 1-3 The Sequential Analysis of Lines of Evidence (SALE) Process for the Terrestrial ERA

1.3 Consultation and External Review

The ERA has benefited from the regular involvement and contributions of several stakeholders. These stakeholders have participated in public meetings, reviewed work plans and provided feedback on the findings of study components. The stakeholders are:

- Teck and the consultants comprising the study team;
- BC Ministry of Environment (BC MOE);
- The Technical Advisory Committee (TAC);
- An external peer reviewer (Dr. Wayne Landis of Western Washington University [WWU]);
- The Public Advisory Committee (PAC); and,
- Individuals from the area.

1.4 Management Goals and Objectives

The approach used to develop management goals followed the guidance provided by U.S. EPA (U.S. EPA, 1998). The process led to the clear identification and articulation of management goals that can lead to decision-making; this clear identification addressed one of the most critical challenges for many ERAs (Landis and Weigers, 1997; Obery and Landis, 2002). The goals, objectives, assessment endpoints and measures were developed by the ERA team with input from the TAC and the PAC. They were reviewed and approved by the British Columbia Ministry of Environment (Harris, 2006 pers. comm.). A brief explanation of management goals and management objectives is presented below. Assessment endpoints are described under each objective in subsequent sections.

A management goal is a general statement about the trend toward achievement of a desired future condition of an ecological value of concern (U.S. EPA, 1998). The U.S. EPA (1998) guidance instructs that management goals may result from regulations or laws, desired outcomes of the community, and interests expressed by affected parties.

A management objective is a specific statement about the desired condition (or direction of preference) of ecological values of concern. The management objectives translate the more general management goal into more specific management objectives about what must occur in order for the goal to be achieved and to identify ecological values that can be measured or estimated in the ecosystem of concern (U.S. EPA, 1998).

The development of management objectives can be very difficult because of the potential for a multitude of ecological values to emerge when the interests of stakeholders and the requirements of regulations are combined. These values often conflict. Therefore, the study team went to considerable effort to ensure that draft management objectives were reviewed and commented upon by the TAC and the external reviewer (Dr. Landis). Thus, management goals and objectives were defined early in the ERA process and have been updated based on information and input from the Project team, the TAC and the PAC (Teck Cominco *et al.,* 2004).

The overall goal that guided the Teck ERA is:

> *No unacceptable residual ecological risk from past or current smelter-related emissions.*

Residual ecological risk refers to ecological risk remaining after natural recovery processes have taken place or after human intervention, such as remediation and re-vegetation.

Several Management Objectives then were defined. A Management Objective is a more specific statement of the desired outcome. The eight Management Objectives related to the terrestrial ERA are:

1) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on the maintenance of dynamic self-sustaining vegetation communities in natural "wildland" areas.
    - **Key Words: Vegetation in Wildland Areas**

2) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on the maintenance of desired native and introduced plant species in "urban" areas.
    - **Key Words: Plants in Urban Areas**

3) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on forage crops, pastureland, vegetable, and fruit production in "agricultural" areas.
    - **Key Words: Crops**

4) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on populations of wildlife in natural "wildland" areas, including resident and migratory birds, small and large mammals, valued charismatic species (*e.g.*, raptors, bears), predators (*e.g.*, coyotes), and hunted and harvested species (*e.g.,* deer), and lower trophic level food resources (*i.e.*, insects and soil dwelling organisms).
    - **Key Words: Wildlife Populations in Wildland Areas**

5) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on wildlife populations in "urban" areas, including resident and migratory birds, small and large mammals, and lower trophic level food sources (*i.e.*, insects and soil dwelling organisms).
    - **Key Words: Wildlife Populations in Urban Areas**

6) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on wildlife populations in "agricultural" areas, including resident and migratory birds, small and large mammals, and lower trophic level food sources (*i.e.*, insects and soil dwelling organisms).
    - **Key Words: Wildlife Populations in Agricultural Areas**

7) Prevent, now and in the future, smelter operation-related direct and indirect effects on individual organisms of threatened and endangered wildlife species in the Area of Interest.
    - **Key Words: Listed Species**

8) Prevent, now and in the future, smelter operation-related direct and indirect effects on individual agricultural animals in the Area of Interest.
    - **Key Words: Livestock**

1.5 Report Organization

This report is organized generally by Management Objective. First, Section 2.0 presents the problem formulation, including a description of the site background, the area of interest, the potential chemicals of concern, the receptors of concern, and the conceptual models. Sections 3.0 through 6.0 present the assessment of risk completed for each Management Objective. Section 7.0 contains the conclusions of this report, and Section 8.0 contains the references cited. Several appendices are provided in a separate volume.

2.0 PROBLEM FORMULATION

Problem formulation includes a description of the area of interest (Section 2.1), description of the levels of refinement in the wildlife modelling (Section 2.2), identification of potential chemicals of concern (Section 2.3) and receptors of concern (Section 2.4), and development of the site conceptual models (Section 2.5). Background information on the smelter operations can be found in the Problem Formulation report (Cantox Environmental *et al*., 2001).

2.1 Area of Interest

The Trail Operations smelter is located in the City of Trail, West Kootenay Region within the Columbia River valley, 15 km north of the International Boundary (Figure 2-1).

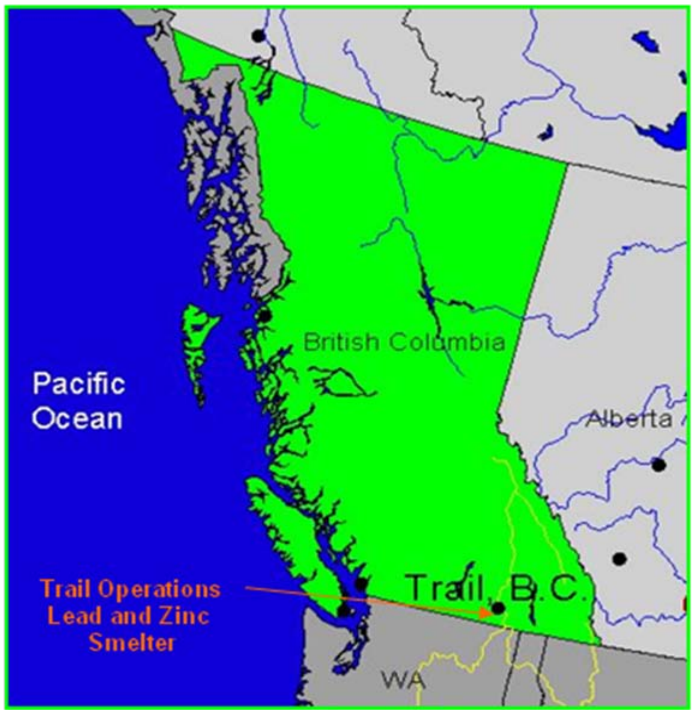


Figure 2-1 Location of Teck Metals Ltd. Trail Operations

The initial AOI for the ERA extended along the Columbia River valley from the International Boundary north to Castlegar, and was approximately defined by the 2,100 m contour at the west boundary, and the 1,200 m contour at the east boundary (*i.e.,* the "height of land" on both sides of the river valley) (Cantox Environmental *et al*., 2001). The size of the initial area of interest was very large (approximately 80,000 hectares) and contained mountainous terrain with elevations ranging from 400 to 1,800 m above sea level (Figure 2-2). The AOI was redefined (Golder, 2007a) by considering the concentrations of arsenic, cadmium, lead and zinc in soil, relative to BC CSR soil standards. The data collected were analyzed using several different methods including geostatistical tools called indicator kriging and conditional simulation. Indicator kriging and conditional simulation were used to create maps where CSR standards were exceeded and would pose a potential risk to ecological receptors. The AOI decreased to approximately 40,000 ha, which was about half the original size after kriging and comparison to CSR standards (Figure 2-2). This reduced area (shown in light green in Figure 2-2) is based on CSR soil standards for the protection of livestock or soil invertebrates and plants, whichever standard is lower for each metal.

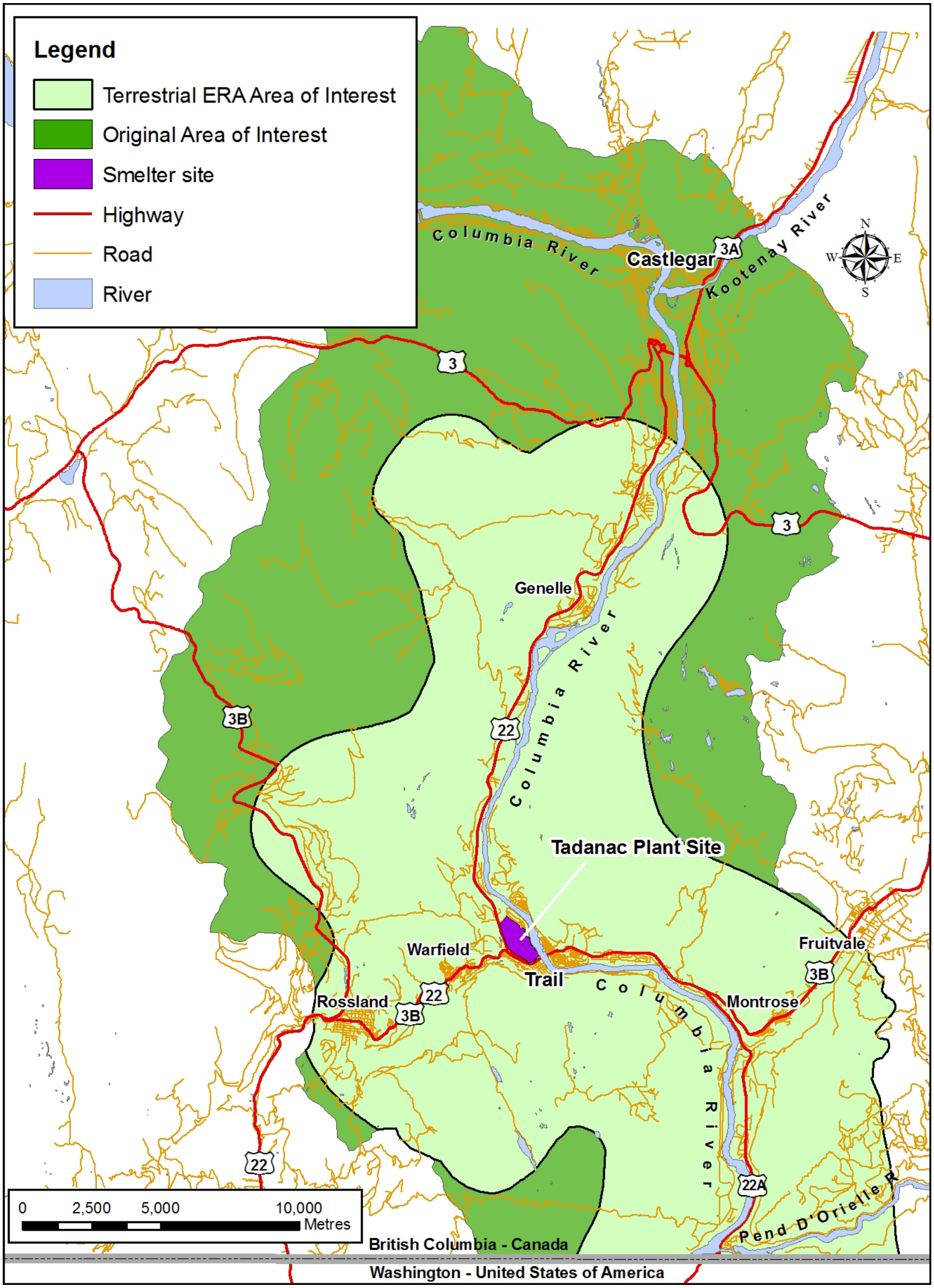


Figure 2-2 Area of Interest for the Terrestrial ERA

2.2 Levels of Refinement (LORs) for the Wildlife ERA

Three Levels of Refinement (LORs) were used in the modelling of direct toxicity to terrestrial wildlife (Cantox Environmental *et al*., 2001; Cantox Environmental, 2003a; Intrinsik, 2007). Seven types of parameters within the exposure assessment were varied for the LORs. In addition, the Toxicity Reference Values (TRVs) were varied as part of the effects assessment. The range of alternative TRVs is described and discussed in Appendix D of the LOR3 report (Intrinsik, 2007). The exposure variables that were changed with each succeeding level of refinement are summarized in Table 2-1 and described in the following paragraphs.

Table 2-1 Evolution of Major Exposure Variables in Each LOR[a]

Variable	*LOR1*	*LOR2*	*LOR3*
i) Food Ingestion Rate	Literature (allometric)	Literature (allometric)	Literature (free metabolic rate)
ii) Diet Apportionment	Generic	Literature	Regional expert judgment and experience
iii) Soil Ingestion Rate	Literature	Literature	Literature
iv) Trophic Transfer Models	Literature	Measure	Measure
v) Bioavailability	100%	Literature	Literature
vi) Area Use Factor/Habitat Quality	100%	Literature	Biophysical Habitat Map and Habitat Suitability Model
vii) Concentrations in Soil, Diet	Model	Measure	Measure

[a] Based on approach in Fairbrother (2003)

i) **Wildlife Food Ingestion Rates.** Both LOR1 and LOR2 relied on general allometric equations to estimate food ingestion rates, as recommended for screening-level ERAs (U.S. EPA, 1993). For LOR1 and LOR2, an average food ingestion rate for each wildlife receptor was assumed. In LOR3, food ingestion rates were estimated using a diet-specific free metabolic rate (FMR) approach, which is considered more realistic (U.S. EPA, 1993; Hope and Sample, 2003). The food item-specific FMR approach recognizes that a terrestrial wildlife receptor must consume enough energy (food) to meet its metabolic needs, and that the energy content of various food items differs (U.S. EPA, 1993).

ii) **Diet Apportionment**. Refinement in the diet composition and apportionment for each wildlife receptor took place in LOR2 and again in LOR3. The number of potential food items was increased from five general categories in LOR1 to 15 specific items in LOR2. This does not include soil, sediment and water ingestion, which were also considered in the exposure model.

iii) **Soil Ingestion Rates**. Soil ingestion rates were obtained from literature sources for LOR1, and no changes were made to the assumed amounts of incidental soil in the diet for LOR2 or LOR3. Soil/sediment ingestion rates were proportional to the food ingestion rate.

iv) **Trophic Transfer Models**. Trophic transfer models were improved for LOR2 and again in LOR3 with the incorporation of probabilistic methods to represent variability in predicted media concentrations.

v) **Chemical Bioavailability**. In LOR1, it was assumed that 100% of the measured concentrations of metals in soil and diet items were bioavailable. In LOR2, average estimates of metal bioavailability in soil were incorporated into the model, based on information from scientific literature. In LOR3, probabilistic distributions were assigned to metal bioavailability in soil and deterministic values were assigned to metal bioavailability in food.

vi) **Area Use Factor/Habitat Quality**. An area use factor (AUF) or habitat quality index was not incorporated into LOR1 or LOR2. Habitat quality was used in LOR3 only for the

American robin. The first step in risk characterization assumed that the entire area of interest provided suitable habitat for each receptor assessed in LOR3.

vii) **Metal Concentrations in Soils, Diet**. Additional measurements of metal concentrations in soil, sediment, water, and food items were available for LOR3.

In summary, each subsequent LOR incorporated a greater amount of site-specific data and used more advanced modelling to assess exposures and risks to terrestrial wildlife. Any receptor for which direct toxicity risks could not be ruled out at the completion of LOR3 was evaluated using the Sequential Analysis of Lines of Evidence (SALE) approach (Hull and Swanson, 2006). In addition, evaluation of overall avian and mammalian communities was completed using the SALE approach. The SALE analysis for wildlife is presented in Section 4.0.

2.3 Potential Chemicals of Concern

Potential chemicals of concern (PCOCs) for the terrestrial wildlife risk modelling were identified during the problem formulation stage (Cantox Environmental *et al*., 2001) and again at the beginning of the LOR2 stage (Cantox Environmental, 2003a). No further PCOC screening was done at LOR3; the PCOCs at the end of LOR2 (those for which risks could not be ruled out) were assessed in LOR3. The processes used to screen PCOCs are detailed in the Problem Formulation and LOR2 reports (Cantox Environmental *et al*., 2001; Cantox Environmental, 2003a) and are summarized below. The changes in PCOCs assessed at each LOR also are summarized.

The risk assessment is based on the net accumulation of emissions from 1897 to the year sampling was conducted (generally 2001/2002). Production at the Trail Operations smelter generally runs at capacity, 24 hours/day, 7 days/week, except during shutdown periods. There is no excess capacity that has not been utilized. Processes will change from time to time, as demand for different products evolves and changes; however, Teck expects and intends that PCOC emissions will further decrease in future, rather than increase. Emissions in recent years are much lower than in 1999/2000. For example, Pb was emitted at 163 tonnes/year in 1996 (pre-KIVCET), 9.5 tonnes/year in 2000 but only at 3.5 tonnes/year in 2007. Zinc was emitted at 383 tonnes/year in 1996 (pre-KIVCET), 170 tonnes/year in 2000 but only at 98 tonnes/year in 2007. Regarding SO_2, emissions were much greater pre-KIVCET (*e.g.*, >14,000 tonnes/year in 1996). Since KIVCET became operational, SO_2 emissions are fairly steady, between 4,000 and 6,000 tonnes/year. Therefore, future exposures and risks are not expected to be greater than past or current exposures or risks.

Sulphur dioxide is not a PCOC for the ERA. It is regulated *via* a permitting process, not under the CSR. Current levels of SO_2 are at concentrations which are not of toxicological concern for plants. However, past releases of SO_2 adversely affected the plant community. Therefore, consideration of previous SO_2 was factored into the plant community screening (Section 3.3).

2.3.1 PCOC Screening for the Problem Formulation

The original list of 15 PCOCs in LOR1 (Cantox Environmental *et al*., 2001) was developed according to procedures as outlined in the CSR (B.C. MELP, 1997). Maximum chemical concentrations in soil, measured between 1995 and 1999 within the AOI, were screened against regional background (B.C. MELP, 2000) and then screened against the lowest generic numeric soil standard (Schedule 4) or the matrix numeric soil standard (Schedule 5), regardless of land use designation (see Appendix A, Cantox Environmental *et al*., 2001). The results of the chemical screening are presented in Table 2-2.

Table 2-2 Results of LOR1 Chemical Screening Against Regional Background and Numeric Standards

Chemical[a]	*Exceeds Background*[b]	*Exceeds Criteria*[c]	*PCOCs for the Terrestrial Ecological Risk Assessment*
Antimony	Yes	Schedule 4	Yes
Arsenic	Yes	Schedule 5	Yes
Barium	Yes	Schedule 4	Yes
Beryllium	No	Schedule 4	No
Boron	Yes	Schedule 4	Yes
Cadmium	Yes	Schedule 5	Yes
Chromium	Yes	Schedule 5	Yes
Cobalt	No	Schedule 4	No
Copper	Yes	Schedule 5	Yes
Fluoride	NA	Schedule 4	Yes
Lead	Yes	Schedule 5	Yes
Mercury	Yes	Schedule 4	Yes
Molybdenum	Yes	<Schedule 4	No
Nickel	Yes	<Schedule 4	No
Selenium	Yes	Schedule 4	Yes
Silver	Yes	<Schedule 4	No
Sulphur	NA	NA	Yes due to prolonged sulphur emissions
Thallium	Yes	Schedule 4	Yes
Tin	Yes	Schedule 4	Yes
Vanadium	Yes	<Schedule 4	No
Zinc	Yes	Schedule 5	Yes

[a] List of PCOCs for which CSR has established background or Schedule 4 or 5 standards
[b] Screened maximum 1995 to 1999 measured soil concentrations against regional Kootenay background concentrations
[c] Screened maximum 1995 to 1999 measured soil concentrations against CSR Schedule 4 or Schedule 5

2.3.2 PCOC Screening for LOR2

The PCOC screening was conducted again at the beginning of LOR2, because new soil data were obtained in 2001 and 2002. The results obtained from the 1995 to 1999 soil surveys were excluded because a quality control assessment was done and data did not meet quality objectives (*e.g.,* the sampling methodologies were inconsistent across the time period, depths of samples varied, some samples were composited while others were not, and sample locations were restricted to locations at low elevations in the valley). The 2001 and 2002 field programs were consistently sampled with similar methodology, which used a random sampling design (Enns *et al*., 2001; 2002). The 2001 and 2002 soil concentrations represent the largest, most homogeneous and unbiased data set available for the terrestrial ERA (for sampling locations see Appendix B; Figure B1.1 of Cantox Environmental, 2003a).

Prior to LOR2 modelling (Cantox Environmental, 2003a), an effort was made to identify which chemicals in the AOI exceeded background concentrations as well as CSR standards, and which could be attributed to historical Teck smelter activities. This was done by:

- Screening against background concentrations as well as CSR standards;
- Simple correlation analysis of soil concentrations *versus* distance, in an attempt to identify which metal concentrations in the AOI do not appear to have been influenced by historical smelter activities; and,
- Mapping of soil concentrations throughout the AOI to provide a visual aid in assessing concentrations in relation to the smelter (Enns, 2003).

The measured 95th percentile composite soil concentrations from the 2001 and 2002 field program were screened against 95th percentile regional background concentrations. For chemicals found by this process to exceed background, measured maximum concentrations were screened against the CSR numeric standards. Regional background concentrations and numeric standards are shown in Table 2-3 and the chemicals identified as elevated in the AOI through this process are shown in Table 2-4.

Site-specific background concentrations also were determined (GSC, 2001) but were not used to eliminate any PCOCs (Table 2-4). Regional background concentrations were used to eliminate sulphur and vanadium, since the 95th percentile measured concentration for both chemicals was less than the 95th percentile regional background concentration (Table 2-4).

Table 2-3 Numeric Standards and Background Concentrations Assumed for LOR2 Screening [ppm]

Chemical	***Regional Bkg***[a]	***Site-specific Bkg***[b]	***Schedule 4 - Generic Numerical Soil Standards***[c]	***Schedule 5: - Matrix Numerical Soil Standards***[d]			
				Inverte-brates and Plants	***Livestock Ingesting Soil and Fodder***	***Microbial Functional Impairment***	***Ground Water***
Antimony	3.0	1.5	20				
Arsenic	15	19.7		50	25		15
Barium	400		750				
Beryllium	1.5		4				
Boron[g]	30[e]		2				
Cadmium	2.0	1.67		70	9		2
Chromium	20			300	150	50	60
Cobalt	10	16.6	40				
Copper	30	51.5		150	150		90
Fluoride			200				
Lead	100	37.9		1,000	350		150
Mercury	<MDC (0.025)[f]	0.07		100	0.6	20	
Molybdenum	1.0	2.82	5				
Nickel	40	42	150				
Selenium	<MDC (4.0)[f]		2				
Silver	<MDC (1.0)[f]	0.39	20				
Sulphur	650		500				
Thallium	<MDC	0.25	2				
Tin	5.0	1.2	5				
Vanadium	65		200				
Zinc	250	168		450	200	320	150

a 95th percentile Kootenay Background with strong acid leachable metals method – SALM; n=56 (B.C. MWLAP, 2003a)
b 95th percentile; n= 33-36 (GSC, 2001)
c Lowest numerical standard for agricultural (AL) environmental protection (B.C. MWLAP, 2002)
d Lowest numerical standard for toxicity to terrestrial organisms (*i.e.*, invertebrates, plants, microbial function, ingestion of soil and fodder by livestock) and the lowest numerical standard for protection of groundwater (*i.e.*, livestock watering and irrigation, and use by aquatic life) (B.C. MWLAP, 2002)
e 95th percentile for Kootenay Region using aqua regia method; n=20 (B.C. MWLAP, 2003a)
f Less than Method Detection Concentration (MDC); value in table represents one-half the detection limit concentration for Kootenay - Region 4 (B.C. MELP, 2000)
g Hot water extraction method

Table 2-4 Statistical Summary for LOR2 Metal Concentrations in Soil in the Area of Interest [ppm]

Chemical	*Average*	*Range*	*95th Percentile Measured*	*% Below Analytical Detection*	*95th Percentile Background*[a]	*B.C. Soil Standard*[b]	*COC*
Antimony	6.1	0.5 to 92	13	82%	1.5	20	Yes
Arsenic	17.2	1.2 to 130	48	0%	19.7	15	Yes
Barium	161.9	14 to 595	341	0%	400	750	No
Beryllium	0.81	0.5 to 2	2	79%	1.5	4	No
Boron[c]	0.14	0.1 to 0.2	0.2	nc	30	2	No
Cadmium	2.8	0.1 to 25.8	9	2%	1.67	2	Yes
Chromium	18.8	1 to 76	34	<1%	20	50	Yes
Cobalt	2.86	0.5 to 26	10	42%	16.6	40	No
Copper	20.1	2 to 326	53	0%	51.5	90	Yes
Lead	177.1	2 to 3,330	662	0%	37.9	150	Yes
Mercury	0.1	0.0005 to 1.45	0.2	1%	0.07	0.6	Yes
Molybdenum	2.0	2 to 5	2	98%	2.82	5	No
Nickel	15.7	1 to 73	33	1%	42	150	No
Selenium	0.3	0.1 to 1.9	0.8	34%	4.0	2	No
Silver	0.29	0.05 to 4.9	1.1	24%	0.39	20	No
Total Sulphur	176	10 to 1,640	566	0%	650	500	No
Thallium	0.2	0.05 to 1.5	0.5	17%	0.25	2	No
Tin	3.2	0.25 to 21	10	75%	1.2	5	Yes
Vanadium	26.5	4 to 443	46	0%	65	200	No
Zinc	149.0	14 to 1,330	401	0%	168	150	Yes

[a] Selected background value from Table 2-3 used in comparison to measured 95th percentile
[b] Lowest standard from Table 2 used in comparison to maximum measured concentration (B.C. MWLAP, 2002)
[c] Result with hot water extraction method
nc Indicates value not calculated
95th percentile indicates the value were only 5% of values are higher than the value shown - for example only 5% of the values measured for lead in the AOI are higher than 662 ppm

The boron results obtained from the 2001 to 2002 field program were not analysed according to the hot-water extraction method specified in the Contaminated Sites Regulation (B.C. MWLAP, 2002). Soil samples were analysed using the strong acid leachable metals (SALM) extraction method. Five soil samples with the highest boron concentrations using the SALM method were re-analyzed using the hot-water extraction method. All sample results using the hot-water extraction were below standards, thus it was assumed that remaining soil samples in the area of interest would yield similar or lower results. Therefore, boron was screened out based on these results.

Fluoride was excluded from the LOR2 model based on results reported in the problem formulation (Cantox Environmental *et al*., 2001). The screening level ERA did not generate Exposure Ratio (ER) values above the threshold of 1.0 for any of the receptors or scenarios; therefore, further evaluation of fluoride was not required.

For the remaining PCOCs (antimony, arsenic, cadmium, chromium, copper, lead, mercury, tin, zinc), correlation and spatial analyses were used to explore the relationship between distance from smelter and concentrations of PCOCs in soil. The assumption was that metals emitted from the smelter are dispersed predominantly in the form of particulate, and that metal deposition decreases with distance from the smelter.

It is known that stack deposition immediately adjacent to the smelter is lower (fugitive is higher) (Goodarzi *et al.*, 2002), but that in general, concentrations of metals in soils decrease with increasing distance from the smelter. Two-way semi-logarithmic scatter plots of chemical concentrations in soil and distance from the smelter illustrate the relationship between these two variables (Appendix A of Cantox Environmental, 2003a). Correlation analysis was used to explore the relationships between these two variables, and the degree in which a change in one variable (distance from smelter) causes a change in the other (concentration of metal in soil). The linear (Pearson's) and rank (Spearman's) correlation coefficients for each chemical concentration in soil with distance are provided in Table 2-5. A negative correlation coefficient indicates that soil concentrations are inversely related to distance from smelter (*i.e.*, lower metal concentrations are found farther from the smelter).

Table 2-5 Correlation Coefficients for Metal Concentration in Soil *versus* Distance from Smelter

Chemical	***Correlation Coefficients ('r')***	
	Pearson's (linear)	***Spearman's (rank)***
Antimony	-0.147*	-0.052*
Arsenic	-0.378*	-0.484*
Cadmium	-0.316*	-0.443*
Chromium	0.015	-0.029
Copper	-0.272*	-0.443*
Lead	-0.299*	-0.457*
Mercury	-0.256*	-0.485*
Tin	-0.028	0.096
Zinc	-0.371*	-0.490*

* Significant value at the level of significance alpha=0.050 (Two-tailed test)

The results shown in Table 2-5 confirm that almost all of the PCOC concentrations in soil decrease with distance from smelter. The linear correlation coefficient is strongly influenced by extreme values; therefore, the rank correlation coefficient was calculated, which is not as sensitive to extreme values (Huntsberger and Billingsley, 1973). In combination, the two statistical measures can be used to provide insight into the skewness of a distribution by observing the difference between the linear and rank correlation coefficients (B.C. Environment, 1995). The histograms provided in Appendix A1 of Cantox Environmental (2003a) demonstrate the fact that most of the PCOCs are positively skewed or have a lot of low values and a relatively low proportion of high values.

The results (provided in Table 2-5 above and Appendix A1 of Cantox Environmental, 2003a) indicate that spatial distributions of chromium and tin in soil are not consistent with the source of these metals being the smelter. In addition, the two-way scatter plots in Appendix A1 (Cantox Environmental, 2003a) for chromium and tin demonstrate that concentrations of these metals in soil do not vary with distance or elevation and that chromium is normally distributed in the AOI. This is supported by the kriging (Enns, 2003) maps of chromium (Figure B 2.4) and tin (Figure B 2.8) in Appendix B of Cantox Environmental (2003a). In addition, as noted in Table 2-4, the 95th percentile measured concentration of chromium was 34 mg/kg, below the BC soil standard of 50 mg/kg. Therefore, while the maximum concentration (76 mg/kg) did exceed the standard, it only exceeded by a factor of 1.5. This, combined with the other information (including the correlation analysis) supports the elimination of chromium as a PCOC. Similarly, although the 95th percentile concentration of tin exceeds the BC soil standard by a factor of 2, the average concentration did not, and 75% of the soil samples had non-detect concentrations of tin. This, combined with the other information (including the correlation analysis) supports the elimination of tin as a PCOC.

For all remaining chemicals in Table 2-5, significant inverse relationships between metal concentrations in soil and distance from the smelter were observed. The two-way scatter plots and the kriging maps in Cantox Environmental (2003a) demonstrate these relationships. However, the correlation analysis does not provide evidence of a 'strong' relationship between metal concentration in soil and distance from smelter. All correlation coefficients are less than -0.5 and there is substantial scatter or variability within the data. A number of factors were thought to contribute including variations in: physiography and prevailing winds, precipitation, bedrock geology, smelter process activities and fugitive dust (GSC, 2001). However, with evidence provided by the two-way scatter plots and correlation analysis, in combination with kriging maps (Enns, 2003) it is concluded that metal concentrations of antimony, arsenic, cadmium, copper, lead, mercury, and zinc in soil are related to past smelter activities. These seven PCOCs were assessed quantitatively in LOR2.

In addition to the metals listed above, B.C. MWLAP (2003b) raised concerns over 10 chemicals measured in the AOI for which no numeric standards exist, but for which regional background concentrations were available (Table 2-6). All of these metals, with the exception of manganese and phosphorus, were found to have concentrations below or within the range observed for regional background. The two-way scatter plots for manganese and phosphorus (Appendix A1 of Cantox Environmental, 2003a) demonstrate no relationship between metal concentrations and distance from the smelter. However, a statistically significant result was observed between phosphorus concentrations and distance using the Spearman's correlation coefficient (Table 2-7).

Table 2-6 Summary of Measured and Reported Background Concentrations for Chemicals of Potential Concern Without Soil Guidelines

Chemical	*Measured Concentration in AOI (2001 to 2002) [µg/g][a]*		*Reported Background Concentrations [µg/g][b]*	
	Average	*95th Percentile*	*Average*	*95th Percentile*
Aluminium	14,585	26,080	30,112	60,000
Calcium	1,873	4,664	23,804	85,000
Iron	16,401	25,080	21,405	40,000
Magnesium	3,100	6,490	10,540	25,000
Manganese	555	1,192	428	1,000
Phosphorus	4,177[c]	8,498[3]	846	2,000
Potassium	855	1,846	6,850	16,000
Sodium	103	197	943	2,000
Strontium	21	44	139	100
Titanium	593	1,242	2,650	2,000

[a] Sample size is 305
[b] Background concentrations obtained with nitric perchloric acid; n= 56 (B.C. MWLAP, 2003a)
[c] Results obtained with the strong acid leachable metals method – SALM

Table 2-7 Correlation Coefficients for Manganese and Phosphorus Concentrations in Soil with Distance from Smelter

Chemical	*Correlation Coefficients ('r')*	
	Pearson's	*Spearman's*
Manganese	-0.083	-0.083
Phosphorus	-0.084	-0.12*

* Significant value at the level of significance alpha=0.050 (Two-tailed test)

Phosphorus was found to exceed background concentrations and was weakly correlated with distance from smelter. However, based on the following factors (Brady and Weil, 1999), phosphorus was dropped as a PCOC for the ERA:

- Phosphorus is an essential nutrient required for proper maintenance of good health in plants and animals;
- Phosphorus tends to undergo sequential reactions in acid and alkaline soils that produce phosphorus-containing compounds with lower and lower solubility. The lower the solubility of phosphorus in soil, the less phosphorus is available for plant uptake; and,

- Inorganic phosphorus in weathered soils is far too insoluble to contribute to plant uptake.

Based on the revised PCOC screening, the following PCOCs were included in the LOR2 exposure modelling of terrestrial receptors:

- Antimony;
- Arsenic;
- Cadmium;
- Copper;
- Lead;
- Mercury; and,
- Zinc.

2.3.3 PCOCs Retained at the Conclusion of each LOR

The PCOCs for wildlife remaining at the completion of each LOR are summarized in Table 2-8. PCOCs were eliminated if all risk estimates for all receptors (expressed as Exposure Ratios) were less than 1.0. LOR2 wildlife risk modelling resulted in the elimination of antimony as a PCOC (Cantox Environmental, 2003a). Completion of LOR3 wildlife risk modelling resulted in only two remaining PCOCs, cadmium and lead (Intrinsik, 2007). The wildlife receptors for which risks could not be ruled out at the completion of LOR3 were assessed in this Final Terrestrial ERA (SALE; Sequential Analysis of Lines of Evidence) Report.

Table 2-8 Potential Chemicals of Concern at Completion of each Level of Refinement (LOR) of the Direct Toxicity Modelling for Wildlife

Chemical	*PCOCs at Completion of LOR1*	*PCOCs at Completion of LOR2*	*PCOCs at Completion of LOR3*
Antimony	Yes		
Arsenic	Yes	Yes	
Barium	Yes		
Boron	Yes		
Cadmium	Yes	Yes	Yes
Chromium	Yes		
Copper	Yes	Yes	
Fluoride	Yes		
Lead	Yes	Yes	Yes
Mercury	Yes	Yes	
Selenium	Yes		
Sulphur	Yes		
Thallium	Yes		
Tin	Yes		
Zinc	Yes	Yes	

2.3.4 Organic Compounds

The Trail Ecological Risk Assessment has focussed on environmental media concentrations and plant community impacts resulting from past releases of inorganic chemicals and SO_2 from the smelter. Emissions of polychlorinated dibenzo dioxins and furans (PCDD/F) were addressed in a memorandum in 2003 (Cantox Environmental, 2003b). The PCDD/F emissions from the Trail smelter were below Environment Canada's source targets for virtual elimination, and as such were not considered further.

2.3.5 Summary of PCOC Screening

In summary, a total of 31 elements were considered to identify PCOCs: aluminium, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, fluoride, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, phosphorus, potassium, selenium, silver, sodium, strontium, sulphur, thallium, tin, titanium, vanadium, zinc.

Following the completion of LOR3, cadmium and lead were the only remaining PCOCs with any potential to cause toxicity to wildlife. However, antimony, arsenic, cadmium, copper, lead, mercury, and zinc all remained as PCOCs for the assessment of risks to plants and soil invertebrates, because the LOR2 and LOR3 modelling assessed only direct toxicity risks to wildlife species (not plants and soil invertebrates).

2.4 Receptors of Concern

An ecological receptor is defined as an organism or group of organisms that have the potential to be affected by a chemical or other stressor (*e.g.*, habitat loss). Because it is not possible to evaluate all ecological receptors at a site, representative receptors were selected for the terrestrial wildlife risk assessment based on several criteria, including:

- Threatened or endangered species;
- Sensitivity to the chemicals and other stressors at the site;
- Biological and ecological relevance;
- Ability to measure or predict effects; and,
- Social relevance (species of recreational, commercial or social importance).

Representative receptors were selected for each wildlife feeding guild (*e.g.*, insectivorous small mammal, herbivorous bird, *etc.*) and for particular land uses (*e.g.*, urban, wildland, and agricultural areas, as well as the Columbia River and its tributaries). Certain receptors (*e.g.*, cow, horse, chicken, forage and fruit crops) were only assessed in one land use (in this case, agricultural). However, the remainder of the receptors were evaluated in all land uses. Receptor communities also were defined, to better understand wildlife use patterns in the AOI. The receptors evaluated in LOR1, LOR2 and LOR3 did not change significantly, although several receptors were not evaluated in LOR3 because no unacceptable risks were predicted at the completion of LOR2 (Table 2-9).

Table 2-9 Receptors of Concern in LOR1, LOR2, LOR3 and for SALE

Receptor	***Receptor of Concern in LOR1, LOR2 and LOR3?***	***Receptor of Concern for SALE[a]***
Receptor Communities		
Terrestrial plant communities (wildlands, urban areas)	Not assessed at LOR1, LOR2 or LOR3	Yes
Avian communities	Not assessed at LOR1, LOR2 or LOR3	Yes
Mammalian communities	Not assessed at LOR1, LOR2 or LOR3	Yes
Wildlife Species Selected as Representatives of Particular Trophic Levels and Feeding Guilds		
American crow	No direct toxicity predicted in LOR3	
American robin	Yes	Yes
Belted kingfisher	No direct toxicity predicted in LOR2	
Black bear	No direct toxicity predicted in LOR2	
Black-capped chickadee	No direct toxicity predicted in LOR3	
Columbian ground squirrel	No direct toxicity predicted in LOR2	
Coyote	No direct toxicity predicted in LOR2	
Deer mouse	No direct toxicity predicted in LOR2	
Dusky shrew	No direct toxicity predicted in LOR3	

Table 2-9 Receptors of Concern in LOR1, LOR2, LOR3 and for SALE

Receptor	***Receptor of Concern in LOR1, LOR2 and LOR3?***	***Receptor of Concern for SALE[a]***
Mallard	Added for LOR2 as representative of benthos-eating ducks; no direct toxicity predicted in LOR2	
Osprey	No direct toxicity predicted in LOR2	
Red-backed vole	No direct toxicity predicted in LOR2	
Red squirrel	No direct toxicity predicted in LOR2	
Red-tailed hawk	No direct toxicity predicted in LOR2	
River otter	No direct toxicity predicted in LOR3	
White-tailed deer	Changed from Mule Deer in LOR1, since white-tailed deer more representative of AOI; no direct toxicity predicted on LOR2	
Agricultural Species		
Chicken	No direct toxicity predicted in LOR3	
Cow	No direct toxicity predicted in LOR2	
Horse	Yes	Yes
Crops (forage, fruit)	Not assessed at LOR1, LOR2 or LOR3	Yes
Listed Species		
Bobolink	Yes	Yes
Canyon wren	Yes	Yes
Great blue heron	No direct toxicity predicted in LOR3	Yes
Lewis's woodpecker	Yes	Yes
Townsend's big-eared bat	Added for LOR2 and LOR3 as a Listed mammal	Yes
White-throated swift	Yes	Yes

[a] Blank cells indicate receptor was not a receptor of concern for SALE

The American robin was the only non-Listed wildlife species for which risks could not be ruled out following the completion of LOR3. It was retained for the SALE evaluation as the representative of its respective trophic level and feeding guild (*i.e.*, omnivorous songbirds which have a substantial component of insects and worms in their diet). Particular Listed wildlife species were assessed, and all were retained for the SALE. While direct toxicity risks were not predicted for the great blue heron, it was retained for assessment in SALE because of the potential for indirect risks from habitat change or change in prey availability. The "receptor communities" and "crops" were not assessed using the LOR approach. Therefore, these were included in the SALE process.

2.5 Conceptual Models

Conceptual models were developed to illustrate both the direct and indirect linkages between PCOCs and assessment endpoint entities. Consideration of indirect effects allows the evaluation of how changes in habitat influence receptors. Changes in habitat can have a much greater effect on receptors than direct chemical toxicity, yet standard risk assessment methods do not incorporate habitat-related effects (with the exception of including the role of habitat in determining exposure to chemicals).

The wildlife conceptual model 1 (Figure 2-3) illustrates the linkages between the PCOCs and wildlife that could result in direct toxicity. The model shows the release of metals and metalloids from stack emissions and fugitive air emissions, and deposition of PCOCs onto soil and directly onto plants (*e.g.*, lichen, conifers). Wildlife are exposed to PCOCs by ingesting soil, water, sediment, and food (*e.g.*, plants, invertebrates, aquatic organisms).

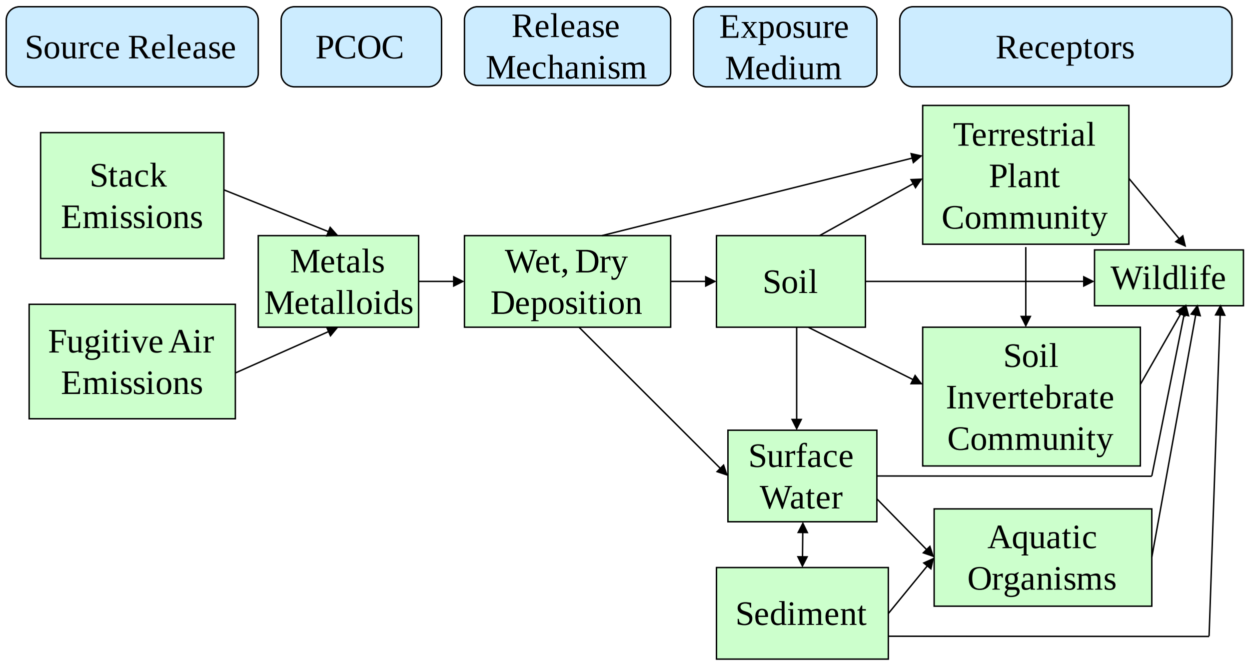


Figure 2-3 Wildlife Conceptual Model 1: Direct Risks from Smelter-Related Emissions

The wildlife conceptual model 2 (Figure 2-4) illustrates the linkages between PCOCs in soil, SO_2 and wildlife that could result in indirect effects. Indirect effects can occur through so-called "trophic cascades", which are effects mediated through interactions between consumer organisms and their food. These effects would include predator influences on lower trophic levels and effects through food/prey influence on higher trophic levels (Fleeger *et al.,* 2003). Indirect effects also include effects on wildlife due to changes in the plant community (*i.e.*, that serves as cover, nesting sites, foraging areas, *etc*.) caused by PCOCs in soil and SO_2.

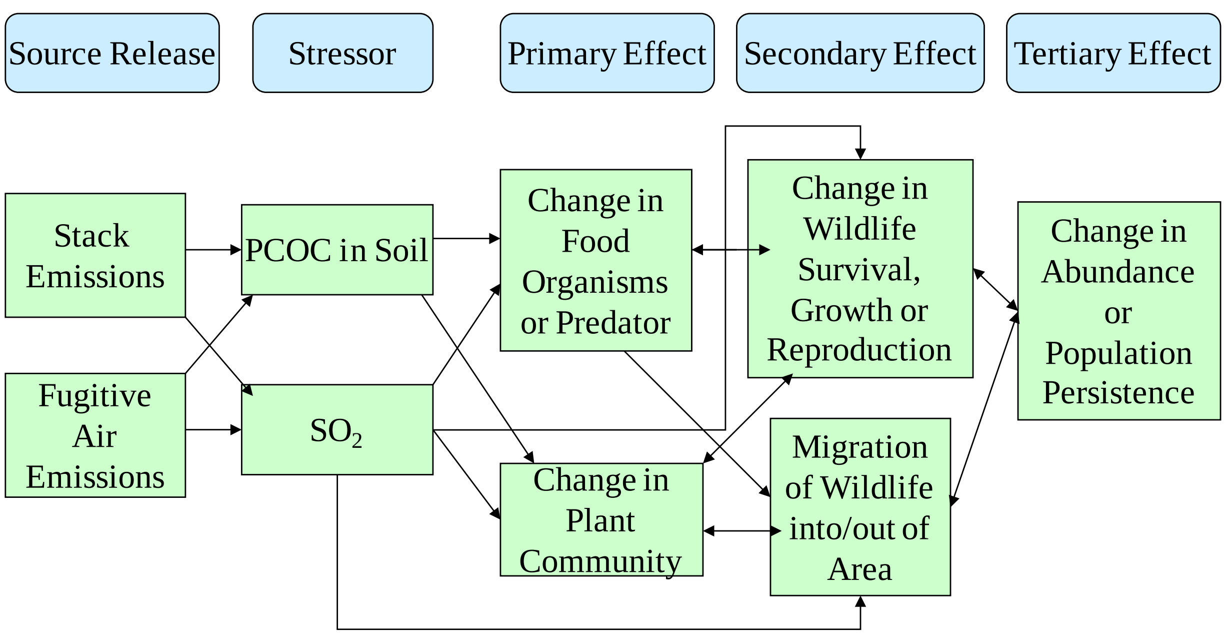


Figure 2-4 Wildlife Conceptual Model 2: Indirect Risks from Smelter-Related Emissions

The conceptual model for plants (Figure 2-5) illustrates both direct and indirect effects. PCOCs in soil can have direct influences on plants, soil biota and herbivores, which then influence plant communities *via* indirect mechanisms. SO_2 also influences the plant community. In the past, SO_2 concentrations resulted in direct toxicity to plants. However, current SO_2 levels are low enough that direct toxicity is not expected. Rather, the influence of SO_2 is considered an indirect effect because there may be current effects due to the historical influence of SO_2 on soil and the plant community. The end result of these direct and indirect effects may be changes in plant community composition and structure.

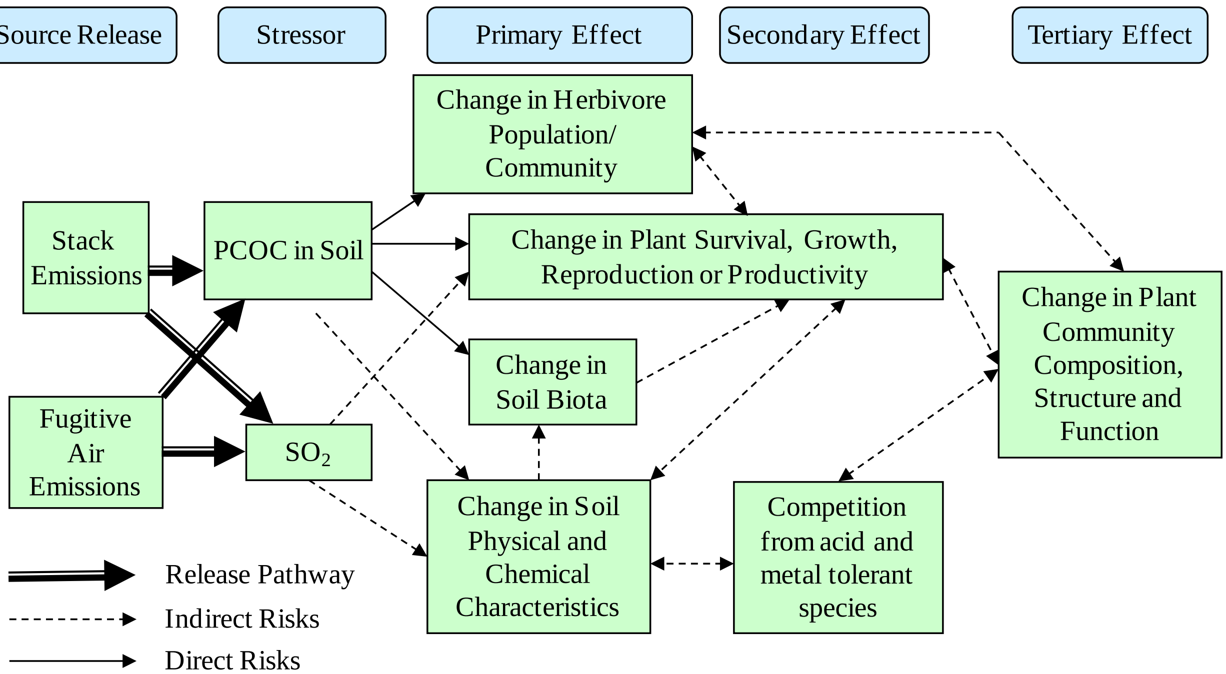


Figure 2-5 Plant Community Conceptual Model: Direct and Indirect Risks from Smelter-Related Emissions

2.5.1 Other Sources of Stress in the Area of Interest

Other sources of stress to plant communities and wildlife exist in the AOI. Fire and logging have had significant influences on plant communities in the past. In addition, linear developments (*e.g*., transmission corridors, roads), and urban/commercial development change habitat suitability for wildlife. These stressors are unrelated to smelter emissions. The effects of linear development (*e.g.,* paved roads) manifest themselves in occurrences of road kill, and reductions in seasonal and or daily movements. Urban development results in the removal of some habitat and creation of other urban habitats. Urban development also results in some wild animal culling where there are conflicts, especially with black bear. Linear right-of-way developments often create useful edge habitats but can increase the predator prey success rate. Fire has a very similar effect as past SO_2, and hence is difficult to discern from smelter-related changes (Murtha, 1972; Mikkola, 1996; Kozlov *et al*., 2009).

Logging and fire are discussed in Section 3.0 in relation to plant communities. Areas that were obviously impacted by logging were screened out of the plant community assessment, as long as metal concentrations in soil did not exceed CSR standards for plants and soil invertebrates (see Section 3.0). That is, areas (polygons in the biophysical habitat map) were eliminated if 100% of the polygon had been logged (clearcut, old logging, selective logging) *and* if there was a >90% probability that PCOC concentrations in soil were less than the CSR standards for plants and soil invertebrates. If a polygon was logged, it was assumed that the polygon supported and can continue to support a productive merchantable forest type.

Fire is identified as a potential confounding factor of the plant community screening conducted in Section 3.0. However, unlike what was done for logging, evidence of fire was not used to screen out areas in the plant community assessment. Therefore, many of the polygons identified as having smelter-impacted plant communities (that is, the polygons were retained by the screening evaluation) also have evidence of severe or moderate past fire. It is not always possible to recognize the effects of old fires in the aerial photographic interpretation used in the mapping. However, fire mapping indicates most of the AOI was burned at some point within the past 100 years, and some areas burned repeatedly (Enns and Enns, 2010; Appendix F). Therefore, some of the polygons mapped as not burned likely were burned. The map identifies only visible evidence of fire, and there is some potential for error in that there may be several fire-affected polygons not classed as affected by fire (Appendix C).

In summary, it was difficult to account for non-PCOC stressors in the terrestrial ERA, because none of the responses (*e.g*., changes in plant community structure) could be considered to be specific to the effects of PCOCs in soil. Several potential confounding natural and anthropogenic factors (*e.g*., fire, logging, disease, land management activities) could contribute to the observed impacts to the plant community. Impacts of fire and logging, in particular, are discussed further in Section 3.0.

2.5.2 Uncertainty

There are four sources of uncertainty in this assessment:

- Natural variability;
- Model uncertainty;
- Measurement error; and,
- Data errors.

Each of these potential sources of uncertainty was evaluated and rated for inclusion in the overall score for each line of evidence.

2.5.2.1 Natural Variability

Natural variability exists in both the chemical concentrations measured within the AOI and in biological variability. Chemical concentrations vary spatially both vertically and horizontally, especially in soil. The distributions of plants and wildlife vary in the AOI, regardless of the presence of PCOCs, due to variations in elevation, topography, soils, climate, *etc*. In cases where these natural variables happen to be spatially correlated with the chemical concentrations, there is the possibility of confounding of the apparent effects of chemicals by this natural variability.

Variability in chemical concentrations was addressed in Step 1 (screening) of the SALE. Distributions of chemical concentrations in various media were used in a probabilistic assessment of direct toxicity in the LOR modelling for wildlife (Intrinsik, 2007). Conditional simulation was used to predict the area within the AOI where there was a >10% of PCOC concentrations in soil exceeding the CSR standards for plants and soil invertebrates, in the plant community assessment (Section 3.0 of this volume). The assessments of risks to plants and wildlife both used conservative assumptions related to variability in chemical concentrations to ensure risks were not incorrectly ruled out.

Potential confounding by natural physical and biological variability was addressed in the modelling for wildlife and by using various field and statistical methods for both wildlife and the plant community. In the LOR modelling, distributions for biological parameters (*e.g*., food ingestion rate) were used in the probabilistic assessment of direct toxicity (Intrinsik, 2007). Field surveys were conducted for various wildlife species at multiple locations and sometimes over multiple years to account for variability. For example, the American robin presence and nesting survey was done only in areas of suitable habitat, to see if there may be an influence of PCOCs in soil rather than simply an influence of habitat suitability on the survey results (*i.e.*, confounding was controlled using stratification of sampling) (Appendix B). The vegetation statistical analysis attempted to account for non-PCOC influences, such as elevation, soil moisture regime and dominant plant community type (*i.e*., coniferous or deciduous) by using methods for statistical control of confounders in the data analysis. Other approaches for dealing with these issues are described in greater detail in the Terrestrial Resources Report (Golder, 2007a).

The SALE process required a score for uncertainty for each line of evidence. The score for uncertainty related to natural variability was determined by evaluating the study design in the context of being able to distinguish differences across a PCOC gradient through the AOI, whether studies were conducted over multiple years, and whether natural variables that could influence the response were measured or accounted for.

2.5.2.2 Model Uncertainty

Model uncertainty is a reflection of our ignorance about how stressors affect terrestrial populations and communities. The conceptual models developed for this assessment put forward the ideas that: 1) PCOCs emitted from the smelter directly affect terrestrial organisms through exposure *via* soil, water, sediments or food items; and, 2) smelter emissions indirectly affect terrestrial organisms through physical changes in habitat quality or through changes in the abundance or distribution of prey and predators. One or both of these models could be in error. Some of the main sources of uncertainty related to the model of direct toxicity of PCOCs on terrestrial organisms are: the bioavailability of PCOCs for uptake from soil; the degree of trophic transfer; and our understanding regarding the amount of PCOCs required to adversely affect terrestrial organisms. These uncertainties were addressed in several ways. Bioavailability was addressed by measuring the PCOC concentrations in plant, soil invertebrate and fish tissue; this allowed an evaluation of bioaccumulation factors from soil to plant and invertebrate or from water to fish. Trophic transfer was addressed by using measured concentrations of PCOC in various wildlife dietary items. Uncertainty related to our understanding of the amount of PCOC required to adversely affect terrestrial organisms was addressed by using multiple toxicity reference values (TRVs) in the LOR wildlife modelling, and using field biological survey data for plants, invertebrates and wildlife to supplement the chemistry data.

The conceptual model of direct toxicity, when accompanied by the risk management objectives and assessment endpoints, assumes that exposure of terrestrial organisms to PCOCs can result in direct effects on the receptor assessment endpoint (such as species diversity or plant productivity). The aim of the risk management goal and objectives is to minimize or prevent these direct effects. SALE addresses the uncertainty inherent in the assumption that exposure to PCOCs above effects benchmarks (such as TRVs or CSR standards) will result in effects by including assessment of other field-based measurements. It also includes assessment of the potential for effects from physical habitat change.

The conceptual models also illustrate modes of indirect effects from PCOCs. It does not include the potential role of other stressors such as urban development, fire, logging, disease, *etc*. It also does not include hypotheses about how multiple stressors (all PCOCs acting together plus other stressors not related to the smelter) would produce effects in terrestrial ecosystems. Some of the main sources of uncertainty related to the model of indirect toxicity of PCOCs on terrestrial organisms are: the ongoing influence of previous SO_2 emissions on plant communities (*e.g.*, previous injury to plant communities, soil erosion); the relative influences of predation pressure or prey availability on receptors; the relative influence of non-smelter stressors on terrestrial organism response. The influence of previous SO_2 on plant communities was addressed in the biophysical habitat mapping. Plant communities were identified in the map if previous SO_2 damage was evident in the aerial photography, and cross-referenced with field data, ground-based photographs and aerial oblique photographs (see Section 3.0). Risks to predators and prey organisms were assessed in the LOR modelling (Cantox Environmental 2003a; Intrinsik, 2007). The influences of non-smelter stressors on plant communities were addressed above (Section 2.5.1) and in Section 3.0. Non-smelter stressor effects on wildlife (*e.g.*, disease) were not addressed.

The SALE process required a score for uncertainty related to confidence in the models for direct and indirect toxicity. This was achieved by examining the extent to which the lines of evidence accounted for confounding natural and anthropogenic variables and whether the response was anomalous in the context of measured PCOC concentrations. The score also was based on the current state of scientific knowledge regarding the mechanisms and processes that produce direct or indirect effects.

2.5.2.3 Measurement Error

Measurement error is the inherent inability of a measuring device or procedure to provide an accurate representation of reality (Warren-Hicks and Moore, 1998). Therefore, all field and laboratory analyses are subject to measurement error. Chemical analyses of soil and biota vary in their measurement errors, but the error may be between 20 and 40% for inorganic parameters. These errors could influence the wildlife risk modelling, although an upper estimate of exposure was used in LOR2 (90^{th} percentile), and the entire distribution of data was used in LOR3. Field measurements also are subject to measurement error. Identification of plant species, and other similar measurements, can be influenced by the experience of the field staff. This could influence the statistical analysis conducted on plant community parameters.

Measurement error was minimized by adherence to Standard Operating Procedures (also called Technical Procedures) for all field sampling and laboratory analyses. Technical Procedures for the field program are described in the Quality Assurance Management Plan report (Golder, 2006). Quality assurance/quality control (QA/QC) was conducted on analytical chemistry data, as well as biological field survey data (Golder, 2007a). Details regarding the mapping QA/QC may be found in Enns and Enns (2007b; Appendix C).

2.5.2.4 Data Errors

Data errors may arise from data management activities. There may be errors in data transcription or manipulation, units conversion, statistical analysis, and modelling. The magnitude of each of these types of errors may vary. However, if the error is too large, it will become obvious (*e.g.*, a units conversion error typically is three orders of magnitude, such as from micrograms to milligrams). Implications of data errors are similar to those of measurement errors.

Standardized office protocols were adhered to as described in the Quality Assurance Management Plan report (Golder, 2006). Data errors were not scored in the SALE process because it was assumed that the degree of data error was controlled in a similar manner across all lines of evidence.

3.0 ASSESSMENT OF RISKS TO EVALUATE OBJECTIVES 1, 2 AND 3 RELATED TO VEGETATION IN WILDLAND, URBAN AND AGRICULTURAL AREAS

The assessment of risks to vegetation includes an introduction (Section 3.1), screening of metal concentrations in soil against soil standards (Section 3.2), the SALE evaluation for wildland plant communities (Section 3.3), a problem formulation for urban plants and agricultural crops (Sections 3.4 and 3.5), and a summary of conclusions regarding plant communities in the AOI (Section 3.6).

3.1 Introduction

There are three objectives related to vegetation in the Area of Interest. The assessment endpoints and associated measures (lines of evidence) for each objective are presented below.

Objective 1 Wildland Vegetation:
Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on the maintenance of dynamic self-sustaining vegetation communities in natural “wildland” areas.

Two assessment endpoints were defined to evaluate this objective:

1) Forest productivity; and,
2) Vegetation species composition.

Previously, in the Management Goal and Objectives report (Teck Cominco *et al*., 2004), two additional assessment endpoints were identified: vegetation presence and condition; and, richness and diversity. However, presence of particular species (such as sensitive species), as well as richness and diversity, are all considered part of the “vegetation species composition” endpoint. Condition of the vegetation also may be reflected in both productivity and community composition.

Several measures were used to evaluate the assessment endpoints. These were combined into four “lines of evidence” (LOE) to evaluate direct and indirect effects as postulated by the conceptual model. For Objective 1, the LOE are:

- Line of Evidence #1: Forest productivity. Three measures of forest productivity were used. 1) Forest productivity, before and after the KIVCET smelter became operational, was measured directly in western white pine (*Pinus monticola*) at five sampling sites (Golder et al., 2007a). 2) Site index was calculated for 61 samples of multiple species at 32 locations (Enns and Enns, 2010; Appendix F). Site index is a measure of site productivity based on the diameter and height of the dominant and codominant trees in relation to species curves developed for individual species. 3) An indirect measure of productivity was used through the analysis of vegetation change over a 7-year period (2000-2007). IKONOS imagery of the area near Columbia Gardens and the Trail Airport, also classed as Plot Type 4 and the *Agrostis* group (see Section 3.3.2.2), was used to compare changes in tree crowns and ground vegetation cover and complexity in 101 polygons (Enns and Enns, 2010).
- Line of Evidence #2: Plant community statistics. Associations were explored between soil parameters (soil metal concentrations, pH) and plant community parameters (plant species richness and diversity, presence of sulphur dioxide sensitive or tolerant plant species, and percentage tree, shrub and herb cover). A second analysis was conducted on vegetation

richness and diversity related to soil metals and soil and topography characteristics (*e.g.*, % sand, bulk density, crown closure, elevation, distance from smelter);

- Line of Evidence #3: Soil physical and chemical characteristics. Associations were explored between litter-fibre-humus (LFH) depth and other soil parameters (*e.g.*, pH, organic matter, soil metal concentrations); and,
- Line of Evidence #4: Herbivorous avian and mammalian community composition. This LOE represents potential indirect effects on plant communities caused by changes in herbivore populations. The changes in herbivore populations would result from direct toxicity of the PCOCs.

Objective 2 Urban Vegetation:

> Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on the maintenance of desired native and introduced plant species in "urban" areas.

Two assessment endpoints were defined to evaluate this objective:

1) Plant productivity; and,
2) Native and introduced vegetation species presence and condition.

The assessment of plants in an urban setting is complicated by the fact that people can alter the system as often and in any way they like. Also, it is not known how well the horticultural requirements of urban plantings are met. Alterations (or maintenance) can include the addition of soil and nutrients, alteration of soil pH through various soil amendments, irrigation, and the addition or removal of plants of various ages. Therefore, it is difficult to evaluate directly and quantitatively the influence of smelter emissions on plants in the urban environment. Instead, several groups involved in growth and maintenance of plants in the urban areas around Trail were interviewed (see Golder, 2007a for the questionnaires and a summary of the results). Although this information is qualitative and anecdotal, it comes from people who have lived and worked in the Trail area for many years, and who have particular interest in the presence, growth and condition of plants in the area. Their observations can contribute to our understanding of the potential influences of smelter emissions on plants in the area. The information collected from the survey was used to evaluate the assessment endpoints specific to Objective 2 using the following LOE:

- Line of Evidence #5: Anecdotal information on plant growth (productivity) over the past 8 to 10 years; and,
- Line of Evidence #6: Anecdotal information on the presence and condition of native and introduced species grown in the area, including sensitive species, and whether or not there are difficulties (that can be related to smelter emissions) in growing particular plants.

The 8 to10 year time-frame referred to in Line of Evidence #5 is relative to the installation of the KIVCET smelter (more detail is provided in Golder, 2007a). This is a relevant time frame, because the ERA is assessing current and potential future risks, not past risks. Historical air-borne emissions (particularly of SO_2) could have been influencing plant communities in the past (more than or rather than metal concentrations in soil, which are subject to risk assessment under the Contaminated Sites Regulation). Therefore, information on changes and status of plants within the past 8-10 years is relevant to the ERA and to the determination of risk management measures, in order to evaluate whether SO_2 was the primary or only cause of impact to plant communities, or whether PCOC concentrations in soil could be continuing to have an effect on plant communities now that SO_2 concentrations are low enough not to have a significant impact.

Objective 3 Agricultural Crops:

> Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on forage crops, pastureland, and vegetable and fruit production in "agricultural" areas

Two assessment endpoints were defined to evaluate this objective:

1) Yield of forage crops or pasture and yield of fruits; and,
2) Quality of forage crops, pastureland and fruits.

Previously, in the Management Goal and Objectives report (Teck Cominco *et al*., 2004), the assessment endpoints were identified as yield and quality of forage crops, vegetables and fruits. However, no significant amounts of vegetables are grown in the AOI. The main fruit produced in the area is grapes, used for wine production. There is forage crop production and pastureland in the AOI. Therefore, the assessment endpoints were modified to remove "vegetable" and add pastureland. The focus related to fruits was on grapes.

The assessment of plants in an agricultural setting is complicated in a way similar to that for urban areas, in that people can alter the system as often and in any way they like. Therefore, area farmers (Columbia Gardens Vineyard and Winery, a greenhouse operator, and a dairy farmer) were contacted (see Golder, 2007a for questionnaires and a summary of the results). Several questions were asked related to: yields over time; cultivation practices, including soil amendments and irrigation; and, concerns about smelter emissions related to their agricultural operation.

This information was used to evaluate the assessment endpoints specific to Objective 3 using the following LOE:

- Line of Evidence #7: Anecdotal information on forage crop and grape yield; and,
- Line of Evidence #8: Anecdotal information on forage crop and grape condition and whether there are difficulties (that can be related to smelter emissions) growing particular crops.

The data used to evaluate the LOE for these three objectives were taken from several sources, as summarized in:

- Golder (2007a) Terrestrial Resources report;
- Enns and Enns (2007b; Appendix C) Biophysical Habitat Mapping report;
- Goodarzi *et al*. (2006); and,
- Enns and Enns (2010; Appendix F) Soils and Vegetation of the Terrestrial Environment report.

3.2 Screening of Metal Concentrations in Soil Against CSR Standards

Metal concentrations in soil were compared to their respective BC Soil Standards for the protection of soil invertebrates and plants. These standards are the same, regardless of land use designation (agricultural, urban park, and residential). The standards for the PCOCs are:

- Arsenic – 50 mg/kg;
- Cadmium – 70 mg/kg;
- Copper – 150 mg/kg;
- Lead – 1,000 mg/kg;
- Mercury – 100 mg/kg; and,
- Zinc – 450 mg/kg.

No concentrations of Cd or Hg measured in soils exceeded their respective standards. One soil sample (of n>300) contained copper at a concentration greater than 150 mg/kg. This occurred within an area south-east of the smelter along the Columbia River where small pockets of higher copper concentrations (> 100 mg/kg) occur (Golder, 2007a). Kriged concentrations of copper in soil are shown in Figure 3-11 of Golder (2007a).

Twenty-three soil samples representing 3.3% of the soil samples collected (from the 2001 data set) contained arsenic at concentrations that exceeded 50 mg/kg. These concentrations are located in areas along the Columbia River valley north and south of the smelter, and in pockets scattered throughout the valley (Golder, 2007a). Kriged arsenic concentrations in soil are shown in Figure 3-9 of Golder (2007a).

Twelve soil samples representing 1.6% of the soil samples collected (from the 2001 data set) contained lead at concentrations that exceeded 1000 mg/kg. The highest concentrations of lead were to the northwest and southeast of the smelter within the Columbia River valley. There were small pockets of high lead concentrations (>1,000 mg/kg) scattered throughout the valley. Kriged concentrations of lead in soil are shown in Figure 3-12 of Golder (2007a).

Eight soil samples representing 2.3% of the soil samples collected (from the 2001 data set) contained zinc at concentrations that exceeded 450 mg/kg. Kriging resulted in a definable area with zinc concentrations greater than 450 mg/kg, both north and southeast of the smelter (Figure 3-14 from Golder, 2007a).

There is a positive correlation between the aerial deposition of Cd, Pb and Zn (measured using moss bags) and surface soil concentrations of these metals in the Trail region (Goodarzi *et al*., 2006). However, Goodarzi *et al*. found that the distributions of Hg, Cu and As are not correlated with aerial deposition; therefore, the variation of these PCOCs in soil samples may be significantly influenced by variations in local soil factors such as fugitive emissions and soil parent materials.

Standard kriging methods were used to illustrate the distributions of PCOC concentrations in soil (Golder, 2007a). To be more conservative, a variation of conventional kriging was used, termed conditional simulation. This technique was used to estimate the area with at least a 10% probability of metal concentrations in soil exceeding the CSR standard for plants and soil invertebrates. In order for a polygon to be considered to have metal concentrations in soil over the CSR standard for plants and soil invertebrates, $\geq$ 2 ha or $\geq$ 15% of the total area of the polygon had to be defined by conditional simulation as having a >10% probability of exceeding the standards for one or more PCOCs. These criteria were added to account for the large difference in scale between the two layers of the GIS; the biophysical habitat polygons are mapped on a much larger scale (1:20,000) than the metal concentrations in soil. There are 327 polygons predicted to contain metal concentrations in soil that exceed the CSR standards (Figure 3-1; Appendix A, Table A1). The total area with metal concentrations in soil that exceeded CSR standards was approximately 6,120 ha, which represents approximately 14% of the AOI.

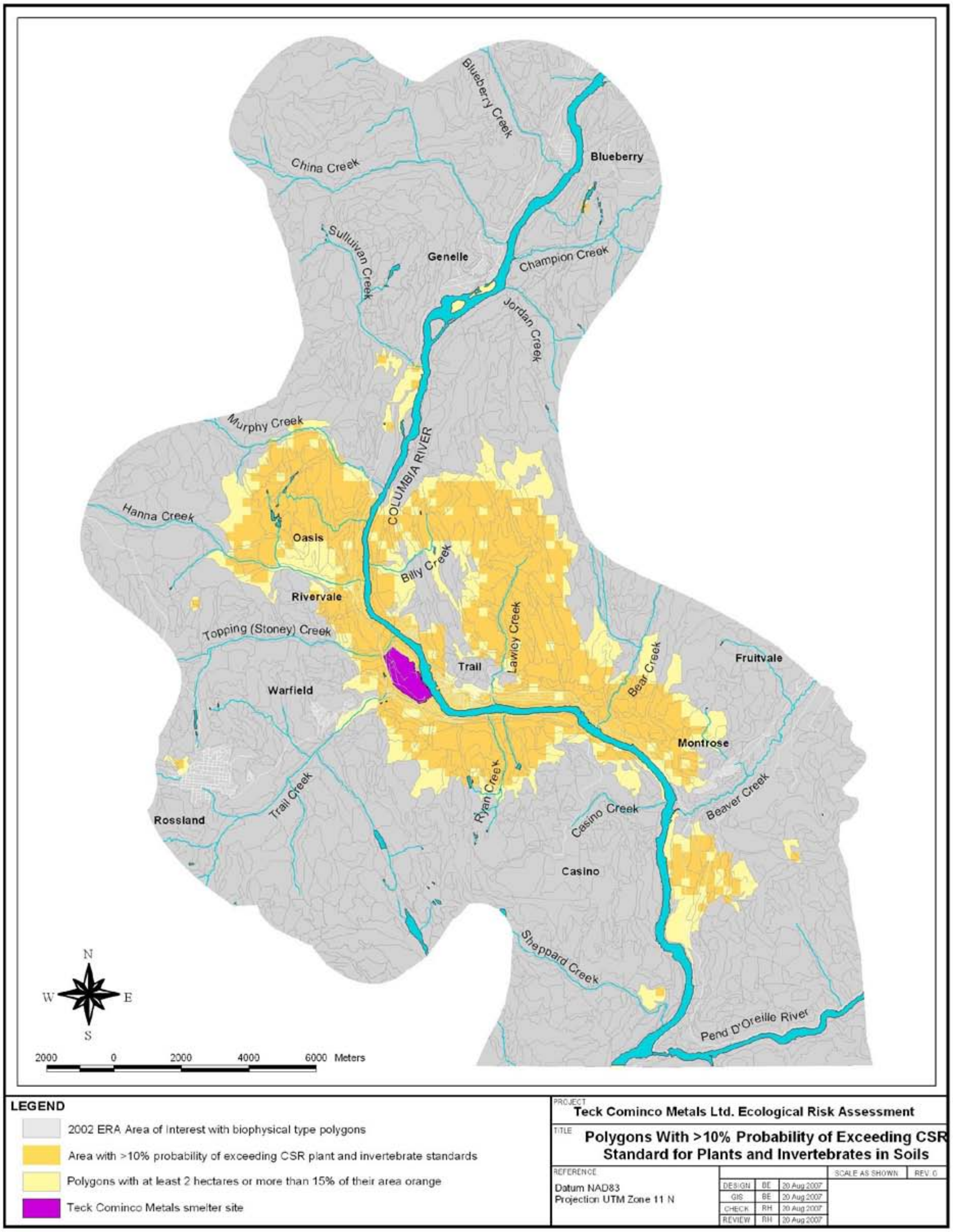


Figure 3-1 Area with a >10% Probability that PCOC Concentrations in Soil Exceed CSR Standards for Plants and Soil Invertebrates

Summary of Screening of PCOC Concentrations in Soil with CSR Standards for Plants and Soil Invertebrates

There are areas north-northwest (NNW) and east-southeast (ESE) of the smelter with PCOC concentrations greater than provincial standards for As, Pb and Zn. This pattern in soil corresponds with observed aerial deposition of Cd, Pb and Zn, where maximum deposition occurs within a short distance from the smelter (approximately 1.5 to 3 km), and where the airborne metals are confined mainly with the NNW and ESE orientation of the Columbia River valley (Goodarzi *et al*., 2006). Arsenic concentrations in soil may be more reflective of parent soil materials, as arsenic concentrations in soils will vary depending on the arsenic content of the parent materials from which they are derived (Goodarzi *et al*., 2006). The exponential decrease in aerial deposition of metals with increasing distance from the smelter is reflected in surface soil concentrations; however, there are several single sample locations scattered throughout the AOI with elevated metal concentrations. These locations may reflect localized physiography and/or local sources of fugitive dust (*e.g*., the Trimac rail/truck re-load facility for zinc concentrate and ferrous granules (treated smelter slag) located approximately 4 km south of the Trail airport, south of Columbia Gardens, on the east side of the river).

Sequential Extraction Data

The distribution of total concentrations of PCOC in soil may not correspond with effects on plants and soil invertebrates because of low bioavailability (*i.e*., low availability for uptake from soil to plant or invertebrate tissue). Sequential extraction of a sub-set of soil samples was conducted in order to provide information on the relative proportion of the total metal concentration in various fractions, ranging from water soluble to tightly bound (Golder, 2007a). The sequential extraction results suggest relatively low mobility (and therefore, assumed low bioavailability) of each of the PCOCs (Golder, 2007a; Enns and Enns, 2010). The results for all of the PCOCs suggest that the highly available (water-soluble) and available (exchangeable) fractions represent the lowest proportion of the metal fractions. Conversely, most of the PCOCs are in the "potentially available" fractions (carbonate, oxide, organic) and unavailable (residual) fraction. The relatively low proportion of PCOCs in the highly available or available fractions indicates that total PCOC concentrations are a conservative indicator of risk. Therefore, a lack of correspondence between observed effects in the field and total PCOC concentrations in soil may reflect, in part, the low mobility and bioavailability of the PCOCs in the AOI.

3.3 SALE Evaluation for Objective 1 (Wildland Plant Communities)

The SALE evaluation for Objective 1 (wildland plant communities) was completed by conducting a screening of plant communities based on biophysical characteristics (Section 3.3.1; Appendix A), an effects assessment (Section 3.3.2), an assessment of causality (Section 3.3.3) and risk characterization (Section 3.3.4). Conclusions are summarized in Section 3.3.5, and a sensitivity analysis is presented in Section 3.3.6.

The remainder of Section 3 will refer often to descriptive labels for the polygons of the biophysical habitat map. Each polygon of the map contains a label consisting of several components:

- Percentages of each of the primary biophysical habitat units within the polygon;
- The biophysical habitat unit labels;
- A soil depth descriptor;
- A plant community structural stage descriptor;

- Modifiers to the structural stage that describe the growth form and distribution of trees in the forest canopy as well as the composition of the canopy as broad-leafed, coniferous or mixed;
- A fire history descriptor, including frequency and severity;
- An air pollution damage code describing visible evidence for injury; and,
- A logging history code.

For example, the map label "6BFs5mM:FsP-4DH5i:LsP" has the following components:

6 = Percentage of the polygon composed of the biophysical habitat type, in this case 60% of the polygon is BF and 40% is DH (Douglas fir-beaked hazelnut thin soil). Each polygon was separated into up to three different biophysical habitat types;
BF = Paper birch-bracken fern terrace biophysical habitat unit. Detailed descriptions of each unit are provided in Appendix C;
s = Shallow soils;
5 = Structural stage 5 [the range is from 1 (sparsely vegetated/non-treed) to 7 (old forest)]. Structural stage 5 indicates a young forest (self thinning evident, canopy differentiation occurring) usually ranging in age from 30 to 65 years;
m = Multi-storied-structural stage modifier (describes the growth form and distribution characteristics of trees in the forest canopy); there are five structural stage modifiers;
M = Mixed-stand composition modifier (describes the composition of the tree canopy as a ratio of broad-leafed (dominant) and coniferous (subdominant) tree species;
Fs = Fire history (four categories of past fire effects), in this case Fs which indicates severe, often repeated fire;
P = Pollution damage (primarily related to SO_2 injury; see Golder, 2007a) evident in the appearance of the aerial photography, cross-referenced with field data, ground-based photographs and aerial oblique photographs; and,
Ls = Logging history (three categories), in this case Ls which indicates selective logging.

The labels of the map provide a considerable amount of information regarding the status of the soils, plant community, and potential confounding factors such as fire and logging. See Appendix C for a complete explanation of all codes used in the polygon labels.

3.3.1 Screening of Polygons based on Biophysical Characteristics

Factors other than PCOC concentrations in soil, such as climate, soil texture and depth, previous air pollution injury, logging and fire have influenced the plant communities in the AOI. Therefore, screening of polygons went beyond screening based on metal concentrations in soil. Additional screening for Objective 1, based primarily on plant community characteristics, was conducted to further focus the ERA on those areas within the AOI where smelter-related emissions could not be eliminated as a factor affecting plant communities.

This screening was conducted for the entire AOI, based on information contained within the biophysical habitat map (Appendix B). Details on the biophysical habitat map, including the review and quality assurance of the mapping, are provided in Appendix B. Complete details on the polygon screening, including lists of polygons screened out at each step, are presented in Appendix A. The screening included four steps:

- Step #1: Elimination of units unrelated to the Objective (*e.g.*, gravel pits, airports, *etc*.);
- Step #2: Elimination of units with advancing structural stages because the presence of such stages indicates that any past impacts (if any) are not preventing the development of the plant community;

- Step #3: Elimination of units with logging impacts IF metal concentrations in soil are less than CSR standards AND the area was not previously impacted by SO_2; and,
- Step #4: Elimination of units in early structural stages IF metal concentrations in soil are less than CSR standards AND the area was not previously impacted by SO_2.

A total of **415 polygons** representing **8,317 ha** (20% of the AOI) remained after the 4-step screening process in Appendix A. These polygons are shown on Figure 3-2 and listed in Appendix A, Table A6.

The list of remaining polygons from the biophysical habitat screening was subdivided into two: 1) those polygons where soil metal concentrations exceeded CSR standards for plants and soil invertebrates; and, 2) those polygons where soil metal concentrations did not exceed CSR standards for plants and soil invertebrates. These lists are provided in Appendix A, Tables A7 and A8. The polygons in the second list may represent plant communities which are very unlikely to have been impacted by metal concentrations in soil, based on screening of current soil concentrations against CSR standards, but which have shown effects from some other stressor (such as previous air pollution injury, fire, *etc*.).

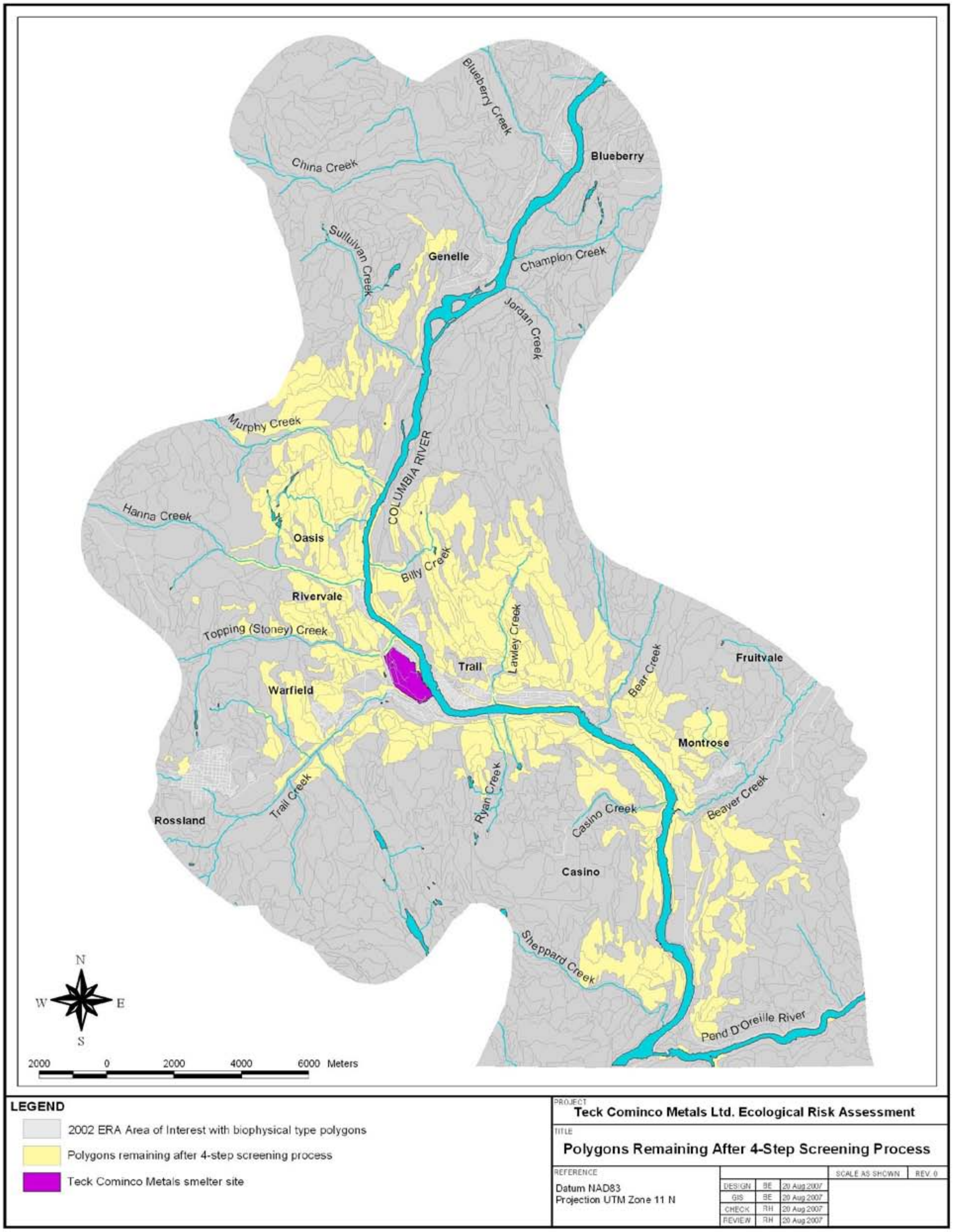


Figure 3-2 Polygons Remaining After 4-Step Screening Process

3.3.2 SALE Effects Assessment

The remainder of the ERA has focused on the 415 polygons remaining after the screening in Section 3.3.1 and Appendix A (Figure 3-2). The evaluation for Objective 1 was completed using four Lines of Evidence (LOE): forest productivity (Section 3.3.2.1); plant species richness and diversity, presence of sulphur dioxide sensitive or tolerant plant species, percentage of tree, shrub and herb cover (Section 3.3.2.2); changes in soil physical and chemical characteristics (Section 3.3.2.3); and, changes to avian and mammalian herbivore populations/communities (Section 3.3.2.4). A summary of the effects assessment is presented in Section 3.3.2.5.

The definitions for magnitude of response and uncertainty are provided in Tables 3.1 and 3.2. There are no standard definitions of magnitude that assist in the delineation between a critical effect and responses that may be statistically significant but fall within the definition of a reference condition. Therefore, definitions of magnitude (Table 3-1) were based on statistical correlations plus professional judgment for three LOE (productivity, plant community parameters, and LFH). Changes in herbivore populations and communities as a result of direct PCOC toxicity were assessed by modelling risks (see the Problem Formulation, LOR2 and LOR3 reports; Cantox Environmental *et al*., 2001; Cantox Environmental, 2003a; Intrinsik, 2007) and considering field survey data (Section 4.0 in this volume).

There are two major sources of uncertainty: natural variability; and, our understanding of how the smelter may cause effects, either directly or indirectly (as portrayed in the conceptual model). Uncertainty in the assessment of magnitude of response was evaluated according to how well natural variability was addressed (Table 3-2).

Table 3-1 Definitions of Magnitude of Response for Lines of Evidence Related to Vegetation in Wildland Areas

Assessment Endpoint	***Line of Evidence***[a]	***Adverse Effects Unlikely (weak)*** o	***Adverse Effects May Occur*** ⦿	***Adverse Effects Likely (strong)*** ●
Forest Productivity	Productivity of western white pine of between 40 and 60 years of age, relative to that of trees near the northern boundary of the AOI	No difference in mean productivity as compared to control site, for at least the last three years	Since 1997 (when KIVCET became operational), mean productivity varies between being less than the control site and similar to the control site	Mean productivity is less than that at the control site
	Site index: a measure of site quality based on the diameter and height of the dominant and codominant trees of the stand in comparison to species productivity curves developed for each species.	No trend in site index with distance from the smelter	Site index frequently lower near the smelter, and higher at distance from the smelter, but this trend is not consistent.	Site index is consistently higher at distance from the smelter, and consistently lower close to the smelter
	Comparison of crown widths and crown differentiation in ortho-rectified high resolution space imagery taken between 2000 and 2007 in area around Columbia Gardens and the Trail airport	Increasing tree crown width and crown differentiation below 800 m elevation in the majority of polygons.	Increasing tree crown width and crown differentiation below 800 m elevation is observed but in less than half of the polygons compared.	No change in tree crown width or differentiation below 800 m elevation, from 2000 to 2007 in most polygons.
Vegetation Species Composition	Plant species richness and diversity, presence of sulphur dioxide sensitive or tolerant plant species, and percentage tree, shrub and herb cover, relative to soil metal concentrations and pH	Zero or one significant ($p<0.05$) positive correlation in community composition metrics with pH, *or* negative correlation ($p<0.05$) with soil metal concentrations, *or* significant correlations but with the incorrect sign (*e.g.*, positive correlation with soil metal concentrations)	More than one significant ($p<0.05$) correlation between a community composition metric and pH, or soil metal concentrations *but* some with the incorrect sign	Several highly significant ($p<0.001$) correlations between community composition metrics and pH, or soil metal concentrations, *and* none with the incorrect sign
	LFH depth relative to soil parameters (pH, organic matter, soil metal concentrations)	No statistically significant correlations between LFH depth and soil parameters	One or a few statistically significant correlations between LFH depth and soil parameters	Several statistically significant correlations between LFH depth and soil parameters
	Avian and mammalian herbivore community composition	No unacceptable direct toxicity risks. Avian and mammalian herbivore community is representative of habitats	Avian or mammalian herbivore community not representative of habitats	Unacceptable direct toxicity risks were predicted for herbivore population(s). Avian and mammalian herbivore community not representative of habitats

[a] Refer to Appendix B for details on soil types, Golder (2007a) for details on productivity, plant community parameters and LFH, Enns and Enns (2010; Appendix F) for details on site index and imagery comparison data, and Section 4 of this report for the analysis of avian and mammalian herbivore communities.

Table 3-2 Definitions of "High", "Moderate" and "Low" Level of Uncertainty Related to Natural Variability and Measurement Error for each Line of Evidence Related to Plants in Wildland Areas

Source of Uncertainty [a]	*Low Uncertainty* ?	*Moderate Uncertainty* ??	*High Uncertainty* ???
Natural Variability and Measurement Error: Forest Productivity	• Productivity measured in several species, *and* soil types *and* across the entire range of PCOC concentrations; *and,* • Sample sizes at each site adequate to distinguish differences across the PCOC concentration gradient; *and,* • Important natural variables that affect productivity were measured and accounted for.	• Productivity measured in one species, in one or more soil types *and* across a representative range of PCOC concentrations (low, moderate, high); *and,* • Sample sizes at each site adequate to distinguish differences across low, moderate and high PCOC concentrations; *and,* • Important natural variables that affect productivity were described, measured or accounted for.	• Productivity measured in one species, in one or two soil types with a limited range of PCOC concentrations; *and,* • Sample sizes at each site inadequate to distinguish differences across the PCOC concentration gradient; *and,* • Few important natural variables that affect productivity were measured or accounted for.
Natural Variability and Measurement Error: Vegetation Species Composition	• Plant community data were obtained for several variables, *and* soil types *and* across the entire range of PCOC concentrations; *and,* • Sample design is adequate to distinguish differences across the PCOC concentration gradient; *and,* • Important natural variables that affect plant community response were measured and accounted for.	• Plant community data were obtained for only a few variables, *or* in a limited number of areas that do not represent the entire range of PCOC concentrations; *and,* • Sample design is inadequate to distinguish differences across the PCOC concentration gradient; *and,* • Many important natural variables that affect plant community response were not measured, described or accounted for.	• Plant community data were obtained for only a few variables, in a limited number of areas that do not represent the entire range of PCOC concentrations; *and,* • Sample design is inadequate to distinguish differences across the PCOC concentration gradient; *and,* • Most important natural variables that affect plant community response were not measured, described or accounted for.
Natural Variability and Measurement Error: LFH Analysis	• Data were obtained for several variables, *and* soil types *and* across the entire range of PCOC concentrations; *and,* • Sample design is adequate to distinguish differences across the PCOC concentration gradient; *and,* • Important natural variables that affect LFH development were measured and accounted for.	• Data were obtained for only a few variables, *or* in a limited number of areas that do not represent the entire range of PCOC concentrations; *and,* • Sample design is inadequate to distinguish differences across the PCOC concentration gradient; *and,* • Many important natural variables that affect LFH development were not measured, described or accounted for.	• Data were obtained for only a few variables, in a limited number of areas that do not represent the entire range of PCOC concentrations; *and,* • Sample design is inadequate to distinguish differences across the PCOC concentration gradient; *and,* • Most important natural variables that affect LFH development were not measured, described or accounted for.
Natural Variability and Measurement Error: Avian and Mammalian Herbivorous Communities	• Density surveys have been conducted across the AOI in areas representative of all suitable habitats and for several years; and, • All important natural variables that affect the community are quantified or described qualitatively and in detail.	• Density surveys have been conducted in most areas across the AOI for >1 year; and, • Most important natural variables that affect the community are, as a minimum, described qualitatively and in detail.	• Density surveys have been conducted in a very limited number of areas in the AOI and only for 1 year; and, • Few important natural variables that affect the response are observed or described either quantitatively or qualitatively.

[a] Refer to Appendix B for details on soil types, Golder (2007a) for details on productivity, plant community parameters and LFH, Enns and Enns (2010; Appendix F) for details on site index and imagery comparison data and Section 4 of this report for the analysis of avian and mammalian herbivore communities.

3.3.2.1 Line of Evidence #1 - Forest Productivity

Line of Evidence #1: Forest productivity. Three measures of forest productivity were used. 1) A direct measurement of forest productivity was taken. Tree ring analysis was conducted on western white pine (*Pinus monticola*) of between 40 and 60 years of age (Golder *et al*., 2007a). 2) Site index was calculated for 61 samples of multiple species at 32 locations (Enns and Enns, 2010; Appendix F). Site index is a measure of site productivity based on the diameter and height of the dominant and codominant trees in relation to species curves developed for individual species. 3) An indirect measure of productivity was used through the analysis of vegetation change over a 7-year period (2000-2007). IKONOS imagery of the area near Columbia Gardens and the Trail Airport, also classed as Plot Type 4 and the *Agrostis* group (see Section 3.3.2.2), was used to compare changes in tree crowns and ground vegetation cover and complexity in 101 polygons (Enns and Enns, 2010).

Forest productivity of western white pine was studied in four polygons, relative to a reference polygon. Although limited in scope, this study provides information on productivity changes relative to the installation of the KIVCET smelter, which was a significant risk management measure. Details on the western white pine productivity study, including a map showing sampled polygon locations, how sample locations were identified, statistical analysis of data, and other information may be found in Golder (2007a).

Site index was calculated for 32 polygons across the study area using data from 2002. The analysis of vegetation change *via* imagery comparison was conducted only for one large area strongly affected by sulphur dioxide in the past. Details on the calculations and interpretation may be found in Enns and Enns (2010).

Magnitude of Response in Forest Productivity

Productivity data show that the emissions levels in the pre-KIVCET period were suppressing conifer productivity as measured by incremental ring growth. Productivity data were collected from western white pine in four polygons, compared to a control polygon near the northern boundary of the AOI (Golder, 2007a).

The current magnitude of response is considered weak (adverse effects unlikely) in three of the four "test" polygons. The lowering of emissions post-KIVCET corresponded with demonstrable increases in conifer productivity in three of the four test areas (polygons 439, 728 and 1483); productivity in these three areas increased to levels comparable to the control area (polygon 32).

The current magnitude of response is considered strong (adverse effects likely) for one of the four test polygons. Western white pine at the fourth site (polygon 447) did not exhibit increased productivity in the post-KIVCET period, which indicates residual effects of smelter emissions (soil metal concentrations > CSR), or possible confounding factors such as lower soil nutrient levels (Golder, 2007a).

The polygons selected to be carried forward to causation analysis on the basis of the productivity data were polygon 447 (strong magnitude score), but also two of the polygons that received a weak magnitude score (polygons 728 and 1,483). The two polygons with a weak magnitude score (polygons 728 and 1,483) were retained because the structural stage was 5i or 5o (*i.e.,* open or intermittent canopy indicating the possibility of residual smelter-related effects) and because there was a >10 % probability of metal concentrations in soil of these polygons exceeding the CSR standards for plants and soil invertebrates.

The Site Index calculations were conducted on data from mesic sites using trees with complete data on location, diameter at breast height, age, and total height. Site index was not measured in any polygons for which productivity data were available from the Golder (2007a) study. Tree data supplied for the original, larger AOI by the Ministry of Forests were included. Both low and high Site Index values were calculated for trees at variable distances from the smelter. Site indices for trees near the smelter were higher than some of the other indices for sites outside the areas impacted by the smelter. The data suggest that Site Index and productivity of conifers is more dependent on site variables such as soil nutrient regime than past emissions effects (Enns and Enns, 2010; Appendix F). Therefore, the magnitude of response is considered weak.

Comparisons of images from 2000 and 2007 showed tree crown width increasing in trees located between 400 to 600 m elevation, in areas known to have been previously heavily impacted by smelter emissions. Ground vegetation cover also increased in polygons that were south-facing (*i.e.*, facing away from the smelter), and that were not in a closed canopy (Enns and Enns, 2010). This indicates that, with reduced sulphur dioxide emissions since KIVCET became operational, recovery of vegetation is still evident in the crown characteristics of trees, and that different sites will recover at different rates in the future, with lower elevation sites showing the most significant increases in growth (Enns and Enns, 2010).

Uncertainty Associated with Forest Productivity

The results obtained from the four polygons of the western white pine study cannot be extrapolated to other polygons. However, the results provide an indication of productivity in an important tree species in four polygons of the AOI over time (particularly pre- and post-KIVCET).

- Uncertainty related to measurement error and understanding of natural variability is considered moderate. Productivity was measured in only one species, and in only four polygons, relative to controls from a single polygon. Sites were standardized for topography, slope, elevation, and soil type. A sufficient number of trees (20) were sampled from each site to distinguish differences from the control site.

- There is uncertainty related to whether or not PCOC concentrations in soil exceed CSR standards in polygon 728 because kriging, which estimates concentrations in specific polygons based on concentrations in nearby polygons, did not predict concentrations to exceed the CSR standards for plants and soil invertebrates in this polygon.

- Polygons 728 and 1483 have been influenced by moderate or severe fire (Fm or Fs) and previous air pollution (P); however, since KIVCET, productivity has returned to being similar to control productivity. No other plant community data were collected from these two polygons.

Site index data were collected in 2002, and measure site productivity in comparison to species-specific growth curves for mesic sites. Productivity also is influenced by climate and soils (*e.g.*, soil type and soil moisture) (Enns and Enns, 2010; Appendix F). Uncertainty is considered moderate because the analysis was conducted for only 32 polygons and did not account for productivity in non-tree species. Because the magnitude of response was considered weak, this study was not considered in the causal analysis.

The use of imagery to assess productivity requires changes of greater than a metre. Changes in crown dimensions of less than a metre may have occurred but were not detected in the analysis. Ground-truthing was not done for this interpretation. Also, the comparison was done for the driest area of the AOI, near Columbia Gardens and the Trail airport (Enns and Enns, 2010). Uncertainty is considered moderate for this study. Because the imagery comparison was completed for only one area within the AOI, this study was not considered in the causal analysis.

3.3.2.2 Line of Evidence #2 - Vegetation Community Statistics

Associations were explored between soil parameters (soil metal concentrations, pH) and plant community parameters (plant species richness and diversity, presence of sulphur dioxide sensitive or tolerant plant species, and percentage tree, shrub and herb cover) (Golder, 2007a). Soil chemistry data (arsenic, cadmium, copper, mercury, lead, zinc) were used to derive a single variable “soil metal concentrations” that would represent the cumulative metals emissions from the smelter, using principle component analysis. Details on this analysis are provided in Golder (2007a, Sections 2.3 and 3.3.2).

Correlations presented for sulphate (Golder, 2007a) were not used because, overall, available sulphate-sulphur is low in parts of the AOI relative to some BC soils (Enns and Enns, 2010; Appendix F). Available sulphate-sulphur is highly soluble, and in well drained soils with very little organic matter, the loading of sulphate-sulphur has likely been continuously leached from soils by the typical heavy spring and fall precipitation (see further discussion in Enns and Enns, 2010).

The results of the statistical analysis of the vegetation data (Section 3.3.3 of Golder, 2007a; Enns and Enns, 2010), combined with the results of the biophysical habitat polygon screening (Section 3.3.1 and Appendix A) provide insight into areas within the AOI which should be considered in the causal analysis (Section 3.3.3). The statistical analyses and the biophysical habitat map were done independently; therefore, similarities and differences between the results of the two analyses can be used as an indicator of uncertainty.

Vegetation Analysis Based on Elevation, Soil Moisture and Dominant Vegetation (Golder, 2007a)

Golder (2007a) divided the vegetation sample plots into eight groups, based on tree cover type (coniferous or deciduous), soil moisture and elevation. A summary of these groups is provided in Table 3-3.

Table 3-3 Summary of Eight Groups Used in Vegetation Statistical Analyses

Group	*Description*	*Number of Samples/ Polygons*	*Number of Polygons Retained from Biophysical Habitat Screening*	*Number of Polygons with Soil Metal Concentration > CSR for Plants?*
1	Lower elevation, dry soils, coniferous	111/85	24	19
2	Higher elevation, dry soils, coniferous	132/100	11	10
3	Lower elevation, moist soils, coniferous	16/15	5	5
4	Higher elevation, moist soils, coniferous	21/19	0	0
5	Lower elevation, dry soils, deciduous	126/98	45	40
6	Higher elevation, dry soils, deciduous	23/21	5	2
7	Lower elevation, moist soils, deciduous	11/11	4	5
8	Higher elevation, moist soils, deciduous	10/9	0	3

Groups 1, 2 and 5 had the largest number of samples and polygons represented.

- Groups 1 and 5 included polygons which were eliminated in the 4-step process in Section 3.3.1 and Appendix A, as well as several samples and polygons which were not eliminated. Many polygons had metal concentrations in soil above CSR standards for plants and soil invertebrates.
- Group 2 contained fewer polygons which were retained after the biophysical habitat screening in Section 3.3.1 and Appendix A. Of those retained, seven samples were from areas where metal concentrations in soil exceed CSR standards for plants and soil invertebrates. A total of 10 polygons in this group contained metal concentrations exceeding the CSR standards.

Groups 3, 4, 6, 7 and 8 had far fewer samples and polygons than the other three groups.

- Groups 4 and 8 contained only polygons that were eliminated in Section 3.3.1 and Appendix A.
- Groups 3, 6 and 7 contained a mix of polygons which were eliminated in Section 3.3.1 and Appendix A, as well retained polygons with metal concentrations in soil either above or below CSR standards for plants.

Vegetation statistics were also run by separating the samples into groups according to dominant vegetation type (Table 3-4). This was done for four biophysical habitat units: BF (paper birch, bracken fern); DO (Douglas fir, Oregon grape); HF (western hemlock, feather moss); and, WF (white pine, falsebox). The separation was done prior to the finalization of the biophysical habitat map. Therefore, some of the polygons were misclassified. This should not have a large impact on the results of the statistics because most polygons were classified correctly.

Table 3-4 Summary of Four Biophysical Habitat Groups Used in Vegetation Statistical Analyses

Group	*Description*	*Number of Samples/ Polygons*	*Number of Polygons Retained from Biophysical Habitat Screening*	*Number of Polygons with Metal Concentrations >CSR*
BF	Paper birch – bracken fern	44/32	11	11
DO	Douglas fir- Oregon grape	20/18	10	11
HF	Western hemlock – Feather moss	24/20	0	0
WF	White pine - Falsebox	45/36	10	7

Paper birch-Bracken fern (BF)

Douglas fir-Oregon grape (DO)

Western hemlock-Feather moss (HF)

White pine-Falsebox (WF)

Magnitude of Response Observed in Plant Community Statistics

Group 1 (lower elevation, dry to mesic soils, coniferous forest). The magnitude of response was strong in Group 1 because there were several significant correlations and all correlations were negative (Golder 2007a). The significant negative correlations were between:

- Tree cover and metals ($p<0.05$);
- Shrub cover and metals ($p<0.005$); and,
- Sulphur dioxide-sensitive species (Douglas fir and thimbleberry) and metals ($p<0.005$).

These results indicate a smelter mediated response because several vegetation indices were negatively correlated with smelter-related parameters (metals) (see Table 3-24 in Golder, 2007a). Group 1 had a large number of sampling plots (20) within 5 km of the smelter and had six sampling plots within 2 km. The results reflected the proximity of Group 1 to the smelter and the location of the sampling plots below approximately 700 m elevation (where most of the smelter deposition has been known to occur) (Golder, 2007a).

Out of the 85 polygons in Group 1, all but 24 were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of those, 14 polygons contained soils with metal concentrations exceeding CSR standards for plants. The vegetation statistics showed significant negative correlations with metals. Therefore, all 24 polygons were retained for the causal analysis in Section 3.3.3 (Table 3-5).

Table 3-5 Polygons within Group 1 Which were not Eliminated in the Plant Community Screening Step

Polygon	*Polygon Label*	*> CSR Standards for Plants**
399	7WFw4oM:P-3WFw1:P	>
403	6WFk5mM:P-4WFw4o:P	>
447	7LR5mM:LsP-3BF4oM:LsP	>
476	6BF3o:P-4BF1:P	>
497	9WFws3o:P-1WFws1:P	
607	5BF4oC:P-5BF3i:P	
634	5DFk4iM:FmP-3DOr3b:FsP-2DHk4iM:FmP	
680	4DHk4i:P-4DOk2b:P-2DHk3i:P	>
691	4DOk2b:P-4DHk3o:P-2ROk	>
730	8WF5mB:P-2SR5iM:P	
1079	5WFws3b:FmP-3WFw3a:FsP-2SSw	
1324	7LR3o:P-2LR6iC:P-1UP:P	>
1343	6BF6mM:P-2RR:P-2BF3o:P	

Table 3-5 Polygons within Group 1 Which were not Eliminated in the Plant Community Screening Step

Polygon	***Polygon Label***	***> CSR Standards for Plants****
1366	7BF5iB:FsP-3TC	
1389	7DHk5iM:P-3SRk4iM:P	>
1444	10DHj3i:P	
1453	10DHk4iM:P	>
1454	8DHk2a:P-2DHk3i:P	>
1559	6DHk3o:P-4DOk2:P	
1561	7DHk3o2:P-2TAw3a:P-1DOk1:P	>
1564	6DO3o:P-3HD2a:P-1DF4mM:P	>
1624	5WFk5mM:P-4WFw3o:P-1SR5iC:P	>
1692	7DFk5mM:F-2BF5oM-1HD5mM	>
1892	7BF5mM:Fm-3BF4i:FsP	

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Group 2 (higher elevation, dry to mesic soils, coniferous forest). The magnitude of response was low in Group 2 because, while there were significant correlations, not all were indicative of smelter-related adverse effects. The significant negative correlation that may be related to smelter emissions was between:

- Tree cover and metals ($p<0.001$).

There also was a positive significant correlation between:

- Tall Oregon grape (sulphur dioxide-resistant species) and metals ($p>0.001$).

Some statistically significant correlations were not in the expected direction of a smelter-related adverse effect (*e.g.*, diversity and shrub cover were positively correlated with metals). Group 2 sampling plots were located above 700 m and more than 2 km from the smelter.

Out of the 100 polygons in Group 2, all but 11 were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of those 11, seven polygons contained soils with metal concentrations exceeding CSR standards for plants. The vegetation statistics did not show consistent correlations with metals. Therefore, the 11 polygons (Table 3-6) were not retained for further consideration in the causal analysis in Section 3.3.3.

Table 3-6 Polygons within Group 2 Which were not Eliminated in the Plant Community Screening Step

Polygon	***Polygon Label***	***> CSR Standards for Plants****
357	8DH5mC-2DO5iC	>
373	5DFsw6mC:P-3DF5mC:P-2DOr5oC:P	>
515	6DHj5oB:FsP-2DHj3o:FsP-2ASk5mB	
689	6DFk5iM:P-4DFk2a:P	
759	9DH5iC-1DO5iC	>
914	5DO5oC-5DH5iC	>
1138	6PMw4i:FsP-3DOw3o:Fs-1TC	
1382	7DHr5mM-3DOr3o	>
1443	4DHk3o:FmP-3DOk3o:FmP-3ROk	
1607	7WFw5iB:FmP-2WFw2a:FmP-1SRw3o	>
1686	5DOj5iC:Fm-4DHh5mC-1ROj	>

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Group 3 (lower elevation, moist soils, coniferous forest). The magnitude of response in Group 3 was moderate. There was a significant negative correlation between:

- Oregon grape (SO_2-resistant species) and metals ($p<0.05$).

Group 3 sampling plots were located below 700 m and just under half were located within 5 km of the smelter. The lower elevation and proximal distance to the smelter were reflected in the results, which show potential impacts to the vegetation community due to smelter emissions (Golder, 2007a).

Out of the 16 polygons in Group 3, 11 were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of the retained polygons, four contained soils with metal concentrations exceeding CSR standards for plants. However, because there was only one significant correlation, none of the five polygons (Table 3-7) were retained for further consideration in the causal analysis (Section 3.3.3) as part of Group 3. Polygon 1564 was retained as part of the DO group, and polygon 1,678 was retained as part of Group 5.

Table 3-7 Polygons within Group 3 Which were not Eliminated in the Plant Community Screening Step

Polygon	***Polygon Label***	***> CSR Standards for Plants****
510	6DOj4i-4HD2	>
698	7DF5iM:FmP-2DF2b:P-1RR	>
699	9DFk5mM:P-1DFk2b:P	
1564	6DO3o:P-3HD2a:P-1DF4mM:P	>
1678	6WFk5mM-3SR5mM-1CRf3i	>

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Group 4 (higher elevation, moist soils, coniferous forest). The magnitude of response in Group 4 was weak. Group 4 sampling plots are located above 700 m and more than 5 km from the smelter. There appeared to be no consistent relationship between vegetation indices and contaminant indices. The combined increase in elevation and distance may contribute to the lack of clear smelter-related effects (Golder, 2007a).

Out of the 19 polygons in Group 4, all were eliminated using the four-step process in Section 3.3.1 (Appendix A). In addition, no polygons contained metals at concentrations greater than CSR standards for plants and soil invertebrates. Therefore, all polygons were removed from further consideration for risk management. The consistency between statistical results and screening results adds confidence that removal of all Group 4 polygons is appropriate.

Group 5 (lower elevation, dry to mesic soils, deciduous forest). The magnitude of response in Group 5 was strong. There were numerous significant negative correlations ($p<0.001$) between vegetation indices and contaminant indices in this group. There also were numerous significant positive correlations ($p<0.001$) between vegetation indices and pH, which indicates potential effects of smelter emissions. Group 5 sampling plots were located below 700 m and many were located close to the smelter. Eight plots were located within 2 km, while 32 were located within 5 km. Due to the lower elevation and proximal distance to the smelter, potential impacts to the plant community could be anticipated (Golder, 2007a).

Out of the 98 polygons in Group 5, all but 45 were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of the 45, 32 polygons contained soils with metal concentrations exceeding CSR standards for plants. The vegetation statistics showed significant negative correlations with metals. Therefore, all 45 polygons (Table 3-8) were retained for further investigation in the causal analysis (Section 3.3.3).

Table 3-8 Polygons within Group 5 Which were not Eliminated in the Plant Community Screening Step

Polygon	*Polygon Label*	*> CSR Standards for Plants**
350	10WFw5oM:P	
403	6WFk5mM:P-4WFw4o:P	>
447	7LR5mM:LsP-3BF4oM:LsP	>
450	7DFk5mM:P-2DHr5mM:P-1DOr5oM:P	
476	6BF3o:P-4BF1:P	>
504	6LRj5oM:P-4RO	>
512	10BF4oM:P	>
521	6ROj-3DO4o:P-1RR	>
566	10WFk4o:P	>
603	6ROw-4DO3i	>
621	6TAw1-3TAw3b-1DHw3o:FsP	>
628	6DHw3i-3ROw-1TAw	>
641	6DHw4iM:P-4SS3i:P	>
656	10WF4iM:P	
663	8SSw3i:P-2DHw3b	>
670	6DHw4iB:P-2ROw-2DO2a	>
674	10DFk3o:P	
677	6DH5oM:P-4DH2:P	>
689	6DFk5iM:P-4DFk2a:P	
691	4DOk2b:P-4DHk3o:P-2ROk	>
695	6DHw3b:P-2SSw3o:P-2DOw2a	>
718	9UR-1WBw4o	>
806	7WBw3o:P-2CR2:P-1CR1:P	
940	7DHk5mM:P-2GRk5mM:P-1DOr5iM:P	
960	6WF5mM-4DHj4i:FmP	>
1010	7DOk3o:FmP-2DH3-1DH5mM	>
1083	5DH5mM:P-3DOk3o:P-2DHj5mM:P	
1123	8BF3:FsP-2BF4iB:FmP	>
1143	8DHkcg:Fm-1CLk-1TAk3a	
1324	7LR3o:P-2LR6iC:P-1UP:P	>
1343	6BF6mM:P-2RR:P-2BF3o:P	
1345	6DOw3o:Fs-2SSw3o:FsP-2ROw	>
1366	7BF5iB:FsP-3TC	
1386	7ROk:P-3DHk5oM:P	>
1389	7DHk5iM:P-3SRk4iM:P	>
1444	10DHj3i:P	
1454	8DHk2a:P-2DHk3i:P	>
1464	8IN-2WFk3o	>
1468	4TAw-4DHw4iM:P-2ROw	>
1474	10SRz3o:P	>
1564	6DO3o:P-3HD2a:P-1DF4mM:P	>
1622	5WBw1:P-5WBw4oM:P	>
1624	5WFk5mM:P-4WFw3o:P-1SR5iC:P	>
1678	6WFk5mM-3SR5mM-1CRf3i	>
1904	7DFk5iM:P-2HDk5mM-1AS5mB	

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Group 6 (higher elevation, dry to mesic soils, deciduous forest). The magnitude of response in Group 6 was weak. There did not appear to be a relationship between vegetation indices and contaminant indices. Group 6 consisted of higher elevation sites (above approximately 700 m) where deposition had not been as great as lower elevations, contributing to the lack of any clear effect on vegetation (Golder, 2007a). In addition, many of the plots used to evaluate Group 6 occur in the Pend D'Oreille Valley or the plateau above the main stem of the Columbia River, and as such have low metals due to distance from the smelter.

Out of the 21 polygons in Group 6, all but five were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of those, 2 polygons contained soils with metal concentrations exceeding CSR standards for plants. The vegetation statistics did not suggest impacts due to smelter emissions. The five polygons (Table 3-9) were not retained for consideration in the causal analysis (Section 3.3.3).

Table 3-9 Polygons within Group 6 Which were not Eliminated in the Plant Community Screening Step

Polygon	*Polygon Label*	*> CSR Standards* for Plants*
689	6DFk5iM:P-4DFk2a:P	
1440	4DHk4iM:FsP-3DOk3b:FsP-3ASk4iB:FsP	
1680	4ASjw5sB:FsP-4DHj3b:FsP-2DOj3o:FsP	
1686	5DOj5iC:Fm-4DHh5mC-1ROj	>
1788	6DOh4oC:Fs-4DHh4o:Fm	>

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Group 7 (lower elevation, moist soils, deciduous forest). The magnitude of response in Group 7 was strong. There were significant negative correlations between:

- Diversity and metals ($p<0.005$); and,
- Richness and metals ($p<0.005$).

These results suggested smelter-related deleterious effects to species diversity and richness. Group 7 sites were located below approximately 700 m elevation, which was an area of higher atmospheric deposition from the smelter (Golder, 2007a).

Out of the 11 polygons in Group 7, all but four were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of those, two polygons contained soils with metal concentrations exceeding CSR standards for plants. The vegetation statistics suggested impacts due to metals. Therefore, four polygons (Table 3-10) were retained for further consideration in the causal analysis (Section 3.3.3).

Table 3-10 Polygons within Group 7 Which were not Eliminated in the Plant Community Screening Step

Polygon	*Polygon Label*	*> CSR Standards for Plants**
359	7LR5oM:FmP-2SR5mM:P-1CR5mB:P	
504	6LRj5oM:P-4RO	>
620	9DHk4iM:FmP-1HD4iM:FmP	
1564	6DO3o:P-3HD2a:P-1DF4mM:P	>

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Group 8 (higher elevation, moist soils, deciduous forest). The magnitude of response in Group 8 was weak. There were no significant correlations between vegetation indices and contaminant indices. Group 8 sampling plots were located at higher elevations away from the greatest smelter-related atmospheric deposition (Golder, 2007a).

All of the nine polygons within this group were eliminated during the four-step process in Section 3.3.1 (Appendix A). Therefore, all of these polygons were removed from further consideration. The consistency between statistical results and screening results adds confidence that removal of all Group 8 polygons is appropriate.

Group BF (Paper Birch - Bracken Fern Terrace). There were strong magnitude responses in the BF Group. Significant negative correlations were identified between:

- Diversity and H+-normalized metals ($p<0.05$); and,
- Richness,% shrub cover and H+-normalized metals ($p<0.005$).

In addition, shrub cover had a significant positive correlation with pH ($p<0.005$).
Sites were located below 800 m elevation, which is an area of higher atmospheric deposition from the smelter (Golder, 2007a).

Out of the 32 polygons in the BF Group, all but 11 were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of those, eight polygons contained soils with metal concentrations exceeding CSR standards for plants. The vegetation statistics suggest impacts due to metals. All retained polygons were identified as having previous air pollution injury (P modifier in the polygon legend), and all retained polygons contained plant communities at early structural stages (1, 3o, 4o, 4i, 5o). All BF sample locations were within Groups 1 or 5 of the vegetation statistical analysis. The vegetation statistics for Groups 1 and 5 indicate adverse effects related to smelter emissions. Therefore, the 11 polygons (Table 3-11) are retained for further consideration in the causal analysis (Section 3.3.3).

Table 3-11 Polygons within the BF Group Which were not Eliminated in the Plant Community Screening Step

Polygon	***Polygon Label***	***> CSR Standards for Plants****
447	7LR5mM:LsP-3BF4oM:LsP	>
476	6BF3o:P-4BF1:P	>
504	6LRj5oM:P-4RO	>
512	10BF4oM:P	>
607	5BF4oC:P-5BF3i:P	
677	6DH5oM:P-4DH2:P	>
1123	8BF3:FsP-2BF4iB:FmP	>
1324	7LR3o:P-2LR6iC:P-1UP:P	>
1343	6BF6mM:P-2RR:P-2BF3o:P	
1624	5WFk5mM:P-4WFw3o:P-1SR5iC:P	>
1892	7BF5mM:Fm-3BF4i:FsP	

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Group DO (Douglas Fir- Oregon Grape Rock). The magnitude of response in the DO group was weak. There was a lack of significant correlations between the primary response variables and the contaminant indices which suggests that there were no smelter mediated effects within the DO units (Golder, 2007a).

Out of the 18 polygons in the DO Group, all but 10 were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of those, nine polygons contained soils with metal concentrations exceeding CSR standards for plants. The vegetation statistics for the DO group do not suggest impacts due to smelter emissions, but this does not mean that impacts have not occurred. All 10 retained polygons were identified as having previous air pollution injury (P modifier in the polygon legend). Several DO units located near the smelter have visible injury, and lack lichens and other sensitive plants. Sample locations within the DO group were from Groups 1, 2 and 5 of the vegetation statistical analysis. The vegetation statistics for Group 2 could not be related to smelter emissions; the DO polygons from Group 2 were all eliminated in the biophysical habitat screening. The statistics for Groups 1 and 5 suggest high magnitude of impact. Nine of the 10 DO polygons were from Groups 1 (680, 691, 1561 and 1564) or 5 (521, 603, 670, 691, 1345, 1386 and 1564). Polygon 1174 was not assigned to a group but could have been placed in either Group 1 or 5 because it is a low elevation, dry soil, mixed coniferous/deciduous polygon. The 10 polygons (Table 3-12) were retained for further consideration in the causal analysis (Section 3.3.3).

Table 3-12 Polygons within the DO Group Which were not Eliminated in the Plant Community Screening Step

Polygon	Polygon Label	> or < CSR Standards for Plants*
521	6ROj-3DO4o:P-1RR	>
603	6ROw-4DO3i	>
670	6DHw4iB:P-2ROw-2DO2a	>
680	4DHk4i:P-4DOk2b:P-2DHk3i:P	>
691	4DOk2b:P-4DHk3o:P-2ROk	>
1174	9DHw4iM:P-1DIw5mM:P	
1345	6DOw3o:Fs-2SSw3o:FsP-2ROw	>
1386	7ROk:P-3DHk5oM:P	>
1561	7DHk3o2:P-2TAw3a:P-1DOk1:P	>
1564	6DO3o:P-3HD2a:P-1DF4mM:P	>

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Group HF (Western Hemlock-Feather Moss). The magnitude of response in the HF Group is low. There was a significant negative correlation (Golder, 2007a) between:

- Oregon grape and H+-normalized metals ($p<0.05$).

In addition, there was a positive correlation between Oregon grape and pH ($p<0.05$).

Out of the 20 polygons in the HF Group, all were eliminated using the four-step process in Section 3.3.1 (Appendix A). None of the 20 polygons had soil metal concentrations exceeding CSR standards for plants. No polygons within this group were identified as having previous air pollution injury (P modifier in the polygon legend). The majority of plant communities in this group were at advanced structural stages (5m, 5s, 6 and 7). All sample locations within this group were also within Group 2 of the vegetation statistical analysis. The vegetation statistics for Group 2 could not be related to smelter emissions. Seven polygons with HF units were retained after the four-step biophysical habitat screening (378, 404, 435, 438, 1586, 1642, 1643). All of these have PCOC concentrations with a >10% probability of exceeding CSR standards for plants and soil invertebrates. However, for six of these polygons, the HF unit within the polygon is at an advanced structural stage (5m, or 6). Only polygon 378 is at 5i, and the remaining 50% of the polygon also is at earlier structural stages (RC2a and RC5i). Therefore, all polygons within the HF Group were eliminated from further consideration in the risk assessment.

Group WF (White Pine-Falsebox). The response in Group WF was moderate. There was a significant negative correlation between:

- Richness and H+-normalized metals ($p<0.05$).

It appears that there may be potential impacts of the smelter on vegetation indices. Most WF sites are located at <800 m elevation (Golder, 2007a).

Out of the 36 polygons in the WF Group, all but 10 were eliminated using the four-step process in Section 3.3.1 (Appendix A). Of the 10 remaining polygons, five had soil metal concentrations exceeding CSR standards for plants. Nine/10 retained polygons were identified as having previous air pollution injury (P modifier in the polygon legend). All 10 retained polygons contained plant communities at early structural stages (1, 2, 3o, 4o, 5o). Most WF sample locations were within Groups 1 or 5 of the vegetation statistical analysis. The vegetation statistics for Groups 1 and 5 indicate adverse effects related to smelter emissions. Therefore, the 10 polygons (Table 3-13) were retained for further consideration in the causal analysis (Section 3.3.3).

Table 3-13 Polygons within the WF Group Which were not Eliminated in the Plant Community Screening Step

Polygon	*Polygon Label*	*> or < CSR Standards for Plants**
350	10WFw5oM:P	
399	7WFw4oM:P-3WFw1:P	>
403	6WFk5mM:P-4WFw4o:P	>
497	9WFws3o:P-1WFws1:P	
656	10WF4iM:P	
1079	5WFws3b:FmP-3WFw3a:FsP-2SSw	
1366	7BF5iB:FsP-3TC	
1464	8IN-2WFk3o	>
1607	7WFw5iB:FmP-2WFw2a:FmP-1SRw3o	>
1624	5WFk5mM:P-4WFw3o:P-1SR5iC:P	>

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

<u>Vegetation Analysis for Plots with Complete Soils and Vegetation Data (Enns and Enns, 2010)</u>

Re-analysis of the vegetation data was conducted by Enns and Enns (2010; Appendix F) for those plots that had complete soils and vegetation data (157 plots representing 147 polygons). Trends in vegetation characteristics were described relative to As, Cd, Cu, Pb, Hg, Zn, S and sulphate sulphur in soil, and soil and topography characteristics (*e.g.*, % sand, bulk density, crown closure, elevation, distance from smelter, *etc.*)

Vegetation richness was influenced by five variables (Enns and Enns, 2010): lead concentration, zinc concentration, elevation, soil bulk density and % sand. Vegetation richness increased with zinc concentration, supporting the finding that zinc is not a significant COPC for plant communities; only 3% of the soil samples in the AOI contained zinc at a concentration that exceeded the CSR standard for plants and soil invertebrates (Section 3.2). Proportion of sand (as opposed to silt) in the soil (a compaction and drought indicator) and elevation also both had a positive influence on richness. Concentrations of lead, and higher bulk density (due to higher silts) had a negative effect. This analysis of factors that influence vegetation richness should be interpreted with caution, because, for example, areas with high concentrations of lead in soil also coincide with areas with previous exposure to high concentrations of sulphur dioxide, and also areas of severe repeated fire (Enns and Enns, 2010).

Similarly, vegetation diversity was influenced by two variables. Diversity increased with increasing copper concentrations in soil. Copper concentrations increased slightly with distance from the smelter. The relationship between copper and diversity may be due to this function of distance, rather than due to changes in copper concentrations (Enns and Enns, 2010). Regardless, like zinc, copper is not a significant COPC for plant communities.

An analysis was conducted to determine whether certain vegetation types might be in recovery from past air pollution, largely unaffected by past air pollution, or in need of further consideration for remediation planning. Two groups were identified (Enns and Enns, 2010): the *Agrostis* group, containing a relatively small number of species (12), including relatively aggressive colonizers such as drought- and sulphur dioxide-tolerant grasses and shrubs, occurs more frequently (*i.e.,* with greater total cover) at low elevation; and, the *Bryoria* group, which included more species (39), including more tender herbaceous species, and lichens and mosses, most of which are sensitive to sulphur dioxide, and occurs more frequently (*i.e*., with greater total cover) at higher elevation (Enns and Enns, 2010).

The cover values of concordant species were added together for each vegetation plot, and relationships with metal concentrations in soils, pH, elevation and distance from smelter were examined graphically and through multiple regression models. The total cover of *Agrostis* group was associated with metals in soils while cover of *Bryoria* group was not. The pattern of occurrence of the two species groups did not align very well with soil pH, or distance from the smelter, but were very strongly influenced by elevation. Both groups occur at high and low elevation but *Agrostis* group is more likely to occur at low elevation, and *Bryoria* group is more likely to occur at higher elevation. Factors related to drought, exposure (*i.e*., steep slopes), soil nutrition, development of crown closure, compaction in soils and emissions influenced the occurrence of the two species groups (Enns and Enns, 2010).

Four types of plots also were identified, based on relationships to soils and residual effects of emissions (Enns and Enns, 2010):

- Plot Type 1 occurs close to the smelter, at low elevation, is dominated by the *Agrostis* group, and has sandy soils. This Plot Type corresponds predominantly to Groups 1 and 5 of the Golder (2007a) analysis.
- Plot Types 2 and 3 are at high elevation, and are mostly dominated by the *Bryoria* group. These Plot Types correspond predominantly to Group 2 of the Golder (2007a) analysis, with some plots in Plot Type 3 also from Groups 4 and 6 of Golder (2007a).
- Plot Type 4 occurs at low elevation to the north and south, on either side of Type 1 (which is centred near the smelter site). This Plot Type corresponds predominantly to Groups 1 and 5 of the Golder (2007a) analysis.

Results of the re-analysis based on these four Plot Types (Enns and Enns, 2010), are fairly consistent with the results for the groups identified by Golder (2007a):

- Plot Type 1 has been influenced by long-term exposure to emissions. Most of the polygons in this Type, which are located at low elevation and near the smelter, were also identified as requiring consideration of risk management based on the analysis in Golder (2007a) for Groups 1 and 5.
- Plot Types 2 and 3 have few emissions related influences but rather natural or forestry-managed vegetation influences. Most polygons in these two Plot Types were eliminated from consideration based on the analysis by Golder (2007a) (only 1 of 18 polygons in Plot Type 2, and 5 of 40 polygons in Plot Type 3 were not eliminated using the Golder (2007a) analysis). Although the Enns and Enns (2010) analysis suggests that these 6 polygons could be eliminated from consideration of risk management, they were retained based on the previous analysis, in order to be conservative.
- Plot Type 4 has a much older influence from historical emissions. The northern portion of Plot Type 4 is dominated by transitional vegetation between the *Agrostis* group and the

Bryoria group, and has historically been considered less exposed than the southern portion. The southern portion of Group 4 has a moderate level of current disturbance. Ten of 42 polygons were retained from the Golder (2007a) analysis (Groups 1 and 5), all but one from south of the smelter.

Uncertainty Associated with the Plant Community Statistics

Overall uncertainty related to measurement error and the understanding of natural variability in plant community measures was low because data were obtained for several variables, at 440 locations within 350 polygons, and represented a broad range of metal concentrations in soil (Table 3-2). Furthermore, several natural variables that could influence the plant communities were accounted for in the study design.

Uncertainty related to measurement error and the understanding of natural variability within particular plant community groups varied from low to moderate because of different levels of sampling effort within groups. Some groups (*i.e*., Groups 3, 4, 6, 7, 8, DO and HF) had relatively few polygons included in the analysis (less than 25), and some groups (*i.e*., Group 4, HF) had no polygons with PCOC concentrations exceeding CSR standards for plants and soil invertebrates. Therefore, uncertainty is greater for these groups.

Uncertainty increased when there was a lack of consistency in the pattern of responses across the various measures (*e.g*., within the statistical correlations). The lack of correspondence between vegetation statistics and PCOC concentrations in soil may result from the relatively low proportion of PCOCs in the available or potentially available fractions as shown in the sequential extraction data (Section 3.2).

However, the consistency between the results of the analyses by Golder (2007a) and Enns and Enns (2010) provides confidence in the overall results of the vegetation community statistical analysis.

3.3.2.3 Line of Evidence #3 – Soil Physical and Chemical Characteristics

Line of Evidence #3: Soil physical and chemical characteristics. Associations were explored between litter-fibre-humus (LFH) depth and other soil parameters (*e.g*., pH, organic matter, soil metal concentrations).

LFH layers on the surface of the soil are a source of nutrients, protect soil water supplies, and often are the main fine rooting zone in a poor or thin soil (Enns and Enns, 2010; Appendix F). The significance of the LFH studies relates to direct response to past, current and future response to metals accumulation. LFH is one of the few indicators that responds primarily to metals and is somewhat independent of sulphur dioxide effects. Both heavy metals and sulphur dioxide from metals smelting are known to be toxic to some microorganisms and alter litter decomposition processes responsible for breakdown of leaf litter for the provision of micro and macronutrients to plants (Freedman and Hutchison, 1979; Wookey and Ineson, 1991; Beyer et al. 1987).

The soil pH is an important indicator of past acidic deposition (Enns and Enns, 2010). The pH and organic matter content of the soil also influence the availability of metals to plants (Kabata Pendias and Pendias, 2001).

Magnitude of Response

The LFH data are presented in Appendix J of Golder, 2007a. The magnitude of response is weak because there were no significant correlations between LFH depth and any soil parameter (*i.e.*, pH, organic matter content, PCOC concentration (arsenic, cadmium, copper, lead, selenium, zinc), or pH-adjusted total PCOC concentration) (analysis not presented). No statistical analyses were conducted to explore the relationship between LFH depth and plant community characteristics.

Uncertainty

Uncertainty in this LOE is moderate. Data were obtained for few variables related to LFH development, but from a large number of sample locations across the PCOC concentration gradient. Many important natural variables were not accounted for in the analysis (*e.g.*, type of plant community contributing to the LFH layer). There was no clear relationship between LFH and PCOCs or other parameters.

3.3.2.4 Line of Evidence #4 – Herbivore Community Changes

Line of Evidence #4: Herbivorous avian and mammalian community composition. This LOE addresses indirect effects on plants due to grazing pressure from herbivores. It was assessed by considering the direct effects of PCOCs on herbivorous avian and mammalian populations and communities. Impacts on herbivores caused by changes in the vegetation community are addressed in Section 4.0. The cascade of effects resulting from changes in plant communities (*e.g.*, habitat) which affect wildlife populations and communities, and which then influences grazing pressure on plant communities, is not addressed herein.

Magnitude of Response

Section 4.0 of this volume presents the results of the avian and mammalian community analysis. No unacceptable direct toxicity risks were predicted to avian or mammalian herbivore populations (Intrinsik, 2007; Section 4.0 of this volume). The avian and mammalian communities are representative of the habitats present in the AOI.

Uncertainty

Section 4.0 of this volume describes the uncertainty associated with the avian and mammalian community analysis. Several LOE were used with an overall moderate level of uncertainty. There is greater confidence in the avian community data than the mammalian community data. Insufficient data were collected to address the potential cascade of indirect effects between plant communities and wildlife.

3.3.2.5 Summary of Evidence for Effects of Smelter Emissions on Plant Communities

There is evidence to support the conceptual model that metals and previous air pollution injury may continue to influence plant communities in portions of the AOI, based on the biophysical habitat screening, the productivity measurements, and the vegetation statistical analyses. The evidence is stronger for some areas (polygons) within the AOI (*e.g.*, polygon 447 based on the productivity measures; BF units and low elevation sites, based on the vegetation statistics). There is very little support for the conceptual model in other areas (*e.g.*, polygons 439, 728 and 1,483 based on productivity measurements, high elevation sites and DO and HF units based on the vegetation statistics). There is little support for the influence of PCOCs on LFH development. There is no evidence of changes to plant communities because of direct toxicity of metals to herbivores. It is not possible to determine whether effects observed on the plant communities are a result of direct effects of PCOCs or indirect effects, as illustrated by the conceptual model. However, it appears that plant community impacts are due to a combination of direct effects (*e.g.*, PCOC toxicity to plants) and indirect effects (*e.g.*, competition from acid- and metal-tolerant plants).

3.3.3 Assessment of Causality

Step 5 of the SALE process continues with an evaluation of causality for all lines of evidence (regardless of the magnitude of response, unless responses are weak or inconclusive). Causality is evaluated using a formal set of criteria presented in Hull and Swanson (2006). These causal criteria assume that there will be a proportional response between exposure and effects. Landis (2002) cautions that we should not expect proportionality (*i.e.*, clear and consistent dose-response relationships), because components of the ecosystem are linked, and may be affected by changes in other ecosystem components. However, many authors have succeeded in illustrating a relationship between population- or community-level responses and the exposure to stressors. The causal criteria used in the SALE process are:

- Spatial correlation: Effects occur at the same place as exposure; effects do not occur where there is no exposure;
- Temporal correlation: Effects occur with or after exposure;
- Biological gradient/strength: Effects are greater where or when exposures are greater. Evidence for cause/effect is stronger if the exposure response is monotonic which produces a relatively high magnitude response;
- Plausibility (mechanism): It is plausible that the observed effects are a result of the stressor, based on what is known about how the stressor causes an effect in the affected organisms. Consideration must be given to indirect mechanisms (*e.g.*, loss of organic matter in soil may cause lower diversity in plant communities);
- Plausibility (stressor-response): The magnitude of response is expected based on the level of the stressor;
- Consistency of stressor/effect association: Repeated observation of effect and stressor in different studies or different locations within the region being studied. In addition, there is existing knowledge from other regions where similar (analogous) stressors have caused similar effects;
- Experimental verification: Effects of the stressor are observed under controlled conditions and there is concordance of these experimental results with field data; and,
- Specificity of Cause: The tendency for effect to be associated with exposure to a particular stressor. Effects should be defined as specifically as possible to increase the specificity of the association between cause and effect. In the extreme case, causation is clear when a stressor results in only one effect, and that effect is only related to that one stressor. However, this is rare in environmental situations.

At least one of the first two causal criteria (spatial or temporal correlation) is considered necessary to make a case for causality. The temporal criterion is essential; however, the spatial criterion may not apply if metapopulation dynamics predominate or if up-gradient movement for reproductive purposes occurs. Both situations can and do result in significant responses being observable first in areas where the particular stressor is very low or non-existent. However, simply having correlation in space or time is insufficient to make a strong case for causality, especially for a large study area such as the AOI with historic contamination and multiple confounding variables (natural and anthropogenic).

A line of evidence was not considered inadequate if it was not supported by all causal criteria. In particular, the "specificity of cause" criterion is rarely met. This is because the measures used are often too general to be linked to one specific stressor.

The results of the examination for causality were summarized by applying scores that reflected the performance of each line of evidence against the causal criteria (Table 3-14). The scoring varied with each criterion because each criterion has a different set of results that apply to causation and each criterion has a different level of relative importance to the overall score. For more details on the scoring, including how to interpret the scores for each causal criterion, please refer to Hull and Swanson (2006) and U.S. EPA (2000).

Table 3-14 Causation Score Criteria

Criterion	***Results***	***Score***
Spatial Correlation	Strong evidence; Compatible; Uncertain; Incompatible	++; +; 0; – – –
Temporal Correlation	Strong evidence; Compatible; Uncertain; Incompatible	++; +; 0; – – –
Biological Gradient/Strength	Strong, monotonic and consistent among responses; Weak or other than monotonic or inconsistent among responses; None; Clear association, but the more stressor, the lower the response	+++; +; –; – – –
Plausible Mechanism	Actual Evidence; Plausible; Not known; Implausible	++; +; 0; – – –
Plausible Stressor-Response	Quantitatively consistent; Concordant; Ambiguous; Inconcordant	+++; +; 0; – – –
Consistency of Association (across sites in the region)	Invariant; In many places and times; At background frequencies or many exceptions to the association	++; +; –
Experimental Verification	Experimental studies: Concordant; Ambiguous; Inconcordant	+++; 0; – – –
Specificity of Cause	Only possible cause; One of a few; One of many	+++; ++; 0

The overall evidence for a cause/effect link between plant community measures and the smelter is moderate (Table 3-15). This conclusion is based on the following reasoning:

Spatial Correlation:

Productivity: There was mixed evidence for spatial correlation between productivity, PCOC concentrations in soil and past SO_2 injury among the polygons sampled for productivity of western white pine. Western white pine in polygon 447 had lower productivity, and PCOC concentrations exceeded CSR standards for plants and soil invertebrates. On the other hand, productivity was similar to the control site for polygons 439, 728 and 1,483. Polygon 439 was eliminated in the biophysical habitat screening step 2, and PCOC concentrations in soil did not exceed the CSR standards for plants and soil invertebrates. Polygons 728 and 1,483 were not eliminated in the biophysical habitat screening because the plant communities are in structural stage 5i or 5o and there is evidence of previous air pollution injury. Although there is a greater than 10% probability of PCOC concentrations in soil exceeding the CSR standards for plants and soil invertebrates using conditional simulation, standard kriging of the soil data did not predict an exceedance of the CSR standards for plants for polygon 728. In addition, although there were no soil samples taken in polygon 728, there were no exceedances of CSR standards for plants for three soil samples taken within approximately 0.5 km of this polygon. Therefore, there is uncertainty as to whether PCOC concentrations in soil exceed CSR standards for plants in polygon 728.

Vegetation Statistics: There is a strong spatial correlation between vegetation indices and smelter-related parameters (*e.g.*, PCOCs in soil, soil pH) in lower-elevation areas closer to the smelter. Vegetation indices were negatively correlated with smelter-related parameters for Groups 1, 3, 5, 7 (sites at low elevation), but not for Groups 2, 4, 6, 8 (sites at high elevation).

Elevation is correlated with PCOC concentrations in soils, as well as evidence of previous air pollution injury. Therefore, the vegetation statistical analysis shows a strong spatial correlation with smelter emissions for Groups 1, 3, 5, 7, BF, DO and WF. However, there is only a weak/uncertain spatial correlation for Groups 2, 4, 6, 8 and HF.

Temporal Correlation:

There is strong evidence for a temporal correlation between smelter emissions and effects on the plant community. More than 100 years of smelting, and release of metals and SO_2, has occurred. Significant historical impacts to plants in the 1930s to 1990s have been documented (*e.g.*, Archibold, 1974; Enns, 2001). The most dramatic positive changes in vegetation have occurred in the 1970s and again in the early 2000s with the installation of KIVCET (Enns, 2001). The biophysical habitat map is based on a 1999 aerial photograph and field observations conducted in 2000, 2001 and 2002. Statistical analyses were performed on vegetation community data collected in 2001. Productivity data were collected and 2006 (for western white pine). These lines of evidence document vegetation community response to several decades of incrementally-decreasing emissions, and a relatively brief period of dramatically reduced smelter emissions post-KIVCET. There is a strong correlation between vegetation indices and smelter-related parameters at low elevations (*e.g.*, PCOCs in soil, soil pH) except for LFH. This correlation is not observed for plant communities at higher elevations (which were not impacted by smelter emissions). The productivity data also show a strong temporal correlation with smelter emissions pre- *vs.* post-KIVCET for three of the four locations. Decreased productivity in western white pine is persistent at the fourth site.

Biological Gradient/Strength:

The map of polygons retained after the biophysical habitat screening shows that plant communities in structural stages 6 and 7 generally are at the edges of the AOI. There are more early structural stage plant communities with canopy openings or bare mineral soil (*e.g.*, 4i, 4o, 5i, 5o) closer to the smelter, at lower elevation, and facing the smelter. These areas contain higher metal concentrations in soil and experienced previous air pollution injury to a greater extent than areas further from the smelter, at higher elevation, and not facing the smelter (Golder, 2004; 2007a). Both stressors frequently co-occur, and therefore it is difficult to distinguish which may be responsible for the observed effect.

The vegetation statistics show correlations with smelter-related parameters for Groups 1, 3, 5, 7 (sites at low elevation), but not for Groups 2, 4, 6, 8 (sites at high elevation). Group 5 has many sites within 2 km of the smelter, and has stronger statistical correlations ($p<0.001$ and $p<0.005$ *vs.* $p<0.05$) than other groups. Therefore, the vegetation statistical analysis shows a gradient in response. There also is a biological gradient when considering vegetation statistics by dominant biophysical habitat unit. However, the gradient is less clear. The correlations between vegetation response and smelter effects are strongest in BF types, especially those close to the smelter. There were fewer correlations between vegetation indices and smelter-related parameters for DO and HF units. Many of these sites are at higher elevation and corresponded to Group 2. Therefore, the gradient for these units is considered weak.

Plausibility- Mechanism:

There are plausible mechanisms for the effects of PCOCs in soil and previous air pollution injury on plant communities in the AOI, primarily at lower elevation and close to the smelter. Injury of plants from airborne emissions of SO_2 is well documented around emissions sources such as smelters. Signs of previous air pollution injury can still be seen in the aerial photographs (Appendix C).

Plausibility – Stressor-Response:

It is plausible that previous air pollution injury could be responsible for observed impacts in the plant community, as shown by the biophysical habitat mapping and vegetation statistical analyses. Historically, the magnitude of response (severe) was concordant with the magnitude of the stressor (large quantities of metals and SO_2) (Golder, 2007a). There is documentation that shows pollution damage to vegetation was severe in the area immediately surrounding Trail, and moderate closer to Castlegar and south of Trail to the US border, where SO_2 levels would have been lower (Golder, 2007a). Many areas with the most dramatic evidence of injury to vegetation from past exposure to air pollutants are on slopes facing into the path of the smelter plume that do not retain moisture (Golder, 2007a). The plant communities are continuing to change (*e.g.*, increased productivity, increased % cover) since KIVCET was installed and emissions of metals and SO_2 were reduced. Current emissions are not at a level of concern for most vegetation as defined for long-term, low-level chronic exposures, when annual averages and maxima from the air quality monitors are compared to threshold values defined in Linzon (1978). Annual average concentrations are below the thresholds set in provincial, federal and U.S. EPA regulatory guidelines and limits. Plant cover is observed to be increasing (Archibold, 1974; Enns, 2001; Enns and Enns, 2007b [Appendix C]) which is an indication that in this environment, SO_2 exposures are not an impediment to the recovery of the vegetation.

Consistency of Association:

There was consistency in the evidence among sites within the AOI related to correlations between vegetation statistics (except LFH) and smelter-related indices, and biophysical habitat screening results and one or both of PCOC concentrations in soil and previous air pollution injury. There are many sites where vegetation community parameters did not correlate with PCOC concentrations in soil. Factors such as soil features, climate, logging and fire history also may influence plant communities in the AOI.

Experimental Verification:

There was no experimental verification of the field-based lines of evidence in the present study (*i.e.*, no laboratory toxicity tests were conducted). Therefore, no score was assigned for this criterion.

Specificity of Cause:

None of the responses could be considered to be specific to the effects of PCOCs in soil. Several potential confounding natural and anthropogenic factors (*e.g.*, fire, logging, disease, land management activities) could contribute to the observed impacts to the plant community. Evidence of previous air pollution injury was specified where observed. A score of “0” was assigned for this criterion, corresponding with “one of many” potential causes.

Undoubtedly, plant communities in the AOI have been adversely affected by smelter emissions in the past. However, there is only moderate evidence (Table 3-15) of an ongoing link between plant community responses and smelter emissions as per the Conceptual Model. Effects are not likely related to PCOC effects on LFH or a result of changes in herbivore communities. There are several potential confounding factors that could have a significant influence on plant communities (*e.g.*, fire).

Table 3-15 Causation Scores for Plant Community Lines of Evidence

Causal Criterion	*Line of Evidence*	
	Productivity (Western White Pine)	Vegetation Statistics (Groups 1, 5, 7, BF, DO [within Groups 1 and 5 only], WF)
Spatial Correlation	+	++
Temporal Correlation	++	++ *
Biological Gradient/Strength	+	+
Plausibility: Mechanism	++	++
Plausibility: Stressor-Response	+	+
Consistency of Association	+	+
Experimental Verification	na	na
Specificity of Cause	0	0
OVERALL STRENGTH OF EVIDENCE	⦿	⦿

o Weak overall strength of causal evidence
⦿ Moderate overall strength of causal evidence
● Strong overall strength of causal evidence
* No historic statistical analysis available for comparison; therefore, rating is based on qualitative historic information

3.3.4 Risk Characterization

The final weighing of evidence involved summarizing magnitude, causation and uncertainty scores for each line of evidence. Consistency of magnitude and causation scores across all lines of evidence provided a higher level of confidence in the recommendation to proceed or not to proceed to a risk management evaluation.

The system for determining how the scores for magnitude, uncertainty and causation “added up” to a recommendation to proceed to risk management (or not) is presented in Table 3-16. If uncertainty scores were “high,” the risk management consideration recommendation may be accompanied with a recommendation to confirm with more data.

Table 3-16 System for Summing the Magnitude, Causation and Uncertainty Scores

Magnitude	*Uncertainty*	*Causation*	*Proceed to Risk Management?*
●	**?**	●	Yes
●	**??**	●	Yes
●	**???**	●	Yes but confirm with more data and revisit the Conceptual model because the high uncertainty could mean that there is Type I error or the Conceptual Model is incorrect
●	**?**	⦿	Yes
●	**??**	⦿	Yes but may want to confirm with more data and revisit the Conceptual model because the moderate uncertainty may lead to Type I errors
●	**???**	⦿	Yes but confirm with more data and revisit the Conceptual model because the high uncertainty which could mean that there is Type I error or the Conceptual Model is incorrect
●	**?**	o	No because no cause/effect link and low uncertainty
●	**??**	o	No because no cause/effect but may want to confirm with more data and revisit the Conceptual model because the moderate uncertainty may lead to Type I or Type II errors
●	**???**	o	No but confirm with more data and revisit the Conceptual Model because the high uncertainty could mean that there is Type I or Type II error or the Conceptual Model is incorrect
⦿	**?**	●	Yes because of the moderate magnitude, strong cause/effect link and low uncertainty

Table 3-16 System for Summing the Magnitude, Causation and Uncertainty Scores

Magnitude	*Uncertainty*	*Causation*	*Proceed to Risk Management?*
⦿	??	●	Yes but may want to confirm with more data and revisit the Conceptual model because the moderate uncertainty may lead to Type I or Type II errors
⦿	???	●	Yes but confirm with more data and revisit the Conceptual Model because the high uncertainty could mean that there is Type I or Type II error or the Conceptual Model is incorrect
⦿	?	⦿	Yes
⦿	??	⦿	Yes but may want to confirm with more data and revisit the Conceptual model because the moderate uncertainty may lead to Type I or Type II errors.
⦿	???	⦿	Yes but confirm with more data and revisit the Conceptual Model because the high uncertainty could mean that there is Type I or Type II error or the Conceptual Model is incorrect
⦿	?	o	No because no cause/effect link
⦿	??	o	No because no cause/effect link but may want to confirm with more data and revisit the Conceptual model because the moderate uncertainty may lead to Type I or Type II errors
⦿	???	o	No but confirm with more data and revisit the Conceptual Model since there is high uncertainty so the lack of a cause/effect link could be due to a Type II error or incorrect conceptual model
o	?	Na	No because of the low magnitude
o	??	Na	No because of the low magnitude
o	???	Na	No, but if it is practicable to obtain data to reduce uncertainty, confirm with more data and revisit the Conceptual Model because the high uncertainty could mean that there is Type I or Type II error or the Conceptual Model is incorrect

Magnitude: o Weak response; ⦿ Moderate response; ● Strong response
Uncertainty: ? Low uncertainty; ?? Moderate uncertainty; ??? High uncertainty
Causation: o Weak causal evidence; ⦿ Moderate causal evidence; ● Strong causal evidence

The AOI has been subdivided into 1997 polygons. The biophysical habitat screening conducted in Section 3.3.1 and Appendix A eliminated 1,582 polygons from further consideration under Objective 1. Therefore, 415 polygons remained for further consideration in the Effects Assessment (Section 3.3.2) and Causal Analysis (Section 3.3.4). The following paragraphs explain the rationale for excluding some of the 415 polygons from further consideration in the risk management planning process (Table 3-17).

Table 3-17 SALE Summary Table for Plant Communities

	Productivity			***Stats Group or Biophysical Habitat Unit***			***LFH***			***Herbivore Community***			
	Magnitude	***Uncertainty***	***Causation***	***Magnitude***	***Uncertainty***	***Causation***	***Magnitude***	***Uncertainty***	***Causation***	***Magnitude***	***Uncertainty***	***Causation***	***Proceed to Consideration of Risk Management Options? ****
Polygons 728, 1483 (Western White Pine Data)	O	??	na										No (related to this measure)
Polygon 447 (Western White Pine Data)	●	??	⦿										Yes
Site Index (Conifers)	O	??	na										No (related to this measure)
Group 1 Polygons retained after biophysical habitat screening (includes polygon 447 and several DO polygons)				●	?	⦿							Yes
Group 2 Polygons retained after biophysical habitat screening (except 1607)				O	?	na							No
Group 3 Polygons retained after biophysical habitat screening				O	??	na							No
Group 4				O	??	na							No
Group 5 Polygons retained after biophysical habitat screening (includes polygon 447 and several DO polygons)				●	?	⦿							Yes
Group 6 Polygons retained after biophysical habitat screening				O	??	na							No
Group 7 Polygons retained after biophysical habitat screening				●	??	⦿							Yes
Group 8				O	??	na							No
BF Polygons retained after biophysical habitat screening (includes polygon 447)				●	?	⦿							Yes

Table 3-17 SALE Summary Table for Plant Communities

	Productivity			Stats Group or Biophysical Habitat Unit			LFH			Herbivore Community			
	Magnitude	Uncertainty	Causation	Magnitude	Uncertainty	Causation	Magnitude	Uncertainty	Causation	Magnitude	Uncertainty	Causation	Proceed to Consideration of Risk Management Options? *
HF				O	??	na							No
WF Polygons retained after biophysical habitat screening (including polygon 1607)				⦿	??	⦿							Yes
Entire AOI							O	??	na	O	??	na	No (related to these measures)

* "Yes" for proceeding to consideration of risk management options should include a confirmation of current conditions within the polygons because there has been continuing development of plant community structure since the aerial photograph (1999) and field work conducted for statistical analysis (2001)
Blank Cell indicates no data available for this line of evidence
Magnitude: o Weak response; ⦿ Moderate response; ● Strong response
Uncertainty: ? Low uncertainty; ?? Moderate uncertainty; ??? High uncertainty
Causation: na not applicable, if low magnitude of response o Weak overall strength of causal evidence ⦿ Moderate overall strength of causal evidence ● Strong overall strength of causal evidence

The productivity data from Golder (2007a) are consistent with the results of the biophysical habitat screening. Polygon 439, which had productivity similar to that of the reference area, had already been eliminated by the biophysical habitat screening. Polygons 728 and 1,483 had past effects on tree productivity but western white pine productivity has increased in these polygons. Polygon 447, which had lower productivity than the reference area, was retained by the biophysical habitat screening. Soil metal concentrations exceeded CSR standards for plants and soil invertebrates at this site. Although 70% of the polygon was in an advancing structural stage (5m), 30% was BF at structural stage 4o. The entire polygon has been selectively logged, and showed evidence of previous air pollution injury. The magnitude of response, uncertainty and causal analysis suggest that this polygon should be retained for consideration in the risk management planning phase, due to the likelihood of elevated PCOC concentrations in soil, the presence of bare mineral soil, and previous air pollution injury. However, the influence of logging on the plant communities will need to be taken into account.

The trend in the Site Index measurements suggests that productivity of conifers is more dependent on site variables such as soil nutrient regime than past emissions effects (Enns and Enns, 2010; Appendix F). In addition, comparisons of images from 2000 and 2007 showed tree crown width increasing at 400 to 600 m elevation. Ground vegetation cover also increased in polygons that were south-facing, and that were not in a closed canopy (Enns and Enns, 2010).

Group 1 (lower elevation, dry soils, coniferous forest), including polygon 447, is recommended for consideration in risk management planning. The magnitude of response was strong, along with low uncertainty and a moderate causal link to smelter emissions. Polygons 680, 691, 1561 and 1,564 were evaluated using vegetation statistics as part of both Groups 1 and DO. DO polygon 1,174 was not assigned a group, but could have been placed in either Group 1 or 5 (lower elevation, dry soils, deciduous forest). Although the statistics for the entire DO group did not suggest smelter-related impacts, these polygons (including polygon 1174) are recommended for consideration in risk management planning, as part of Group 1.

The magnitude of response was weak with low uncertainty for polygons within Group 2 (higher elevation, dry soils, coniferous forest), except for polygon 1607 which was also assessed as part of the WF group. Therefore, all polygons within Group 2, with the exception of polygon 1607, are not recommended for consideration in risk management planning. Polygon 1607 is recommended for consideration in risk management planning, along with the WF group polygons which were retained after the biophysical habitat screening (see below).

The magnitude of response was low for polygons within Group 3 (lower elevation, moist soils, coniferous forest). Uncertainty was moderate. None of the retained polygons were assessed as part of the biophysical habitat unit statistical analysis. Therefore, the polygons within Group 3 are not recommended for consideration in risk management planning.

None of the polygons within Group 4 (higher elevation, moist soils, coniferous forest) were retained after the biophysical habitat screening. In addition, the magnitude of response was weak and the uncertainty was moderate for this group. Therefore, none of the polygons assessed as part of Group 4 are recommended for consideration in risk management planning.

Group 5 (lower elevation, dry soils, deciduous forest), including polygon 447, is recommended for consideration in risk management planning. The magnitude of response was strong, the uncertainty was low, and there was a moderate causal link to smelter emissions. Polygons 521, 603, 670, 691, 1,345, 1,386, and 1,564 were evaluated using vegetation statistics as part of both Groups 5 and DO. DO polygon 1174 was not assigned a group, but could have been placed in either Group 1 or 5. Although the statistics for the entire DO group did not suggest smelter-related impacts, these polygons (including polygon 1174) are recommended for consideration in risk management planning, as part of Group 5.

The magnitude of response was weak and the uncertainty was moderate for polygons within Group 6 (higher elevation, dry soils, deciduous forest). None of the retained polygons were assessed within the biophysical habitat unit statistical groups. Four of the five retained polygons within this group show evidence of moderate or severe fire and only two retained polygons have a greater than 10% probability of exceeding CSR standards. Many of the plots used to evaluate Group 6 occur in the Pend D'Oreille Valley or the plateau above the main stem of the Columbia River, and as such have low metals due to distance from source. Two of the five retained polygons also were eliminated as part of Group 2 (higher elevation, dry soils, coniferous forest). Therefore, none of the polygons assessed as part of Group 6 are recommended for consideration in risk management planning.

The magnitude of response was strong for polygons within Group 7 (lower elevation, moist soils, deciduous forest). Uncertainty was moderate, as was the strength of causal association with smelter emissions. None of the retained polygons were assessed as part of the biophysical habitat unit statistical analysis. Therefore, all of the retained polygons within Group 7 are recommended for consideration in risk management planning.

None of the polygons within Group 8 (higher elevation, moist soils, deciduous forest) were retained after the biophysical habitat screening. In addition, the magnitude of response was weak and the uncertainty was moderate for this group. Therefore, none of the polygons assessed as part of Group 8 are recommended for consideration in risk management planning.

The magnitude of response was strong, uncertainty was low, and there was a moderate causal association with smelter emissions for polygons within the BF group. All of the retained polygons with the BF group were also evaluated as part of either Group 1 or Group 5. Both Groups 1 and 5 had strong magnitudes of effects, and moderate strength of causal association with smelter emissions. Therefore, all of the retained polygons within the BF group are recommended for consideration in risk management planning.

None of the polygons within the HF unit were retained from the biophysical habitat screening. The magnitude of response was weak and the uncertainty was moderate for the HF group. Therefore, no polygons within the HF group are recommended for consideration in risk management planning.

For the WF group, the magnitude of response was moderate, with moderate uncertainty, and moderate strength of causal association with smelter emissions. Therefore, polygons within this group, which were retained after the biophysical habitat screening, are recommended for consideration in risk management planning.

The magnitude of response was weak and uncertainty was moderate for the entire AOI related to the LFH data and the herbivore community. No specific area within the AOI requires consideration of risk management to address these measures. It is recommended, however, that once risk management planning reaches the level of the individual polygon (that is, specific actions are being considered for small areas within the AOI), indirect effects such as LFH development or grazing pressure be considered as part of the integrated risk management plan.

The productivity data and the results of the vegetation community statistical analyses support the removal of 16 of the 415 polygons retained from the biophysical habitat screening step. These polygons were within Groups 2, 3, 4, 6, 8 and HF (with the exception of polygon 1607).

Therefore, 399 polygons remain to be considered in the risk management planning process. This represents approximately 7,900 ha or 18.4% of the AOI. The final list of retained polygons is presented in Appendix A, Table A9. These polygons are identified in Figure 3-3.

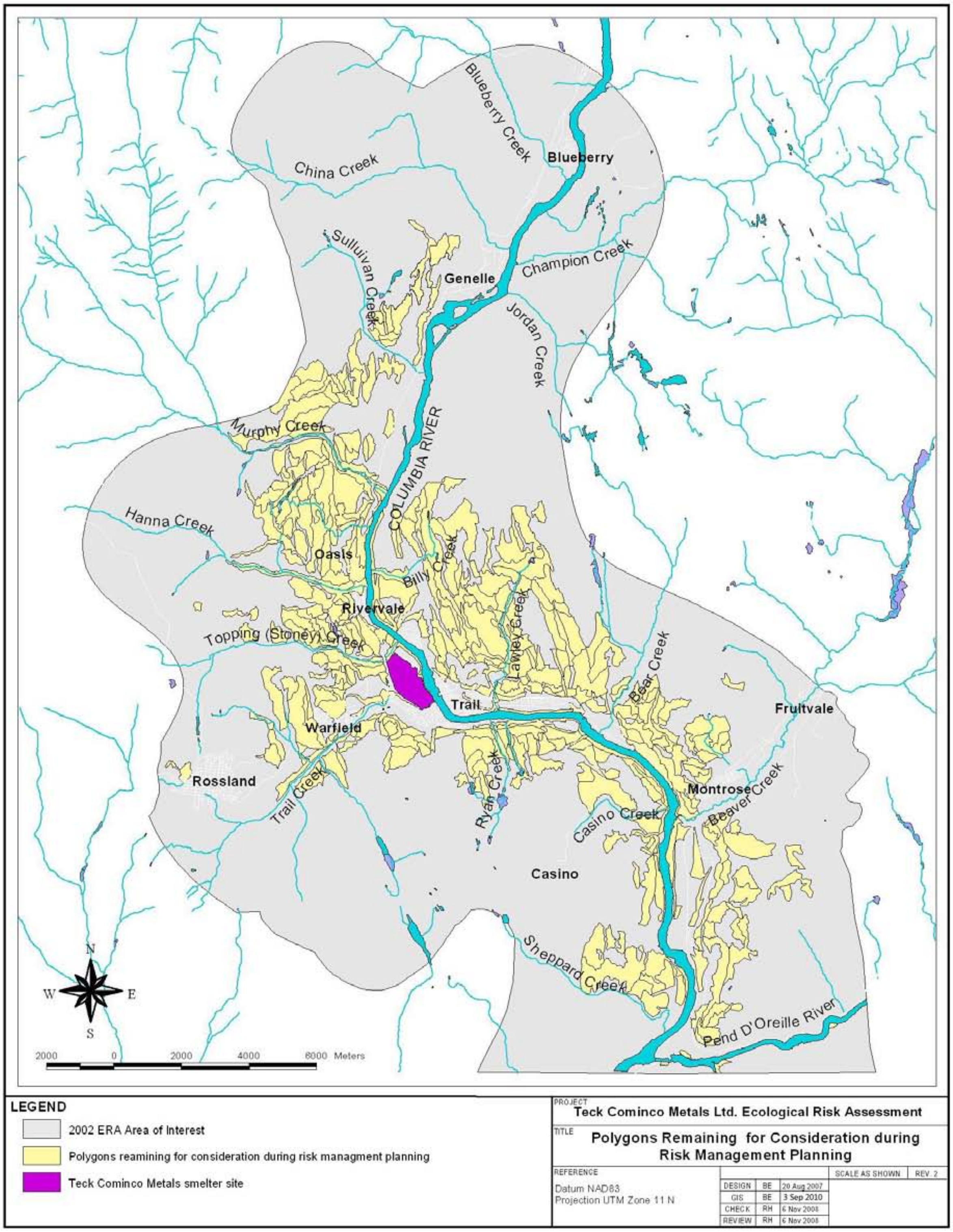


Figure 3-3 Polygons Remaining for Consideration during Risk Management Planning

As is shown in Figure 3-3, there are polygons retained for consideration of risk management on the border of the AOI boundary. The single polygon to the south (1212) is 90% in structural stage 6, with 10% in an early structural stage, but with no visible air pollution [SO_2] damage. The retained polygons to the west of the AOI include: 264, 269, 271, 1,712, 1,717 and 1,718 (Figure 3-4). These are located above 800 m elevation (the yellow line in Figures 3-3 and 3-4). It is possible that historical SO_2 impacts extend beyond the AOI on the western boundary between Murphy and Sullivan Creek. The combination of topography, winds, *etc.*, may have contributed to this, for this particular area. These polygons also all (except 264) had moderate to severe fire history which likely influenced the plant communities. In addition, the aerial photographs upon which the biophysical habitat map was based were taken in 1999. KIVCET was installed in 1997, resulting in decreased SO_2 emissions. Plant communities in these polygons may be improving, as there has been an expansion of existing clusters of vegetation in gullies and depressions, and overall greening has occurred (Archibold 1975, Enns, 2001). Thus, the previous SO_2 injury may no longer be a significant factor influencing the plant communities in this area. However, this would have to be verified using more recent photographs (since much of this area is inaccessible).

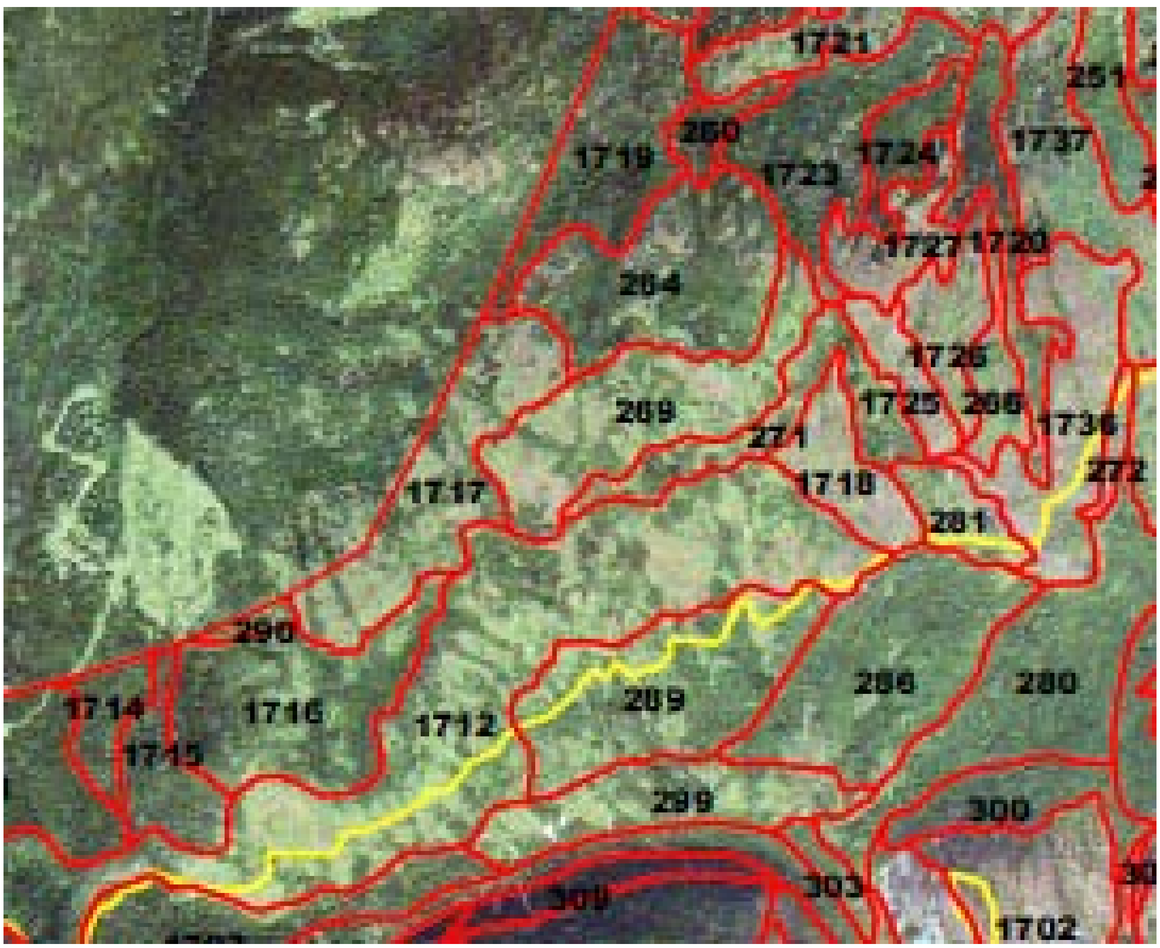


Figure 3-4 Polygons Remaining for Consideration during Risk Management Planning from the Western Border of the AOI

3.3.5 Conclusions and Recommendations Related to Risk Management

Risk management objectives are being met for vegetation, or the polygons are assessed under other objectives (*e.g.*, for agricultural and urban land uses), for 1,598 of the 1997 polygons in the AOI. Sixteen of the 415 polygons retained from the biophysical habitat screening are recommended for removal from the risk management planning process because of the low magnitude of response and low to moderate uncertainty revealed by the analysis of plant community measures. These polygons are within Groups 2, 3, 4, 6, 8 and HF (with the exception of polygon 1607). Therefore, 399 polygons remain to be considered in the risk management planning process.

Two assessment endpoints were used to assess the plant community in wildland areas: productivity and community species composition. The data for western white pine show that productivity has been affected in the past. Since the operation of the KIVCET smelter began in 1997, productivity returned to being similar to that in the reference area for portions of the AOI. However, lower productivity is observed in some areas, as represented by polygon 447 (*e.g.*, within 2 km of the smelter, PCOC concentrations in soil exceeding CSR standards for plants and soil invertebrates). Therefore, it is recommended that risk management planning consider productivity of plant communities in areas close to the smelter, such as polygon 447.

The productivity data were not used to eliminate polygons from consideration in risk management. Polygon 439 (productivity similar to reference area) was already eliminated in the biophysical habitat screening. Although polygons 728 and 1483 have productivity similar to that of the reference area, there are other reasons to retain these polygons for consideration in risk management planning (*i.e.*, i and o structural stage modifiers, indicating openings and bare mineral soil). In addition, the Site Index data provided results only for conifers in 32 polygons. Therefore, these data were not used to eliminate polygons from consideration in risk management.

The results of the risk assessment were based on a net accumulation of emissions effects culminating from 1897 to 2000. Emissions in recent years are much lower than in 1999/2000 or prior to the installation of the KIVCET smelter. Effects typical of chronic sulphur dioxide such as crown thinning, chlorosis, loss in productivity, suppressed growth in exposed sensitive conifers have not occurred in sites near the smelter in recent years (Enns and Gibeau, 2009), whereas symptoms did occur in 1995 (Enns, 2001), and prior to 1974 (Archibold, 1974). Concentrations of sulphur dioxide are expected to decline further with increasing pollution control technology. Vegetation is recovering near the smelter in response to lower concentrations over the past three decades. A net gain in vegetation biomass and diversity is evidenced in the productivity study, and in recent change detection comparing vegetation from imagery in 2000 to imagery in 2006 (Enns and Gibeau, 2009). Field work conducted during biomonitoring and the risk assessment (Archibold 1974; Enns, 2001) showed a dramatic increase in species diversity in permanent plots established in 1975 and re-evaluated in 2000. Therefore, while sulphur dioxide emissions may fluctuate since the installation of KIVCET, and subsequent dramatic reduction in emissions, they are still thought to be low enough to not restrict the recovery of sensitive vegetation in the Trail environment. Therefore, future risks are not expected to be greater than past or current risks.

In summary, the plant communities within the AOI have continued to develop since the time period used to develop the biophysical habitat map (aerial photograph taken in 1999) and the field data were collected for statistical analysis of plant community characteristics (2001). Therefore, consideration of risk management options should be based on an updated assessment of the status of plant community structure.

3.3.6 *Sensitivity Analysis*

A sensitivity analysis was completed for selected parameters and assumptions to determine their influence on the overall conclusions for Objective 1. Specifically, the results and conclusions were evaluated based on:

1) Removal of consideration of the productivity data;
2) Changes in the magnitude definition for Line of Evidence #2 (vegetation community statistics);
3) Changes in the magnitude scores;
4) Changes in the uncertainty scores; and,
5) Changes in the causation scores.

Removal of Productivity Data

As mentioned in Section 3.3.5, the productivity data were not used to eliminate polygons from consideration in risk management. Therefore, if the productivity data were removed entirely, there would be no change in the conclusions of the ERA. The productivity data do provide some insight to support the other analyses used to assess the plant community:

- Condition (as measured by growth) of conifers was measured in four polygons;
- The Site Index data suggest that factors beyond smelter emissions should be considered during risk management planning; and,
- The imagery comparison data support the recommendation that consideration of risk management options should be based on an updated assessment of the status of the plant communities.

Changes in Magnitude Definition for Line of Evidence #2

To meet the definition of “Adverse Effects Likely” for the vegetation species composition endpoint, there must be several highly significant ($p<0.001$) correlations (Table 3-1). The results of this Line of Evidence were re-evaluated assuming the definition changed to be that there must be several significant ($p<0.05$) correlations. This change in definition of “Adverse Effects Likely” would not have resulted in any change to the magnitude scores for this Line of Evidence for any vegetation group.

Changes in Magnitude Scores

A change in the magnitude score, from “Adverse Effects Unlikely” to either “Adverse Effects May Occur” or “Adversely Effects Likely” would have the most significant influence on the overall conclusion of the risk assessment. However, a change between “Adverse Effects May Occur” and “Adverse Effects Likely” would not change the overall conclusion and recommendation regarding consideration of risk management. This issue would be a concern in any risk assessment (*i.e.*, an evaluation finding no effects *versus* effects likely), and thus it is not unique to the SALE process.

Changes in Uncertainty Scores

A change in an uncertainty score from “low” to “moderate” to “high” does not change the overall conclusion of a recommendation to proceed, or not proceed, to consideration of risk management (see Table 3-16). However, having the three scores for uncertainty allows the ERA to be transparent with the degree of uncertainty associated with a particular Line of

Evidence or type of data. In addition, with high uncertainty, there may be reason to confirm the result with additional data or analysis. Therefore, the overall conclusions of the ERA are not sensitive to the uncertainty score.

Changes in Causation Scores

The only significant changes in conclusions that result from changes in causation scores are when the causation score goes from a "weak strength of causal evidence" score to a "moderate" or "strong strength of causal evidence" score (see Table 3-16). Causation scores for all Lines of Evidence for Objective 1 were considered moderate. If these were all changed to "strong", the same recommendation to "proceed to consideration of risk management" would result. If the causation scores were changed from "moderate" to "weak", the recommendation would change to "not proceed to consideration of risk management". Therefore, it is likely that any uncertainty or error in the causation scores is resulting in a conclusion that is conservative (*i.e.,* is recommending consideration of risk management when it may not be necessary).

Overall, the sensitivity analysis shows that the use of the SALE approach does not introduce additional parameters that are sensitive to different scores, such that the recommendation to proceed to risk management is not made, when in fact it should have been made. The SALE analysis provides transparency to the magnitude, uncertainty and causation scores of each Line of Evidence.

3.4 Problem Formulation for Objective 2 (Urban Plants)

Objective 2 is to minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on the maintenance of desired native and introduced plant species in urban areas. "Desired" plants refer to those that are currently present or that people would like to have present. Objective 2 focused on the polygons which are identified as UR (urban/suburban), RR (rural) and UP (urban park) (Figure 3-4). Polygons which are identified as "Residential" in the land use map but which do not contain UR, RR or UP units, were considered under Objective 1.

Urban/Suburban (UR) Rural (RR) Urban Park (UP)

Figure 3-4 Examples of Polygon Units Evaluated under Objective 2

The lines of evidence for assessing Objective 2 are:

- Line of Evidence #5: Anecdotal information on improved plant growth (productivity) over the past 8 to 10 years; and,
- Line of Evidence #6: Anecdotal information on the presence and condition of native and introduced species grown in the area, including sensitive species, and anecdotal information on whether or not there are difficulties (that can be related to smelter emissions) growing particular plants.

3.4.1 Identification of Urban Areas Considered in the Problem Formulation

There are 81 polygons with at least 10% urban (UR), urban park (UP) or rural (RR) in the polygon. The total area represented by UR, UP or RR in the AOI is approximately 1,900 ha. The 27 polygons listed in Table 3-18 contain soil metal concentrations with a greater than 10% probability of exceeding CSR standards for plants and soil invertebrates. The total UR, UP and RR area represented by these polygons is approximately 610 ha.

Table 3-18 Polygons Containing UR (Urban), UP (Urban Park) and RR (Rural) Site Series and Exceeding the CSR Standard for Plants

Polygon	*Hectares*	*Polygon Label*	*Community*
501	5.584	7DHk3o:P-2DOk3o:P-1RR	Rivervale
521	11.417	6ROj-3DO4o:P-1RR	Rivervale
548	9.971	10UP	East Trail (Gyro Park)
601	70.769	10UR	East Trail
614	18.168	8SRw5mM:FmP-2UR	Waneta Junction (north of Waneta mall)
626	29.026	10UR	Shavers Bench
631	10.174	7UR-3WFw4oM:P	Glenmerry
636	64.471	8UR-1SR5mM-1HD5mM	Warfield
645	65.989	9UR-1DHk5mM	West Trail
649	27.966	10UR	West Trail
682	36.134	9IN-1UR	Waneta Junction
698	6.507	7DF5iM:FmP-2DF2b:P-1RR	West Trail
718	44.819	9UR-1WBw4o	Waneta
908	19.795	4RR-4GP-2PA	Columbia Gardens
919	58.554	6RR-3PA-1CF	Columbia Gardens
954	22.5	4DH4iM:Fo-4BF5mM-2RR	Columbia Gardens
1324	31.372	7LR3o:P-2LR6iC:P-1UP:P	Columbia Gardens
1457	10.855	5UR-4WFw4oM-1SRxw3o	East Trail
1459	5.051	10UR	East Trail
1467	2.173	10UP	Glenmerry
1469	93.03	10UR	Glenmerry
1545	40.802	10UR	Sunningdale
1547	24.021	10UR	Tadanac
1616	26.841	7RR-3BFu5mM	Oasis
1617	37.556	6UR-2DO4oM:P-2WL:P	Oasis
1897	9.07	10UR	Waneta Junction (north of Waneta mall)
1905	34.313	10UR	Rivervale

These polygons are considered further in the Problem Formulation for Objective 2.

3.4.2 Information Sources for the Problem Formulation

The information used to evaluate the assessment endpoints was taken from:

- Golder (2007a) Terrestrial Resources report; and,
- Communities in Bloom 2006 report (CiB, 2006).

These sources should be consulted for information on sampling methods, the surveys given to horticulturalists, chemical and statistical analysis, results, conclusions and quality assurance/quality control.

3.4.3 Summary of Information

Observations from representatives of the Trail Parks Department, the Horticultural Society and Communities in Bloom included:

- Organic matter and fertilizer have been added to city gardens;
- No reports of health problems with flower or vegetable gardens in the area;
- No changes in productivity of the gardens;
- Improvements in the growing conditions in the City of Trail flower beds (Trail was the 2006 Communities in Bloom National Award winner for cities with a population between 5,001 and 10,000 people; Trail received the highest score of 5 blooms for landscaped areas; CiB, 2006) (Figure 3-5);
- An increase in growth of species such as juniper trees and black locust in the downtown area; and,
- A belief that smelter emissions were not responsible for any persisting plant health concerns; near the smelter, there are areas with very sandy soil and low soil moisture and nutrients.

Figure 3-5 Examples of Gardens in the Urban Areas of Trail

There are no quantitative estimates for "magnitude of response" for this objective. The assessment of plants in an urban setting is complicated by the fact that people can alter the system as often and in any way they like. Therefore, the assessment of this objective relied on anecdotal information from stakeholders in the City of Trail. This information suggests:

- No significant impacts to urban plants: no concerns were raised with flower or vegetable gardens; landscaped areas of Trail received the highest award (5 blooms) from the Communities in Bloom program; no changes in productivity were noted: and there is a general belief that smelter emissions were not responsible for any persisting plant health concerns; and,
- There are significant uncertainties: data are qualitative, and from only a few people. There could be impacts at individual properties which may not be identified *via* the interview process. In addition, people were not interviewed from areas distant from Trail (*e.g.*, Waneta). However, the people interviewed have broad experience over many years living and working in the Trail area, the Communities in Bloom judges were from outside Trail and BC and therefore are impartial, and responses were consistent among the people interviewed. The qualitative anecdotal information suggests native and introduced plants in urban areas (including gardens, landscaped areas) are growing well.

3.4.4 Conclusions of the Problem Formulation

At this time, consideration of risk management is not indicated by the results of the problem formulation. However, if property-specific issues arise in future, site-specific data on PCOC concentrations in soil may be required to assess individual properties to ensure that the risk management objective is met.

3.5 Problem Formulation for Objective 3 (Agricultural Crops)

Objective 3 focused on polygons containing CF (cultivated field) and PA (pasture) units (Figure 3-6). The lines of evidence for evaluating Objective 3 are:

- Line of Evidence #7: Anecdotal information on forage crop and grape yield.
- Line of Evidence #8: Anecdotal information on forage crop and grape condition and whether there are difficulties (that can be related to smelter emissions) growing particular crops.

Cultivated Field (CF)

Pasture (PA)

Figure 3-6 Examples of Polygon Units Evaluated under Objective 3

3.5.1 Identification of Agricultural Areas Evaluated in the Problem Formulation

There are 34 polygons with at least 10% cultivated field (CF) or pasture (PA) in the polygon (Table 3-19). The total area represented by CF or PA in the AOI is approximately 460 ha. There is at least a 10% probability that six polygons contain COPC concentrations greater than CSR standards for plants and soil invertebrates. The total CF and PA area represented by these polygons is approximately 93 ha.

Table 3-19 lists the polygons retained for further consideration under Objective 3. Six polygons have a greater than 10% probability of containing PCOC concentrations in soil which exceed CSR standards for plants and soil invertebrates. Twenty-eight polygons were eliminated from further consideration under this objective for the following reasons:

- Fourteen polygons in Table 3-20 were eliminated because they contain advancing structural stages in the non-CF or non-PA portion of the polygon, and soil metal concentrations do not exceed CSR standards for plants or soil invertebrates (polygons 132, 1134, 1176, 41, 443, 733, 784, 788, 827, 1277, 1340, 1422, 1728, 1902);
- Two polygons were eliminated because the non-CF or non-PA portions of the polygon were logged, and soil metal concentrations do not exceed CSR standards for plants or soil invertebrates (polygons 1784, 1257);
- Three polygons were eliminated because the non-CF or non-PA portions of the polygon were in early structural stages, but soil metal concentrations do not exceed CSR standards for plants or soil invertebrates and the polygon was not previously impacted by SO_2 (polygons 153, 922, 1578);
- Eight polygons were eliminated because they contain 100% CF or PA, alone or in combination with non-site series units, and soil metal concentrations do not exceed CSR standards for plants or soil invertebrates (polygons 1167, 1261, 50, 474, 734, 1115, 1421, 1967); and,
- Polygon 722 is 20% PA and 30% road. The remaining 50% is DF in structural stage 5o, which has experienced severe fire and previous air pollution injury. Because soil metal concentrations do not exceed CSR standards for plants and soil invertebrates, polygon 722 is assessed only under Objective 1.

Table 3-19 Polygons Containing CF (Cultivated Field) and PA (Pasture) Units

Polygon Number	*Hectares*	*Polygon Label*	*>CSR**
Cultivated Field Polygons:			
132	12.059	9BF5mM-1CF	
153	10.266	9CF-1DF5iM	
919	58.554	6RR-3PA-1CF	>CSR
1134	14.144	7GR6iC:Ls-3CF	
1167	16.728	8CF-2RR	
1176	34.645	8CF-1GP-1GR5sB	
1261	16.163	10CF	
1326	28.345	10CF	>CSR
1784	65.386	9CF-1BF4iM:Ls	
Pasture Polygons:			
41	11.797	8PA-2DF5mC	
50	13.145	10PA	
443	25.296	5PA-3HD6iM:Ls-2DF6iM:Ls	

Table 3-19 Polygons Containing CF (Cultivated Field) and PA (Pasture) Units

Polygon Number	*Hectares*	*Polygon Label*	*>CSR**
474	7.158	10PA	
722	5.413	5DFw5oM:FsP-3RP-2PA:P	
733	9.244	8PA-1RR-1AS5mB	
734	8.004	10PA:P	
784	16.712	6PA-3HD6mM-1SR5mC	
788	20.812	6PA-2DF6iC:Ls-2RR	
827	10.017	8LR5mM:P-2PA:P	
908	19.795	4RR-4GP-2PA	>CSR
919	58.554	6RR-3PA-1CF	>CSR
922	3.823	9PA-1HD5iC	
968	34.233	5PA-5BF3a	>CSR
1008	4.464	10PA	>CSR
1115	2.849	10PA	
1257	32.117	7DF5mC-2DF3:Lc-1PA	
1277	20.324	5DF5mM-4PA-1SR5mM	
1339	31.089	5PA-3BF2a-2BF6iC	>CSR
1340	6.727	8PA:P-1BF5mM:P-1RR:P	
1421	25.414	10PA:P	
1422	126.933	6DFy5mM:Ls-3PA-1RP	
1578	24.152	6DF5mC-3HD5iM-1PA	
1728	9.147	7PA-2RP-1BF5mB	
1902	47.986	7PA-2RR-1DF5mC	
1967	54.812	6RR-4PA	

* > Indicates metal concentrations in soil exceed CSR standards for plants and soil invertebrates; a blank cell indicates metal concentrations in soil are less than these CSR standards

Only the six polygons with >10% probability of PCOC concentrations in soil exceeding CSR standards were retained for further consideration under Objective 3 (Table 3-20). All of these polygons are in the Columbia Gardens area.

Table 3-20 Polygons Containing CF (Cultivated Field) and PA (Pasture) Units with >10% Probability of PCOC Concentrations Exceeding CSR Standards for Plants and Soil Invertebrates

Polygon Number	*Hectares*	*Polygon Label*	*Location*
Cultivated Field Polygons:			
1326	28.345	10CF	Columbia Gardens
919	58.554	6RR-3PA-1CF	Columbia Gardens
Pasture Polygons:			
908	19.795	4RR-4GP-2PA	Columbia Gardens
919	58.554	6RR-3PA-1CF	Columbia Gardens
968	34.233	5PA-5BF3a	Columbia Gardens
1008	4.464	10PA	Columbia Gardens
1339	31.089	5PA-3BF2a-2BF6iC	Columbia Gardens

3.5.2 Information Sources for the Problem Formulation

The information used to evaluate the assessment endpoints was taken from:

- Golder (2007a) Terrestrial Resources report.

This source should be consulted for information on soil sampling methods, the surveys given to farmers, chemical and statistical analysis, results, conclusions and quality assurance/quality control.

3.5.3 Summary of Information

Information was obtained from both the vineyard and a farmer in the Columbia Gardens area. These individuals made up the entire agricultural component of this sparsely populated area, at the time the data were collected.

Observations from the local vineyard in Columbia Gardens (Figure 3-7), which has been in operation since 2001, included:

- There have been no health issues with the grapevines at the vineyard that could be attributed to smelter emissions;
- The soil is nutrient-rich and therefore fertilizers are not used; and,
- The vineyard is drip-irrigated using water from a nearby groundwater spring.

Observations from the local dairy farmer in Columbia Gardens, who maintains 50 acres of hay and corn fields, include:

- Soil acidity had been problematic in the past, but has been addressed with lime treatments;
- Crops are amended with fertilizer and manure annually, and with lime every eight years;
- Crops are irrigated with groundwater; and,
- His crops grow very well.

Figure 3-7 Columbia Gardens Vineyard

There are no quantitative estimates for "magnitude of response" for this objective. The assessment of plants in agricultural areas is complicated by the fact that people can alter the system as often and in any way they like. Therefore, the assessment of this objective relied on anecdotal information from stakeholders in the area around the City of Trail, and in particular in the Columbia Gardens area.

Of the six polygons identified in Table 3-18, one contains cultivated field (CF), four contain pasture (PA) and one contains both CF and PA. No interviews were conducted regarding issues for pastures. Concerns related to the use of pastures for livestock grazing are addressed under the livestock objective (Section 6).

The information available for agricultural areas suggests:

- No significant impacts to agricultural plants: no concerns were raised by farmers growing fruit or forage crops in Columbia Gardens, the area with the potential for PCOCs in soil to exceed CSR standards for plants and soil invertebrates; and,
- There are significant uncertainties: data are qualitative and from only two people from unique farms, the vineyard has only been operating since 2001, and there could be impacts at individual properties which may not be identified *via* the interview process. However, responses were consistent between the people interviewed and people were interviewed in the area suspected to be most at risk due to PCOC concentrations in soil.

3.5.4 Conclusions of the Problem Formulation

At this time, consideration of risk management is not indicated by the results of the Problem Formulation. However, if property-specific issues arise in future, site-specific data on PCOC concentrations in soil may be required to assess individual properties to ensure that the risk management objective is met.

3.6 Summary of Conclusions Regarding Plant Communities in the Area of Interest

The risk management objective for plant communities in wildland areas is not being met in the polygons identified in Table A9 and Figure 3-3. There is low to moderate uncertainty associated with the identification of polygons requiring consideration of risk management. One of the most significant sources of uncertainty is the continuing development of the plant communities within the AOI since the time period used to develop the biophysical habitat map (aerial photograph taken in 1999) and the field data were collected for statistical analysis of plant community characteristics (2001). Therefore, consideration of risk management options within the polygons identified in Table A9 and Figure 3-3 should be based on an updated assessment of the status of plant community structure.

Based on the available evidence, consideration of risk management for urban plants and agricultural plants is not indicated at this time. However, there are significant uncertainties. There are no quantitative or published data documenting urban or agricultural plant growth, presence or condition. However, qualitative anecdotal information suggests native and introduced plants in urban areas (including gardens, landscaped areas) and fruit and forage crops in agricultural areas (in particular, Columbia Gardens) are growing well.

Consideration of risk management is not recommended for current urban or agricultural areas. In future, it is possible that lands currently identified as wildland could become either urban or agricultural. Urban and agricultural plants could be adversely affected in areas where PCOC concentrations in soil exceed CSR standards for plants and soil invertebrates. However, the current assessment illustrates that this is not always the case. Therefore, if property-specific issues arise in future, site-specific data on PCOC concentrations in soil and other tests may be required to assess individual properties to ensure that the risk management objective is met.

4.0 ASSESSMENT OF RISKS TO EVALUATE OBJECTIVES 4, 5 AND 6 RELATED TO WILDLIFE

The assessment of risks to wildlife includes an introduction (Section 4.1), the SALE screening (Section 4.2), the SALE evaluation for American robin (Section 4.3), the SALE evaluations for the avian and mammalian wildlife communities (Sections 4.4 and 4.5), and a summary of conclusions and recommendations regarding wildlife (Section 4.6).

4.1 Introduction

The three objectives relating to wildlife populations in the AOI, and their respective assessment endpoints, are:

4) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on populations of wildlife in natural "wildland" areas, including resident and migratory birds, small and large mammals, valued charismatic species (*e.g*., raptors, bears), predators (*e.g*., coyotes), hunted and harvested species (*e.g.,* deer), and lower trophic level food sources (*i.e*., insects and soil-dwelling organisms);

5) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on wildlife populations in "urban" areas, including resident and migratory birds, small and large mammals, and lower trophic level food sources (*i.e*., insects and soil-dwelling organisms); and,

6) Minimize, now and in the future, smelter operation-related direct and indirect effects within the Area of Interest on wildlife populations in "agricultural" areas, including resident and migratory birds, small and large mammals, and lower trophic level food sources (*i.e*., insects and soil-dwelling organisms).

The assessment endpoints used to evaluate these objectives were:

- Wildlife population persistence;
- Wildlife habitat utilization; and,
- Wildlife habitat suitability.

In this ERA, the definition of habitat includes both the physical location (*i.e*., the types of plants required for cover, the presence of nesting or den sites, *etc*.) as well as the availability of adequate food resources. Therefore, the assessment endpoints related to habitat include both of these components. In addition, indirect effects include those on the predators and prey/food of a species. Therefore, this again is covered within the habitat assessment endpoints.

Several measures were used to evaluate the assessment endpoints. These were combined into various "lines of evidence" (LOE) for the Sequential Analysis of Lines of Evidence (SALE). For Objectives 4, 5 and 6, the LOE include:

- Line of Evidence #1: wildlife habitat suitability mapping, based on the biophysical habitat map and accompanying interpretation. This was done for receptors for which risks could not be ruled out in the final stage of wildlife risk modelling (American robin), plus another four species (black-capped chickadee, mallard, white-tailed deer and river otter);
- Line of Evidence #2: field survey data for American robins;

- Line of Evidence #3: field survey data for avian and mammalian populations and communities in the AOI; and,
- Line of Evidence #4: soil invertebrate diversity and abundance measures.

The data used to evaluate these LOE were taken from several sources, as summarized in:

- Golder (2007a) Terrestrial Resources Report;
- Enns and Enns (2007b) Mapping Methods and Expanded Legends Report (Appendix B);
- Enns and Enns (2007a) Memorandum on American Robin and Chickadee in the AOI (Appendix C); and,
- Enns (2007a) Memorandum on Mammals in the AOI (Appendix D).

4.2 SALE Screening

Of the list of wildlife receptors (Table 2-9) evaluated in the ERA (at LOR1, LOR2 and LOR3 of wildlife risk modelling), only American robin remained at the end of LOR3 to be considered using SALE (Intrinsik, 2007). Direct toxicity to other representative wildlife species was ruled out. However, potential indirect effects are considered in Section 4.3 for American robin and in Sections 4.4 and 4.5 for other wildlife populations and communities.

American robin was selected as a representative of invertebrate-eating birds for urban and agricultural areas (Cantox Environmental *et al*., 2001). However, potential exposures to American robin in wildland areas were assessed, since there could be future changes from wildland to urban or agricultural land uses.

Since the high consumption rate of earthworms contributed significantly to the predicted unacceptable risks to robins, other birds that consume large amounts of earthworms also may be at risk in all land use areas. However, earthworms are not common in wildland areas, where soils are not cultivated. Therefore, the robin is considered to be an adequate representative for all birds that consume a high proportion of earthworms in their diet regardless of land use because it is highly unlikely that any other bird species living in wildland areas would have a higher consumption of earthworms.

The black-capped chickadee was selected as the representative invertebrate-eating bird for wildlands. It does not consume significant amounts of earthworms but rather consumes other invertebrates. No unacceptable risks were predicted for the chickadee.

Risk characterization in LOR3 for the American robin did not rule out risks, either across the AOI or in areas of ideal habitat, from exposure to Pb and Cd (Table 4-1). However, predicted ERs exceed the benchmark of ER=1 at the 90th percentile by only a factor of 2 to 4. Therefore, the LOR3 analysis considered alternative TRVs (Intrinsik, 2007) such as those based on lead oxide (the form of lead most likely in the AOI due to smelter emissions) or for other avian species. When these alternative TRVs are used, the 90th percentile ER becomes <1 for both Cd and Pb (see Figures 4-1 and 4-2). A detailed uncertainty analysis was completed, and the likelihood of underestimating risks to robins was considered low (Intrinsik, 2007). Therefore, impacts on robin populations in the AOI are not expected to be significant. However, field data on robin and other songbird populations were reviewed to determine whether they support this conclusion.

Table 4-1 Summary of ER Values for the American Robin[a]

Chemical	*Average*	*Percentile*				
		10th	*25th*	*50th*	*75th*	*90th*
Across the AOI:						
Cadmium	1	0.3	0.7	1	**2**	**2**
Lead	1	0.07	0.2	0.9	**2**	**3**
In Areas of Good to Excellent Habitat:						
Cadmium	1	0.3	0.7	1	**2**	**3**
Lead	**2**	0.1	0.4	1	**2**	**4**

[a] For details regarding methods used to estimate ERs, and an expanded discussion of results, uncertainties, *etc*., please refer to Intrinsik, 2007.

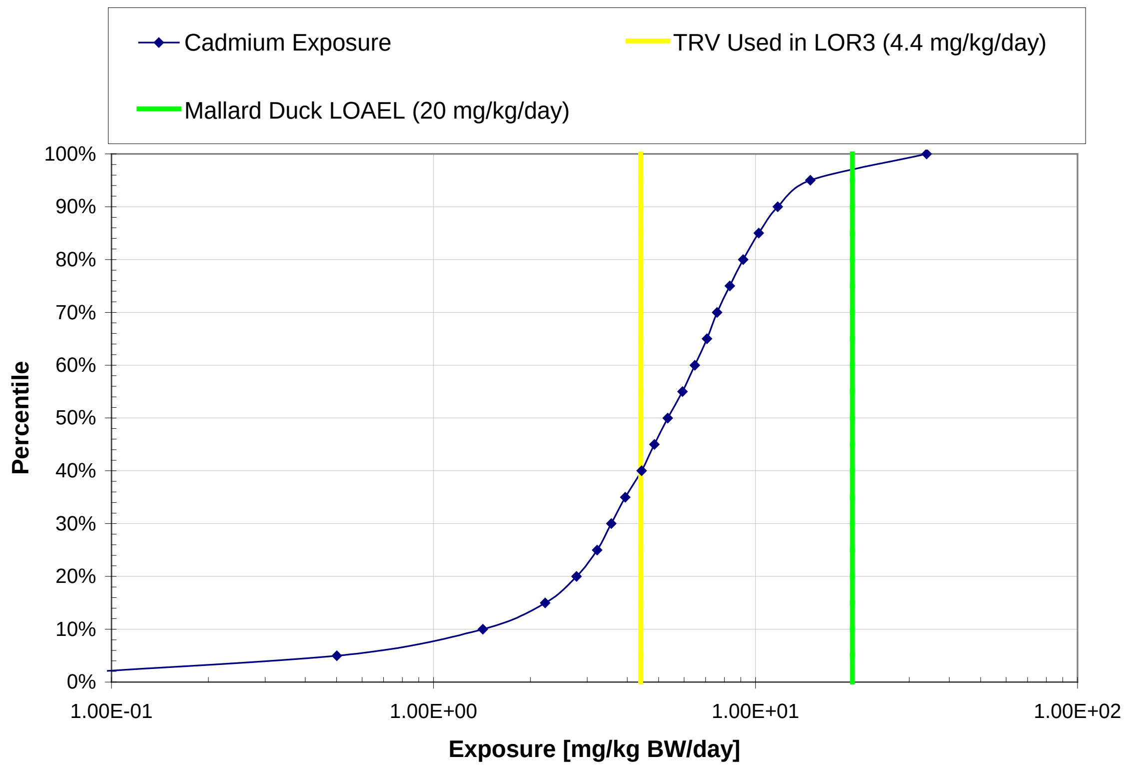


Figure 4-1 Probability that an American Robin Will Receive a Particular Cadmium Exposure in the Area of Interest

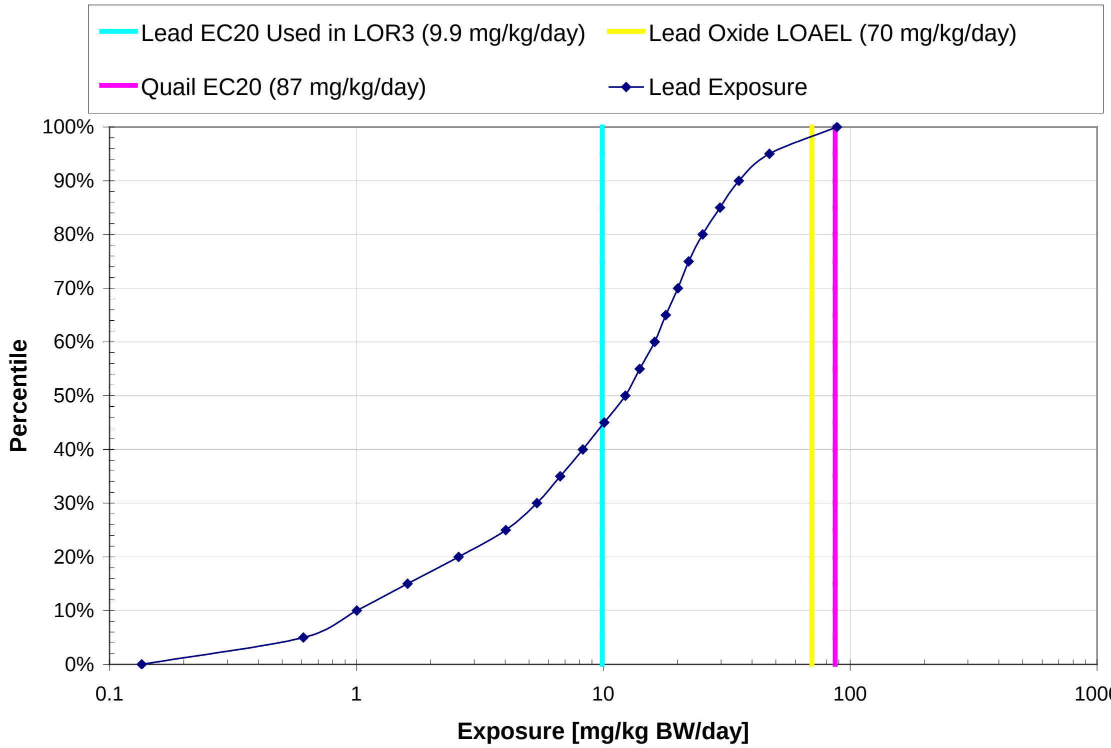


Figure 4-2 Probability that an American Robin Will Receive a Particular Lead Exposure in the Area of Interest

The remainder of the SALE process was conducted separately for the following receptors:

- American robin populations (Section 4.3);
- Avian communities (Section 4.4); and,
- Mammalian communities (Section 4.5).

4.3 SALE Evaluation for American Robin

The SALE process for American robin includes Step 2 - the evaluation of indirect effects *via* changes in predator abundance or in availability of prey, or because of physical changes in habitat suitability (Conceptual Model 2) (Section 4.3.1); Step 3 – the evaluation of field survey evidence for direct effects (Conceptual Model 1) or indirect effects (Conceptual Model 2) (Section 4.3.2); and Step 4 – evaluation of the magnitude of response, which is incorporated into the evaluation of indirect effects and field survey data, and summarized in Section 4.3.3. Uncertainty is also evaluated as part of Step 4; and, uncertainty plus magnitude determine whether or not to proceed to Step 5 (causation analysis). Risk characterization is presented in Section 4.3.4.

The definitions for magnitude of response and uncertainty, for the three lines of evidence, are in Tables 4-2 and 4-3, respectively.

Table 4-2 Ranking Scheme Used to Evaluate the Magnitude of Response for Lines of Evidence Related to American Robin Populations and the Overall Avian Community Within the AOI

Lines of Evidence	***Evaluation Used***	***Adverse Effects Unlikely***	***Adverse Effects May Occur***	***Adverse Effects Likely***
		o	◉	●
Physical Effects on Habitat for American Robin and for Overall Avian Community	Vegetation community assessment compared to habitat requirements for the species observed in surveys.	Suitable habitat present in the AOI and the habitat availability has not been restricted due to changes in the vegetation community caused by smelter emissions; *or* primary factors limiting habitat availability are not related to smelter emission.	Suitable habitat present in the AOI, but the habitat availability has been reduced in some areas due to changes in the vegetation community caused by smelter emissions.	Availability of suitable habitat reduced in large portions of the AOI because of changes in the vegetation community caused by smelter emissions.
Field Survey Data for American Robins	Qualitative analysis of American robin abundance and nesting in areas of suitable habitat in the AOI, relative to soil metals and distance from smelter.	Robins are abundant; no negative trend between abundance or nesting and soil metal concentrations and no positive trend with distance from smelter.	Robins are observed infrequently; a negative trend between abundance or nesting and soil metal concentrations or a positive trend with distance from smelter.	Robins are not abundant; a strong negative trend between abundance or nesting and soil metal concentrations and a strong positive trend with distance from smelter.
Field Survey Data for Avian Community	Analysis of abundance, density, and community composition relative to other areas of BC.	Abundance, density and community composition in the AOI are similar to other areas of BC with comparable habitat (Slocan, Salmo and Syringa).	Abundance or density of some species is lower in the AOI than in other areas of BC with suitable habitat.	Abundance and density of several species is lower in the AOI than in other areas of BC with suitable habitat.
Soil Invertebrate Abundance and Diversity	Qualitative evidence of earthworm presence/abundance where they would be expected to be found corresponding to areas of suitable robin habitat.	Earthworms found consistently and commonly.	Earthworms found occasionally or inconsistently.	Earthworms not present or found rarely.
	Analysis of invertebrate abundance and diversity (mean number of individuals and mean number of orders) in Reference areas relative to Low, Moderate and High metal areas (as identified by lead concentrations in soil) (Golder, 2007a).	No difference or fewer in Reference areas as compared to Low, Moderate and High metal areas.	Significant difference, with fewer individuals or Orders at Moderate and High metal areas relative to Reference areas.	Significant difference, with fewer individuals and Orders at Low, Moderate and High metal areas relative to Reference areas.
	Analysis of invertebrate abundance (number of individuals and Orders/Classes) in five impact zones (one High, two Moderate and two Low) (Brusven, 2000).	No difference, fewer in Low impact areas as compared to High impact areas.	Significant difference, with fewer individuals of a few Orders/Classes in Moderate or High metal areas relative to Low impact areas.	Significant difference, with fewer individuals and several fewer Orders/Classes at Moderate and High metal areas relative to Low areas.

Table 4-3 Ranking Scheme Used to Evaluate Uncertainty in the Magnitude of Response for Lines of Evidence Related to American Robin Populations and the Overall Avian Community

Source of Uncertainty	***Uncertainty Score***		
	Low ?	***Moderate ??***	***High ???***
Natural Variability: Invertebrate data	• Invertebrate surveys conducted in several habitats and across a representative range of PCOC concentrations, and across a significant portion of the AOI; • Sample sizes at each site adequate to distinguish differences across the PCOC concentration gradient; and, • Several important natural variables that affect invertebrate abundance and diversity were measured or observed.	• Invertebrate surveys conducted in more than one habitat and across a representative range of PCOC concentrations, in representative areas of the AOI; • Sample sizes at each site adequate to distinguish differences at Moderate and High PCOC concentration zones, but not in the Low concentration zone; and, • Several important natural variables that affect invertebrate abundance and diversity were measured or observed.	• Invertebrate surveys conducted in only 1 habitat with a limited range of PCOC concentrations covering a small portion of the AOI; • Sample sizes at each site inadequate to distinguish differences at High PCOC zone; and, • Few important natural variables that affect the response are observed or described.
Natural Variability: Field Surveys	• Density surveys have been conducted across the AOI in areas representative of all suitable robin habitats and for several years; • Sample size at each survey point adequate for a robust estimate of density; • All important natural variables that affect American robin density along each survey route or in each area where presence and nesting were observed are quantified or described qualitatively and in detail; and, • All measurements of the response (*e.g.*, density, as well as presence and nesting) show consistent direction, magnitude of response.	• Density surveys have been conducted in most areas representative of suitable robin habitats and for at least three years; • Most important natural variables that affect American robin density along each survey route or in each area where presence and nesting were observed are, as a minimum, described qualitatively and in detail; and, • Most measurements of the response show consistent direction, magnitude of response.	• Density surveys have been conducted in a very limited number of areas representative of suitable robin habitats and for only 1 or 2 years; • Few important natural variables that affect the response are observed or described either quantitatively or qualitatively; and, • Measurements of the response do not show consistent direction, magnitude of response.
Natural Variability and Measurement Error: Physical Effects on Habitat for American Robin and for Overall Avian Community	• Habitat suitability assessed directly, or using mapping methods which have been ground-truthed or results checked using alternate methods, such as aerial photographs; standard approaches used or modified using local knowledge; habitat requirements well documented; changes in wildlife use by season accounted for.	• Habitat suitability assessed using mapping methods which have only partially been ground-truthed or checked using alternate methods; standard approaches not always used (or modifications from the standard approach are not well documented or justified); habitat requirements generally known; changes in wildlife use by season may not have been accounted for.	• Habitat suitability assessed using mapping methods which have not been ground-truthed or checked using alternate methods; standard approaches not used; habitat requirements generally unknown; changes in wildlife use by season have not been accounted for.

4.3.1 Assessment of Evidence for Indirect Effects (Conceptual Model 2)

In this ERA, indirect effects are defined as effects mediated through interactions between consumer organisms and their food as well as effects on the physical habitat of a species.

Magnitude of Response of PCOCs on Predators of American Robin

No adverse indirect effects on robins due to changes in predator abundance are predicted, based on the fact that no unacceptable direct toxicity risks were predicted for avian or mammalian predators in the AOI (Cantox Environmental, 2003a; Intrinsik, 2007). Also, a major predator of American robins, particularly in urban areas, is the domestic cat, whose populations are influenced by factors other than PCOCs (most significantly, people) (Appendix B).

Magnitude of Response of PCOCs on American Robin Food Supply

American robins consume a varied diet, including earthworms, insects, and various types of fruit and other vegetation. The proportion of each dietary item changes during the year, with more invertebrates being consumed in the spring and summer, during reproduction (U.S. EPA, 1993; Campbell *et al*., 1997).

Three independent studies were conducted on soil invertebrates, each designed for a purpose other than the assessment of the American robin food supply. In the first study, earthworms were collected from 24 different sites within two land use types (residential/ urban lawns and gardens; lands classed as Agricultural Land Reserve or used for agriculture) (Golder, 2007a). Tissues were analyzed for total metal concentrations; these data were used to predict exposures to American robins and other wildlife species in the LOR3 report (Intrinsik, 2007). No evaluations were conducted on earthworm populations. However, qualitative observations during soil sampling indicated that earthworms are not abundant in wildland portions of the AOI, due to habitat limitations (low pH, low organic matter, low clay or fine silt content and lack of soil structure). Earthworms are found in parks, gardens and agricultural fields where soils have been amended. Therefore, factors other than soil concentrations of PCOCs are the primary determinants of earthworm presence and abundance (Chapman and Enns, 2005).

The areas where soils have been amended coincide with optimal habitat for robins (see below). Therefore, although there are no earthworm population data, the available qualitative evidence indicates that any effects of PCOCs (or past sulphur dioxide emissions creating low pH) on earthworm abundance are most likely to be present in areas where robins do not occur because of other habitat characteristics. For example, they are known to be most frequent in urban areas, and although they do occur in wildlands, their choice habitats tend to be cultivated and/or irrigated.

In the second study, seventeen (17) sites were sampled for ground-dwelling invertebrates (insects and spiders) to identify the types and abundance of invertebrates and determine the metal concentrations in tissues. The tissue data were used to predict exposures to wildlife in the LOR3 report (Intrinsik, 2007). A total of 4,659 invertebrates were counted from seventeen (17) orders within the classes Arachnida and Insecta. Phylum Gastropoda (slugs and snails) and three Classes from Phylum Arthropoda (Diplopoda, Chilopoda and Isopoda) were sampled but not included in the data analysis because individuals were not identified to the Order level (Golder, 2007a).

There was no difference in the mean number of invertebrate orders in the Reference, Low, Moderate and High zones (Golder, 2007a). The mean number of individual invertebrates was higher at the Low, Moderate and High zones than in the Reference zone (Golder, 2007a). The diversity indices and overall invertebrate abundance were plotted against the soil metal concentrations of arsenic, cadmium, copper, lead and zinc. There was no relationship between invertebrate abundance and arsenic, cadmium, copper, lead or zinc concentrations in soil. There were as many or more invertebrates (number of individuals and number of orders captured) in the moderate and high lead concentration areas that were sampled as there were in reference areas (Tables 3-47 and 3-48 in Golder, 2007a). There was a very weak inverse relationship between invertebrate diversity and lead concentration in soil (R^2=0.0566) and between invertebrate diversity and arsenic concentration in soil (R^2=0.0462). There was no relationship between invertebrate diversity and abundance compared with distance from the smelter (Golder, 2007a, Section 3.5.4).

In the third study, Brusven (2000) evaluated the feasibility of using ground-inhabiting invertebrates as bioindicators. Twelve sites were sampled, with at least two in each of five “impact” zones, representing one of two habitat types (birch fern sandy terraces or open forest on till). A total of 7,111 ground-inhabiting invertebrates were collected. The following associations were noted (Brusven, 2000): ants were the most abundant invertebrate, although their distribution was highly variable; carabid and staphylinid beetles were abundant, and showed a spatial trend (with more beetles present in the “low” impact zone); and, the rhaphidophorine grasshopper showed a spatial trend, but was less abundant than the beetles. However, for many other invertebrate classes and orders, there was no relationship between the number of individuals and contamination level.

The spatial trends recorded in the Brusven (2000) study were not observed in the Golder (2007a) data (*e.g*., the lowest number of Coleoptera (to which the carabid and staphylinid beetles belong) was found in the Reference areas). However, the Golder (2007a) study was not designed to challenge or corroborate the earlier studies. In summary, the data and analyses from studies of invertebrates in the AOI suggest that there may be, at most, a weak relationship between the abundance of some invertebrate species and metals in soil.

<u>Uncertainty Associated with Effects on Robin Food Supply</u>

Uncertainty related to the measurement error and understanding of natural variability in soil invertebrate abundance and community structure is moderate. There are several limitations to the invertebrate data. The 2004 (Golder, 2007a) evaluation of invertebrate composition and PCOC concentrations in invertebrates was restricted to low-elevation areas within a single vegetation cover-type. Identification of invertebrates was only to Order, and in some cases, only to the Class level, which limited the scope of comparisons among sample sites. There were two episodes of sampling within one sample year. The total number of sampling sites and the number of samples within each site were not sufficient to produce high statistical power; therefore, there is a moderate probability that differences across the PCOC gradient could be distinguished from natural variability (Golder, 2007a). Important confounding variables (natural habitat characteristics and anthropogenic stressors not related to the smelter) were observed and accounted for (*e.g*., sites with other anthropogenic disturbances such as roads were not sampled; the habitat was as homogeneous as to soils and vegetation as possible, and reflected a series of slightly more complex birch fern terrace species composition with increasing distance from the smelter). The study conducted by Brusven in 2000 covered a wider concentration gradient of PCOCs in soil and included two vegetation cover types; however, it was also a single-season survey only. The analysis of earthworm presence was qualitative.

Magnitude of Response of PCOCs on American Robin Physical Habitat

American robin habitat was evaluated using Line of Evidence #1: robin habitat suitability mapping, based on the biophysical habitat map and accompanying interpretation.

Moist, rich forests with highly diverse vegetation consisting of a rich shrub and tree layer are not abundant in the AOI, especially at lower elevations. This lack of habitat excludes some American robins from wildland habitats. The highly prevalent early to mid-seral stages of relatively dry savannah-style habitats are not well suited to American robin (Appendix B). In fact, American robin was selected as a representative bird for the urban and agricultural areas, and not wildland areas.

Robin habitat suitability was mapped (Figure 4-3). Most areas of “excellent” or “good” habitat for robin are urban and agricultural areas, including areas identified as RR (rural), PA (pasture) and CF (cultivated field). Robin abundance is strongly influenced by habitat; however, the habitat features that affect robin presence the most appear to be: well-tended gardens, watered lawns, freshly turned soil, presence of fruit trees (Appendix B). It is noted that robins prefer to have conifer cover nearby, and the presence of conifers in the AOI was impacted by previous SO_2 emissions from the smelter. However, the re-growth of conifers in the valley is dramatic, and is resulting in emergent mixed-wood stands in the valley (Appendix B).

There is some excellent or good robin habitat in wildland areas that are immediately adjacent to urban, industrial or rural areas (Figure 4-3). Some of this habitat coincides with polygons where the weight of evidence indicates the need to consider risk management to address risks to vegetation communities (Section 3.5).

Uncertainty of Effects on Robin Habitat

Uncertainty related to measurement error and understanding of natural variability in habitat suitability is low. The habitat requirements and preferences of American robin are well known, and the methods used to assess suitability were modified from BC standard methods to account for unique aspects of the AOI. The mapping of suitability was not extensively ground-truthed at the higher elevations in the map area, but approximately 20% of the low elevation mapped polygons were ground-truthed (Appendix C). Nesting success and occurrences of American robin were field verified in urban and adjacent wildland areas of the AOI.

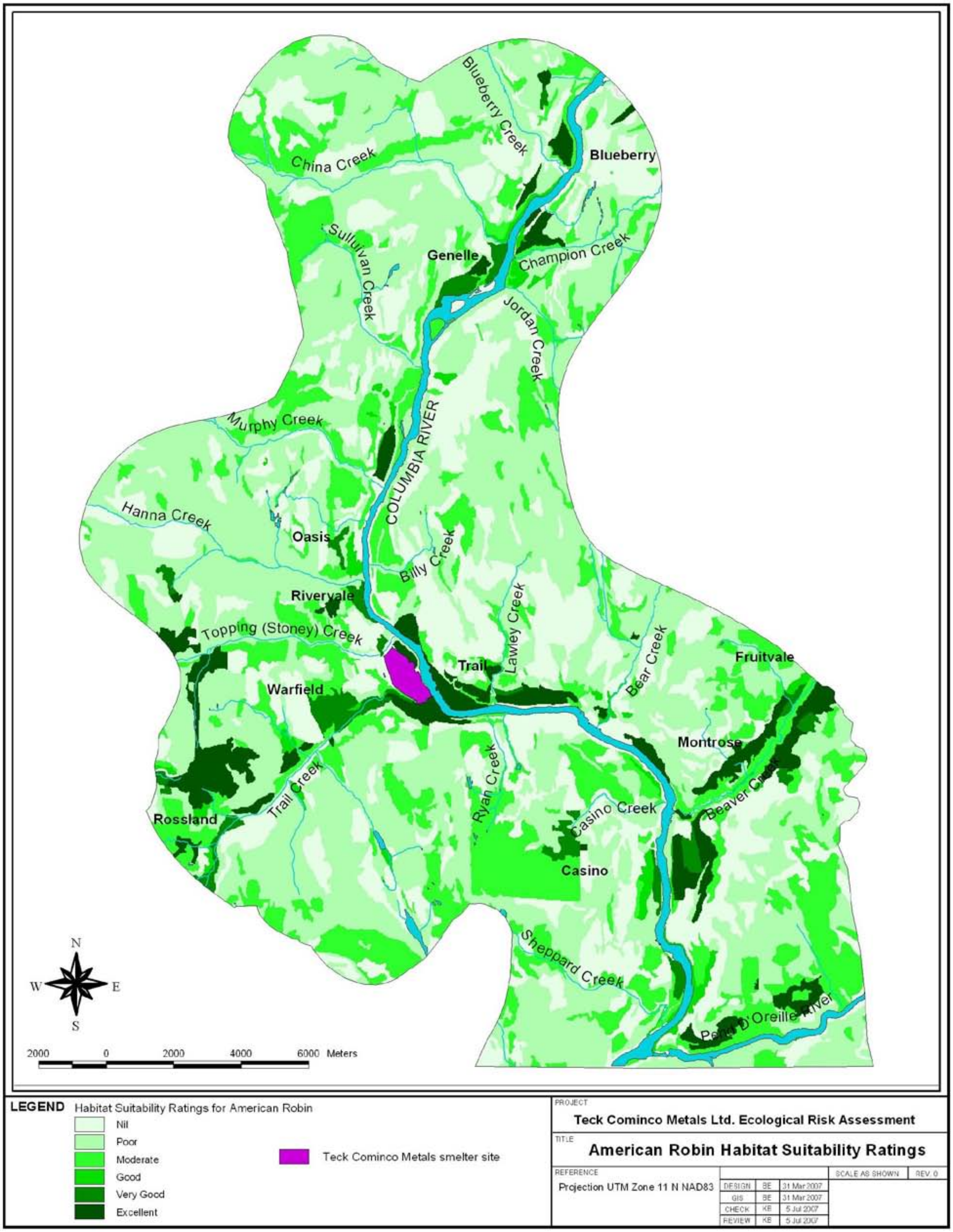


Figure 4-3 Habitat Suitability Ranking for the American Robin

4.3.2 Assessment of Evidence From Field Surveys

There are two sources of field survey data for American robins. First, bird community diversity and relative abundance data were collected from 2000 to 2004 (Golder, 2007a). Data from these surveys were used to compare bird communities within the AOI to those outside the AOI. Second, American robin presence and nesting were surveyed in 2004 (Appendix B). Numbers of adults and juveniles were recorded, as well as activity (*e.g*., feeding, perching), and presence of nests (and eggs or young within the nest).

Magnitude of Response Observed in the Field Surveys

The bird community survey data show that American robin is the 15th most common bird in the AOI. Abundance and density of robins in the AOI are similar to those in other comparable areas of BC (Golder, 2007a).

The evidence does not support the occurrence of adverse effects according to Conceptual Model 1 (direct effects). Neither the abundance of robins, nor the presence/absence or status of nests, were related to metal concentrations in soils or distance from the smelter (Appendix B).

The survey data do not support the occurrence of adverse effects according to Conceptual Model 2 (indirect effects). The presence of American robin, including active nests, was documented in areas of suitable habitat including areas with elevated soil metals (Appendix B). The number of robins was evaluated according to four parameters: i) presence of conifer habitat; ii) naturalness of the habitat iii); cultivation; and, iv) influence of previous SO_2 emissions (as evident in air-photo interpretation). Fewer robins were observed in wildland areas because wildland areas do not contain preferred habitat. American robin had a significant preference for urban, cultivated, moist and grassy habitats in the AOI (*i.e*., urban, cultivated field, pasture, and urban park biophysical habitat units) (Appendix B). Robins also are found in the aspen snowberry and western hemlock-red osier dogwood biophysical habitat units. These are wildland units, but have soil moisture characteristics that allow their use by robins. For example, aspen snowberry units include pole sapling stages that usually have a well defined gap between the crowns and the shrub layer, which is important for some bird species, such as robin (Appendix C). Western hemlock-red osier dogwood units are considered only moderately important as habitat for song birds, including robins (Appendix C). Robins also have been observed at golf courses, and in the birch fern, Douglas fir falsebox, Douglas fir beaked hazelnut and Grand fir rose units, because many of these units are in open early structural stages (with a high abundance of fruit-bearing shrubs), which are important for songbirds (Appendix C). More robins were found in areas of preferred habitat, which for robins includes i) areas with a few conifers or conifers nearby (within 100m); ii) disturbed areas iii) urban areas or large cultivated areas and iv) areas not affected by previous SO_2 emissions from the smelter. As summarized in Golder (2007a; see Section 5.4.2), considerable amounts of early- to mid-seral stage deciduous-dominated habitat are found near the smelter in areas that are recovering from previous vegetation loss. These stages contain some of the characteristics of preferred habitat for robin.

Uncertainty Associated with the Field Surveys

Uncertainty related to measurement error and the understanding of natural variability of American robin populations is low for the Breeding Bird Survey data and moderate for the nesting survey. The frequency of data collection and coverage of the AOI were different for the two sources of field survey data. The field survey of robins was conducted only once, in a limited number of locations within the AOI and at only one time of the year. The bird community surveys were conducted from 2000 to 2004 at a standard time of year and in several locations within the AOI (Figure 3-29 in Golder, 2007a). However, locations for the 2000 to 2004 bird community surveys were not selected based on suitability of American robin habitat, but rather as representative low elevation habitats for all songbirds in the AOI.

The number of endpoints was limited in both sources of field survey data. The survey of robins noted only presence and occurrence of nests. The bird community surveys produced presence/absence data, as well as abundance and density.

There is no evidence to support adverse effects by either Conceptual Model 1 (direct effects) or Conceptual Model 2 (indirect effects) based on the field data. Robins are abundant where habitat is suitable, and suitable habitat is found close to the smelter.

4.3.3 Summary of Magnitude and Uncertainty for the American Robin

The magnitude of indirect effects on American robin *via* food chain changes or effects on habitat is low (Table 4-4). The uncertainty associated with natural variability (and thus measurement error) varies according to the source of data (Table 4-3). The data do not support adverse effects according to either Conceptual Model 1 (which hypothesizes direct effects of PCOCs) or Conceptual Model 2 (which hypothesizes indirect effects *via* food web changes).

Table 4-4 Magnitude of Response and Associated Uncertainty for American Robin Population Lines of Evidence

Line of Evidence	*Magnitude*[a]	*Uncertainty Due To Measurement Error/Natural Variability*[b]
Physical Effect on Habitat	o	?
Indirect Effects *Via* Food Supply:		
Soil Invertebrate Abundance and Diversity (Golder, 2007a data)	o	??
Soil Invertebrate Abundance (Brusven, 2000 data)	o	??
Earthworm data	o	??
Field Surveys:		
Robin Presence and Nesting	o	??
Bird Community	o	?

[a] o Adverse effects unlikely
[b] ? Low uncertainty: ?? Moderate uncertainty

The rationale for selection of the magnitude and uncertainty scores is as follows:

- Physical effects on habitat:
  - Low Magnitude: the preferred habitat of robins in the AOI largely corresponds with urban and agricultural land uses where soil amendments and the planting of crops, trees, grasses, and ornamentals have produced conditions preferred by this species. Furthermore, past effects of SO_2 emissions on conifers (important for cover for robins) are declining in the AOI and conifer abundance is increasing;
  - Low uncertainty due to natural variability and measurement error: Habitat suitability was assessed using mapping methods which have been checked using aerial photographs; standard methods were used (modified using local knowledge); habitat requirements generally are known; and,
  - Low support for effects as predicted by the Conceptual Models: there is evidence of past indirect effects due to smelter-related alteration or elimination of

vegetation, but current evidence indicates no adverse indirect effects to robin habitat are occurring in the areas of the AOI where past injury to vegetation communities occurred.

- Soil invertebrate abundance and density:
  - Low magnitude: there was no difference in the numbers of invertebrates (individuals or orders) with PCOC concentration in soil. Earthworms were found where they were expected based on habitat;
  - Moderate uncertainty due to natural variability and measurement error because of the limited range of PCOC concentrations and habitats covered by the studies; and,
  - Low support for effects predicted by the Conceptual Models: the evidence was limited and not consistent with the hypotheses of either direct or indirect effects caused by toxicity of PCOCs to invertebrates and subsequent food-web related changes.

- Field survey for robins:
  - Low magnitude: robins are abundant where habitat is suitable;
  - Low to moderate uncertainty due to natural variability and measurement error: abundance data were available over multiple years from the Breeding Bird Survey, and from several areas/transects in the AOI. Nesting data were available from only one sampling period during one year; and,
  - Low support for effects as predicted by the Conceptual Models: neither direct (Conceptual Model 1) nor indirect effects (Conceptual Model 2) are supported by the field data.

- Field survey for the avian community:
  - Low magnitude: abundance and density of robins in the AOI are similar to those in other areas of BC;
  - Low uncertainty due to natural variability and measurement error: data were available over several years and from several transects in the AOI; and,
  - Low support for effects as predicted by the Conceptual Models: neither direct (Conceptual Model 1) nor indirect effects (Conceptual Model 2) are supported by the field data.

Uncertainty also surrounds our understanding of the potential influence of multiple stressors. These stressors may include other chemicals (metals, pesticides, hydrocarbons, *etc*.), as well as physical stressors (*e.g*., habitat alternation due to urban development or logging) and biological stressors (*e.g*., disease organisms, presence of non-native species, *etc*.). Although this uncertainty is acknowledged, it has not been incorporated into the SALE ranking either qualitatively or quantitatively, because this uncertainty would always be ranked as "high".

Decision Regarding the Need for Analysis of Causation

All responses were classified as "adverse effects unlikely". The uncertainty due to natural variability and measurement error was low or moderate, and the support for adverse effects according to the Conceptual Models was low (*i.e*., the hypotheses of direct and indirect effects were not supported by the evidence). Therefore, no causal analysis (SALE Step 5) was conducted for the American robin.

4.3.4 Risk Characterization for American Robin

American robins were evaluated under three risk management objectives, related to minimizing direct and indirect effects on populations of wildlife in wildland, urban and agricultural areas. The assessment endpoints for the American robin were “population persistence”, “habitat utilization” and “habitat suitability”.

The combined results presented above support the conclusions that:

1) American robin populations persist in the AOI;
2) Habitat is being utilized by American robin; and,
3) There is suitable habitat for American robin in the AOI.

These conclusions are supported by lines of evidence that show low-magnitude effects with associated low-to-moderate uncertainty related to natural variability and measurement error. The evidence does not support adverse effects according to Conceptual Models 1 (which hypothesizes direct toxicity) or 2 (which hypothesizes indirect effects mediated through food chain interactions or physical changes in habitat).

Any adverse effects on American robin populations due to smelter emissions are minimal and should continue to diminish with time. Populations of American robin persist in the AOI in areas of suitable habitat, which coincide more frequently with urban and agricultural land use than with wildlands. The habitat for American robin in the AOI is strongly influenced by factors unrelated to the smelter emissions (*e.g.*, watered lawns, freshly turned soil, presence of fruit trees, and absence of house cats). Previous impact of SO_2 on conifers is acknowledged; however, the regrowth of conifers in the valley has been dramatic in recent years with the reduction of SO_2 emitted from the smelter, such that many areas now have adequate numbers of sufficiently sized conifers to provide the cover habitat favoured by robins.

4.4 SALE Evaluation for Avian Wildlife Communities

The assessment of smelter-related risk to the overall avian community was limited to indirect risks *via* physical effects on habitat and/or effects mediated through interactions between birds and their food supply. Direct risks to representative species of carnivorous and piscivorous birds (red-tailed hawk, osprey, kingfisher), and omnivorous and herbivorous birds (American crow, American robin, black-capped chickadee, mallard) were assessed through Step 1 of the SALE process. At the end of LOR3, direct toxicity risks were ruled out for all non-Listed species except American robin (Intrinsik, 2007).

The SALE process for avian communities includes Step 2: the evaluation of indirect effects *via* changes in predator abundance or in prey species (Section 4.4.1); Step 3: the evaluation of evidence for indirect effects from field survey results (Section 4.4.2); and Step 4 magnitude of response with associated uncertainty (incorporated into the discussion of results of Steps 2 and 3) and summarized in Section 4.4.3. The risk characterization is presented in Section 4.4.4.

4.4.1 Assessment of Evidence for Indirect Effects via Food Chain Interactions

The evidence does not support adverse effects *via* changes in predator or prey populations predicted by Conceptual Model 2. No unacceptable direct toxicity risks were predicted for avian or mammalian predators or prey in the AOI (Cantox Environmental, 2003a; Intrinsik, 2007). Therefore, indirect effects on avian communities due to changes in predator or prey abundance were not carried forward in the SALE evaluation. The evidence for effects on soil invertebrates was weak (Section 4.3.1). Therefore, no adverse effects *via* reduction in invertebrate food supply are expected. The uncertainty related to this LOE was moderate (Section 4.3.1).

The remaining potential indirect effects would be any due to smelter-related changes in plant communities, both as a food resource, and related to habitat suitability for cover, nesting sites, *etc*. These are discussed in the following sections.

4.4.2 Assessment of Evidence for Indirect Effects from Field Surveys

Magnitude of Response on Avian Abundance, Density, and Community Composition

Evidence from Bird Surveys

Bird community diversity and relative abundance data were collected from 2000 to 2004 (see data summary in Golder, 2007a). Data from these surveys were used to compare bird communities within the AOI to those outside the AOI (data obtained from the Breeding Bird Survey [BBS]). This analysis is presented in Golder (2007a). Conclusions from this analysis (Golder, 2007a) are provided below.

Evidence from bird surveys indicates that the magnitude of smelter-related indirect effects on bird density and abundance is low. Density and abundance estimates from surveys conducted in 2001 to 2004 consistently were highest at sites closest to the smelter and lowest at sites further from the smelter. Densities were variable in relation to lead concentration in soil but were highest at concentrations in the 350 to 1,000 mg/kg range (Golder, 2007a).

Evidence from bird surveys indicates that the magnitude of smelter-related indirect effects on bird community composition is low. The community composition in the AOI was similar to the community composition within nearby survey areas (Salmo, Slocan and Syringa). The results of the avian community composition comparison using the Jaccard Index showed that similarity was not greater or lesser between the sites located in the AOI and outside of the AOI (Golder, 2007a).

Evidence Related to Habitat Suitability

The bird community composition in the AOI can be explained by the habitat present. Early- to mid-seral stage, deciduous-dominated habitat is common near the smelter. Bird communities that prefer early- to mid-seral deciduous-dominated shrub and forest habitats are likely increasing as vegetation increases in cover and abundance in areas previously affected by smelter emissions. Some species of birds occurred in these habitats in relatively high abundances, and at densities that were comparable to some of the best areas for those species elsewhere in British Columbia (*e.g.*, Nashville warbler, warbling vireo, red-eyed vireo, veery, American redstart, black-capped chickadee, black-headed grosbeak). This group of species includes birds that are mainly insectivorous (warblers, vireos and chickadees), eat a wide variety of berries, insects and other invertebrates (veery), or are largely seedeaters (black-headed grosbeak). Some sites (*e.g.*, along the low elevation Columbia River terraces and slopes near Warfield and Oasis) are densely vegetated with relatively lush understories and deciduous-dominated forest interspersed with open grassy areas. This cover type provides numerous habitat niches for many bird species. Even areas with relatively poor understories (few shrub, herb or grass species and low densities) have numerous bird species breeding if a fairly rich tree overstory exists.

Because deciduous and riparian dominated habitats tend to have richer (*i.e.,* higher species richness and abundance) bird communities than coniferous-dominated areas, it is not surprising that some sites nearer the smelter, which are near the Columbia River and have re-vegetated mainly with deciduous species, have more birds than some sites further away (which have generally retained their coniferous-dominated component). Over longer periods, as coniferous forest begins to replace deciduous vegetation, those species will decline and species that prefer more coniferous forest will increase.

Habitat suitability mapping for black-capped chickadee (Figure 4-4) showed that forested, urban, moist riparian and creek-side habitats rate higher for this species than non-tree or sparsely vegetated habitats (Appendix C). Areas of high habitat suitability exist close to the smelter in areas with high soil metal concentrations. This species remains in the AOI all year, and winter habitat use patterns are different than those in summer (Appendix C). Chickadees glean insects from black locust trees in winter; this tree occurs in previously severely-disturbed, low elevation areas. However, this use of habitat could not be accounted for in the habitat suitability mapping (Appendix C).

Habitat suitability mapping for mallard (Figure 4-5) showed that there are few areas in the AOI that provide habitat for mallard. These include large open wetlands and slow moving or still water, and riparian areas. The Columbia River is relatively swift-flowing and there are few still water areas or large wetlands in the AOI. Therefore, for the mallard, as well as the robin and chickadee, natural habitat features dominate as the main influence on habitat suitability (rather than smelter emission related impacts).

In summary, the available habitat suitability analyses indicate that the magnitude of smelter-related effects on bird habitat is low; *i.e*., adverse effects are unlikely, because the availability of suitable habitat has not been restricted due to changes in the vegetation community caused by smelter emissions; or the primary factors limiting habitat availability are not related to smelter emissions.

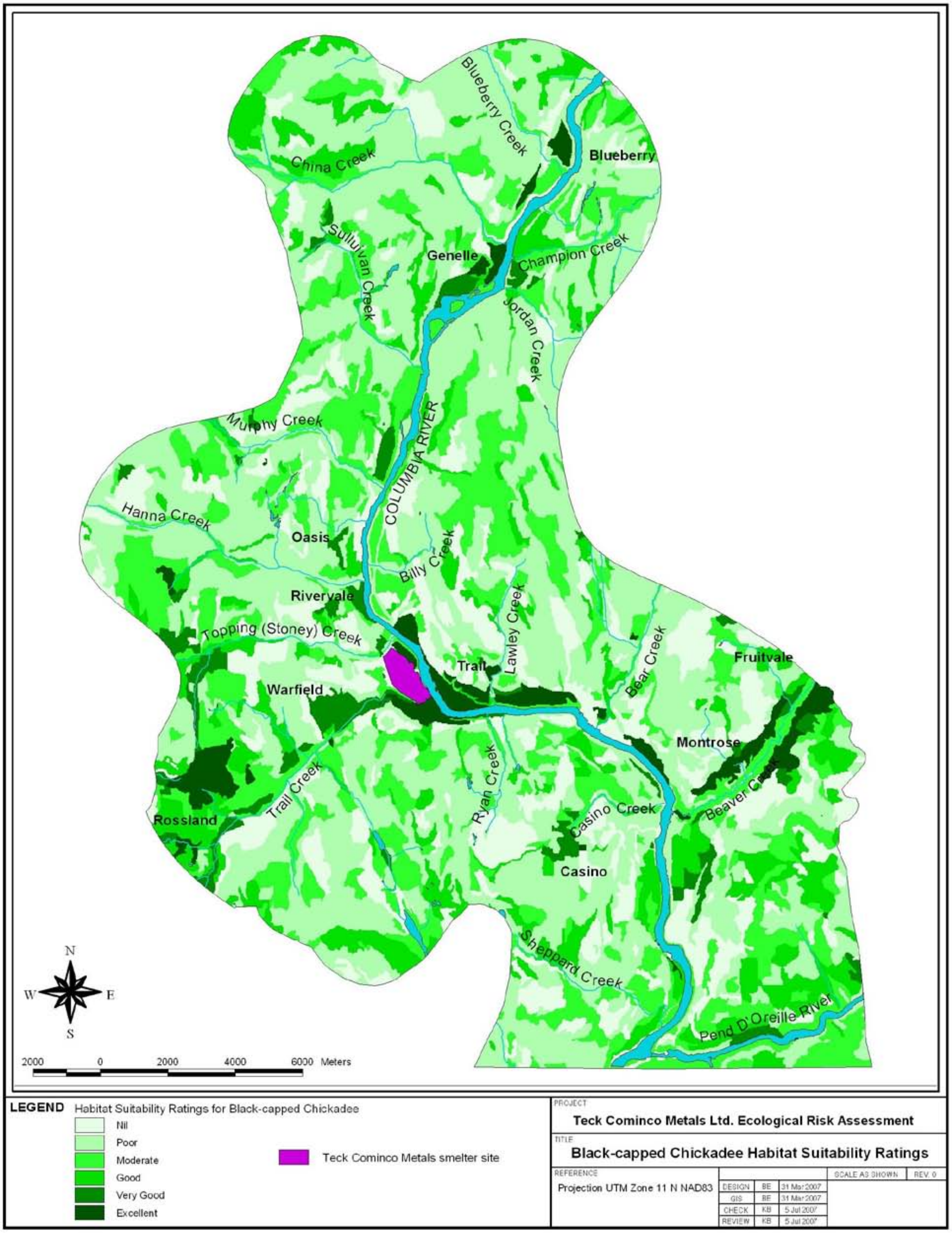


Figure 4-4 Habitat Suitability Ranking for Black-capped Chickadee

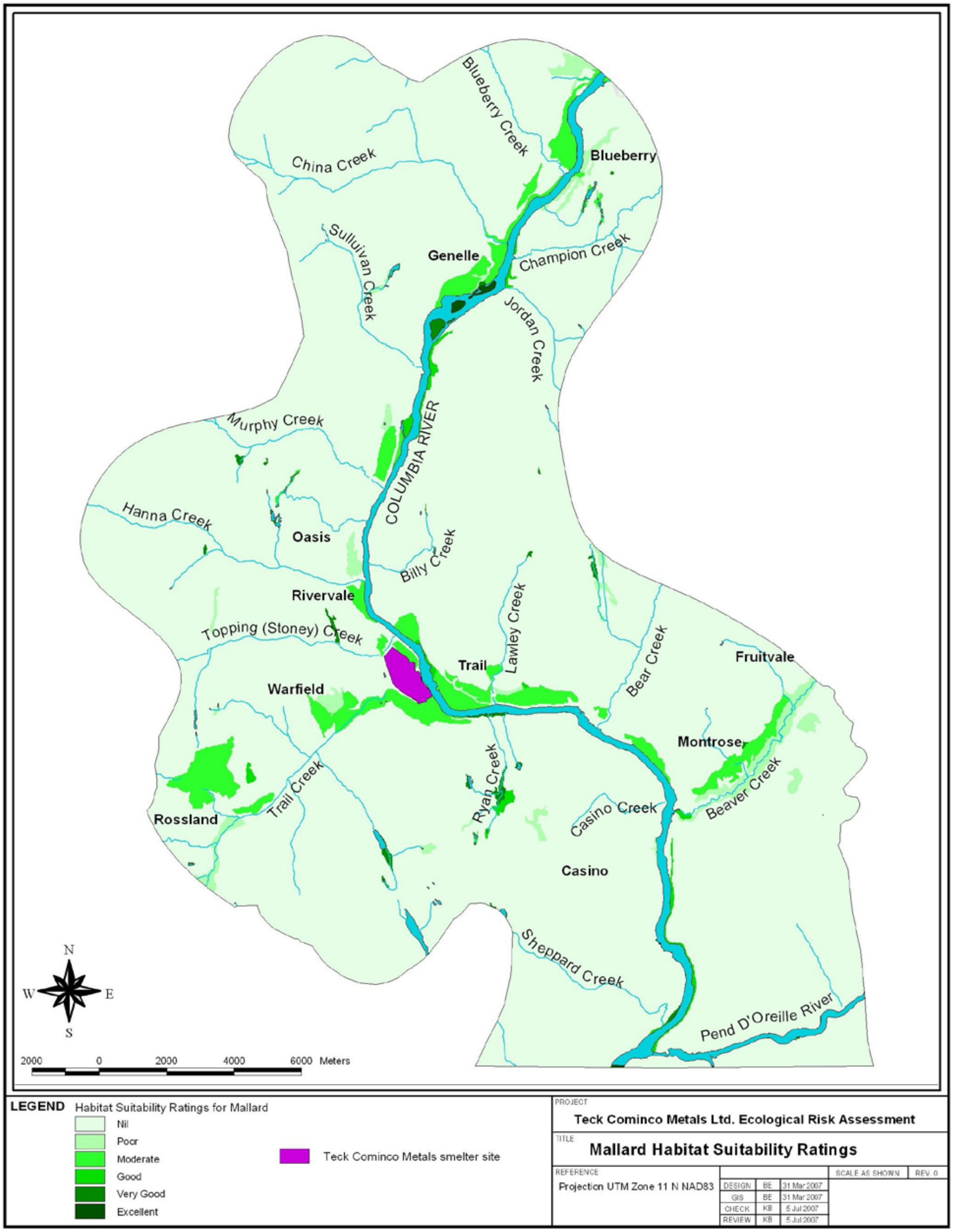


Figure 4-5 Habitat Suitability Ranking for the Mallard

Qualitative Evidence on Occurrence of Wildlife Habitat in the AOI

Qualitative evidence for the occurrence of wildlife habitat and the use of that habitat by wildlife was assembled as part of the biophysical habitat mapping (Appendix C). The AOI was divided into ten individual geographic areas (Figure 4-6; Appendix C). Each of these areas was described in terms of the main terrain features, the dominant biophysical habitat units, the occurrence of "non-site series units" such as urban or agricultural areas, and the existence of habitat for specific wildlife species.

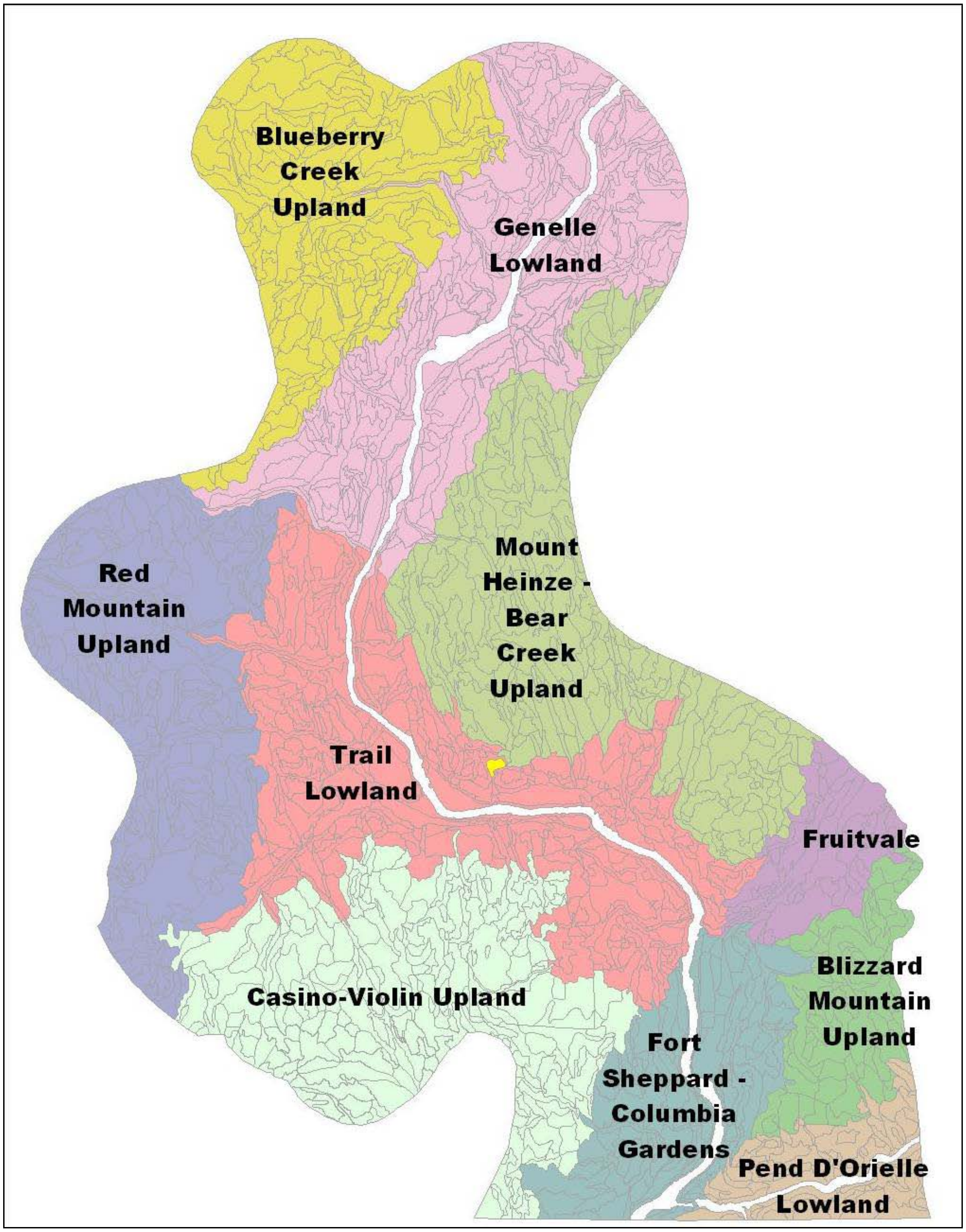


Figure 4-6 Ten Geographic Areas of the AOI (from Appendix C)

The following points summarize the bird habitat information provided by Enns and Enns (2007b):

- The Fort Sheppard Columbia Gardens geographic area in the southern-most portion of the AOI (with individual pockets of elevated PCOC concentrations in soil) - land use includes wildland (mesic to dry forest), semi-cultivated or farmed field, a small airport and the industrial area at Fort Sheppard (Trimac). Typical species include wood warblers, thrushes and flycatchers. Cavity nesting birds occur to a greater extent than near the smelter, due to the size of the Ponderosa pine, and the presence of trembling aspen at low elevation. Species include pine siskin, spotted towhee, Swainson's thrush, veery, northern flicker, Downy Woodpecker, Orange-crowned Warbler, Wilson's Warbler, Yellow Warbler, Yellow-rumped warbler, American goldfinch, song sparrow, Vesper sparrow, chipping sparrow, White-crowned Sparrow, Lazuli Bunting, Black-capped Chickadee, Tree Swallow, Violet-green swallow, Cliff swallow, red-breasted nuthatch, red crossbill, Vaux's swift, western tanager, willow flycatcher, western wood-pewee, Hammond's flycatcher, pacific-slope flycatcher, western kingbird, Cassin's vireo, warbling vireo, Calliope hummingbird, Rufous hummingbird. Some of the wider ranging birds such as American crow, brown-headed cowbird, common raven, turkey vulture, osprey, and bald eagle are also regular visitors to this area.

- The Pend d'Oreille lowland in the south-eastern corner of the AOI at low- to mid-elevation provides excellent habitat for pine siskin, great-horned owl, northern pygmy owl, pileated woodpecker, golden-crowned kinglet and several other species of woodpecker including Lewis' woodpecker (a Listed species); the Listed yellow-breasted chat was observed on a power-line ROW in this area; land use includes several roads, hydroelectric development, forestry and farming;

- The south-facing slopes of the Blizzard Mountain upland in the southwestern corner of the AOI, south of Fruitvale at 800 to 1,560 m has excellent habitat for northern goshawk, mountain chickadee and blue grouse; land use is primarily forestry and hydro rights of ways (ROW);

- The Casino-Violin upland on the low relief, rolling flanks of Lookout Mountain (extending from the U.S. boundary to above and south of Trail) contains a logged block. Townsend's solitaire, Cassin's vireo, wild turkey and various species of grouse have been observed in this area; land use consists primarily of forestry with past mining exploration or small mining development sites; this area includes a large wetland complex which is the source of Ryan Creek;

- The Fruitvale area on the eastern side of the AOI in the Beaver Creek valley above the main Columbia River valley provides excellent habitat for American robin, black-capped chickadee, evening and black-headed grosbeaks, northern flicker, yellow warbler, willow flycatcher, violet-green swallow and European starling; land use consists primarily of rural, suburban and urban development with relatively large areas in cultivation or used as pasture or hay fields;

- The Trail lowland in the center of the AOI has the most extensive evidence of disturbance from past sulphur dioxide exposure together with past logging and severe and repeated fire; this area contains cliffs and rock outcrops; therefore, it provides excellent habitat for a mix of both riparian and dry cliff-using species including rock wren, canyon wren, osprey, bank swallow, cliff swallow, Cooper's hawk, northern rough-winged swallow, red-tailed hawk, and red crossbill;

- The Red Mountain upland at the western edge of the AOI provides good habitat for black-capped and mountain chickadees, hermit thrush, northern goshawk, pine siskin, pacific-slope flycatcher, red-breasted nuthatch and Townsend's warbler; land use is primarily wildland with the city of Rossland at the southern boundary;

- The Mount Heinze area on the eastern boundary of the AOI constitutes a fairly large proportion of the total wilderness area in the AOI and provides excellent habitat for bald eagle, blue grouse, mountain chickadee, pine siskin, red-tailed hawk, Townsend's warbler and various woodpeckers;

- The Genelle lowland in the upper central portion of the AOI has a diverse assemblage of habitat for a large number of species; most common and abundant are Nashville warbler, American redstart, Barrow's goldeneye, barn swallow, belted kingfisher, blue-headed vireo, bank swallow, Bullock's oriole, Cassin's vireo, chipping sparrow, cliff swallow, Eastern kingbird, gray catbird, Lazuli bunting, western wood-peewee, vesper sparrow, warbling vireo and Wilson's warbler plus many other birds; several Listed species occur, notably Lewis' woodpecker and bobolink; land uses include isolated suburban areas in wild lowland settings with some roads, gravel pits and refuse disposal sites plus hydro ROW and the railway; there is almost no forestry use; and,

- The Blueberry Creek upland on the northwestern edge of the AOI provides good habitat for black-capped and mountain chickadee, hermit thrush, northern goshawk, pine siskin, turkey vulture, Pacific-slope flycatcher, red-breasted nuthatch, Townsend's warbler and turkey; land use consists primarily of forestry.

The AOI provides a range of habitat for a wide variety of avian species. Natural terrain features (*e.g.*, cliffs) and land use activities (*e.g.*, logging) influence wildlife use of particular areas within the AOI. The information does not provide a species-by-species evaluation of possible relationships between smelter-related changes in habitat and habitat use; however, the vegetation communities of the Trail lowland area with historic smelter-related damage are now providing habitat for a large number of species.

The qualitative information does not indicate any pattern of wildlife habitat use or habitat quality that could be related to past or current smelter emissions. The information is very limited and cannot be related to gradients of PCOCs in the AOI. The information also cannot be used in concert with the polygons retained for evaluation for risk management in Chapter 3 (because of risk to vegetation communities and their further development) because the information is too general.

Uncertainty Related to Effects on Abundance, Density, and Community Composition

Uncertainty related to the natural variability of avian abundance and density estimates is moderate. The variance in some of the abundance and density estimates was quite high, possibly due to either a poor fit of the model used to produce the estimates, or to low sample sizes (Golder, 2007a). Some habitat types and some classes of PCOC concentrations were much better represented than others.

Uncertainty related to natural variability of community composition is low. Although the survey data from the AOI and the data from the reference routes were not collected in exactly the same way, the Jaccard similarity index only requires presence/absence data, so different data collection methods are relatively unlikely to cause spurious results in this type of comparison. The differences in bird species detected between this study and the reference survey routes elsewhere can be explained by the different geographic locations of the reference survey routes, different habitat types that are likely present and the duration of the study periods. Some species not detected in the AOI are very habitat specific and would not be expected at the sites surveyed in the AOI (*e.g*., Cassin's finch) due to the lack of stands with heavy conifer cover.

None of the evidence indicates the presence of direct effects from PCOCs in the AOI or indirect effects *via* changes in the invertebrate food supply or habitat. Therefore, adverse effects according to Conceptual Models 1 and 2 are not supported by the data.

4.4.3 Summary of Magnitude and Uncertainty Evaluation for the Lines of Evidence Related to the Avian Community

The magnitude of indirect effects on the avian community *via* food chain changes or effects on habitat is low (Table 4-5). The uncertainty associated with natural variability (and thus measurement error) is moderate. The magnitude of response for the avian community as determined by field survey data is low. Uncertainty in these survey data is also low. Support for Conceptual Model 1 (which hypothesizes direct effects of PCOCs) and Conceptual Model 2 (which hypothesizes indirect effects *via* food web or habitat changes) is low.

The rationale for selection of the magnitude and uncertainty scores in Table 4-5 is as follows:

- Field survey for birds within the AOI, compared with outside the AOI:
    - Low magnitude: abundance, density and community composition are similar to those in other areas of BC;
    - Low uncertainty due to natural variability and measurement error: data were available for several species, over several years, from several transects in the AOI, compared with multiple areas outside the AOI; and,
    - Low support for adverse effects predicted by the Conceptual Models: neither direct (Conceptual Model 1) nor indirect effects (Conceptual Model 2) are supported by the data.

- Availability of suitable habitat:
    - Low magnitude: bird communities present associated with re-growth of early- to mid-seral vegetation communities; therefore, any past adverse effects related to loss of vegetation cover are now absent; as vegetation communities continue to develop, bird communities may shift in accordance with the change to more conifer-dominated vegetation communities;
    - Moderate uncertainty due to natural variability and measurement error: Habitat suitability assessed using mapping methods which have not been ground-truthed (results checked using aerial photographs); standard approaches used (modified using local knowledge); habitat requirements generally known; changes in wildlife use by season was accounted for; and,
    - Low support for adverse effects predicted by the Conceptual Models: there is evidence of past indirect effects due to smelter-related alteration or elimination of vegetation, but current evidence indicates no adverse indirect effects are occurring in the areas of the AOI where past injury to vegetation communities occurred.

- Soil invertebrate abundance and density:
  - Low magnitude: there was no difference in the numbers of invertebrates (individuals or orders) with PCOC concentration in soil. Earthworms were found where expected;
  - Moderate uncertainty due to natural variability and measurement error because of the limited range of PCOC concentrations and habitats covered by the studies; and,
  - Low support for adverse effects predicted by the Conceptual Models: the evidence was limited and not consistent with the hypotheses of either direct or indirect effects caused by toxicity of PCOCs to invertebrates and subsequent food-web related changes.

Table 4-5 Magnitude of Response and Associated Uncertainty for Avian Community Lines of Evidence

Line of Evidence	*Magnitude*[a]	*Uncertainty Due to Measurement Error/Natural Variability*[b]
Field Survey of the Avian Community – Abundance and Density	o	?
Field Survey of the Avian Community – Community Composition	o	?
Availability of Suitable Habitat	o	??
Soil Invertebrate Abundance and Diversity	o	??

[a] o Adverse effects unlikely
[b] ? Low uncertainty; ?? Moderate uncertainty

Decision Regarding the Need for Analysis of Causation

All responses were classified as "adverse effects unlikely". The uncertainty due to natural variability and measurement error was moderate, and the support of adverse effects according to the Conceptual Models was low (*i.e.*, the hypotheses of direct and indirect effects were not supported by the evidence). Therefore, no causal analysis (SALE Step 5) was conducted for avian communities.

4.4.4 Risk Characterization for Avian Communities

The avian community was evaluated under the three risk management objectives related to minimizing direct and indirect effects on populations of wildlife in wildland, urban and agricultural areas. The assessment endpoints for avian wildlife were "population persistence", "habitat utilization" and "habitat suitability".

The combined results presented above support the conclusions that:

1) Avian wildlife populations persist in the AOI;
2) Available habitat is being utilized to a similar extent as in reference habitat areas; and,
3) The habitat (including areas that are in early- to mid-seral stages) is suitable for a wide range of avian species (although in different proportions than would have been present prior to historical, smelter-related effects).

These conclusions are supported by lines of evidence that show low-magnitude effects with associated low-to-moderate uncertainty caused by natural variability and measurement error. The evidence does not support adverse effects according to Conceptual Models 1 (which hypothesizes direct toxicity) or 2 (which hypothesizes indirect effects mediated through food chain interactions or physical changes in habitat).

4.5 SALE Evaluation for Mammalian Wildlife Communities

The LOR3 modelling ruled out direct toxicity risks for all mammalian receptor species (Intrinsik, 2007). The mammalian receptor species were representative species of carnivorous and piscivorous mammals (coyote, river otter), ungulates (white-tailed deer), and other small and large mammals (black bear, Columbian ground squirrel, deer mouse, dusky shrew, red-backed vole, red squirrel). Therefore, the remainder of the assessment of risk to mammalian wildlife communities focused on indirect risks *via* changes in habitat suitability (Conceptual Model 2).

Steps 2-4 of the SALE process for mammalian communities consisted of the evaluation of the evidence for indirect effects (Section 4.5.1) including habitat suitability mapping for selected representative species. The mammals of the AOI have been described in several documents (summarized in Enns, 2007a; Appendix D), and although predominantly qualitative, are evaluated in Step 3 (Field Data) (Section 4.5.2). Magnitude of response and evaluation of uncertainty (Step 4) are summarized in Section 4.5.3. The risk characterization for mammalian wildlife is presented in Section 4.5.4.

4.5.1 Assessment of the Evidence for Indirect Effects

<u>Indirect Effects *Via* Changes in Food Chain Interactions</u>

The evidence does not support adverse effects according to Conceptual Model 2 regarding indirect effects *via* changes in predator or prey populations. No unacceptable direct toxicity risks were predicted for avian or mammalian predators or prey in the AOI (Cantox Environmental, 2003a; Intrinsik, 2007). Therefore, indirect effects on mammalian wildlife communities due to changes in mammalian or avian predator or prey abundance were not carried forward in the SALE evaluation. The evidence for effects on soil invertebrates was weak (Section 4.3.1). Therefore, no adverse effects *via* reduction in invertebrate food supply are expected. The uncertainty related to this LOE was moderate (Section 4.3.1).

The remaining analysis of indirect effects considered effects related to smelter-related changes in plant communities, both with respect to food supply and with respect to physical habitat characteristics required for cover, den sites, *etc*.

<u>Indirect Effects *via* Changes in Habitat Suitability</u>

Habitat suitability was evaluated for deer and river otter, representing ungulates and aquatic mammals, respectively. White-tailed deer uses mixed forests, and the brushy open savannah-style vegetation of the AOI is prime habitat for this species. Winter habitat is available at higher elevation, although wintering still occurs at all elevations (Appendix D). There is abundant deer habitat in the “very good” or “good” category in the AOI (Figure 4-7). There is no consistent relationship between good-to-excellent deer habitat and smelter-related effects on vegetation (as identified by the “retained polygons” in Chapter 3). White-tailed deer is common and abundant throughout the AOI, and is only partially excluded from urban areas, industrial sites, scree slopes, cliffs and high elevation ridges (Appendix D). Browse of shrubs by white-tailed deer was noted by Machmer and Steeger (2005) to be heaviest on middle elevation areas of the Waneta area and the Pend D’Oreille. Records for white-tailed deer are the most numerous of all the mammals in the AOI (Appendix D).

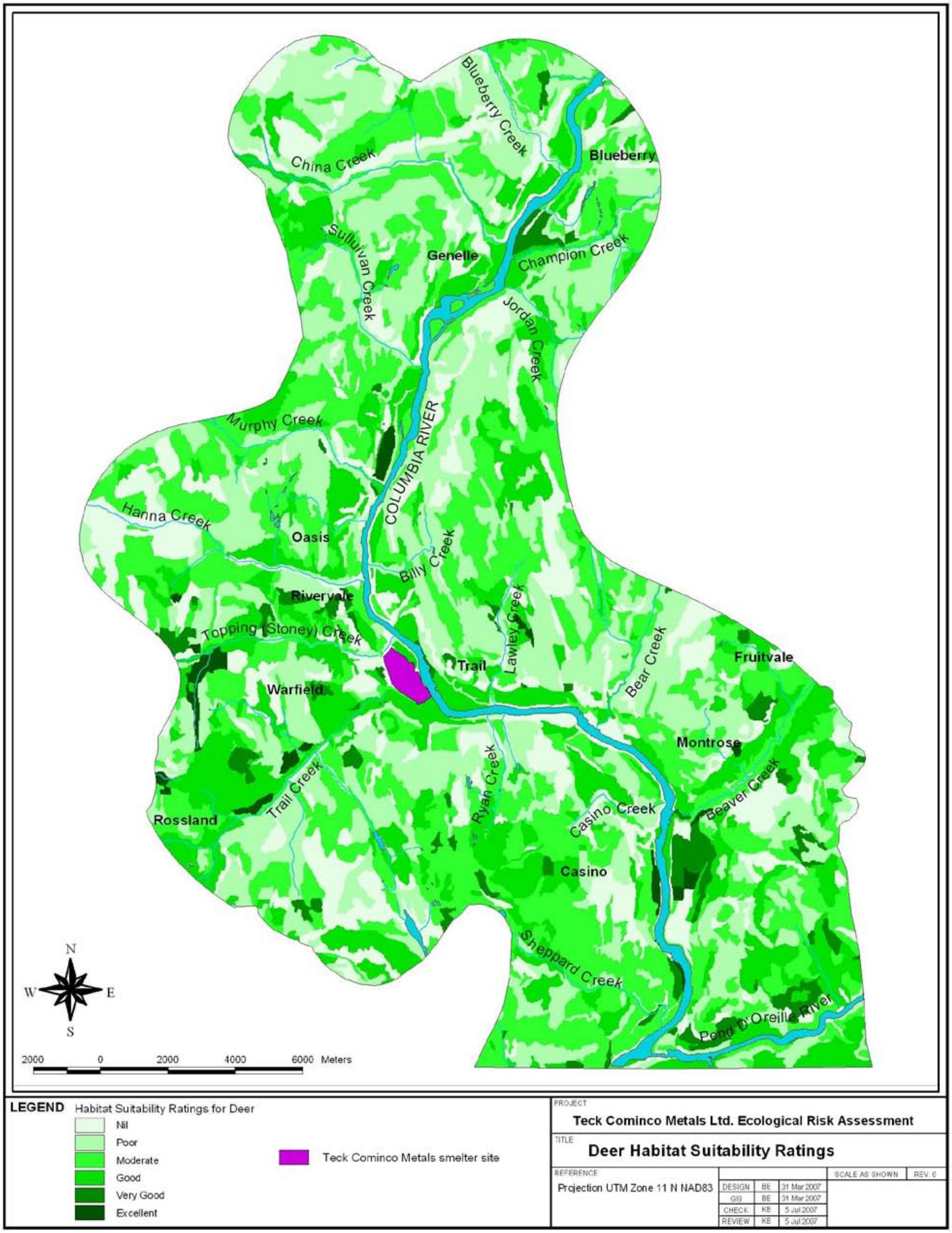


Figure 4-7 Habitat Suitability Ranking for White-tailed Deer

River otter habitat is mapped as rare in the AOI (Figure 4-8), but that is only because it is limited to the Columbia and Pend D'Oreille River drainages. River otter will use riparian habitats for denning as far as 300 meters uphill from pullouts (Appendix D). Brush piles are commonly used, and the abandoned dens of beaver. Some of the characteristics of the Columbia River riparian habitat may be limiting for river otter. The Columbia has several inaccessible areas dominated by massive steep escarpments over 70 metres tall in some areas, and the river can flow very swiftly in some parts of the channel. Backwaters at Waterloo Eddy and Birchbank and stream inlets at Blueberry Creek, Sullivan Creek, Bear Creek, Beaver Creek, *etc*. all provide habitats for river otter, and this species has been noted at the tailrace at Waneta and at various locations throughout the Columbia River channel. Otter kits have been seen each summer by local fishers and although the population of river otter is thought to be small, it is a viable population (Appendix D). There is no relationship between river otter habitat and smelter-related effects on vegetation in the AOI.

Summary of Magnitude of Response and Uncertainty With Respect to Indirect Effects *Via* Changes in Habitat Suitability

The habitat suitability evaluation for white-tailed deer and river otter does not indicate impacts *via* smelter-related changes in vegetation communities. Uncertainty related to indirect impacts on the mammalian community is moderate because, although diverse habitats are known to exist in the AOI, suitability was mapped for only two species.

4.5.2 Assessment of Evidence from Field Surveys

The mammals of the AOI have been described in several documents (summarized in Enns, 2007a; Appendix D), based on habitat characteristics and actual records. Many studies focussed at the southern end of the AOI, at Beaver Creek, Sheppard Flats, and the area south of Waneta to the junction of the Pend D'Oreille River (Dulisse, 1999; Schaeffer *et al*., 2002; Machmer and Steeger, 2005). Inventories were conducted annually within the AOI by wildlife biologists from 2000 to 2003, noting wildlife sign or actual sightings (Appendix D). Most of these inventories were done at low elevation from south of Castlegar to Trail. They do not cover the entire AOI, only the middle portion of the low elevation valley bottom (Bennett, 2000; 2002; Cooper, 2000; 2003; Cooper and Beauchesne, 2001). A map showing the location of field surveys for wildlife is shown in Figure 4-9. Informal and incomplete records of wildlife sign and sightings were also taken during the soil sampling periods in 2000 to 2003 in the vicinity of the soil sample plots throughout the AOI (Appendix D). A list of mammals in the AOI was compiled based on various field studies (Table 4-6).

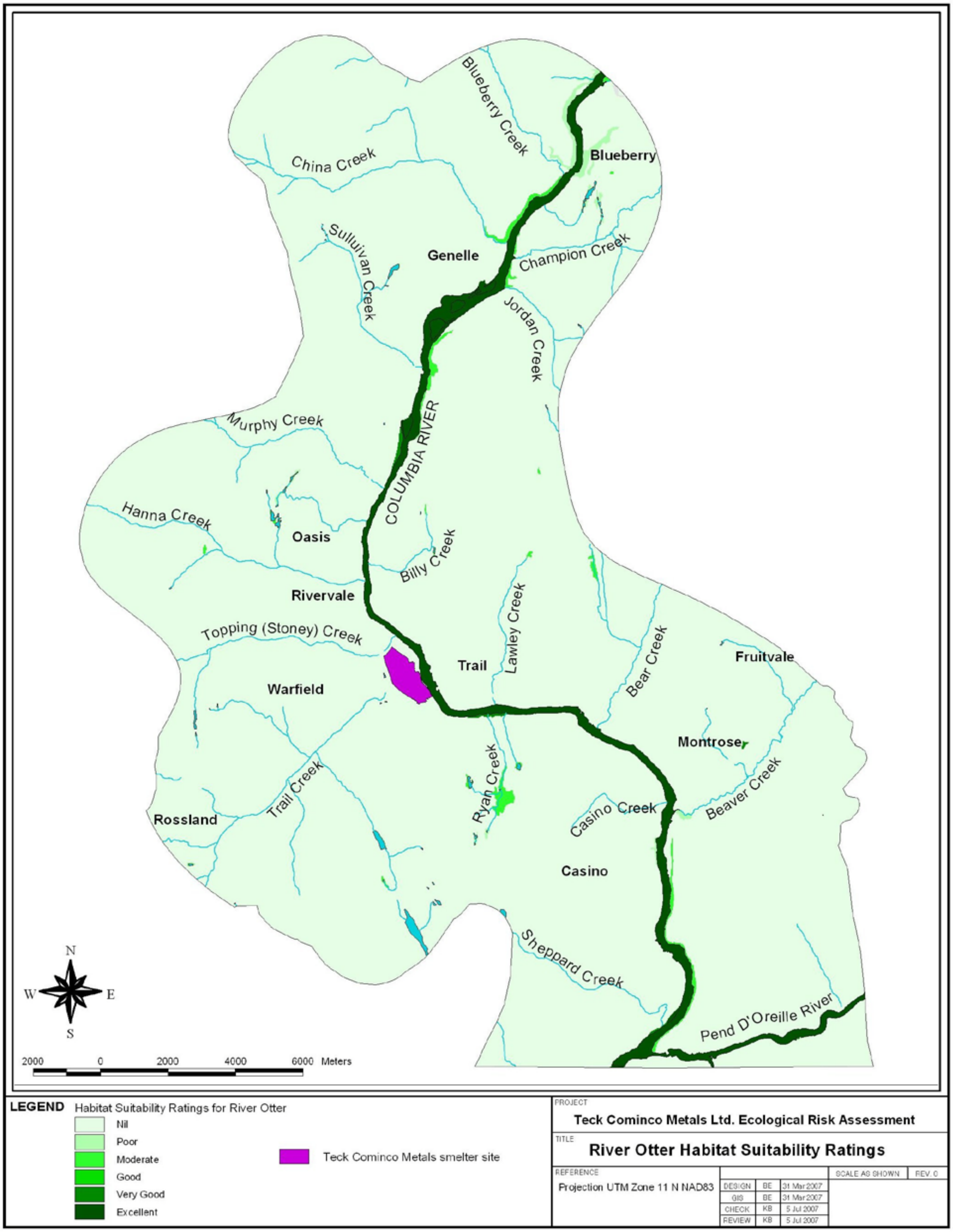


Figure 4-8 Habitat Suitability Ranking for River Otter

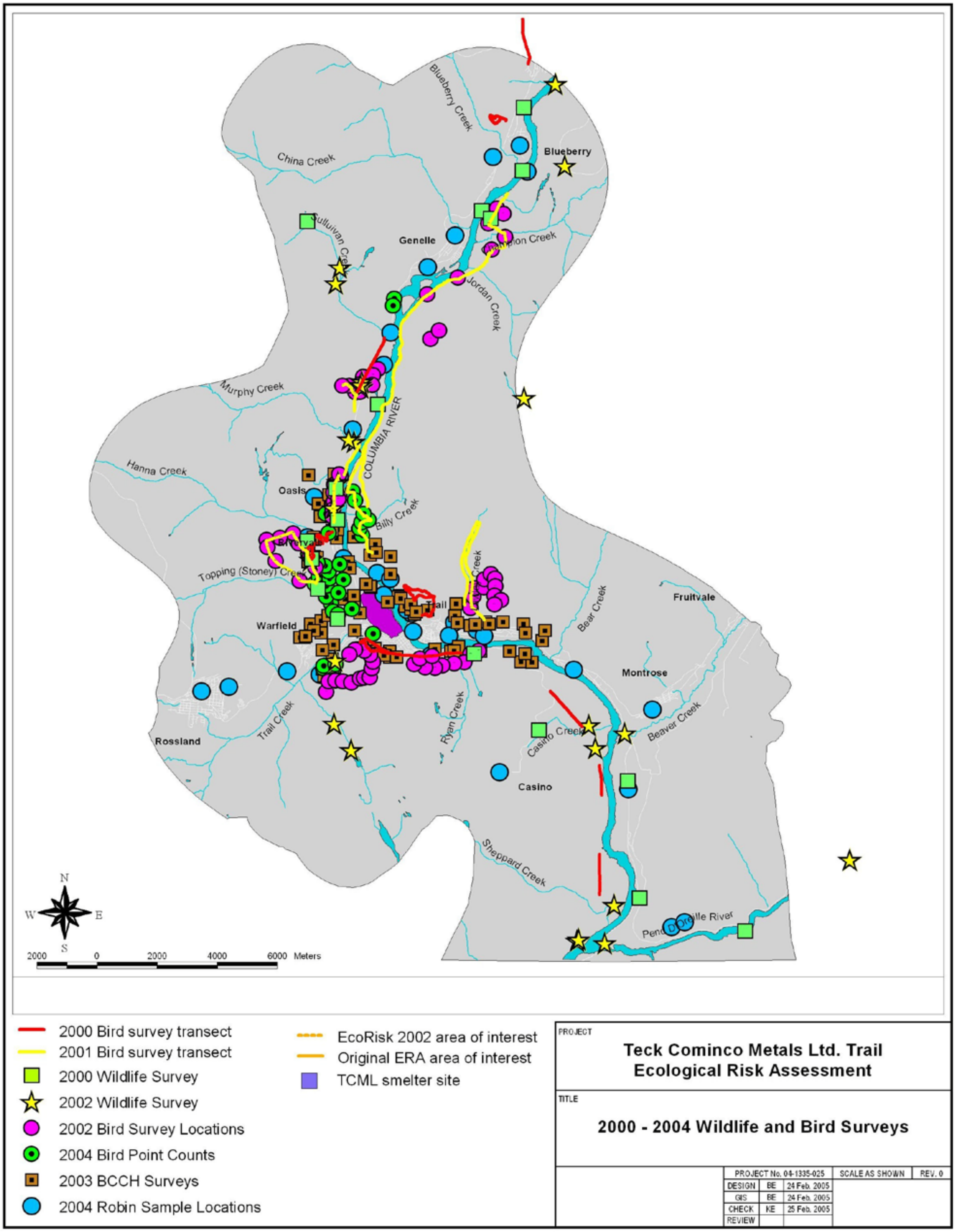


Figure 4-9 Wildlife Survey Locations in the AOI

Table 4-6 Mammals in the Area of Interest (Enns, 2007a; Appendix D)

Common name	***Latin name***	***Provincial Status***	***ERA field surveys***	***ERA concurrent field studies[a,b]***	***Regional background studies[c]***
SHREWS (Order Insectivora)					
Common Shrew	*Sorex cinereus*	Yellow		●	●
Common Water Shrew	*Sorex palustris*	Yellow	●		
BATS (Order Chiroptera)					
Little Brown Myotis	*Myotis lucifugus*	Yellow	●		●
Yuma Myotis	*Myotis yumanensis*	Yellow		●	●
Western long-eared Myotis	*Myotis evotis*	Yellow		●	●
Long-legged Myotis	*Myotis volans*	Yellow			●
California Myotis	*Myotis californicus*	Yellow			●
Silver-haired Bat	*Lasiurus noctivagans*	Yellow		●	●
Big Brown Bat	*Eptesicus fuscus*	Yellow		●	●
Hoary Bat	*Lasiurus cinereus*	Yellow			●
Townsend's Big-eared Bat	*Corynorhinus townsendii pallescens*	Blue		●	●
Pallid Bat	*Antrozous pallidus*	Red			●
CARNIVORES (Order Carnivora)					
Black bear	*Ursus americanus*	Yellow	●	●	●
Grizzly bear	*Ursus arctos*	Blue	●	●	●
Racoon	*Procyon lotor*	Yellow	●	●	●
American marten	*Martes americana*	Yellow			●
Ermine	*Mustela erminea*	Yellow		●	●
Long-tailed weasel	*Mustela frenata*	Yellow		●	●
Mink	*Mustela vison*	Yellow		●	●
Northern River Otter	*Lutra canadensis*	Yellow	●	●	●
Wolverine	*Gulo gulo*	Blue		●	●
American badger	*Taxidea taxus*	Red		●	●

Table 4-6 Mammals in the Area of Interest (Enns, 2007a; Appendix D)

Common name	***Latin name***	***Provincial Status***	***ERA field surveys***	***ERA concurrent field studies***[a,b]	***Regional background studies***[c]
Striped skunk	*Mephitis mephitis*	Yellow	●	●	●
Coyote	*Canis latrans*	Yellow	●	●	●
Red fox	*Vulpes vulpes*	Yellow		●	●
Cougar	*Felis concolor*	Yellow	●		●
Lynx	*Lynx canadensis*	Yellow			●
Bobcat	*Lynx rufus*	Yellow		●	●
RODENTS (Order Rodentia)					
Yellow-bellied marmot	*Marmota flaviventris*	Yellow	●	●	●
Columbian Ground Squirrel	*Spermophilus columbianus*	Yellow	●	●	●
Yellow-pine Chipmunk	*Tamias amoneus*	Yellow	●	●	●
Red Squirrel	*Tamiasciurus hudsonicus*	Yellow	●	●	●
Northern Flying Squirrel	*Glaucomys sabrinus*	Yellow	●	●	●
Northern Pocket Gopher	*Thomomys talpoides*	Yellow	●	●	●
Beaver	*Castor canadensis*	Yellow	●	●	●
Deer Mouse	*Peromyscus maniculatus*	Yellow	●	●	●
Bushy-tailed Woodrat	*Neotoma cinera*	Yellow		●	●
Southern red-backed Vole	*Clethrionomys gapperi*	Yellow			●
Meadow Vole	*Microtus pennsylanicus*	Yellow	●		●
Muskrat	*Ondatra zibethicus*	Yellow		●	●
Porcupine	*Erethizon dorsatum*	Yellow	●	●	●
HARES AND RABBITS (Order Lagomorpha)					
Common Pika	*Ochotona princeps*	Yellow			●
Snowshoe Hare	*Lepus americanus*	Yellow	●	●	

Table 4-6 Mammals in the Area of Interest (Enns, 2007a; Appendix D)

Common name	***Latin name***	***Provincial Status***	***ERA field surveys***	***ERA concurrent field studies[a,b]***	***Regional background studies[c]***
UNGULATES (Order Artiodactyla)					
Elk	*Cervus elaphus*	Yellow	●	●	●
Mule Deer	*Odocoileus hemionus*	Yellow	●	●	●
White-tailed Deer	*Odocoileus virginianus*	Yellow	●	●	●
Moose	*Alces alces*	Yellow	●	●	●
Mountain Goat	*Oreamnos americanus*	Yellow	●	●	
California Bighorn Sheep	*Ovis canadensis californiana*	Blue	●		

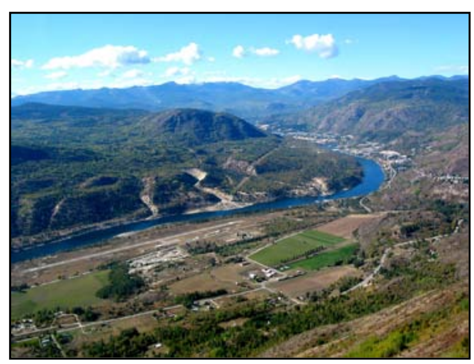
[a] Schaeffer *et al*. (2002) Biodiversity Inventory within the ICHxw at Fort Shepherd
[b] Machmer and Steeger (2005) Terrestrial Environmental Impact Assessment for the Waneta Expansion Project
[c] Includes the AOI. From various reports, summarized in Machmer and Steeger (2005)

Large-bodied mammals such as black bear, grizzly bear, elk, mule deer, white-tailed deer and moose are relatively commonly occurring (Appendix D). Species that are considered common and increasing in B.C. such as black bear, coyote, raccoon, striped skunk, Columbian ground squirrel, yellow pine chipmunk, deer mouse, porcupine and (increasing in some areas) snowshoe hare are also frequently occurring in the AOI. These species have been able to adapt to present habitats or disperse from other habitats to the AOI. They require seral or early structural stage, deciduous dominated brushy forests, and rock outcrops that are common in the AOI (Appendix D).

Small mammals such as shrews and voles are poorly known in the AOI (Appendix D). This may be due to the lack of small mammal surveys conducted in the AOI. Pitfall traps were used to collect insects (Enns and Anderson, 2002) and as a consequence, deer mice, common water shrew and common shrew are known to occur in the AOI. Common shrews were also found by Machmer and Steeger (2005) at Waneta (Appendix D).

Habitat is present in the AOI for several species for which no records are available (Appendix D). These are summarized in Cooper (2007) and Schaeffer *et al*. (2002), and include Preble's shrew, Merriam's shrew, vagrant shrew, pygmy shrew, dusky shrew, fringed myotis, western small-footed myotis, northern long-eared myotis, western red bat, spotted bat, great basin pocket mouse. The lack of field records for bats may be because few studies have been done. However, both Schaefer *et al*. (2002) and Machmer and Steeger (2005) obtained records for Townsend's big-eared bat near Sheppard Cliffs. Townsend's big-eared bat is a Listed species. Its presence indicates that other species of bats also may occur. Little brown myotis is common from Castlegar to Waterloo Eddy of the Columbia River, approximately 1 km from the northern boundary of the AOI. The massive cliffs, water features, and insect prey are available for many of these species (Appendix D).

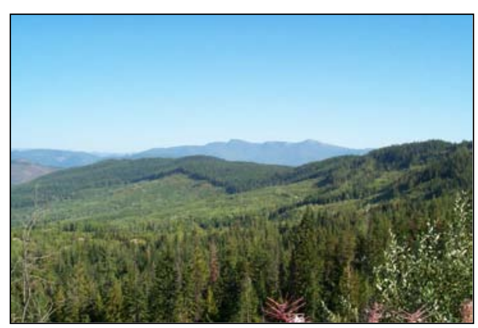
As described above for avian communities, the AOI was divided into 10 individual geographic areas (Figure 4-6; Appendix C; Appendix D). Each of these areas was described in terms of the main terrain features, the dominant biophysical habitat units, the occurrence of "non-site series units" such as urban or agricultural areas, and the existence of habitat for specific wildlife species.



- The **Fort Sheppard/Columbia Gardens** geographic area is in the southwest portion of the AOI. The wildlife habitat of this area is highly variable, is relatively disturbed by past human activity (although wildlands still predominate) and has had considerable numbers of wildlife related field surveys completed in it. It consists of very dry lowland grasslands and dry open, Ponderosa pine dominated forests, upland dry deciduous forests, farmlands, industrial land (including an airport), the Columbia River and the mouth of the Pend D'Oreille River and the rocky flanks of Blizzard Mountain. This area receives heavy use by white-tailed deer, elk and mule deer. Common shrew was trapped in this area on Sheppard Flats, one of the few records for the AOI. However, it was not noted in the site-specific surveys on the east side of the Columbia River. Townsend's big-eared bat also occurs on both sides of the Columbia River, but possibly using the massive cliffs as roosting sites on the western shore. Records exist for river otter, yellow-pine chipmunk, Columbia ground squirrel, northern pocket gopher, American badger, coyote, striped skunk, raccoon, black bear, deer mouse, and others in this area. Other species of bats and small mammals undoubtedly occur;

- The **Pend d'Oreille Lowland** geographic area is in the southeastern corner of the AOI at low to mid elevation and is dominated by the lower flanks of Blizzard Mountain and the Pend D'Oreille Mountains on either side of the Pend D'Oreille River. The wildlife habitat of this area is uniformly coniferous forests of variable seral stages, but predominantly mature forests. This area also has had considerable historical wildlife surveys completed for it, and its wildlife use patterns are relatively well known in comparison to other areas of the AOI. It consists primarily of closed to moderately open moist Douglas fir dominated forests at low to middle elevation, with larch and Douglas fir at higher elevation. A small amount of closed to open Ponderosa pine occurs on the western margin of the area. Some previously logged, cultivated areas and farms occur. Stands dominated by trembling aspen are also relatively common. More is known about wildlife use of the south-facing slopes north of the Pend D'Oreille than the southern mountain sides. This area provides habitat for white-tailed deer, mule deer, elk, cougar, lynx, bobcat, black bear, and grizzly bear. American marten, ermine, mink, long-tailed weasel, and wolverine also occur at high elevation. The bushy-tailed woodrat, red squirrel, northern flying squirrel, and yellow-bellied marmot also occur. American badger is known to occur on the western margin of this area, in association with open fields and open forests;

- The **Blizzard Mountain Upland** geographic area is in the middle southeastern portion of the AOI, at high elevation between the Pend D'Oreille River to the south and the Fruitvale valley to the north. It has had fewer wildlife surveys than the Pend D'Oreille River area, but shares some of the wildlife characteristics of the upper elevation Pend D'Oreille River area (see above). It consists of Douglas fir, lodgepole pine and larch dominated upper montane to subalpine forests with some subalpine fir at the highest elevation. Forest harvesting in relatively small irregular clear cut blocks is uncommon. It is possible the woodland caribou occurred in this geographic area but no recent records occur. There is excellent habitat for white-tailed and mule deer, porcupine, snowshoe hare, and northern flying squirrel. Grizzly bear, wolverine, American marten, ermine, long-tailed weasel and cougar probably co-occur with populations known in the Pend D'Oreille;



- The **Casino-Violin Upland** geographic area occurs on the plateau and mountains on the western side of the AOI, including the low relief, rolling flanks of Lookout Mountain, extending from the U.S. boundary to south of Trail. Very few records for wildlife exist for this area, but wildlife sign was noted during the soil surveys. It consists of relatively closed Douglas fir, western hemlock, lodgepole pine and western red cedar-dominated forests, with one very large open deciduous tree dominated clear-cut logged block. The western boundary of the area includes some subalpine fir and open subalpine tundra vegetation. Most of the area is outside the boundaries of urban areas; however Casino, Trail, and Rossland are nearby. This area includes a large wetland complex which is the source of Ryan Creek. It is also possible that woodland caribou occurred in this geographic area but there are no recent records. The lower elevation plateau provides summer habitat for mule deer, white-tailed deer and both winter and summer habitat for moose. Cougar, black bear, porcupine, and snowshoe hare have been observed in this area. Grizzly bear, wolverine, American marten, ermine and long-tailed weasel probably occur;

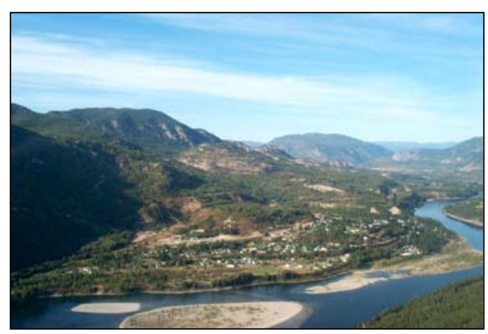
- The **Fruitvale** geographic area occurs on the eastern side of the AOI in the Beaver Creek valley above the main Columbia River valley. It includes the town of Fruitvale. Few formal surveys for wildlife have been conducted in this area. The Fruitvale area consists of small scale farms, urban and suburban housing and development, riparian cottonwood forests at Beaver Creek, and the lower forested slopes of both Blizzard Mountain and Mount Heinz to the north. The south facing forested slopes are very open, often consist of patches of trembling aspen or lodgepole pine, and have been previously disturbed by fire. The north-facing slopes are dense, and dominated by western hemlock and Douglas fir. The wildlife in this geographic area is influenced by development and includes such mammalian species as black bear, raccoon, striped skunk, coyote, Columbia ground squirrel, beaver, deer mouse, and porcupine. There is excellent habitat for northern pocket gopher, meadow vole, and water shrew. Ungulates also occur but are less common, including white-tailed deer and elk. It is likely that little brown bat and red fox also occur;

- The **Trail Lowland** geographic area is in the center of the AOI. It has the most extensive evidence of disturbance from past sulphur dioxide exposure together with past logging and severe and repeated fire. Urban and suburban development is predominant in this area, but still does not cover the majority of the area. The Trail geographic area includes large tracts of open mixed wood to deciduous dominated forests on both steep slopes and flat to undulating terraces, as well as low stature, shrubby forests over thin soils, and open brush dominated slopes. This area also has some massive cliffs and rock outcrops as well as various types of wetlands including small rock controlled, brushy pocket wetlands, fens, shrub carrs, cattail marshes, and willow dominated seeps. The main stem of the Columbia River and its steep escarpments occur in the center of the Trail Lowland geographic area. Several wildlife surveys were conducted in this area, but concentrated mainly on birds; therefore mammal sign may have been missed in the surveys. The area provides excellent habitat for a mix of riparian, mixed forest, urban-suburban and dry cliff-using species. These include black bear and grizzly bear, northern river otter, striped skunk, coyote, big brown bat and yellow-bellied marmot. Columbia ground squirrel and pocket gopher have a very high density and are increasing. Deer mouse, meadow vole, muskrat, porcupine, snowshoe hare, and common pika all occur. White-tailed deer is more common than mule deer, and moose has been noted at low elevation wetlands 3 km north of the smelter. Mountain goat records were taken southwest of Trail, and big horn sheep sign was noted at Stoney Creek in 2001;

- The **Red Mountain Upland** geographic area is on the western edge of the AOI at high elevation. Almost no dedicated wildlife field work has been done in this geographic area. It consists mostly of wildlands with the exception of the north Rossland suburban and rural interface. Some clear-cut logging has occurred on the eastern boundary. The Red Mountain Upland consists mainly of high elevation plateau forests, headwaters of creeks and high rock ridges, as well as small but important subalpine and alpine tundra. The area provides good upland habitat for grizzly bear, black bear, wolverine, American marten, ermine, long-tailed weasel, and cougar. Pika and snowshoe hare records exist for this area;

- The **Mount Heinze/Bear Creek Upland** geographic area occurs on the eastern boundary of the AOI and includes the peaks of Mount Heinz and the Bear Creek plateau forests on the eastern margin. Only anecdotal wildlife records are available. This area consists of wildlands, with some forest harvesting on the eastern boundary. It is largely unroaded. It is comprised of late seral to maturing seral forests often on dry, thin soil with a high amount of bedrock to surface. Minor cliff features and rock outcrops, small box canyons, pocket wetlands and springs are common. Mature larch-dominated north-facing forests (not common in the AOI) occur on the western boundary. A large number of spring fed creeks originate in this area, and drain usually to the west. Common pika and snowshoe hare are probably very common, as are mountain goat, and possibly California big horned sheep. Mule deer may be more common than white-tailed deer here. Red-tailed chipmunk, Selkirk chipmunk, yellow-bellied marmot, northern flying squirrel, wolverine, cougar, lynx, bobcat, black bear and grizzly bear may use these habitats;

- The **Genelle Lowland** geographic area occurs in the upper central portion of the AOI and includes the main stem of the Columbia River, its escarpments and the low elevation sandy terraces and low elevation mixed wood forests. Several wildlife surveys for the AOI were conducted in this geographic area. It has a diverse assemblage of habitat types including both low and massive cliffs, both steep and gently sloping mixed-wood forests, flat birch-dominated terraces, steep riparian and often bouldery pine-dominated streamside forests and open brush-dominated lands. There are scattered rural settlements at low elevation and linear corridors, but most of the area is wildlands. A grassland area at Champion Creek and some of the largest trees in the AOI occur in this geographic area. Little brown myotis is known to occur, along with black bear, grizzly bear, racoon, northern river otter, striped skunk, coyote, red fox, cougar, Columbia ground squirrel, yellow-pine chipmunk, northern pocket gopher, meadow vole, water shrew and deer mouse. Porcupine may occur and snowshoe hare is very abundant. Also very abundant are white-tailed deer. Mountain goat, elk and mule deer probably also occur; and,



- The **Blueberry Creek Upland** geographic area occurs on the northwestern edge of the AOI at high elevation and includes the upland forests of the Blueberry Creek drainage and the northern edge of the heavily forested Sullivan Plateau. Subalpine and alpine ridges occur on the western boundary. This area has had a small number of wildlife surveys covering a very limited area. It has mainly moist to dry forested habitats dominated by Douglas fir, lodgepole pine and western white pine. Forestry activity is common in this geographic area, and several ages of regenerated clear cut forests occur from herb stages to advanced regeneration of pole saplings. The area is bisected by several forestry roads. The Blueberry Creek Upland provides habitat for mule deer, elk and white-tailed deer, as well as cougar, lynx, bobcat, snowshoe hare, bushy-tailed woodrat, porcupine, grizzly bear, black bear and possibly American martin, ermine and long-tailed weasel. Wolverine possibly occurs as well. The subalpine and alpine ridges are dominated by blocky scree and pica is known to be common. California big-horned sheep may occur, and it is possible that woodland caribou occurred at one time but no recent records exist.

Magnitude of Response and Uncertainty With Respect to Mammalian Species Presence, Abundance and Diversity

The combination of information illustrates that the AOI provides a range of habitat to a wide variety of mammalian species. Natural terrain features (*e.g*., cliffs) and land uses (*e.g*., logging) influence the wildlife use of particular areas within the AOI. The information does not provide a species-by-species evaluation of possible relationships between smelter-related changes in habitat and habitat use; however, the vegetation communities of the Trail lowland area that historically had smelter-related damage are now providing habitat for a large number of species. Therefore, the magnitude of response is considered low.

The qualitative information does not indicate any pattern of wildlife habitat use or habitat quality that could be related to past or current smelter emissions. The information is very limited and cannot be related to gradients of PCOCs in the AOI. The information also cannot be used in concert with the polygons retained for evaluation for risk management in Chapter 3 (because of risk to vegetation communities and their further development) because the information is too general. Therefore, there is a high level of uncertainty.

4.5.3 Summary of Magnitude and Uncertainty Evaluation for the Lines of Evidence Related to the Mammalian Community

The magnitude of indirect effects on the mammalian community *via* food chain changes or effects on habitat is low (Table 4-7). The uncertainty associated with natural variability (and thus measurement error) is moderate. The magnitude of response for the mammalian community as determined by field survey data is low. Uncertainty in these survey data is high. Support for Conceptual Model 1 (which hypothesized direct effects of PCOCs) and Conceptual Model 2 (which hypothesized indirect effects *via* food web or habitat changes) is low.

Table 4-7 Magnitude of Response and Associated Uncertainty for Mammalian Community Lines of Evidence

Line of Evidence	***Magnitude[a]***	***Uncertainty Due to Measurement Error/Natural Variability[b]***
Field Surveys of the Mammalian Community – Presence and Abundance	o	???
Availability of Suitable Habitat	o	??
Soil Invertebrate Abundance and Diversity	o	??

[a] o Adverse effects unlikely; Data do not support adverse effects *via* pathways described in the conceptual models
[b] ? Low uncertainty; ?? Moderate uncertainty; ??? High uncertainty

The rationale for selection of the magnitude and uncertainty scores in Table 4-7 is as follows:

- Field surveys for mammals within the AOI:
  - Low magnitude: a diversity of mammalian species may be found in the diverse habitats present in the AOI;
  - High uncertainty due to natural variability and measurement error: data were qualitative; more observations generally are available for larger species (*e.g.*, deer) and at low elevations; however, the LOR 3 modelling did not suggest risks from direct exposure to PCOCs for any non-listed mammals; and,
  - Low support for adverse effects predicted by the Conceptual Models: neither direct (Conceptual Model 1) nor indirect effects (Conceptual Model 2) are supported by the data.

- Availability of suitable habitat:
  - Low magnitude: there are large areas of undisturbed forest, with no roads or other developments, which is uncommon in BC, particularly at low elevations (Appendix D); conifer cover is increasing; diverse mammalian species are present in the various habitats;
  - Moderate uncertainty due to natural variability and measurement error: habitat suitability was assessed for only a few species; habitat requirements are generally known; changes in wildlife use by season was considered; and,
  - Low support for adverse effects predicted by the Conceptual Models: mammalian communities were affected previously, but many species have adapted to the present habitats or have dispersed from other habitats to the habitats available in the AOI (Appendix D).

- Soil invertebrate abundance and density:
  - Low magnitude: there was no difference in the numbers of invertebrates (individuals or orders) with PCOC concentration in soil. Earthworms were found where expected;
  - Moderate uncertainty due to natural variability and measurement error because of the limited range of PCOC concentrations and habitats covered by the studies; and,
  - Low support for adverse effects predicted by the Conceptual Models: the evidence was limited and not consistent with the hypotheses of either direct or indirect effects caused by toxicity of PCOCs to invertebrates and subsequent food-web related changes.

Decision Regarding The Need for Analysis of Causation

Because indirect effects *via* food web interactions and smelter-related changes in vegetation were classified as "adverse effects unlikely", no causal analysis (SALE Step 5) was conducted for mammalian communities.

4.5.4 Risk Characterization for Mammalian Wildlife

The mammalian wildlife community was evaluated under three risk management objectives related to minimizing direct and indirect effects on populations of wildlife in wildland, urban and agricultural areas. Agricultural areas are not intended to provide wildlife habitat (and sometimes actively discourage wildlife use). It is unlikely that agricultural or urban areas would be managed to improve mammalian wildlife habitat suitability.

The assessment endpoints for mammalian wildlife were "population persistence", "habitat utilization" and "habitat suitability". No unacceptable direct toxicity risks were predicted for mammals. Similar to birds, it can be expected that mammalian populations and communities are influenced by the habitats present in the AOI. A formal habitat evaluation was not conducted for mammals, except the white-tailed deer and river otter.

4.6 Conclusions and Recommendations Related to Risk Management for Avian and Mammalian Wildlife

The SALE evaluation related to risks to American robin, the avian community and the mammalian community indicated that the risk management objectives are being met in the AOI. Suitable habitat is present for American robins, and that habitat is being utilized by American robin populations in the AOI. A diversity of avian and mammalian populations persists in the AOI, utilizing the diverse habitats that are available. Therefore, risk management is not indicated for avian or mammalian wildlife (Table 4-8). Stakeholder consultation will be required to discuss and evaluate trade-offs associated with risk management of vegetation communities where smelter-related effects on vegetation persist because some of these areas provide habitat for valued species.

Table 4-8 Recommendations Related to Risk Management for Objectives 4, 5 and 6 (Wildlife in Wildland, Urban and Agricultural Areas)

Objective	*Community*	*Recommendation*[a]
4: Wildlife in Wildlands	Birds	None
	Mammals	None
5: Wildlife in Urban Areas	Birds	None
	Mammals	None
6: Wildlife in Agricultural Areas	Birds	None
	Mammals	None

[a] No risk management recommended. However, consideration should be given in the Wide Area Remediation Plan to the influence of management of plant communities on wildlife.

5.0 ASSESSMENT OF RISKS TO EVALUATE OBJECTIVE 7 RELATED TO THREATENED AND ENDANGERED WILDLIFE

The assessment of risks to threatened and endangered wildlife includes an introduction (Section 5.1), the direct toxicity screening (Section 5.2), the SALE evaluation (Section 5.3), risk characterization (Section 5.4), and a summary of conclusions and recommendations (Section 5.5).

5.1 Introduction

Threatened and endangered species are ranked and Listed according to their status in B.C., based on criteria developed by international experts. Red-listed species include indigenous species that are or may be extirpated, endangered or threatened in B.C. Blue-listed species are indigenous species of special concern (formerly termed vulnerable). Species become Listed Species for many reasons, including: occurrence at the limit of their range; habitat loss or fragmentation; *etc*.

In all aspects of the field work and interpretation, both the Federal and Provincial Listed species were included and considered. The ERA evaluated both Red-listed and Blue-listed species. While it is acknowledged that if only "threatened and endangered" species were evaluated, only Red-listed species would be assessed, it was considered important to evaluate species of special concern as well. Therefore, both Red- and Blue-Listed species were treated the same under this objective.

The objective related to threatened and endangered wildlife species (referred to in this section as Listed Species) is:

7) Prevent, now and in the future, smelter operation-related direct and indirect effects on individual organisms of threatened and endangered (Listed) wildlife species in the Area of Interest.

The assessment endpoints used to evaluate this objective are:
- Presence of Listed Species;
- Survival and reproduction of individuals of Listed Species; and,
- Habitat suitability for Listed Species.

Three lines of evidence were used to assess the assessment endpoints:

- Line of Evidence #1: prey diversity and abundance (*i.e*., soil invertebrate, benthic invertebrate, and forage fish diversity and abundance measures);
- Line of Evidence #2: records of Red and Blue Listed species presence in the AOI; and,
- Line of Evidence #3: knowledge of the presence of suitable habitat in the AOI.

The data used to evaluate these LOE were taken from several sources, as summarized in:

- Golder (2007a) Terrestrial Resources report;
- Cooper and Enns (2003) Red and Blue Listed Species report;
- Machmer *et al*. (2006) Pend d'Oreille Wildlife Management Plan; and,
- Enns (2007b) Listed Species in the AOI memorandum (Appendix E).

The national and provincial lists of Listed Species are continuously changing as more information is collected. A cut-off date for considering these changes was needed in order to complete the ERA. Therefore, the species assessed under this objective were selected from the list available in 2005. Other Listed Species (*e.g.,* American badger, western screech owl, yellow-breasted chat, lark sparrow) were considered earlier in the ERA study (LBC, 2003). See additional information in Enns (2007b) in Appendix E.

Listed wildlife are highlighted separately because the modelling of Listed wildlife species is done slightly differently (related to selection of TRV) than for non-listed populations of wildlife. Listed plant species/communities are considered under Objective 1. The approach to treating the plant community as a whole, including Listed plants, was reviewed and accepted during the management goal and objective development process.

As part of the field work on vegetation for the mapping and during the soil sample survey, records for Listed plant species were compiled for the ERA. Other studies that took place within the ERA Area of Interest also were referenced (Dulisse and Wood, 2000; Enns, 2006) and records from the Conservation Data Centre were reviewed. Rare plant occurrences appear to be increasing, especially rare grasses, and efforts to re-introduce them in some areas are currently underway, including collection of seed from rare plants and reintroduction in the AOI (Enns, 2007c). *Hesperstipa spartea* is an example of a red listed rare grass that was likely introduced by reclamation grass seed mixes.

5.2 SALE Step 1: Direct Toxicity Screening

Avian and mammalian Listed Species were identified and reviewed for recommendation as receptors for the ERA (LBC, 2003). Five birds and one mammal were recommended: bobolink, canyon wren, great blue heron, Lewis's woodpecker, white-throated swift and Townsend's big-eared bat.

Direct toxicity screening was conducted through the use of a series of increasingly refined risk models. There were three levels of refinement (LOR) used, starting with a highly conservative model (LOR1) and ending with a model that incorporated more realistic assumptions regarding exposure (LOR3) (Intrinsik, 2007).

At the end of LOR3, risks from direct toxicity of PCOCs in soil, water and food were ruled out for great blue heron (Intrinsik, 2007). For the five remaining species, exposures were compared to a variety of alternative toxicity reference values (TRVs) (Intrinsik, 2007).

Alternative TRVs were considered for several reasons. First, there is no single standard approach for TRV development; therefore, a conservative approach was used to derive the TRVs for use in the wildlife modelling. Second, the TRVs for Listed Species are based on no-observed-adverse-effect levels (NOAELs) because Listed Species are assessed at the individual organism level, whereas other wildlife receptors are protected mostly at the population level. The dose at which adverse effects would first be observed cannot be determined from a NOAEL. Comparisons between an observed effect level (*e.g.*, an EC20 or LOAEL) and a NOAEL can illustrate the difference between the dose of a metal required to produce an actual effect *versus* an estimated no-effect dose that is subject to potentially large error, depending upon the range of doses used in the toxicity test. Third, TRVs for the same metal can vary because different forms of the metal are used in toxicity tests. The lowest TRVs generally are associated with the most bioavailable forms of metals, which sequential extraction data show are not the dominant forms present in the AOI. In summary, alternate TRVs can provide additional context to the modelled assessment of risks. However, the comparison to alternate TRVs was not used to eliminate receptors from consideration in the SALE analysis.

The results from the LOR3 modelling and comparison to alternate TRVs showed that risks could not be ruled out for the five species, particularly for cadmium. An example is shown in Figures 5-1 and 5-2 for the bobolink exposed to cadmium and zinc, respectively. Similar figures for the other Listed Species are provided in Intrinsik (2007).

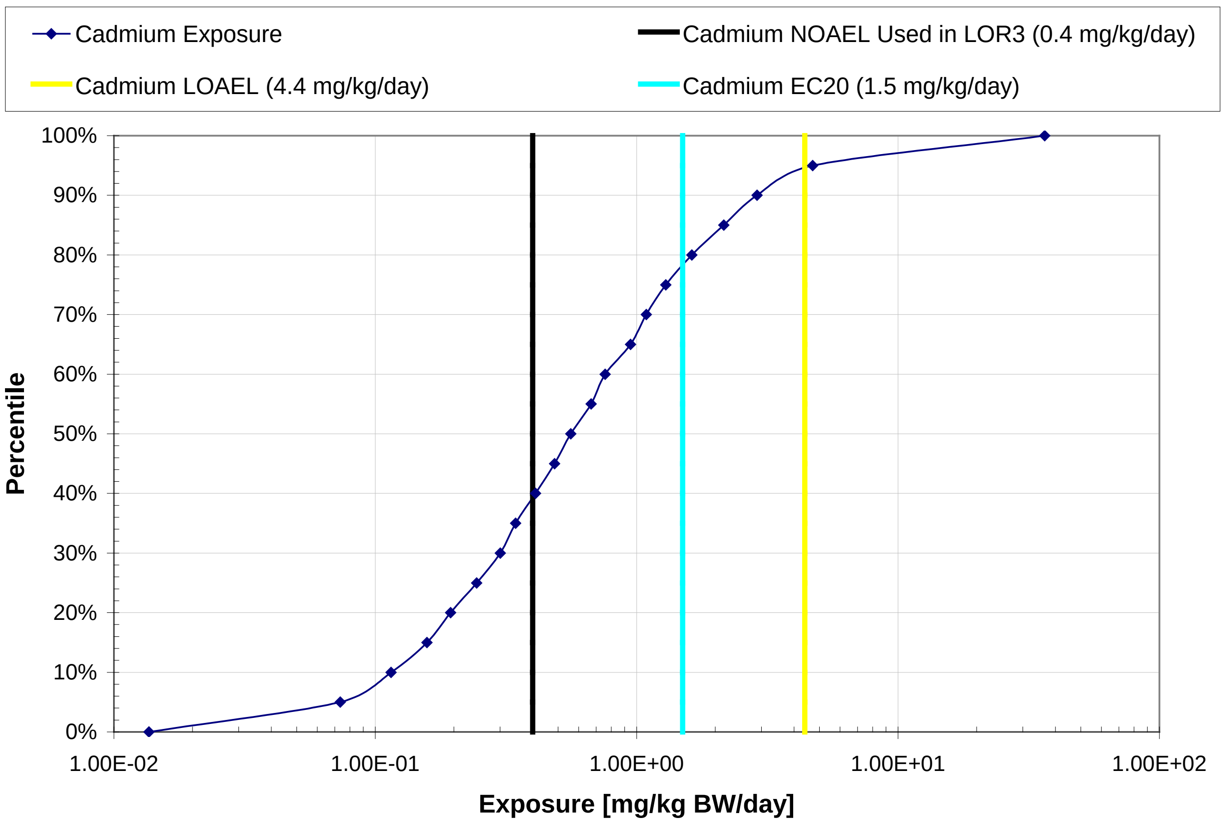


Figure 5-1 Probability that a Bobolink Will Receive a Particular Cadmium Exposure within 5 km of the Smelter

The likelihood of predicted bobolink exposures exceeding the cadmium EC20 is approximately 20%, while that of exceeding the cadmium LOAEL is lower (approximately 5%). The likelihood of exceeding the zinc EC20 or LOAEL is less than 5%. Therefore, unacceptable risks to the bobolink could not be ruled out. The results were similar for the other species, where risks could not be ruled out, particularly for cadmium within 5 km of the smelter (risks decreased with increasing distance from the smelter). The probabilities of exceeding the cadmium TRVs were between 20 and 50%, except for Lewis's woodpecker, for which the probability was 10%.

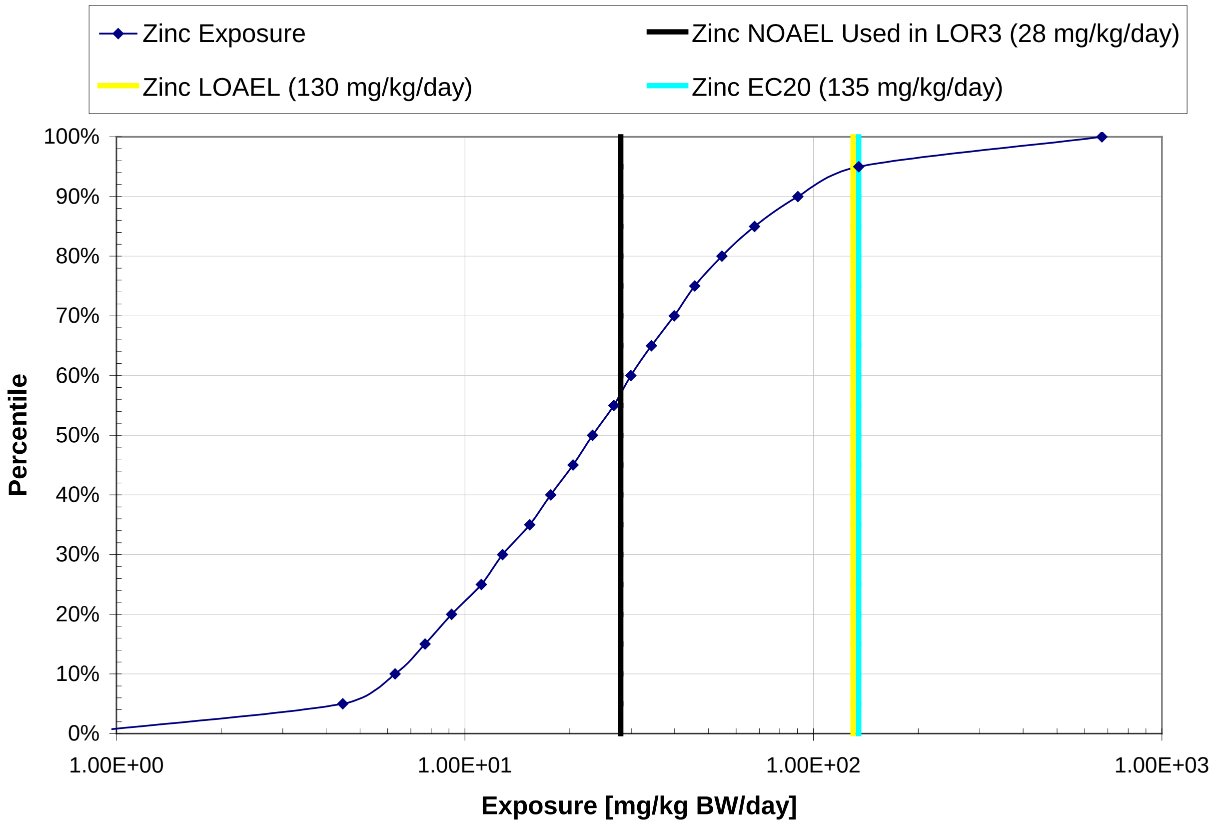


Figure 5-2 Probability that a Bobolink Will Receive a Particular Zinc Exposure within 5 km of the Smelter

5.3 SALE Steps 2-4: Magnitude of Response and Uncertainty

SALE Steps 2 to 4 include the assessment of the magnitude and uncertainty related to indirect effects and field evidence of effects. This assessment was conducted for five of the six Listed Species evaluated for direct toxicity (white-throated swift is no longer Listed) plus all Listed Species as of 2005.

Generally, Listed Species are declining throughout their range in various parts of North America (National Research Council. 1995). The records for Listed Species in the Trail area were reviewed and compared to the neighbouring wildlife sanctuary at Creston to the east, and prime habitat for Listed Species at Christina Lake, to the west (Enns and Enns 2006). The records were compiled from various sources (Biodiversity Centre for Wildlife Studies, 2007; BC Conservation Data Centre, 2006; Dulisse, 1999; Fraser *et al*. 1999; Schaeffer *et al*., 2002; Machmer and Steeger, 2005; and others). There were records for 34 Listed Species for the Area of Interest in comparison to 47 at the Creston Wildlife Sanctuary[1]. The AOI also has 7 unique records, of species not found at either Creston or Christina Lake. Therefore, there is a surprising number of records for Listed Species in the area around Trail, despite the fact that habitat had been destroyed for all species in the vicinity of the smelter from the late 1890s to the mid-1930s. The habitat capability and suitability for the Listed Species in the low elevation areas near Trail is of very high relative quality, largely due to the fact that large areas remain

[1] Abundance of individual Listed Species is much higher at Creston, with a longer period of actual record taking, and it is possible that not all records for Creston were compiled in Enns and Enns (2006).

undisturbed by roads or development, and intact undisturbed mixwood forests, massive cliffs, and abundant water resources are available. For example grizzly bear occurs at low elevation in the AOI, which is unique in southern B.C. and is likely due to the large area of undisturbed habitat from the height of land to the Columbia River valley bottom, a situation that is no longer common throughout southern B.C. Most low elevation habitats (including the Okanagan and the Creston Valley) are fragmented with multiple disturbances to habitat.

The SALE evaluation relied on documentation based on collected records taken by local and provincial biologists in the AOI. Documentation included published records in Provincial status reports and other published and non-published documents (referenced in Enns and Enns, 2006). This level of information is often all that is available for Listed Species in B.C. It is a characteristic of Listed Species to have few records or noted occurrences, and an absence of detailed and comprehensive fieldwork directed at locating populations or individuals.

5.3.1 Assessment of Evidence for Indirect Effects

Magnitude of Indirect Effects

In this ERA, indirect effects are considered to be direct effects of PCOCs on predators, prey and other food items, and effects on the suitability of physical habitat of a species *via* smelter-related changes to vegetation communities and other biophysical attributes. No unacceptable direct toxicity risks were predicted for avian or mammalian predators in the AOI (Cantox Environmental, 2003a; Intrinsik, 2007). Therefore, indirect effects due to changes in predator abundance are not considered further.

Effects of PCOCs on terrestrial invertebrates (a major food source for five of the species) were assessed in Section 4.3.1. The data and analyses suggest that there is only a very weak relationship between soil invertebrate diversity and metals in soil. The magnitude of response *via* changes in soil invertebrate food supply was judged to be low.

Effects on great blue heron diet sources (*e.g.*, fish, benthos, small mammals) were addressed in LOR2 and LOR3 for small mammals (no unacceptable risks predicted) and in the aquatic ERA. Although risks to forage fish in wetland areas have not been quantified (Golder and Intrinsik, 2007), great blue heron occur in the Columbia River drainage near Trail, but do not make significant use of wetlands in the AOI due to the small size and limited extent of wetland habitats (Appendix E). The aquatic ERA (Golder, 2007c) concluded that the risk management objective for forage fish populations in the AOI was being met; *i.e.*, that there were no unacceptable smelter-related direct or indirect risks to forage fish. The aquatic ERA found that the risk management objective for benthic invertebrates was not being met at two sites. These sites were the Maglios site – a very small depositional area about 1.5 km downstream of the smelter, and the Waneta site – a depositional area within the Waneta eddy immediately upstream of the U.S. border. A third site at Fort Sheppard (a small shoreline area adjacent to the Fort Sheppard eddy) had conflicting evidence for smelter-related risks. The total benthic invertebrate habitat represented by these three sites is a small proportion of the total benthic habitat in the AOI (much less than 0.1%). Therefore, it is highly unlikely that a significant reduction or shift in the composition of the benthic invertebrate food supply for great blue heron in the AOI would be caused by the smelter-related effects on benthic invertebrates in these three areas.

Effects on physical habitat *via* smelter-related changes to the plant community were considered. Impacts on plant communities *per se* are assessed in Section 3.0. Habitat-related impacts specific to selected Listed Species are described below.

Habitat suitability was evaluated qualitatively for 21 Listed Species. Changes in habitat (either positive or negative) resulting from past (higher) smelter emissions, as well as changes likely to result from current and future (lower) emissions are described in Table 5-1. Detailed information is provided for five of the six Listed Species assessed in LOR3 (white-throated swift is no longer considered a Listed Species). The information below has been extracted from Machmer *et al*. (2006), Cooper and Enns (2003) and Enns (2007b).

Table 5-1 Changes in Habitat from Past, Current and Future Smelter Emissions

Listed Species	***Changes from Past Emissions***	***Changes from Current and Future Emissions***
Western Skink	Negligible. Removed vegetation and exposed bedrock to weathering.	Negligible. Rock outcrop vegetation cover and abundance have increased since the 1970s. Rock rubble and other choice habitats for Western Skink will likely be maintained in the future because of the intrinsic control that bedrock has on vegetation character.
Rubber Boa	Positive. Past emissions may have kept habitats open and shrubby, which is preferred by this species.	Positive. Forest crown closure may increase downed woody debris (used by this species) but will also cause overgrowth of some of the chaparral type habitat, preferred by this species, over time. Eventually crown closure and increasing conifer cover may exclude this species from some of its habitats. This is due to recovery from past emissions.
Racer	Positive. Emissions influenced the openness of the habitat, but other influences likely more important.	Negligible because they are found in various open habitats.
Townsend's Big-eared Bat	Negligible. Use of habitats (caves, mine sites, rock outcrops) is independent of smelter effects	Negligible. Most habitat features are independent of smelter impacts.
Grizzly Bear	Negative. Created habitats that were too open for this species.	Negligible. Most restrictions to use of habitat are related to disturbance that is not related to emissions. Habitat has recovered to early seral stages required by this species.
American Badger	Positive. Smelter emissions may have increased habitat by creating open areas and allowing increase of prey species.	Negative. Increased crown closure and increased conifer cover in forests over time may decrease some habitat availability through eventual loss of habitat for its main prey, Columbia ground squirrel. However, squirrel numbers have increased in the area.
Rocky Mountain Big-horned Sheep	Negative. Emissions may have influenced the openness of the habitat, but other influences such as urban development and disturbance in their prime open rocky habitats near the smelter, are likely more important.	Negligible. Habitat is very common but status of species in the AOI is poorly known. Only one record collected during the ERA fieldwork was found.
Western Grebe	Negligible. Does not breed in area; uses area for feeding and resting.	Negligible. Does not breed in area; uses area for feeding and resting.
Double-crested Cormorant	Negligible. Does not breed in area; uses area for resting.	Negligible. Does not breed in area; uses area for resting.
Great Blue Heron	Negative. Large cottonwood trees that could be used for rookeries may have been impacted.	Negligible. Emissions are not likely to restrict the use of habitats in the area. Also, numbers of cottonwood trees and their sizes are increasing.
Surf Scoter	Negligible. Infrequent user of river waters.	Negligible. Infrequent user of river waters.

Table 5-1 Changes in Habitat from Past, Current and Future Smelter Emissions

Listed Species	***Changes from Past Emissions***	***Changes from Current and Future Emissions***
Broad-winged Hawk	Negative. Past emissions and fire may have prevented the development of more mature structural stages used for breeding.	Negligible. Hardwood and mixed wood forests unlikely to be impacted by current or future emissions.
California Gull	Negligible. Does not breed in area; uses area for resting while on migration route.	Negligible. Does not breed in area; uses area for resting while on migration route.
Caspian Tern	Negligible. Does not breed in area; uses area for resting while on migration route.	Negligible. Does not breed in area; uses area for resting while on migration route.
Western Screech Owl	Negative. Past emissions may have impacted the maturation of riparian trees needed by large-cavity nesters.	Negligible because emissions will not continue to impact maturation of riparian trees preferred by this species.
Lewis' Woodpecker	Negative. Past emissions may have impacted the availability of trees needed by large-cavity nesters.	Negligible. Other impacts such as fire suppression may be more important.
Barn Swallow	Negligible. Use of habitat is independent of smelter impacts.	Negligible. Use of habitat is independent of smelter impacts.
Canyon Wren	Negative. Cliff faces may have been kept too open for this species.	Positive. Emissions are low enough to allow increased cover on cliffs.
Yellow-breasted Chat	Positive. Habitat (shrubby, open areas) was created by fire, emissions, *etc*.	Negative. Habitat may decrease with decreased emissions.
Lark Sparrow	Positive. Emissions may have resulted in increased habitat (open areas, grasslands).	Negligible. Habitat may become more vegetated, but habitat availability is generally independent of smelter emissions.
Bobolink	Negative. Emissions may have increased drying trends in grasslands.	Negligible. Agricultural land management is the major influence on the supply of habitat. This land use generally is declining in the AOI.

Townsend's Big-eared Bat:

This species is classified as "blue-listed" in BC, and has not been classified by the Government of Canada (Committee on the Status of Endangered Wildlife in Canada [COSEWIC]). It is associated with arid grassland habitat, and prefers low-elevation areas. Its distribution is strongly correlated with caves and cave-like roosts, and it feeds for insects in open habitats. The essential habitat elements for this species include: cliffs, caves, rocky outcrops and ridges, rock crevices; adjacent to forest/woodlands and shrubland or grasslands; and, rivers and streams, pools, lakes/ponds/reservoirs, riverine wetlands, marshes (Blood, 1998). Maintenance of wetlands or other open areas for foraging is important to this species. This species has been found in the Pend d'Oreille and Fort Sheppard areas (Schaeffer et al., 2002; Machmer *et al*., 2006). Smelter emissions are unlikely to have had a significant adverse effect on physical habitat of this species because of its preference for massive rock features adjacent to rivers and open vegetation. These features are independent of smelter effects (Appendix E). It is possible that noise and disturbance from the smelter and the City of Trail have restricted Townsend's big-eared bat from using highly suitable habitat for this species adjacent to the smelter but this exclusion is not caused by emissions-related direct or indirect impacts.

Bobolink:

This species is classified as "blue-listed" in BC, and has not been classified by COSEWIC. This species frequents moist fields and agricultural lands such as pastures and hayfields. Only small numbers occur in the AOI, in open, abandoned farm fields along the valley bottom to the south of the smelter. Bobolink forages on seeds and insects and nest on the ground in grassy fields. Habitat for this species is considered limited in the AOI, due to the lack of extensive wet meadows and farmland (Cooper and Enns, 2003). Bobolink were present in the abandoned farmland and irrigated farmland of the AOI through the high smelter impact period of the 1930s. They may be less prevalent now due to urban expansion and abandonment of some types of farming in the AOI (Appendix E). The future expansion of farmland and grassland beyond what is currently available for this species is unpredictable. An increase in farm development may expand or limit the potential for breeding in the AOI, depending on land management but this is not influenced by smelter emissions (Cooper and Enns, 2003). Smelter-related effects on vegetation communities do not coincide with the habitat requirements for bobolink. The occurrence of farmland and wet meadows is not correlated with smelter emissions, but rather on valley bottom soils capability to support wet, grass-dominated vegetation and on long-term land use patterns. The soils of the valley bottom consist of sands or silt-sands, which are occasionally bouldery, and very well drained. Grasses and open grassland areas are common in the AOI, but the moister grassland types preferred by bobolink are not common, and are dependent on irrigation. Therefore the population dynamics of this species are independent of the past or present smelter emissions (Appendix E).

Canyon Wren:

This species is classified as “blue-listed” in BC, and classified as “not at risk” by COSEWIC. This species is restricted to dry, rocky habitats along valley bottoms in the AOI. It is known to occur among the massive cliffs directly northeast of the smelter, and is likely a year-round resident at Fort Sheppard. Canyon wrens are secretive birds and are difficult to detect (Campbell et al. 1997; Cannings, 1995). They forage on a variety of insects in rocky talus at the base of cliffs. Nests are built inside a rock crevice or ledge within the talus (Cooper and Enns, 2003). There is abundant, high-suitability habitat in the AOI and they do occur at the northern edge of the AOI. Historic smelter emissions may have increased the presence of dry rocky habitats due to the elimination of vegetative cover, followed by erosion (*i.e*., cliff faces were in too open a condition near the smelter for this species). Smelter emissions are now reduced enough to allow increased vegetation cover on cliffs (Appendix E). Habitat use by canyon wren of massive cliffs near the smelter may be restricted by noise and disturbance, as noted above for Townsend’s big-eared bat; however these factors are not related to emissions, either directly or indirectly.

White-throated Swift:

This species was classified as “blue-listed” in BC, but recently was downgraded and no longer is considered a Species at Risk. It also has not been classified by COSEWIC. This species forages aerially on small insects and nests in vertical cliffs. There is only one record for white-throated swift at a site with massive cliffs near Castlegar (Campbell *et al*., 1990), to the north of the AOI. Although the habitat structure near the smelter may be suitable for white-throated swift, the climate is possibly too wet for this species. It is more commonly found in the very hot and dry habitats of the Okanagan and Kamloops areas of B.C. (Campbell *et al*., 1990). It is unlikely that smelter emissions have had a significant adverse effect on physical habitat of this species (Cooper and Enns, 2003).

Great Blue Heron:

The interior subspecies of the great blue heron is blue-listed in BC but has not been assessed by COSEWIC (although the coastal subspecies is listed by COSEWIC as a species of Special Concern). This species forages in wetlands and open fields where it preys mainly on fish, small mammals, amphibians, nestling birds and aquatic insects. Feeding sites are limited in the AOI (Cooper and Enns, 2003). Great blue heron nest in large trees along rivers or lake edges. The numbers of this species are known to be increasing in the AOI and its habitat is improving as large cottonwood trees are rapidly growing in several areas. Cottonwoods on fluvial material at China Creek and Sullivan Creek have potential as sites for heron colonies. The small fluvial fan at Beaver Creek may have been important before most of the cottonwoods were removed. There also is potential habitat along Sheppard Creek (Cooper and Enns, 2003). Previous impacts on habitat (*e.g*., loss of riparian habitat diversity, loss of large trees on the river bank, and on gravel bars) may have resulted from both flooding (due to hydro-electric development) and from smelter emissions (Appendix E). Because wetlands in the AOI are small, rock-controlled and mostly far away from the main source of food in the valley (the Columbia River), wetlands are not used as much by great blue heron as might be expected (Appendix E).

Lewis's Woodpecker:

This species is blue-listed in BC and is listed by COSEWIC as a species of Special Concern. Foraging habitat includes open areas with diverse shrub and herb layers for insect production. Foraging habitat is widely available in the AOI, especially in the Sheppard Flats area, on the east side of the Columbia River at Castlegar and in open areas near Trail. Records for Lewis's woodpecker occur at Sheppard Flats and in Castlegar; the latter record was for nesting in urban habitat. Nesting habitat includes areas of mature Douglas-fir, ponderosa pine, and riparian forests with larger trees with defects (large snags, or live trees with defects, often caused by lightning). Nesting habitat is present at both the north and south boundaries of the AOI. The scarcity of large suitable nest trees that are adjacent to good foraging habitat has limited the numbers of this species in the AOI (Cooper and Enns, 2003). Seral stages in the AOI are almost exclusively young forests (structural class 5 or younger/smaller. The Lewis's woodpecker has been observed in the Pend d'Oreille area, and single active nests were known previously from Beaver Creek Provincial Park and fields near the Trimac Reload Facility in the lower Columbia Valley (Machmer *et al*., 2006). Open forest with suitable large, dead and decaying ponderosa pine and cottonwood trees would be most suitable nesting habitat for Lewis's woodpecker (Machmer *et al*., 2006). These areas are limited within the AOI, due to the past effects of logging and fire, primarily. However, there are areas where habitat maintenance or enhancement could be conducted (Machmer *et al*., 2006).

Because Lewis' woodpecker needs large half-dead or fire-killed Ponderosa pine, previous effects of the smelter may have actually been positive for this species in the past (as far as the creation of nesting sites) (Appendix E). Possible effects of past smelter emissions on woodpecker habitat also include a shift to western white pine due to a reduction in infestations of this species with blister rust (due to the historic reduction in the secondary host for this disease – the sulphur dioxide-sensitive current (*Ribes*.)). Western white pine are now reaching the size associated with cavity nesters; however, they are not preferred by cavity nesters because they contain copious amounts of pitch. Resinosis could increase with decreasing emissions, causing further exclusion of use of white pine by cavity nesters (Appendix E).

<u>Uncertainty With Respect to Indirect Effects</u>

In summary, the physical habitat requirements for these species are well known and do not appear to coincide with areas shown to have been affected by smelter-related emissions except for great blue heron and Lewis' woodpecker. However, the habitat features required by each species may be too small-scale to be easily identified or mapped in the AOI. Also, surveys have not been conducted specifically for these species in most of the AOI, and they may be present in greater abundance and frequency of occurrence than indicated from the standard wildlife transects done for the ERA. Therefore, the abundance of habitat and the utilization of habitat by these species are not well known. It is worth noting that where additional work has been done, red-listed and blue-listed species have been found in the AOI.

There is low uncertainty with respect to the predicted lack of direct toxicity to predator and mammalian prey species because this evaluation is based upon the LOR3 modelling (Intrinsik, 2007).

There is low uncertainty with respect to predicted lack of effects on forage fish populations (part of the diet of great blue heron) in the Columbia River and its tributaries based on the aquatic risk assessment (Golder, 2007c). However, there is high uncertainty related to potential impacts to forage fish in wetlands (Golder and Intrinsik, 2007), although wetlands are not important areas for great blue heron to forage (Appendix E).

There is low to moderate uncertainty related to the measurement error and understanding of natural variability in soil invertebrate (*i.e.*, a component of the diet of Listed Species) abundance and community structure. As explained in Section 4.0, the 2004 evaluation of invertebrate composition and PCOC concentrations in invertebrates and forage was restricted to a single low-elevation zone and a single vegetation cover-type. Identification of invertebrates was only to Order, and in some cases, only to the Class level, which limited the scope of comparisons among sample sites. There was only one season of sampling, and the full PCOC concentration gradient in soil was not represented. The total number of sampling sites and the number of samples within each site were not sufficient to produce high statistical power; therefore, there is a lower probability that differences across the PCOC gradient could be distinguished from natural variability. Important confounding variables (natural habitat characteristics and anthropogenic stressors not related to the smelter) were not always observed and/or measured. The earlier study conducted by Brusven in 2000 covered a wider concentration gradient of PCOCs in soil and included several vegetation cover types; however, it also was a single-season survey only.

There is low uncertainty related to the measurement error and understanding of natural variability in benthic invertebrate abundance and community structure (Golder, 2007c). As explained above, the localized smelter-related effects on benthic invertebrate communities at three sites in the Columbia River represent a very small portion of total invertebrate habitat; therefore, effects on aquatic invertebrate prey availability, either as aquatic larvae or aerial adults, are highly unlikely.

There is low confidence in the validity of Conceptual Model 2 with respect to the predicted indirect effects on Listed wildlife species *via* changes in invertebrate food supply. The available evidence does not support adverse impacts *via* this pathway; however, overall uncertainty related to this evidence is moderate.

The uncertainty due to measurement error and natural variability in habitat suitability for Listed wildlife species is low to moderate because habitat requirements are well known but there was little or no formal field work for these species.

Confidence in Conceptual Model 2 with respect to habitat is difficult to ascertain because of the lack of quantitative analysis of habitat suitability for Listed wildlife species in the AOI. Past indirect effects due to smelter-related alteration or elimination of vegetation have occurred for some species. However, current qualitative evaluation indicates no adverse indirect effects are expected in the AOI because the habitat requirements for the Listed Species are unrelated to the observed residual effects on vegetation or other biophysical components.

5.3.2 Assessment of Evidence from Field Surveys

Formal field surveys were not conducted for Listed Species in the AOI as part of the ERA. All of the species listed in Section 5.3 are known to occur in or just outside of the AOI because of records gathered by observers living or working within the AOI. However, there are few data regarding abundance or habitat utilization patterns of these species in the AOI. The limited amount of information on presence of each species is as follows:

Townsend's Big-eared Bat:

This species has been found in the Pend d'Oreille, Fort Sheppard (Machmer *et al*., 2006), Casino and Columbia Gardens (Appendix E).

Bobolink:

Small numbers of this species occur in the AOI, in farm fields along the valley bottom (Cooper and Enns, 2003). Six records exist for Columbia Gardens, Fruitvale and Trail in the 1980s (Appendix E).

Canyon Wren:

This species is known to occur among the massive cliffs directly northeast of the smelter, and is likely a year-round resident at Fort Sheppard (Cooper and Enns, 2003).

Great Blue Heron:

Great blue heron has the largest number of records of any of the Listed Species in the AOI; there are 165 records for this species in the AOI between 1980 and 2002, at Beaver Creek Provincial Park, Columbia Gardens, East Trail, Trail, Fruitvale, Rossland (1 record only), Waneta and West Trail (Appendix E). Machmer and Steeger (2005) also have records of great blue herons near the Waneta Dam. The numbers of this species are known to be increasing in the AOI and its habitat is improving as large cottonwood is rapidly growing in several areas (Cooper and Enns, 2003). No active nesting colonies in the AOI were reported in a recent status report (Grebauer and Moul, 2001). Feeding has been observed at Waterloo Eddy, Zuckerberg Island and on the alluvial fan below the college (Cooper and Enns, 2003).

White-throated Swift:

There is one record for white-throated swift to the north of the AOI. Although the habitat structure near the smelter may be suitable, the climate may not be what this species requires.

Lewis's Woodpecker:

The scarcity of suitable nest trees with areas that are good foraging habitat likely have limited the numbers of this species in the AOI (Cooper and Enns, 2003). There are 19 records for this species at Beaver Creek Provincial Park, Columbia Gardens, Fruitvale, Rossland, Trail, Waneta, Selkirk College and at Castlegar from 1980 to 2006 (Appendix E). The Lewis's woodpecker has been observed both nesting and foraging in the AOI near the Waneta Dam (Machmer and Steeger, 2005) and at Castlegar. Single active nests were known previously from Beaver Creek Provincial Park and fields near the Trimac Reload Facility in the lower Columbia Valley (Machmer *et al*., 2006).

Uncertainty with Respect to Field Surveys

There is moderate uncertainty regarding Listed Species presence in the AOI and specifically near the smelter. The main reason for this uncertainty is the lack of systematic surveys directed at determining the occurrence of Red- or Blue-listed species with the exception of the Sheppard Flats and Pend D'Oreille areas at the southern end of the AOI (Appendix E). Analysis of records for Listed Species shows that records tend to occur where there have been recorders (Appendix E), in other words, when people look for Listed Species in the AOI, they find them. Therefore, there is low confidence in the validity of Conceptual Model 1 with respect to direct effects of PCOCs on Listed Species.

5.3.3 Summary of Magnitude and Uncertainty Assessment

The assessment of magnitude for Listed Species did not follow the same procedure as that used for other wildlife because of the lack of quantitative data (and therefore the lack of any basis for a statistical definition of magnitude or uncertainty). The exceptions were for effects on the invertebrate food supply, where magnitude was rated according to the statistical evidence for differences among categories of soil metal concentrations (see Section 4.0), or statistical evidence for differences among sampling stations along a gradient of exposure in the Columbia River (benthic invertebrates and forage fish) (Golder, 2007c).

Magnitude of response for habitat was evaluated by: (1) noting the presence of suitable habitat within the AOI for each species and whether this habitat is increasing or decreasing; (2) noting whether suitable habitat is present close to the smelter (where PCOC concentrations are highest); (3) referring to the results of the analysis of smelter-related effects on vegetation communities from Section 3.0 to examine whether the habitat required by the Listed Species coincides with areas shown to be affected; and, (4) noting the qualitative evidence for the presence of the Listed Species within the AOI, including close to the smelter.

The available evidence for magnitude (Table 5-2) indicates:

- The magnitude of indirect effects *via* changes in food supply is low;
- Suitable habitat is abundant or increasing in the AOI for canyon wren, great blue heron and white-throated swift;
- Suitable habitat occurs near the smelter where PCOC concentrations are highest for Townsend's big-eared bat, great blue heron, Lewis' woodpecker, white-throated swift and canyon wren;
- Suitable habitat and smelter-related effects on habitat coincide for great blue heron and Lewis' woodpecker, but not for the other species; and,
- Great blue heron, Lewis' woodpecker and canyon wren are known to occur relatively near the smelter, as well as other areas, whereas the other species have not been observed near the smelter, but are present in or just outside of the AOI.

The uncertainty associated with indirect effects of smelter emissions on food resources is moderate for Townsend's big-eared bat, canyon wren and white-throated swift, but low for the other species.

There is generally low uncertainty associated with the presence of suitable habitat in the AOI as well as whether habitat requirements coincide with smelter-related effects on vegetation communities. Although habitat suitability surveys or mapping for Listed Species have not been conducted, there are several sources of qualitative, observational information on habitat presence within the AOI. Therefore, uncertainty was rated as low to moderate.

There is moderate uncertainty associated with the presence of the Listed Species within the AOI. There have been no formal surveys focussed on documenting the presence of these species; however, there are several sources of observational information on the presence of these species. There is no information on abundance of these species in the AOI.

5.4 Risk Characterization

Risks to each Listed Species were evaluated with respect to several lines of evidence (Table 5-2). The available evidence indicates that the risk management objective for most of the Listed wildlife species is being met, with the possible exception of Lewis' woodpecker. The evidence for this includes:

- Canyon wren and white-throated swift have abundant suitable habitat near the smelter, and their foraging habits (on rocky talus at the base of cliffs for wren and aerially on small insects near vertical cliffs for swift) minimize the potential for exposure to PCOCs in soil or soil-based food chains;
- Most of the Townsend's big-eared bat habitat is located farther away from the smelter (*e.g.*, in the Pend d'Oreille) and is not influenced by smelter emissions;
- The number of great blue heron is increasing in the AOI as habitat improves. Risks from wetland areas within the AOI are likely to be low (Golder and Intrinsik, 2007), and wetlands are not used as much as other areas for foraging, as backwaters of the main stem of the Columbia River are preferred (Appendix E);
- Impacts on bobolink habitat suitability are not related to smelter emissions, but more due to agricultural land management, urban development, *etc*. (Appendix E); and,
- Lewis' woodpecker may be limited in the AOI due to the lack of old growth forest availability in the AOI (Cooper and Enns, 2003; Appendix E).

There are significant uncertainties, mostly due to the lack of species occurrence records.

In summary, past indirect effects *via* smelter-related changes in the vegetation community cannot be ruled out for Lewis' woodpecker.

Table 5-2 Magnitude of Response and Associated Uncertainty for Listed Wildlife Species

Species	*Indirect Effects: Effects of Smelter Emissions on Food Resources*		*Indirect Effects: Effects of Smelter Emissions on Habitat*				*Species Presence*		
	*Magnitude **	*Uncertainty*	*Habitat Abundant or Increasing*	*Habitat Occurs Near Smelter*	*Habitat Requirements and Smelter-related Effects on Vegetation Coincide*	*Uncertainty*	*In AOI*	*Near Smelter*	*Uncertainty*
Townsend's Big-Eared Bat	o	??	N	Y	N	?	Y	N	??
Bobolink	o	?	N	N	N	?	Y	N	??
Canyon Wren	o	??	Y	Y	N	??	Y	Y	??
Great Blue Heron	o	?	Y	Y	Y	?	Y	Y	??
Lewis' Woodpecker	o	?	N	Y	Y	?	Y	Y	??
White-throated Swift	o	??	Y	Y	N	?	N (just outside AOI)	N	??

* See Section 4.0 for the full analysis of magnitude of smelter-related effects on terrestrial invertebrate, and the Aquatic ERA (Golder, 2007c) for the full analysis of magnitude of smelter-related effects on forage fish and benthic invertebrates.
o Low magnitude of response
? Low uncertainty
?? Moderate uncertainty
Y Yes
N No

5.5 Conclusions and Recommendation related to Risk Management

Recommendations related to consideration of risk management are summarized in Table 5-3. The highest priority for consideration of risk management is for Lewis's woodpecker, related to availability of suitable nesting habitat. There are areas within the AOI where habitat maintenance or enhancement could be conducted for this species (Machmer *et al*., 2006).

Best management practices for maintaining or enhancing habitat suitability in the Pend d'Oreille for some of the Listed Species are described in Machmer *et al*. (2006). In addition, prior to any risk management activity, a field survey for presence of individuals of Listed Species, as well as an evaluation of habitat suitability for Listed Species, should be conducted at an appropriate scale within the area subject to remediation.

Table 5-3 Recommendations Related to Risk Management for Objective 7 Related to Listed Wildlife Species

Species	***Priority for Consideration of Risk Management***
Townsend's Big-eared Bat	No
Bobolink	No
Canyon Wren	No
Great Blue Heron	No
Lewis's Woodpecker	Yes (Habitat)
White-throated Swift	No

6.0 ASSESSMENT OF RISKS TO EVALUATE OBJECTIVE 8 RELATED TO LIVESTOCK

The assessment of risks to livestock includes an introduction (Section 6.1), the direct toxicity screening (Section 6.2), the SALE evaluation for cattle (Section 6.3), risk characterization (Section 6.4), and a summary of conclusions and recommendations (Section 6.5).

6.1 Introduction

The objective related to livestock is:

8) Prevent, now and in the future, smelter operation-related direct and indirect effects on individual agricultural animals in the Area of Interest.

The assessment endpoints defined to evaluate this objective are:

- Survival, growth, development, and reproduction of individuals of livestock species

Golder (2007a) presents information on soil sampling methods; the surveys given to farmers; chemical and statistical analysis, results, conclusions; and, quality assurance/quality control.

The SALE process was used for evaluation of risks to livestock; however, Step 2 (Indirect Effects) was not used because indirect effects *via* trophic cascade mechanisms or *via* physical changes in habitat suitability do not apply to domestic livestock. Impacts to feed crops are addressed under Objective 3.

6.2 SALE Step 1: Screening

Three types of animals were selected as representatives of domestic livestock: chickens, cattle and horses. Risks to chickens were ruled out in the Level of Refinement 3 (LOR3) risk modelling report (Intrinsik, 2007). Risks to cattle were ruled out in the LOR2 report (Cantox Environmental, 2003a). However, because the risk modelling does not specifically address overall “health” or milk production of dairy cows, a local dairy farmer was interviewed. The dairy farm was selected because there is no other cattle grazing in the Columbia River valley proper (there is some in Fruitvale and the Pend d’Oreille) (Duncan, personal communication July 20, 2006). Risks to horses could not be ruled out *via* conservative LOR2 or LOR3 risk modelling.

Metal concentrations in soil were compared to their respective BC CSR soil standards. The CSR soil standards are conservative to use for screening for potential effects on livestock for these PCOCs. The CSR soil standards for the protection of livestock ingestion of soil and fodder, and groundwater used for livestock watering are presented in Table 6-1.

The portions of the AOI where CSR soil standards are exceeded for one or both of the CSR standards in Table 6-1 are shown in Figure 6-1.

Table 6-1 CSR Soil Standards for Livestock (mg/kg)

	Soil and Fodder Ingestion by Livestock	***Contamination of Groundwater used for Livestock Watering***
Arsenic	25	15
Cadmium	9	2.5 [a]
Copper	150	150 [a]
Lead	350	150 [a]
Mercury	0.6	ns
Zinc	200	150 [a]

[a] Assumes soil pH <5.5
ns Indicates no standard available

The results of the sequential extraction analysis of soils (Golder, 2007a) document relatively low mobility and presumably low bioavailability of PCOCs. Most of the metals in the 17 surface horizon samples analyzed were in the potentially-available fractions (carbonate, oxide, organic) and unavailable fraction (residual). The lowest proportion of metals was in the highly available (water soluble) and available (exchangeable) fractions (Golder, 2007a). Although agricultural soils were not tested, these results suggest that the mobility of metals in natural soils is low. Lower mobility may lead to less leaching of metals into groundwater, and less uptake of metals from soil into crops and forage.

As mentioned earlier, modelling of uptake of PCOCs into forage and assessment of risks to cattle and chickens did not predict unacceptable risks. Risks to horses were ruled out for all PCOCs except lead.

An evaluation of groundwater quality was completed (Golder, 2007b) to determine whether groundwater has been impacted by soil (that is, to determine whether groundwater would be considered safe for livestock watering and crop irrigation). The evaluation included data from 33 wells within the AOI, and 12 wells outside the AOI but near Castlegar, Rossland or Fruitvale. Concentrations of PCOCs were assessed for four time periods: 1972 to 1989; 1990 to 1994; 1995 to 1999; and, 2000 to 2007. Results include:

- No measured concentrations of cadmium, chromium, cobalt, copper, selenium or zinc exceeded the livestock watering (LS) or crop irrigation (IR) standards;
- Detection limits for arsenic, cadmium, mercury and selenium were too high for several samples (between 5 and 30% of samples) to determine whether standards were exceeded;
- One arsenic measurement from outside the AOI (near Rossland) exceeded the LS standard but a sample taken at the same location one month later did not result in an exceedance;
- One mercury measurement from outside the AOI (near Castlegar) exceeded the LS and IR standards (in 1999) but samples taken at the same location in 2002 and 2006 did not result in an exceedance; and,
- One lead measurement within the AOI (Birchbank Golf Course) exceeded the LS and IR standards in 1997 but not in subsequent years.

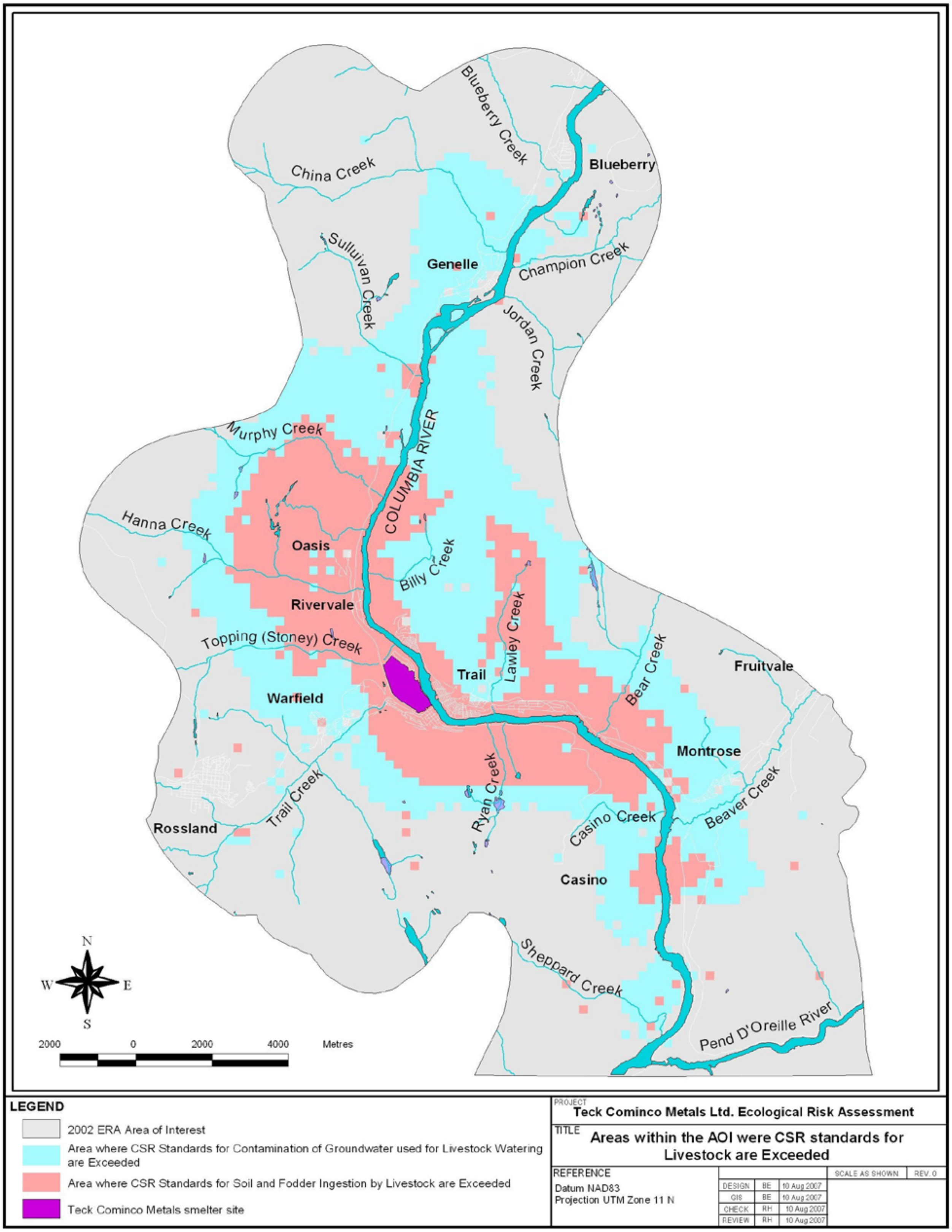


Figure 6-1 Areas Within The AOI Where CSR Standards For Livestock Are Exceeded

There are several uncertainties associated with this screening:

- Metal concentrations in soils of agricultural areas are uncertain (except where samples were taken from specific pastures);
- The mobility and bioavailability of the metals in agricultural soils is unknown (and can be influenced by soil amendments, irrigation, *etc*.), although sequential extraction data from natural soils suggest low mobility;
- Groundwater samples were taken from only 33 wells within the AOI, and predominantly at lower elevations;
- There are no irrigation (IR) and livestock watering (LS) soil standards for selenium; and,
- CSR standards are intended to be conservative and protective. The standards were developed to protect all livestock species, including the most sensitive species. The standards assumed 100% bioavailability of metals, used literature-based uptake factors, and applied uncertainty factors (up to 10-fold) to TRVs. The ERA incorporated bioavailability, used site-specific uptake models, and minimized the use of uncertainty factors for TRVs. Therefore, the screening using the CSR standards may identify areas as potentially causing risk, which the ERA did not predict to adversely impact livestock.

6.3 SALE Step 4: Magnitude of Response for Cattle

The assessment of livestock is complicated in a way similar to that for agricultural crops, in that people can alter the environment that supports livestock as often and almost in any way they like. This alteration can include amending the soil, changing the diet or nutritional supplements of livestock, and other factors that would influence livestock production. Therefore, it is difficult to directly evaluate the influence of smelter emissions on livestock. Instead, a local dairy farmer, who has been farming for 21 years in the Columbia River valley, was interviewed (see summary in Golder, 2007a). Mr. Bouma's farm is the only dairy farm known to be present in the AOI. It is located in the Columbia Gardens area, which is an area with elevated As, Cd, Pb and Zn concentrations in soil (above the LS or IR soil standards; Cu and Hg concentrations do not exceed these standards in this area; Golder, 2007a).

Mr. Bouma was asked several questions related to:

1. Health of cows;
2. Forage and feed for cows;
3. Milk production; and,
4. Concerns about smelter emissions related to cows.

Mr. Bouma irrigates his forage crops (hay and corn) with groundwater, and amends his fields. He reported that the forage crops grow very well. He did not report any incidences of health issues with his livestock (150 head of dairy cattle, two beef cattle and other livestock) during the time he has been in operation. He did report an increase in milk production over the years, and attributed this to improvements in feed and breeding practices.

The magnitude of response can be assessed only qualitatively. No impacts, attributable to the smelter, were identified by the farmer. There are several uncertainties associated with this survey, including the fact that conditions at only one farm were surveyed (although it is the only farm known to exist in the AOI). Responses could have been different at other locations (where metal concentrations in soil or groundwater could be different), and if different farming practices were used (*e.g.*, fewer soil amendments).

6.4 Risk Characterization

Impacts on survival, growth, development and reproduction of individual cattle due to smelter emissions are not predicted, based on the direct toxicity modelling for cattle (Cantox Environmental, 2003a), and the results of the survey with the dairy farmer (Golder, 2007a). Risk modelling for both chickens and cattle considered the full distribution of metal concentrations in soils and assumed all forage and feed was from the area (*i.e*., no supplementation with feed from outside the AOI). Site-specific data for uptake of PCOCs into forage were used in the modelling.

The results of the groundwater quality assessment (Golder, 2007b) combined with the risk modelling (Cantox Environmental 2003a; Intrinsik, 2007) suggest that groundwater quality within the AOI will not adversely impact livestock due to crop irrigation or livestock watering.

Impacts on survival, growth, development and reproduction of individual horses, due to smelter emissions, could not be ruled out in LOR3. The predicted 90^{th} percentile ER = 2 for lead. Comparisons of recent soil and forage data to older data (when impacts on foals were observed) suggest risks are up to 16-fold lower now than in the early 1970s (Intrinsik, 2007). Smelter emissions also are much lower now than in the early 1970s. No additional data or information is available regarding horses and thus no additional SALE analysis could be conducted.

Figure 6-2 Horses at Pasture in the AOI

6.5 Recommendation Related to Risk Management

The risk management objective is being met for chickens and cattle in the AOI. Impacts on chickens and cattle due to smelter emissions are not predicted, based on the direct toxicity modelling as well as the results of the survey with the dairy farmer. The results of the groundwater quality assessment combined with the risk modelling also suggest livestock will not be adversely impacted due to crop irrigation or livestock watering. The risk management objective for horses may not be met under very specific scenarios; however, the uncertainty regarding this statement is high. The recommendations related to risk management are summarized in Table 6-2 and as follows:

Chickens and Cattle:

Consideration of risk management is not indicated by the results.

Horses:

Raising foals is prevented on Teck-sold lands through a restrictive covenant on title. In addition, there is an advisory against raising foals in the area; notification was given to veterinarians in the area. It is recommended that the restrictive covenant on title for lands currently holding such a covenant be maintained, as well as any future Teck lands that are sold. Local veterinarians will be reminded about the restrictive covenant. However, it is also recommended that any future opportunities to study exposures to horses, particularly young horses, be acted upon by Teck.

Table 6-2 Recommendations Related to Risk Management for Livestock

Receptor	*Recommendation*
Chickens	No current risk management considerations required
Cattle	No current risk management considerations required
Horses (Foals)	Maintain restrictive covenants

7.0 CONCLUSIONS REGARDING THE NEED TO CONSIDER RISK MANAGEMENT

The SALE analysis indicated that risk management objectives were being met for urban plants, agricultural crops, avian and mammalian wildlife, most Listed Species, and most livestock. Therefore, an evaluation of risk management options is not required for these receptors.

Risk management objectives may not be met for up to 7,900 ha of the AOI for wildland plant communities. However, the plant communities within the AOI have continued to develop since the time period used to develop the biophysical habitat map (aerial photograph taken in 1999) and the field data were collected for statistical analysis of plant community characteristics (2001). Therefore, consideration of risk management options should be based on an updated assessment of the status of plant community structure.

Risk management should be considered for the Lewis' woodpecker (a Listed Species) related to availability of suitable nesting habitat. In addition, it is recommended that the restrictive covenant on title for lands currently holding such a covenant be maintained, as well as for any future Teck lands that are sold, due to the potential risks to young horses.

Prior to any risk management activity, a field survey for presence of individuals of Listed Species, as well as an evaluation of habitat suitability for Listed Species, should be conducted at an appropriate scale within the area subject to remediation.

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GLOSSARY

Adverse Effect	A harmful result on the environment or health from specified actions.
Agricultural Land	The use of land for the primary purpose of producing agricultural products for human or animal consumption including, without limitation, livestock raising operations, croplands, orchards, pastures, greenhouses, plant nurseries and farms.
Allometric Scaling	For a given species, estimating a value for a physiological parameter (*e.g*., food ingestion rates, toxicity reference values). Based on the mathematical relationship between the parameter and measure of body size (*e.g*., body weight) determined for a given or similar species.
Anthropogenic	Man-made or related to human activities.
Area of Interest (AOI)	The particular study area being examined within the risk assessment context.
Assessment Endpoint	What is to be evaluated and protected through the use of ecological risk assessment? It is defined by an ecological entity (*e.g*., shrew) and an attribute (*e.g*., abundance).
Attribute	The characteristic of the entity of concern that is important to protect and which is potentially at risk (*e.g*., richness).
Bioaccumulation	The accumulation of a substance in a living organism as a result of its intake both from food and also from the environment.
Bioavailability	The amount of chemical that enters the general circulation of the body following administration or exposure.
Bioindicator	An organism used to detect or signal the condition/health of the ecosystem.
Biological Gradient/Strength	Biological response to increased levels of stressors.
Biophysical	The combined biological and physical influences on ecological entities of an area, *i.e.*, soils, topography, vegetation, wildlife, geology, climate and time.
Biota	The animal and plant life of a region.
Blue Listed	List of ecological communities, and indigenous species and subspecies of special concern (formerly vulnerable) in British Columbia.
Causal Relationship/ Causation	A relationship that may produce an effect from a particular cause.
Chronic	Occurring during a relatively long period of exposure, usually a significant portion of the life span of the organism such as 10% or more.
Community Composition Metrics	Measurements of species richness and diversity within a defined ecological component (*e.g*., vegetation, avian, mammalian, *etc*.).

Conceptual Model	A model in which the relationships and pathways between stressors (and the sources of the stressors) and receptors is shown.
Concordance	Agreement with.
Conditional Simulation (of PCOC Distributions)	A variation of convention kriging which uses a form of stochastic simulation to calculate a range of values at unmeasured locations. It is conditional because the values at measured locations are honoured. Conditional simulation is able to produce a final interpolated surface which captures the heterogeneity and connectivity most likely present in the data, and can produce a standard deviation for the estimated values.
Confounding Factors	Parameters that can affect or distort the results of the exposure/outcome relation.
Control	A treatment in an investigation or study that duplicates all the conditions and factors that might affect the results of the investigation, except the specific condition being studied.
Correlation Analysis	A statistical technique for measuring/quantifying the degree or strength of a linear association between any two variables (in the case of a simple correlation or bivariate analysis) or among many variables using the partial correlation coefficient while controlling for the effects of one or more variables (in the case of a multiple correlation or multivariate analysis).
Deterministic Values	Point estimates.
Direct Effects	Impacts caused by the direct toxic action of the chemicals of concern that have been emitted by the smelter.
Diversity	The variety, distribution and abundance of different plant and animal communities and species within an area.
Ecological Entity	A general term referring to a species, population, community, ecosystem, valued habitat, *etc*.
Ecosystem	A community of organisms and their environment functioning as an ecological unit.
Effect Concentration	Concentration or dose of a particular chemical resulting in an effect (usually inhibitory) on x % of test organisms.
Effects Benchmarks	Values derived through toxicological studies and literature searches that represent concentrations of substances at which an effect is observed on an organism or a population.
Exposure Assessment	In the context of ecological risk assessment, the phase that estimates the amount of a chemical that enters or comes into contact with the receptor. An exposure assessment also takes into consideration the length of time and the nature of a population exposed to a chemical.

Exposure Ratio (ER)	Ratio of a PCOC exposure level to a TRV. Analogous to the commonly-used term “Hazard Quotient”. An ER $\leq$ 1 indicates an acceptable level of risk while an ER > 1 indicates the potential for unacceptable risk, and the need for further evaluation or risk management.
Forest Productivity	The rate at which forest biomass is produced. Can be measured through tree ring analysis to determine overall tree growth.
Free Metabolic Rate (FMR)	Metabolic cost of basic functions, including basal metabolism, thermoregulation, locomotion, feeding, predator avoidance, alertness, posture, digestion and food detoxification, reproduction and growth.
Ground Truth	Visiting sites to confirm the accuracy of remote sensing information (*e.g.*, use of satellite imagery or air photos).
Habitat	The place or environment where a plant or animal naturally or normally lives.
Habitat Quality Index	Measures ranging from qualitative (suitable, non-suitable) to highly quantitative models that relate landscape features to species abundance.
Indirect Effects	Impacts caused by changes in habitat quality.
Jaccard Similarity Index	Widely used in zoogeographic comparisons and was used here to assess if the region contained dissimilar bird communities than those found within the AOI.
KIVCET	Is the name of the lead smelter used at Teck Cominco in Trail, B.C. KIVCET is a Russian acronym for “flash-cyclone-oxygen-electric smelting”.
Kriging	A regression technique used in geostatistics to approximate or interpolate data. The calculation of a weighted average value for an unmeasured location from surrounding measured locations that are spatially auto-correlated.
Levels of Refinement (LOR)	Tiers of complexity that can be used in a risk assessment. Initial analysis is done to determine areas required for more in-depth analysis. Increasing tiers (levels) indicate reduction of uncertainty and conservatism, as well as increased site specificity, in the risk model.
Linear Developments	Man-made landscape features present over long distances (*e.g.*, transmission corridors, roads).
Lines of Evidence (LOE)	Data assembled concerning an objective or question pertaining to a risk assessment.

Litter-Fibre-Humus (LFH)	Litter (the non-decomposed organic material which gathers on the surface of the forest floor such as conifer needles, deciduous leaves and other plant materials), fibre * (the material beneath the litter horizon and above the humus; it is usually partially decomposed to the point that fragmented plant structures are still recognizable as to origin. This horizon is in transition from litter to humus. Humus (well decomposed plant residue in which plant structures are not recognizable). Humus is the organic component of soil and is situated on top of the first horizon of mineral soil. LFH occurs near the surface (top 25 cm) organic and mineral layers which are a rich source of native plant propagules (seeds, rhizomes, roots). Also a source of microbially active organic matter in varying stages of decay to contribute to and promote nutrient cycling.
Lowest Observed Adverse Effect Level (LOAEL)	Lowest level of an agent (*e.g.*, chemical) evaluated in a toxicity test or biological field survey that has a statistically-significant adverse effect on the exposed organisms compared with organisms in a control or reference site.
Management Goal	A general statement about the desired condition (or direction of preference) of ecological values of concern.
Management Objective	Specific statement about the desired condition (or direction of preference) of ecological values of concern.
Measure	Measurements used to evaluate the assessment endpoint. Includes Measures of Exposure, Measures of Effect and Measures of Ecosystem and Receptor Characteristics.
Measure of Ecosystem and Receptor Characteristics	A measure that influences the behaviour and location of ecological entities of the assessment endpoint, the distribution of a chemical (or other stressor), and life-history characteristics of the assessment endpoint or its surrogate that may affect exposure or response to the stressor.
Measure of Effect	A measure that describes a change in a characteristic of an assessment endpoint or its surrogate.
Measure of Exposure	A measure of chemical (or other stressor) presence and movement in the environment and its contact with the assessment endpoint.
Mesic	A class used for describing soil moisture regime. Water is removed somewhat slowly in relation to supply; soil may remain moist for significant, but sometimes short periods of the year.
Minimize	To reduce ecological risks from smelter operations to levels that will protect populations and communities.
Monotonic	Of a sequence or function; consistently increasing and never decreasing or consistently decreasing and never increasing in value.
No Observed Adverse Effect Level (NOAEL)	Highest level of an agent (*e.g.*, chemical) evaluated in a toxicity test or biological field survey that causes no statistically-significant difference in effect compared with the controls or a reference site.

Non-Point Source	A contaminant source that does not have a single origin.
Non-Site Series Units	Sites or units that are not appropriate to remediate (*e.g.*, cliffs, roads, gravel pits, *etc*.).
Parameter	Distinguishing or defining characteristic or feature, esp. one that may be measured or quantified.
Pearson's Linear Correlation Coefficient	Parametric statistic that indicates the degree of linear dependence between two variables. The closer to the value of "1", the stronger the correlation between the variables and a value closer to -1 is indicative of a decreasing linear relationship.
Physiography	A description of the surface features of the Earth, with an emphasis on the origin of landforms.
Polygon	The spatial area delineated on a map to define one feature unit.
Potential Chemical of Concern (PCOC)	A chemical that may negatively affect ecological receptors.
Prevent	To eliminate effects from smelter operations to individual organisms (as opposed to populations or communities).
Primary Effect	The most direct influence of a stressor on a receptor.
Problem Formulation	The initial step in a risk assessment that focuses the assessment on the chemicals, receptors and exposure pathways of greatest concern.
Probabilistic Method	Used to calculate the uncertainty for the estimation and characterization of exposures and risks. Necessary to quantify the likelihoods associated with a range of possible outcomes and exposure levels.
Receptor	The organism subjected to exposure to chemicals or physical agents.
Red Listed	Indigenous species and subspecies that are or may be extirpated endangered or threatened in British Columbia.
Release Mechanism	Pathway by which a PCOC present in a source is discharged into an ecosystem (*e.g.*, particulate release, volatilization, surface runoff, groundwater seepage.
Residual Ecological Risk	Ecological risk remaining after natural recovery processes have taken place or after human intervention, such as remediation and re-vegetation.
Resinosis	Flow of resin in a conifer in response to infection, wounding, or insect attack.
Richness	The number of different species occupying a given area.

Secondary Effect	An effect on a receptor caused by an effect of a stressor on another receptor.
Sequential Analysis of Lines Evidence (SALE)	An approach to analyze an assemblage of data pertaining to a risk assessment that follows a process whereby lines of evidence (data) are assessed in an increasingly focused assessment, incorporating spatial and temporal contexts and direct and indirect risks. It includes a transparent process for evaluating the magnitude of response and causation.
Shannon Wiener Diversity Index	One of several diversity indices used to measure biodiversity. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having more unique species, or by having greater species evenness.
Source Release	Point of origin of stressors emitted from the smelter.
Spatial	Of or concerning space.
Spatial Autocorrelation	The degree to which the measured concentration of metal in soil is similar to other measured locations nearby. Low spatial autocorrelation implies high variability over short distances, while high spatial autocorrelation implies low variability over short distances
Spearman Correlation Analysis	A non-parametric statistic, usually calculated when it is not convenient, economic, or even possible to give actual values to variables, but only to assign a rank order to instances of each variable. May be a better indicator that a relationship exists between two variables when the relationship is non-linear.
Statistical Power	The ability to distinguish a particular level of effect from the natural background variability.
Stressor	Something that causes stress; may be physical (*e.g.*, logging), biological (*e.g.*, insect pest) or chemical (*e.g.*, heavy metal).
Strong Acid Leachable Metals Extraction (SALM)	Metals that are typically analyzed for when a solid sample is digested in high heat with nitric acid and then examined *via* inductively coupled plasma or atomic absorption spectroscopy.
Structural Stage	The existing dominant stand appearance or physiognomy for a land area. Factors such as disturbance history, stand age, species composition and chance all influence structural stage. Structural stages range from non-vegetated to old forests.
Taxa	A taxon (plural taxa), or taxonomic unit, is a grouping of organisms (named or unnamed). Once named, a taxon will usually have a rank and can be placed at a particular level in a hierarchy (kingdom; phylum (animals or plants) or division (plants); class; order; family; genus; species; subspecies).
Temporal	Of or relating to time.
Tertiary Effect	An effect on a receptor caused by secondary effects on other receptors.

Trophic Cascade	Effects mediated through interactions between consumer organisms and their food.
Trophic Level	The feeding position of an organism in the food chain.
Trophic Transfer	The movement of the PCOC(s) from one organism to others within a food chain.
Uncertainty	Imperfect knowledge concerning the present or future state of the system under consideration.
Urban Land	Areas within municipalities, including residential, commercial-industrial, institutional areas, and urban parks, playgrounds, *etc*.
Weight of Evidence (WOE)	A type of analysis that considers all available data and is used to reach a conclusion based on the amount and quality of data supporting each alternative conclusion.
Wildland	Areas that have not undergone development or are not in use for agriculture.