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FINAL REPORT

ECOLOGICAL RISK ASSESSMENT FOR THE LUPIN MINE TAILINGS CONTAINMENT AREA

Submitted to:

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EXECUTIVE SUMMARY

Introduction

Kinross Gold Corporation (Kinross) retained Golder Associates Ltd. (Golder) to conduct an assessment of human and ecological risks due to exposure to metals and cyanide at the Lupin Gold Mine site. As part of the closure plan for the Lupin Gold Mine Tailings Containment Area (TCA), water clarification ponds (Pond 1 and Pond 2) will remain in place and esker sand will be used to cover exposed tailings. The objective of this risk assessment was to estimate the potential human and wildlife risks after closure of the mine, based on the reclamation plan for the Lupin Gold Mine. Aquatic risks were not evaluated because Ponds 1 and 2 are not intended to be aquatic habitat, and controls will be constructed to prevent fish movement into the ponds. The results of the risk assessment can be used by Kinross as inputs to decisions regarding optimum remediation and/or mitigation strategies following closure of the mine.

Three main sources of metals and cyanide from the TCA were considered in the risk assessment:

- Tailings Containment Area: Tailings that have settled in Ponds 1 and 2 will remain during closure. These tailings may have contributed to elevated concentrations of metals and cyanide in water and sediment in Ponds 1 and 2.
- Seepage from Esker-Covered Tailings: The closure plan at the Lupin Gold Mine includes covering exposed tailings with esker sand. The additional weight of the sand may cause water to be pushed out of the tailings and move up into the esker sand where it can be taken up by plants growing at the surface. Seepage of water from tailings to nearby water bodies is considered to be unlikely (Golder 2004).
- Wind-Blown Tailings: Exposed tailings contained within Cells 3 and 5 may have blown to the clean esker cover in Cell 1 of the TCA. Wind-blown tailings will not be a source of metals after all the cells are covered, but this source may account for a significant portion of metals concentrations currently measured in vegetation and sand in Cell 1.

Risk Assessment Approach

The risk assessment focused on the potential risks to wildlife health due to exposure to food (vegetation, invertebrates and prey, as applicable), water and incidental soil ingestion. Risks to human health were also evaluated based on consumption of caribou that could be exposed to metals and cyanide from the TCA. All applicable and available data that have been collected from the TCA were considered for use in the assessment. Therefore, the risk assessment is based on currently available data. It was assumed that currently available data represent worst-case conditions since metals and cyanide concentrations are expected to decrease following closure of the mine.

The following wildlife receptors were evaluated in the risk assessment:

- muskoxen (*Ovibos moschatus*);
- caribou (*Rangifer tarandus*);
- grizzly bears (*Ursus arctos horribilis*);
- wolverine (*Gulo gulo*);
- fox (*Alopex lagopus*);
- wolves (*Canis lupus*);
- hare (*Lepus arcticus*);
- arctic ground squirrel (*Spermophilus parryii*);
- ptarmigan (*Lagopus lagopus*);
- rough legged hawk (*Buteo lagopus*);
- common snipe (*Gallinago gallinago*); and,
- long-tailed duck (*Clangula hyemalis*).

Humans are not expected to be directly exposed to metals and cyanide in the TCA at Lupin by incidental ingestion of tailings or via drinking effluent. Inhalation of dust containing wind-blown tailings was also eliminated as a pathway since exposed tailings will be covered with sand as part of the reclamation strategy, such that wind-blown tailings will not occur. The only exposure pathway evaluated for the human health risk assessment was ingestion of caribou meat. Large-bodied fish that are consumed by people (e.g., Arctic char, lake trout), will not be present in Ponds 1 and 2, since a spillway will be constructed to prevent movement of fish into the ponds.

Fish-bearing lakes outside of the TCA were not part of the scope of work for this risk assessment. Currently, there are no berry-producing plants growing on the esker-covered cell. Therefore, the only pathway evaluated for the human health risk assessment was ingestion of caribou, where caribou are assumed to have taken up metals and cyanide from drinking water, food, and incidental soil ingestion from the Lupin mine site.

Potential effects on human and wildlife health can be determined by assessing risk, which is defined by two components, exposure and hazard, as follows:

- Exposure: the intake of a metal (e.g., via ingestion) for a particular time period; and,
- Hazard: the type of adverse health effect(s) that can occur as a result of exposure.

Exposure to metals and cyanide by wildlife that may inhabit areas near the mine and people that may consume caribou meat is estimated by determining the following:

- the concentrations of substances in soil, sediment, plants and water;
- the types of receptors (i.e., wildlife) that could be in the vicinity of the mine or consume organisms that spend time in the area;
- the pathways by which receptors may come in contact with substances (i.e., incidental ingestion of soil, ingestion of food and water);
- the amount of time receptors may spend within the mine site (i.e., days/year);
- typical soil, sand, water and food ingestion rates and body weights for wildlife receptors;
- typical meat ingestion rates and body weights for human receptors; and,
- the quantity of metals that receptors are likely to take into their bodies by each pathway.

In the risk assessment, the hazard potential of substances is estimated by considering the following:

- determining whether the quantity of substances in soil, sediment and water exceeds applicable regulatory guidelines;
- reviewing the toxicity information associated with each substance; and,

- determining the total amount of exposure from all applicable pathways that would be unlikely to cause adverse health effects in receptors (called toxicity benchmarks).

Chemicals that were not essential nutrients, and were present in soil at concentrations greater than guidelines (or for which guidelines were not available), and were present in the TCA at concentrations greater than concentrations measured in areas not impacted by the TCA were identified as Chemicals of Concern (COC) and were evaluated in the risk assessment. The following COCs were evaluated for all receptors and exposure pathways (i.e., soil, food and water ingestion for wildlife and meat ingestion for people) in the risk assessment:

- aluminum;
- arsenic;
- barium;
- boron;
- chromium;
- cobalt;
- copper;
- lead;
- manganese;
- molybdenum;
- nickel;
- selenium;
- silver;
- strontium;
- thallium;
- vanadium;
- zinc; and,
- cyanide.

Receptors may be exposed to substances from the Lupin mine via several pathways (Table 1).

Table 1
Ingestion Pathways Evaluated in the Risk Assessment

Receptor	Ingestion Pathways					
	Soil	Sediment	Water	Vegetation	Wild Game/ Prey	Benthic Invertebrate
People					√	
Caribou	√		√	√		
Muskox	√		√	√		
Grizzly bear	√		√	√	√	
Wolverine	√		√		√	
Fox	√		√		√	
Wolf	√		√		√	
Arctic hare	√		√	√		
Arctic ground squirrel	√		√	√		
Ptarmigan	√		√	√		
Rough-legged hawk	√		√		√	
Snipe		√	√			√
Long-tailed duck		√	√			√

The final step in a risk assessment, referred to as risk characterization, involves comparing the estimated exposure to the toxicity benchmark. If the estimated exposure is less than the toxicity benchmark, no health risks are expected. If the estimated exposure is greater than the toxicity benchmark, then mitigation measures that reduce exposure to metals in the TCA may need to be examined. Risk estimates were calculated as the exposure ratio (ER), which is a ratio of the estimated exposure of metals from the TCA to the toxicity benchmarks, as follows:

$$ER = \frac{\text{Estimated Exposure}}{\text{Toxicity Benchmark}}$$

The ER indicates whether the amount of a substance taken in by people or animals is greater than the amount of the substance below which there would be no health effect or no unacceptable risk of cancer. If the ER is greater than 1 (or 1 in 100,000 for carcinogenic substances such as arsenic), then the amount taken in is greater than the threshold amount for which there are no health effects. This does not mean that there will be health effects; rather that there is a potential risk. Further consideration may be necessary to reduce uncertainty in the risk assessment, especially if the ERs are only slightly greater than 1, since making risk management decisions based on slight exceedances may result in unnecessary remediation action. If the ER is less than 1 (or 1 in 100,000 for arsenic), then we can be certain that no health effects or unacceptable risks would occur.

In some cases, it is necessary to reduce the acceptable ER value since other sources of exposure need to be considered. For example, since the earth's crust is made up of metals, they are all around us. They are in the food we eat, the air we breathe and the water we drink. Therefore, the ER calculated from exposure in the study area must be adjusted to consider exposure from other sources. For this assessment the acceptable risk threshold for the human health risk assessment was an ER of 0.2 because it is assumed that people are exposed to metals from multiple sources.

For wildlife, the acceptable risk threshold is an ER of 1 since the risk assessment conservatively assumed wildlife obtained all of their food, water and soil from the Lupin Gold Mine. No other significant exposure sources would occur while wildlife are in the vicinity of the mine site.

Layers of Safety

In this risk assessment, exposures and toxicity benchmarks were estimated from available information about how exposure might take place and the potential health effects that could result. There is always uncertainty associated with these estimations, depending on the quality, quantity and variability associated with the available data. When information is uncertain, it is standard practice in a risk assessment to make assumptions that are biased towards safety, so that even if there is uncertainty, human and wildlife health will still be protected.

There are several layers of safety applied in this study. For example, maximum concentrations were used in the risk assessment to estimate exposure. The assumption that all concentrations are at maximum accounts for the potential variability in concentrations in soil, water, sediment and vegetation. Conservative assumptions regarding the amount of time that wildlife spent near the TCA were also applied to the risk assessment. In addition, it was assumed that people ate caribou meat every day (365 days per year) from caribou that were exposed to maximum metals concentrations from the TCA for 10% of the year.

There is also uncertainty associated with estimating toxicity benchmarks. Extrapolating from animal studies in the laboratory to the possible effects that may result from exposure to metals from the study area is uncertain. For wildlife health, toxicity benchmarks were chosen from studies that were credible and that evaluated subtle health effects such as changes in blood chemistry and growth. For human health risk assessments it is a standard practice to assume that people are more sensitive to the toxic effects of a substance than laboratory animals. Therefore, the toxicity benchmark for human health is set at a much lower level than the animal benchmark (typically 100 to 1,000 times lower). This large margin of safety ensures that doses less than the toxicity benchmarks are safe and that minor exceedances of these benchmarks are extremely unlikely to cause adverse health effects.

All of these layers of safety ensure that risk from exposure to metals at the TCA has not been underestimated.

Results

Wildlife Health

Based on the results of this preliminary risk assessment, there is a potential for risk to individual shorebirds and waterfowl due to arsenic and cyanide exposure. Risks to populations of shorebirds and waterfowl are unlikely. However, the characterization of risks to populations is uncertain. Risks are not expected due to any other COCs or for any other receptors.

Conservative assumptions and many layers of safety were applied to the wildlife health risk assessment that might have lead to an overestimation of risks for shorebirds and waterfowl. This is standard practice for a screening level risk assessment, which means that there is a high degree of certainty that risks have not been underestimated.

Human Health

For the human health risk assessment, for all of the metals evaluated in the assessment, estimated exposure was less than the toxicity benchmarks, with the exception of arsenic. It is very unlikely that the scenario used to estimate human exposure to arsenic via caribou ingestion would be realized. In addition, potential ERs of 0.3 for non-carcinogenic effects and 14 in 100,000 for carcinogenic effects are only slightly above 0.2 and 1 in 100,000; the levels for which no effects are expected. It is very unlikely that health effects would be observed based on these assumptions. Therefore, there is no risk to health due to the ingestion of caribou meat. Conservative assumptions and many layers of safety were used to estimate exposure and to derive toxicity benchmarks. This means that there is a high degree of certainty that risks have not been underestimated and that all members of a family would be safe from exposure to metals from the study area.

What Does this Mean for the Lupin TCA Closure Plan?

The closure plan for the Lupin TCA includes two major features; covering exposed tailings with 1 m of esker sand and constructing a spillway between Pond 2 and the receiving environment and keeping water and sediment within Ponds 1 and 2.

No wildlife or human health risks are expected due to placement of 1 m of esker sand over exposed tailings.

The exposure pathways related to covering exposed tailings with esker sand are direct soil ingestion and ingestion of plants growing on the tailings areas. This risk assessment shows that risks from sand-covered tailings are acceptable, both for humans and wildlife. This is because the exposure via these two primary pathways does not result in ERs greater than 1. Furthermore, exposure via water from within the capped tailings will not be a concern. This is because, based on the results of the engineering feasibility of covering exposed tailings with esker sand, it is not expected that excessive water will seep into the ponds. Nor is it expected that water will move upward into the root zone of plants growing at the surface of the esker sand (Golder 2004). Therefore, water quality is not expected to worsen in the future.

Risks to individual shorebirds and waterfowl were predicted due primarily to exposure to arsenic and cyanide in invertebrates living in ponds 1 and 2. This leads to the risk management questions:

- Should ponds 1 and 2 remain as features in the reclaimed landscape? and,
- If ponds 1 and 2 remain, should measures be taken to reduce exposure to arsenic and cyanide via invertebrates in contact with sediments?

These two questions cannot be answered with confidence because of the uncertainties in the risk assessment. The risks are very likely to be greatly over-estimated. Therefore, it would not be advisable to proceed to risk management since there may be a large mis-match between the cost of remediation and the actual risk reduction achieved. Therefore, it is recommended that uncertainties in the assessment of risk to waterfowl and shorebirds be reduced. The following two steps should be considered as preliminary steps to reduce uncertainty:

(1) Sensitivity analysis of the exposure model to reveal which parameters "drive" the risk estimates; and,

(2) Collection of information from the Canadian Wildlife Service and other sources regarding migratory bird populations to better estimate the time that birds may actually spend during the breeding season in the area.

Completion of steps (1) and (2), will allow a re-examination of the level of conservatism in the exposure models, and will also allow a more confident characterization of risks to populations. If the combination of confirmation of highly-conservative risks to individuals plus a more confident prediction of no risks to populations results in a conclusion that risk management is not required, then no further work will be necessary. However, if risks to populations cannot be ruled out and/or if regulatory acceptance of risks to individuals (despite the lack of risks to populations) is not forthcoming, then proceeding with further reduction of uncertainty may be necessary. Further reduction of uncertainty would involve proceeding with additional data collection.

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1. INTRODUCTION

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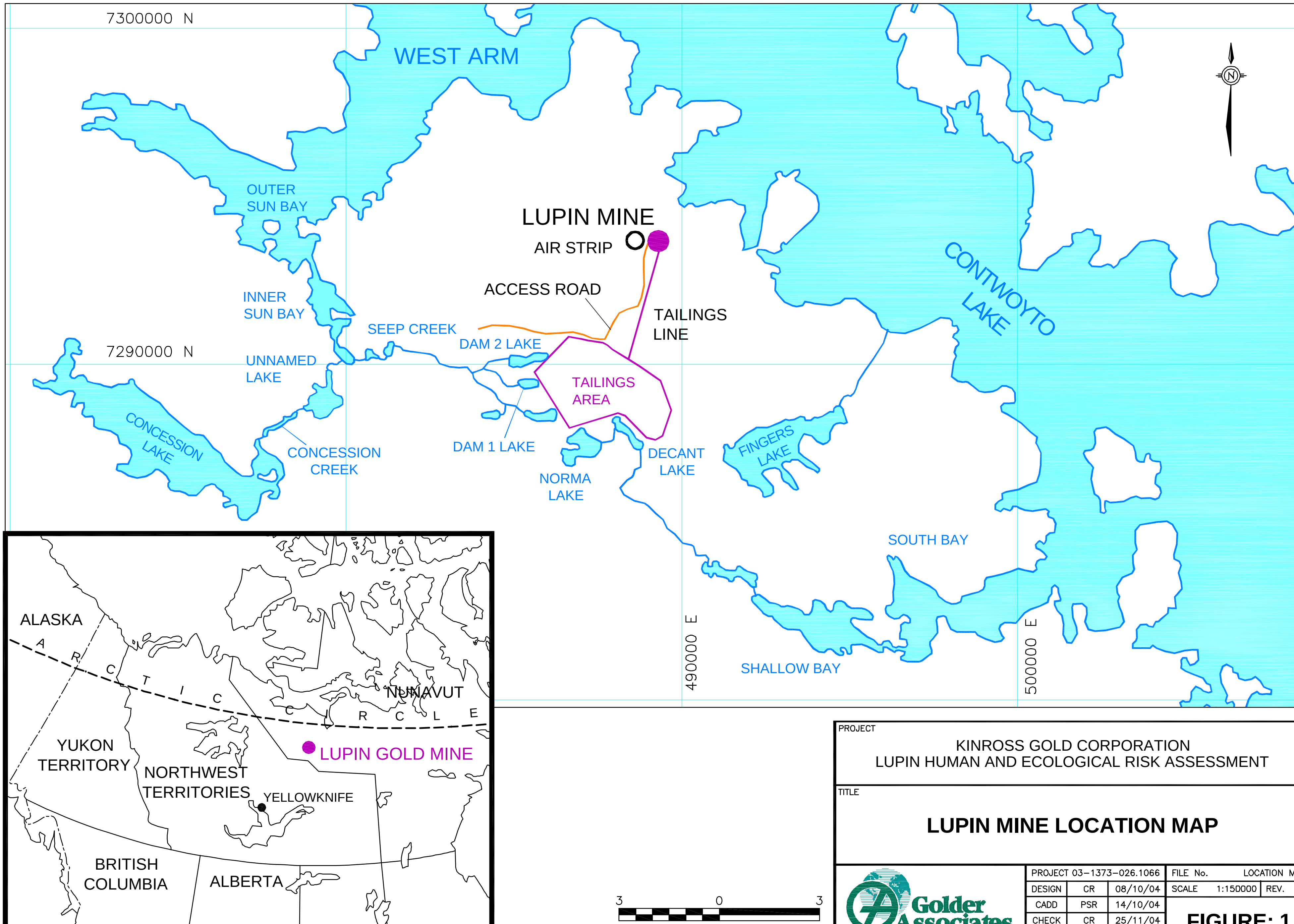
1.1 Background

The Lupin Gold Mine (65°46’N, 111°15’W) is on the west shore of Contwoyto Lake, Nunavut, 400 km northeast of Yellowknife and approximately 90 km south of the Arctic Circle (Figure 1). Access to the site is by air or by winter road (February to March).

The Lupin gold deposit was discovered in 1960 by Canadian Nickel Company Ltd., a subsidiary of INCO Ltd. In 1979, Echo Bay Mines Ltd. (EBM) obtained an option on the Lupin property from INCO and proceeded with an underground exploration program in 1979 and 1980. Mine site construction began in 1980 and was completed in 1982 when pre-production commissioning began. The Lupin Gold Mine operated continuously from 1982 to January 1998, when operations were suspended due to low gold prices. In November 1999, EBM re-opened the Lupin Gold Mine and production resumed in April 2000. In 2003, EBM merged with Kinross. Since the start of production in 1982, the Lupin Mine has produced over 3.3 million ounces of gold.

The Lupin mine site is comprised of two principal clusters of buildings: the residential complex, which consists of accommodations, a kitchen and recreation center; and the industrial complex, which houses the mine, mill, powerhouse, maintenance facility, warehouse and offices. Ancillary features include a sewage lagoon immediately to the south of the industrial complex, a 1.9 km long airstrip, and tailings area located approximately 5 km south of the mine (Figure 1).

R:\CAD\2004\1370-Edmonton\1373-ES\04-1373-026\1066\ Drawing file: Fig 1 LOCATION MAP.dwg Nov 25, 2004 – 11:48am



PROJECT

KINROSS GOLD CORPORATION
LUPIN HUMAN AND ECOLOGICAL RISK ASSESSMENT

TITLE

LUPIN MINE LOCATION MAP

Golder Associates
Calgary, Alberta

PROJECT 03-1373-026.1066			FILE No.	LOCATION MAP
DESIGN	CR	08/10/04	SCALE 1:150000	REV. 1
CADD	PSR	14/10/04		
CHECK	CR	25/11/04	**FIGURE: 1**	
REVIEW	CR	25/11/04		

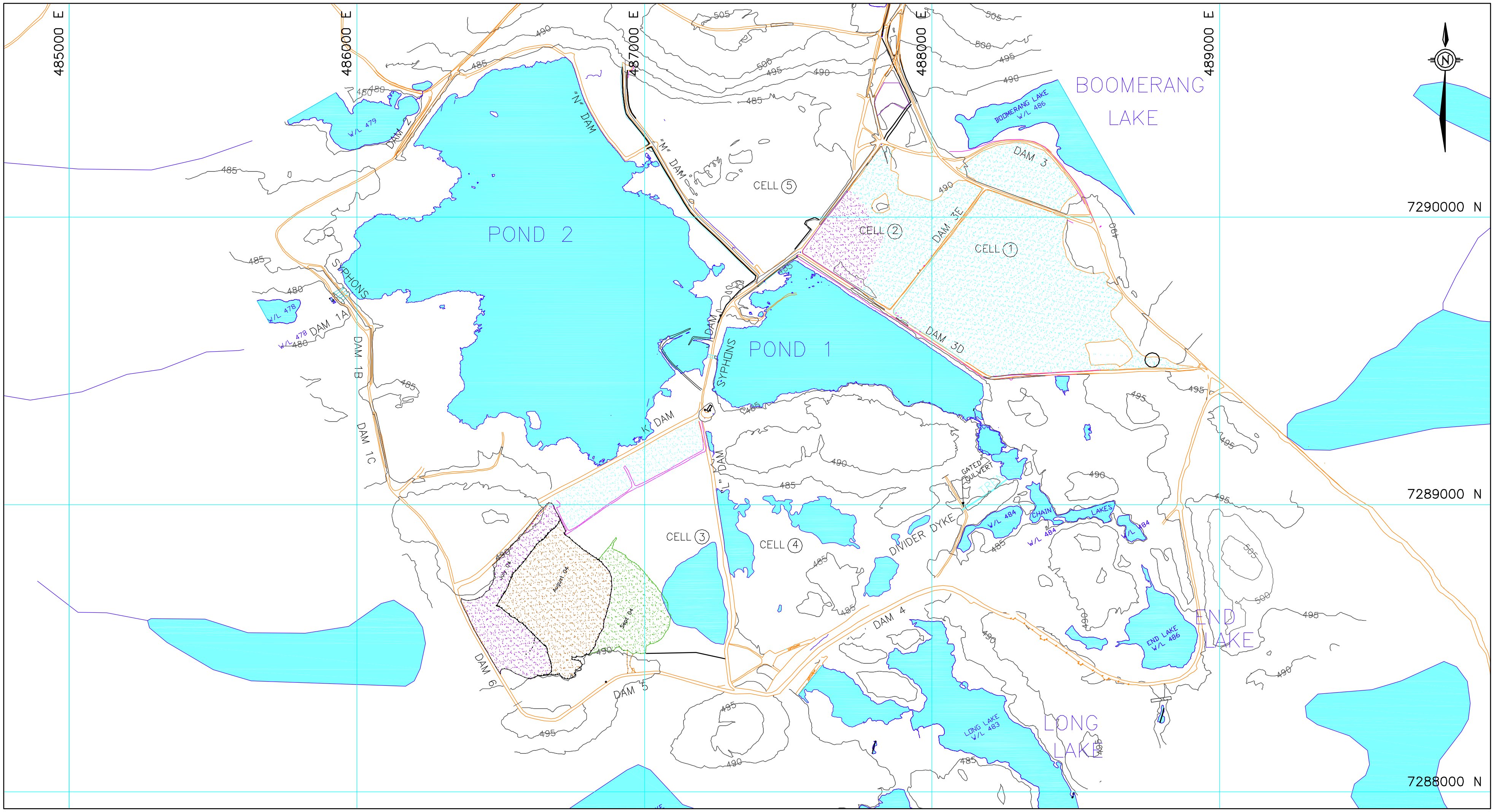
1.2 Gold Mining Process at Lupin

The Lupin milling process incorporates crushing, grinding, pre-aeration, leaching, filtration, and recovery. The ore from the mine is crushed underground and then fed to a secondary crushing facility contained within the surface facilities. At peak production, the crushing circuit operated at a rate of 240 tonnes per hour (EBM 2001). Pre-aeration and leaching liberates gold particles into solution via the reaction of cyanide, oxygen and water. A two-stage filtration system separates dissolved gold from the waste solids (filter cake), which are pumped to the tailings containment area (TCA). Zinc dust and fluxes are used to recover any precipitate gold, which is returned to the mill to be reprocessed. The bullion contains approximately 85% gold and 12% silver, the balance being base metals (EBM 2001).

Originally, all liquid waste was contained within the tailings ponds; however, as mine capacity increased, it became necessary to expand the tailings ponds and discharge effluent from the tailings pond to the receiving environment. Beginning in 1982, water was discharged in mid-summer (when water quality achieved NWT Water Board Requirements or Metal Mining Effluent Regulations [MMER]), typically beginning on 15 July and continuing for periods that extended into early September. This practice will continue until mine closure. Effluent is discharged into Seep Creek, which drains into Contwoyto Lake at the south end of Inner Sun Bay (Figure 1).

Tailings from gold processing is in the form of a slurry that is pumped from the mill to one of two solids retention cells (currently, Cell 3 or Cell 5) where the solids settle. Each spring, meltwater and tailings water is decanted from Cells 5 and 3 into Cell 4. Water is held in Cell 4 for one year to allow natural degradation of cyanide by exposure to sunlight, air, and agitation by wind action. Water is released from Cell 4, through a gated culvert, into Pond 1, where it is held for an additional one-year period, before being siphoned into Pond 2. If necessary, the water is treated with ferric-sulphate during the siphoning process to precipitate arsenic in Pond 2. Depending on water level and water quality in Pond 2, water is released to the environment after 15 July of any year (as per Nunavut Water Board water license). The TCA is presented in Figure 2.

R:\CAD\2004\1370-Edmonton\1373-ES\04-1373-026\1066\ Drawing file: Fig 2 Lupin Tailings Area.dwg Nov 25, 2004 – 11:46am



LEGEND

ESKER COVERED TAILINGS

400 0 400
SCALE METRES

PROJECT
KINROSS GOLD CORPORATION
LUPIN HUMAN AND ECOLOGICAL RISK ASSESSMENT

TITLE
LUPIN TAILINGS AREA

Golder Associates
Calgary, Alberta

PROJECT 04-1373-026.1066			FILE No. Lupin Tailings Area	
DESIGN	CR	08/10/04	SCALE AS SHOWN	REV. 0
CADD	MJ	25/11/04	**FIGURE: 2**	
CHECK	CR	25/11/04		
REVIEW	CR	25/11/04		

1.3 Closure Plan

Reclamation activities have been ongoing at the Lupin Gold Mine since 1988, when tailings in Cell 1A were covered with up to 1 m of esker sand. The effect of this practice was to control acid rock generation by creating an oxygen barrier that, in turn, prevents oxidation of pyritic materials in the tailings. The sand layer also prevents access to surface tailings by wildlife in the area. In 1995, the remainder of Cell 1 and 75% of Cell 2 were similarly covered. The remainder of Cell 2, as well as a significant portion of Cell 3, was covered with esker sand in the summer of 2004. The remainder of Cell 3, and all of Cell 5, will be covered with esker sand during the summer of 2005 and, if necessary, summer 2006. Water in Cell 3 will be pumped to Cell 4, prior to covering with esker sand and water from Cell 4, after a suitable retention period, will be released to Pond 1.

Since structural dams require regular maintenance inspections, Kinross is planning to breach Dam 1A as one of the final stages of closure. The current plan is to construct a spillway through Dam 1A, at approximately the 480m elevation, following the final siphon discharge. At this elevation, Pond 2 will continue to provide a deep water cover over the pond sediments. The spillway will provide an outlet for annual precipitation buildup in Pond 2, which will be permitted to naturally flow into Dam 1a Lake. Water quality is expected to be within MMER guidelines. Although Ponds 1 and 2 will decrease in area, it is expected that volume will be 50% to 75% of current levels.

1.4 Sources of Metals and Cyanide Evaluated in the Risk Assessment

Three main sources of metals and cyanide from the TCA were considered in the risk assessment:

- Tailings Containment Area: Tailings that have settled in Ponds 1 and 2 will remain during closure. Metals are naturally-occurring and are present in mineral rocks. Areas with gold deposits also tend to have higher deposits of other metals, such as arsenic. Cyanide is used in gold processing to dissolve and concentrate gold from the ore. Although cyanide is typically recycled, some cyanide can be deposited with tailings. Cyanide is highly water soluble; therefore, cyanide is typically measured both in water and in sediment.

- Seepage from Esker-Covered Tailings: The closure plan at the Lupin Gold Mine includes covering exposed tailings with esker sand. The additional weight of the sand may cause water to be pushed out of the tailings and move up into the esker sand where it can be taken up by plants growing at the surface. Seepage of water from tailings to nearby water bodies is considered to be unlikely (Golder 2004).
- Wind-Blown Tailings: As described in Section 1.3, exposed tailings are contained within Cells 3 and 5. Part of Cell 3 was covered with esker sand in the summer of 2004; however, tailings from Cell 3 and the other cells may have blown to the clean esker cover in Cell 1. Wind-blown tailings will not be a source of metals after all the cells are covered, but this source may account for a significant portion of metals concentrations currently measured in vegetation and sand in Cell 1.

1.5 Previous Site Investigations

A comprehensive summary of previous site investigations conducted at the Lupin mine is provided in a historical report prepared by Golder (2003). The investigations summarized in the historical report include the following:

- fisheries and fish tissue analysis reports provided for the purposes of the on-going Environmental Effects Monitoring program at the Lupin Gold Mine (R.L.&L. Environmental Services Ltd. 1991; 1995; 1996);
- hydrogeology assessments of the Lupin mine and associated tailings (Klohn-Leonoff, 1992; Klohn-Crippen 1995);
- water chemistry, sediment chemistry and benthic macroinvertebrate community assessment (R.L.&L. Environmental Services Ltd. 1996; EVS Environmental Consultants 1996);
- summary report on water quality, benthic macroinvertebrate communities, and fish tissue data based on previous investigations of the Lupin mine (AQUAMIN 1996); and,
- annual reports produced by Echo Bay Mines in fulfillment of Water Licence Agreement NWB1LUP0008 (Echo Bay Mines 2000; 2001; 2003).

In addition to the above investigations, Kinross has collected water quality data in and around the Lupin Gold Mine. These data have been stored in the Lupin Gold Mine database and have not been reported previously.

1.6 Supplemental Field Work

Additional data were required to conduct the human and wildlife health risk assessments. Data gaps included metals concentrations in vegetation, sediment and soil. Environmental technicians from Kinross collected samples in August 2004 (sample locations are presented in Figure 3) and submitted the samples to an analytical laboratory for metals analyses (including mercury and arsenic). The following samples were collected:

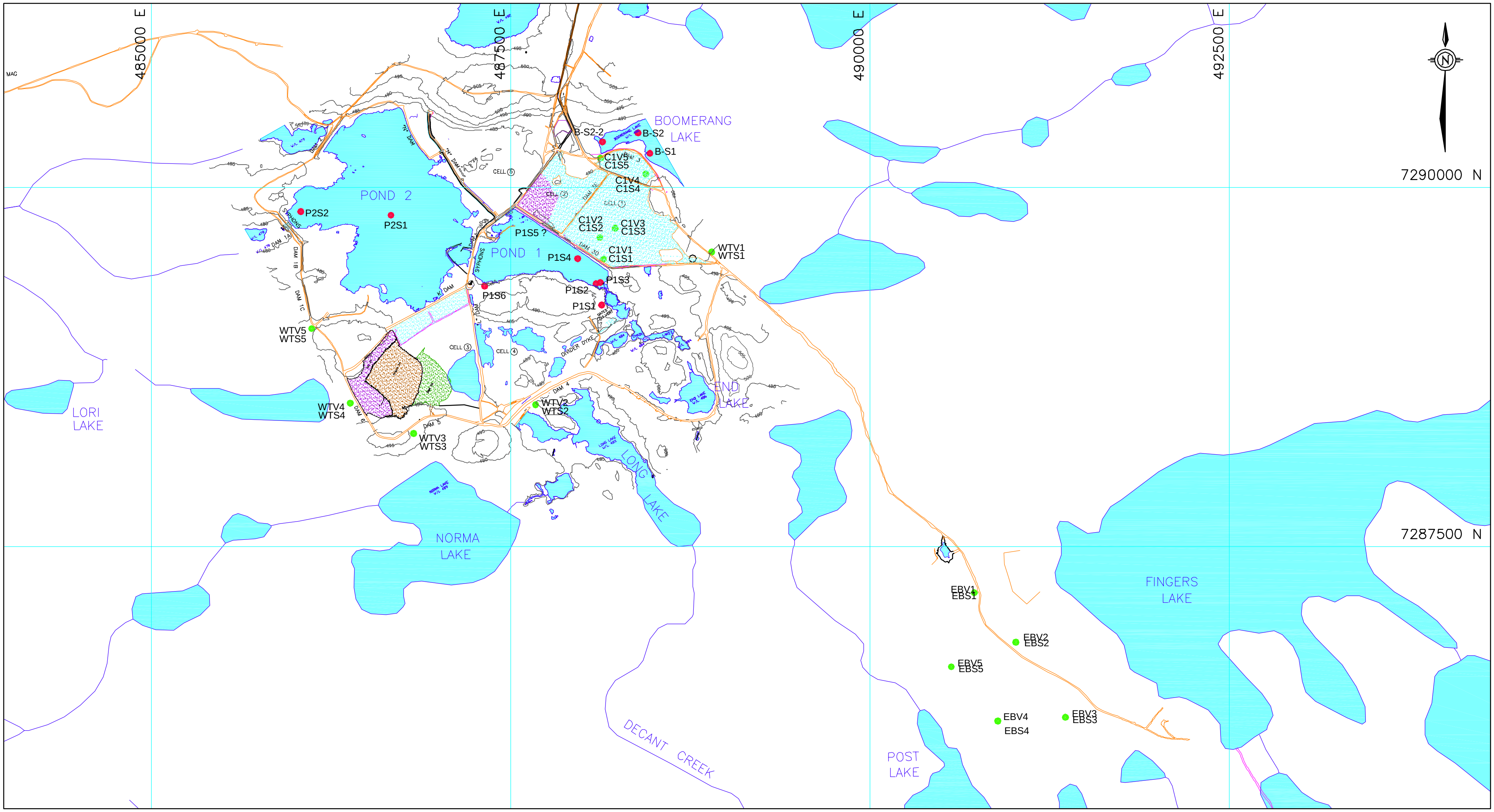
- vegetation growing on esker sand in Cell 1 and areas known to have been impacted by wind-blown tailings;
- vegetation from a reference location in the esker sand borrow area;
- esker sand from Cell 1 and the esker sand borrow area;
- soil from areas known to be impacted by wind-blown tailings; and,
- sediment from Pond 1, Pond 2, Boomerang Lake and a reference location in Shallow Bay.

Data from the supplemental field work are presented in Appendix I.

1.7 Scope of Work

The purpose of the risk assessment was to evaluate risks to wildlife and human health as a result of concentrations of metals expected to be present at the Lupin Gold Mine following closure. The overall goal for the risk assessment was to provide a risk-based evaluation in order to guide risk management and reclamation decisions, including guidance with respect to the adequacy of 1 m of esker sand cover over tailings. All applicable and available data that have been collected from historical investigations on the site and supplemental data collected for the purposes of this assessment were used in the risk assessment. It was assumed that currently available data represent worst-case conditions since metals and cyanide concentrations are expected to decrease following closure of the mine.

R:\CAD\2004\1370-Edmonton\1373-ES\04-1373-026\1066\ Drawing file: Fig 3 2004 Sampling Locations.dwg Nov 25, 2004 - 11:51am



LEGEND

P2S1 SEDIMENT SAMPLING LOCATION

WTV4 WTS4 PLANT AND SOIL SAMPLING LOCATION

1 0 1

SCALE KILOMETRES

PROJECT

KINROSS GOLD CORPORATION
LUPIN HUMAN AND ECOLOGICAL RISK ASSESSMENT

TITLE

2004 SAMPLE LOCATIONS

Golder Associates
Calgary, Alberta

PROJECT 04-1373-026.1066			FILE No. 2004 Sample Locs.	
DESIGN	CR	08/10/04	SCALE AS SHOWN	REV. 0
CADD	JEF	18/10/04	FIGURE: 3	
CHECK	CR	25/11/04		
REVIEW	CR	25/11/04		

The risk assessment method used to evaluate potential risks is considered to be a Level 1 (or screening-level) risk assessment, which is characterized by CCME (1996) as being a study that uses comparative methods and is focused mainly at the species level. Levels 2 and 3 are more sophisticated and complex evaluations that focus on the population and community levels. Level 2 and 3 risk assessments would only be required if a Level 1 risk assessment identified risks to individual animals and if an understanding of how potential health risks for individuals may impact populations is required.

1.8 Organization of Report

The remainder of the report is structured as follows:

Section 2	Site Description: provides a brief description of the environmental setting.
Section 3	Sources of Data: provides a summary of the data used in the risk assessment. A more detailed summary of the data is presented in Appendix I.
Section 4	Definition of Reference: provides a definition of the sources of the reference data used in the risk assessment.
Section 5	Risk Assessment Approach: provides a brief description of the approach and methods used to determine the potential for adverse effects on people and wildlife. Detailed methods are described in Appendix II.
Section 6	Risk Assessment Results: provides a summary of the results of the human and wildlife health risk assessments.
Section 7	Conclusions: provides a brief summary of the report.

2. SITE DESCRIPTION

2.1 Environmental Setting

The Lupin Gold Mine is on the west shore of Contwoyto Lake, Nunavut, in the southern arctic ecoregion. The site is in the tundra zone of the Canadian Shield, an area of continuous permafrost. Terrain is generally low and undulating, ranging between 470 and 505 m elevation. The tundra zone is characterized by typical barren ground vegetation. Moss, lichens, heather, and dwarf shrub communities are predominant in well-drained areas, while grasses and sedges are more dominant in wet ground adjacent to stream courses and around the perimeters of lakes (Golder 2003). Characteristic wildlife species include caribou, muskox, grizzly bear, hare, fox, wolf, raptors, shorebirds, and waterfowl.

Contwoyto Lake is the major water body in the region and has two outlets, the Burnside River on the northwest end of the lake, and the Back River at the southeast end of the lake. The main body of Contwoyto Lake lies to the east and south of the mine site. To the north of the mine, the West Arm of the lake extends to the west and south, terminating in Sun Bay, which lies directly west of the mine site (Golder 2003).

3. SOURCES OF DATA USED IN THE RISK ASSESSMENT

Risk assessment was used in this study to evaluate the potential for adverse effects on wildlife and people as a result of exposure to metals from the Lupin Gold Mine.

The risk assessment required information on metal and cyanide concentrations in the following parts of the food chain:

- reference water, soil, sand, sediment and native plant species for comparison and screening purposes;
- sediment from Ponds 1 and 2, and Boomerang Lake;
- soil from wind-blown tailings area;
- esker sand covering tailings containment cells;
- plants present in Cell 1 and in the wind-blown tailings area;
- water in the Pond 1 and 2 and Boomerang Lake;
- invertebrate tissue (calculated); and,
- animal tissue (calculated).

Reference water quality data were obtained from R.L. & L. (1995; 1996). In addition, water quality data from Kinross' database of monitoring results were used. Since no previous reference or study area data had been collected for soil or esker sand, and limited sediment data were available, samples were collected to fill these data gaps for the purposes of this assessment.

Animal tissue concentrations (i.e., caribou) were calculated based on uptake from soil, water and vegetation into animal tissue. Similarly, benthic invertebrate tissue concentrations were calculated based on uptake from sediment. These calculations are based on uptake factors for each metal and cyanide reported in peer-reviewed scientific literature.

More detailed descriptions of the sources of the data, the data, summary statistics and tissue calculations are presented in Appendix I.

4. DEFINITION OF REFERENCE

Reference concentrations are an important component of risk assessments. A reference concentration is the amount of a chemical found in an area that is similar to the study area but without the source being studied (in this case, tailings or effluent from the mine). In a risk assessment, reference concentrations are one of the screening tools used to evaluate the significance of concentrations of substances found in an area of interest. The use of reference concentrations as a screening tool is consistent with risk assessment protocols developed by Health Canada (2003).

Reference concentrations are required because some substances, particularly metals, are naturally occurring, especially in an area rich in mineral and gold deposits. Since metals are common and widespread, soil and water always contain some metals. Metals are a major component of the earth's crust; therefore, metals can be measured in all environmental samples (e.g., soil, sediment, water, and plants) no matter where the samples are taken from. Thus, comparisons between the study area concentrations and reference area concentrations were used to check whether or not metals measured in the study area are increased due to activities at the site.

Reference locations for each of the media required for the risk assessment are presented in Table 1.

Table 1
Reference Sample Locations for Each Media Used in the Risk Assessment

Media	Reference Location
water	South Bay
sediment	Shallow Bay
vegetation	near the esker borrow area
sand	near the esker borrow area

As part of the chemical screening step in the risk assessment, maximum metals concentrations measured in soil, sand, vegetation, water, and sediment from the TCA were compared with mean concentrations measured in each of the reference areas. Also, maximum concentrations of cyanide measured in the TCA were compared with mean concentrations measured in the reference area. If the study area concentrations were less than reference concentrations, the chemical was screened out; that is, it was not considered a chemical of concern and not considered further in the risk assessment. In other words, if concentrations are lower in the study area than in the reference areas, the source of metals and cyanide in the study area is not from the mine. If the study area concentrations were greater than the reference values, the substance was carried forward to the next step of the screening process. The screening process used in the risk assessment is described in more detail in Appendix II, Section 3.

5. RISK ASSESSMENT APPROACH

This risk assessment was conducted according to established health risk assessment protocols endorsed by Health Canada, the Canadian Council of Ministers of the Environment, Alberta Environment (AENV) and the United States Environmental Protection Agency (Health Canada 1994, 2003; CCME 1996 a,b,c; AENV 2000; U.S. EPA 1998) and risk assessment principles outlined in a report to Health Canada (Health Canada [unpublished] 1995).

Standard risk assessment terminology used in these guidance documents has been modified in this report to convey the information in a less technical manner. Refer to Appendix II for more detailed technical information.

What is Risk Assessment?

Risk assessment is a standard procedure for answering three fundamental questions about an area:

- How safe is it? (Section 5.1)
- How sure are we? (Section 5.2)
- Is it acceptable? (Section 5.3)

These questions must be answered in the context of the overall risk management goal. The overall goal for the closure plan at the Lupin Gold Mine is “No significant risks to wildlife populations using the area as a source of food and water and no risks to individual humans that consume caribou meat”.

5.1 How Safe Is It?

Risk assessment is a standard process used to characterize potential adverse health effects of human and wildlife exposures to potential environmental hazards (Paustenbach 2002). This is done by defining two components, *exposure* and *hazard*, as follows:

- Exposure: the intake of a metal (e.g., via ingestion) for a particular time period; and,
- Hazard: the type of adverse health effect(s) that can occur as a result of exposure.

Exposure to metals and cyanide by wildlife that may inhabit areas near the mine and people that may consume caribou meat is estimated by determining the following:

- the concentrations of substances in soil, sediment, plants and water;
- the types of receptors (i.e., wildlife) that could be in the vicinity of the mine or consume organisms that spend time in the area;
- the pathways by which receptors may come in contact with substances (i.e., incidental ingestion of soil, ingestion of food and water);
- the amount of time receptors may spend within the mine site (i.e., days/year);
- typical soil, sand, water and food ingestion rates and body weights for wildlife receptors;
- typical meat ingestion rates and body weights for human receptors; and,
- the quantity of metals that receptors are likely to take into their bodies by each pathway.

In the risk assessment, the hazard potential of substances is estimated by considering the following:

- determining whether the quantity of substances in soil, sediment and water exceeds applicable regulatory guidelines;
- reviewing the toxicity information associated with each substance; and,
- determining the total amount of exposure from all applicable pathways that would be unlikely to cause adverse health effects in receptors (called toxicity benchmarks).

The final step in a risk assessment, referred to as risk characterization, involves comparing the estimated exposure to the toxicity benchmark. If the estimated exposure is less than the toxicity benchmark, no health risks are expected. If the estimated exposure is greater than the toxicity benchmark, then mitigation measures that reduce exposure to substances from the tailings containment area may need to be examined.

5.1.1 Identifying Chemicals of Concern

The first step of the risk assessment was to identify chemicals that are of concern in the study area, as a result of tailings deposition. First, maximum concentrations of substances in soil, vegetation, water and sediment measured in the study area were compared to mean reference concentrations. The assessment focussed on metals concentrations in soil, water, vegetation and sediment and cyanide in water and sediment. Chemical concentrations that were lower in the study area than reference concentrations were not considered further. Comparison of maximum concentrations from the Lupin site to average reference area concentrations is conservative, since such a comparison over-estimates the metal concentrations present throughout the Lupin site (since most concentrations would be less than maximum). It also does not account for the higher natural background metal concentrations since average reference concentrations were used.

Chemicals with concentrations that were greater in the study area than in reference areas were then compared to CCME Environmental Quality Guidelines for soil, water and sediment quality (guidelines are not available for vegetation quality). The published guidelines used in this assessment are conservative; that is, they err on the side of safety in order to ensure the protection of the health of the most susceptible individuals in a population under daily exposure conditions. Environmental quality guidelines are derived using data for the most sensitive test species and are derived to be protective of all receptors, 100% of the time (CCME 1999). Therefore, concentrations less than guidelines can be assumed to be safe. Substances that were present at concentrations less than these guidelines were not evaluated further in the risk assessment.

The final step in determining the list of chemicals of concern was to determine if the chemical is an essential nutrient (e.g., calcium). Chemicals that were not essential nutrients, and were present in soil at concentrations greater than guidelines (or for which guidelines were not available), and were present at concentrations greater than reference values were identified as Chemicals of Concern (COC) and were evaluated in the risk assessment. Further details on the screening process are provided in Appendix II, Section 3. The COCs evaluated for wildlife health were also evaluated for human health, since the only exposure pathway evaluated for human health was meat ingestion. The following COCs were evaluated in the risk assessment:

- aluminum;
- arsenic;
- barium;
- boron;
- chromium;
- cobalt;
- copper;
- lead;
- manganese;
- molybdenum;

- nickel;
- selenium;
- silver;
- strontium;
- thallium;
- vanadium;
- zinc; and,
- cyanide.

5.1.2 Identifying Receptors

5.1.2.1 Wildlife Receptors

Receptors are humans or wildlife species chosen as representative species that receive exposure to the chemicals of concern. There are many species that could be present in the arctic environment. However, it is not practical to evaluate all species. Receptors that were selected for the risk assessment: are representative of the local ecosystem; have the greatest potential for exposure; play a key role in the food web; and have sufficient characterization data to facilitate calculations of exposure and health risks. The short-listed receptors are defined as resources or environmental features that include the following:

- are important to human populations (i.e., used as a food source);
- have economic and/or social value (i.e., animal that are trapped for furs, recreational value);
- have intrinsic ecological significance (i.e., endangered species, key species in the food web); and,
- serve as a baseline from which the impacts can be evaluated (CCME 1996a).

The receptor selection process is described in detail in Appendix II, Section 4.1.1. The following receptors were evaluated in the risk assessment:

- muskoxen (*Ovibos moschatus*);
- caribou (*Rangifer tarandus*);
- grizzly bears (*Ursus arctos horribilis*);
- wolverine (*Gulo gulo*);
- fox (*Vulpes vulpes*);
- wolves (*Canis lupus*);

- hare (*Lepus arcticus*);
- arctic ground squirrel (*Spermophilus parryii*);
- ptarmigan (*Lagopus lagopus*);
- rough legged hawk (*Buteo lagopus*);
- snipe (*Gallinago gallinago*); and,
- long-tailed duck (*Clangula hyemalis*).

5.1.2.2 Human Receptors

Humans are not expected to be directly exposed to metals and cyanide in the TCA at Lupin by incidental ingestion of tailings or via drinking effluent. Inhalation of dust containing wind-blown tailings was also eliminated as a pathway since dust deposition from the tailings occurs in a limited area immediately adjacent to the source tailings and still on mine property. Furthermore, exposed tailings will be covered with sand as part of the reclamation strategy, such that wind-blown tailings will not occur. The only exposure pathway evaluated for the human health risk assessment was ingestion of caribou meat. The Lupin mine site is not in close proximity to any communities (i.e., closest community is Bathurst Inlet, approximately 150 km northeast of Lupin). There are four families that live near the Lupin mine site. Two families currently live year-round approximately 10 km south of Lupin mine, while two families live 3 km away near the shore of Contwoyto Lake in the summer months. However, it is unlikely that these families will continue to live in these locations after closure of the mine as they rely on the mine for most of their provisions (pers. comm. M. Tansey). Large-bodied fish that are consumed by people (e.g., Arctic char, lake trout), will not be present in Ponds 1 and 2, since a spillway will be constructed to prevent movement of fish into the ponds. Fish-bearing lakes outside of the TCA were not part of the scope of work for this risk assessment. Currently, there are no berry-producing plants growing on the esker-covered cell. Therefore, the only pathway evaluated for the human health risk assessment was ingestion of caribou, where caribou are assumed to have taken up metals and cyanide from drinking water, food, and incidental soil ingestion from the Lupin mine site. Concentrations of metals and cyanide in caribou meat were estimated using uptake factors from published literature (Appendix I).

Both a hypothetical adult and toddler were evaluated for exposure to metals via ingestion of caribou meat. Consistent with risk assessment guidance (Health Canada 2003), the toddler life phase (i.e., seven months to four years) was chosen as the most susceptible child lifestage for evaluation of non-carcinogenic metals. The toddler phase is the most susceptible childhood phase due to their ratio of body size to ingestion rates compared to other life stages.

5.1.3 Identifying Exposure Pathways

Receptors may be exposed to substances from the Lupin mine via several pathways (Table 2).

Table 2
Ingestion Pathways Evaluated in the Risk Assessment

Receptor	Ingestion Pathways					
	Soil	Sediment	Water	Vegetation	Wild Game/ Prey	Benthic Invertebrate
People					√	
Caribou	√		√	√		
Muskox	√		√	√		
Grizzly bear	√		√	√	√	
Wolverine	√		√		√	
Fox	√		√		√	
Wolf	√		√		√	
Arctic hare	√		√	√		
Arctic ground squirrel	√		√	√		
Ptarmigan	√		√	√		
Rough-legged hawk	√		√		√	
Snipe		√	√			√
Long-tailed duck		√	√			√

Direct skin contact was not considered to be a significant exposure pathway for fur- or feather-bearing receptors since fur and feathers provide effective protection of skin. Water and soil on fur or feathers is more likely to be ingested during grooming than absorbed through the skin. Grooming was considered as part of the ingestion pathway. The details of the exposure pathway analysis are presented in Appendix II, Sections 4.1.2, and 5.1.2 for wildlife and humans, respectively.

5.1.4 Risk Assessment Endpoints

This step involves establishing assessment and measurement endpoints. An assessment endpoint is a general statement describing what is being protected. The measurement endpoint is the method for measuring whether the assessment endpoint is being achieved.

5.1.4.1 Assessment Endpoints

In human health risk assessment, protection of individual health is the assessment endpoint. This means that no one individual person may be exposed to concentrations of metals that may pose a health risk.

The risk management objective for the human health assessment endpoint is:

> *There will be no unacceptable risks to the health of individual children or adults consuming their entire daily meat intake from caribou that have been exposed to substances from the Lupin Mine.*

In ecological risk assessment, the overall goal is to ensure that the structure and function of the ecosystem is not changed to the point where populations and communities cannot be sustained and where human uses are curtailed. The assessment endpoints may be different depending on the type of species being evaluated. Listed species are typically protected at the individual level. Wolverine and grizzly bears are listed as “sensitive” (COSEWIC 2002; SARA 2002). Other wildlife are protected at the population level. Protection of the population means that the population of a species within an area of interest should not be affected; however, a small number of individual animals within the population may be affected.

The risk management objective for wildlife receptors that are not listed species for this risk assessment are:

> *There will be no unacceptable risks to the population of caribou, muskoxen, wolves, fox, hare, ground squirrel, hawk, snipe, long-tailed duck, and ptarmigan that may be exposed to metals and cyanide from the tailings containment area at the Lupin Gold Mine.*

The assessment endpoint corresponding to this objective is population persistence in the Contwoyto Lake area, where population persistence is defined as the continuing presence of viable populations with sustainable birth rate and death rate. Unacceptable risks to populations are defined as sufficient effects on individuals that the viability of the population declines due to increased death rate or decreased birth rate.

The risk management objective for listed wildlife receptors is:

> *There will be no unacceptable risks to individual wolverines and grizzly bears that may be exposed to metals and cyanide from the tailings containment area at the Lupin Gold Mine.*

The assessment endpoint corresponding to this objective is health of individual animals. Unacceptable risks to individuals are defined as risks of sub-lethal effects (such as slower growth or lower capacity to reproduce).

5.1.4.2 Measurement Endpoints

Human Receptors

The measurement endpoint for humans must be protective to ensure that there will not be unacceptable risks to individual children or adults consuming caribou that may have been exposed to substances from the Lupin mine. The primary measurement endpoint is the toxicity benchmark or toxicity reference value (TRV). TRVs are safe exposures below which there is minimal risk of adverse health effects. The TRVs used in the human health assessment were obtained from government agencies such as Health Canada (Health Canada 2003; TERA 2004), the Netherlands Institute of Public Health (RIVM 2001) and the U.S. EPA's Integrated Risk Information Service database (IRIS 2004). The ratio between estimated exposure to individuals and the TRV, called an Exposure Ratio (ER), should be less then the acceptable threshold value, 0.2. This acceptable threshold value is less than 1 to account for exposure to the COCs from other sources, which is the approach used by CCME (1999) and Health Canada (2003).

Wildlife Receptors

For wildlife receptors, two types of measurement endpoints are defined. Primary measurement endpoints assess risks to individual animals, in the same way that risks to individual human receptors are evaluated (as discussed above). However, in most cases for ecological receptors, it is more important to assess risks to the population, rather than to individual animals. In this case, secondary measurement endpoints are defined that evaluate risks to the population. However, if an ecological receptor has special status (i.e., listed as endangered, threatened or sensitive), risks to individual animals are evaluated (this is the case for wolverines and grizzly bears). Primary and secondary measurement endpoints for each of the ecological receptors are described in the sections below.

Primary Measurement Endpoints

In order to meet the assessment endpoint for wildlife ecological receptors, the primary measurement endpoint (or TRV) is the Lowest Observed Adverse Effect Level (LOAEL). As is done in the human health assessment, an ER is calculated for each exposure pathway, by calculating the ratio between estimated exposure and the toxicity benchmark. ERs values from each exposure pathway are added together to determine the total ER value. The acceptable ER value for risks to individual wildlife receptors is 1, since all of the exposure for wildlife is assumed to be from the tailings containment area at Lupin.

Secondary Measurement Endpoints

A secondary measurement endpoint has been defined for species where risks are predicted for individuals. The secondary measurement endpoint is that the number of individuals affected must be less than 20% of the probable population size (Suter et al. 1995). This threshold for effects on populations is based upon an understanding of the natural variability in the factors that control the sustainability of populations (e.g., birth rate and death rate). It is a very conservative benchmark, since the natural variability in birth and death rates is usually much higher than 20%. The number of individuals affected is estimated from the home range size of each of the receptors. Species with small home range sizes (e.g., arctic hare) may have more than one home range overlapping the area. In these cases, the total number of individuals relative to the probable population size is evaluated.

5.1.5 Estimating Exposure

5.1.5.1 Wildlife Health

The amount of exposure that receptors might receive from the study area was determined for all of the exposure pathways defined in Table 2, in Section 5.1.3. The amount of exposure depends on the concentrations in various media (e.g., maximum metal concentrations measured in soil, plant tissue, and water and calculated prey tissue concentrations), the amount of time an animal is in contact with these media and the rates at which the receptors take in food and soil. Some of these factors (e.g., water ingestion rates, food ingestion rates) are available from government agencies (i.e., U.S. EPA) while others required professional judgement (i.e., time in the area). Whenever there was uncertainty and in order to account for the variability in animals' habits, conservative assumptions were used to ensure that exposure would not be underestimated.

5.1.5.2 Human Health

The amount of exposure to metals that people would get from the study area was determined for the caribou meat ingestion pathway. The amount of exposure depends on the concentration of metals and cyanide in caribou meat resulting from caribou ingestion of vegetation, water and soil from the TCA, meat ingestion rates and the frequency of meat ingestion. Default food ingestion rates for aboriginal people were obtained from Health Canada (2003). It was assumed that people consumed caribou meat 365 days per year from caribou that have spent 37 days per year (i.e., 10% of the year) ingesting vegetation, water and soil from the Lupin Mine site.

The assumptions used in the wildlife and human risk assessment are presented in Table 3. These assumptions, together with maximum measured metal and cyanide concentrations and literature values for parameters such as ingestion rates, were used as input to exposure equations for humans and wildlife.

5.1.5.3 Conservative Assumptions Used in the Risk Assessment

The conservative assumptions used in the human and wildlife exposure assessments are presented in Table 3. Further details on methods to estimate exposure are presented in Appendix II, Section 4.2 and 5.2 for wildlife and humans, respectively.

Table 3
Conservative Assumptions Used in the Risk Assessment and the Reasons Why Assumptions Are Conservative

Assumption Used in the Risk Assessment	Reason Why Assumption Is Conservative
Wildlife consume 100% of their food (i.e., vegetation or prey) and water while in the vicinity of the tailings containment area	Animals will not be confined to the Lupin Mine but rather are free to get drinking water and food from throughout the their home range. The grasses might grow on the esker cover are not necessarily preferred vegetation types for wildlife. In addition, there are many sources of water in the vicinity of the mine so it is very unlikely that wildlife would consume all of their daily drinking water from Ponds 1 and 2.
Receptors are exposed to maximum concentrations in plants, soil and water.	Animals are not confined to areas with the maximum concentration. While in the vicinity of the Lupin Mine, animals are most likely to be exposed to a range of metals concentrations.
People consume their entire meat intake per year from caribou that have been exposed to metals and cyanide from the Lupin Gold Mine.	It is unlikely that all of the meat that people would consume would be from caribou that have been exposed to maximum concentrations of metals and cyanide from the Lupin mine site. The majority of the caribou hunted in Nunavut are unlikely to encounter the mine at all.
Benthic invertebrates inhabit Ponds 1 and 2.	Ponds 1 and 2 in the tailings containment area of the Lupin Gold Mine are not intended to be aquatic habitat. It is very unlikely that substantial numbers of invertebrates are present and the numbers that might be present are unlikely to fully support dietary needs of snipe and long-tailed duck.
Caribou spend 10% of the year (37 days) at the Lupin site.	Caribou are migratory animals that travel through the barrenlands to and from their calving grounds near Bathurst Inlet. It is very unlikely that caribou would spend as much as 10% of the year at the Lupin Mine Site because they are constantly moving with movement rates ranging from 2 to 23 km/day (Gunn et al. 2002).

5.1.6 Determining the Toxicity Benchmark

Toxicity assessment involves identification of the potentially toxic effects of substances, and determination of the amount of a substance that a receptor can be exposed to without experiencing unacceptable effects. The results of the toxicity assessment are expressed as the TRV, or toxicity benchmark. TRVs are safe exposures below which there is minimal risk of adverse health effects. Further details on determining toxicity benchmarks for this risk assessment are presented in Appendix II, Section 4.4, and 5.4 for wildlife and humans, respectively.

5.1.6.1 Wildlife Toxicity Benchmarks

TRVs for the wildlife health assessment were obtained from Sample et al. (1996). These TRVs are based on laboratory toxicity studies. Ideally, toxicity test species should be the same species being evaluated in the risk assessment, but this is rarely possible. Usually, laboratory toxicity studies using rats, mice, mallard ducks or other captive species provide dose-response information that can be extrapolated to wildlife. The Lowest-Observed-Adverse-Effect Level (LOAEL) for sublethal effects was selected for each metal, where available. In studies where mortality was the endpoint or where a LOAEL was not identified, the No-Observed-Adverse-Effect Level (NOAEL) was selected. The LOAELs and NOAELs from laboratory studies were extrapolated to TRVs for wildlife species by incorporating differences in physiology between large and small animals using the methods provided by Sample and Arenal 1999 (see Appendix II).

5.1.6.2 Human Health Toxicity Benchmarks

The TRVs used in the human health assessment were obtained from government agencies such as Health Canada (Health Canada 2003; TERA 2004) and the U.S. EPA's Integrated Risk Information Service Database (IRIS 2004). The majority of toxicity information comes from the results of experiments with laboratory animals. Some additional information on human health effects is also available for some substances where cases of workplace exposures and associated health effects have been documented.

Animal studies provide dose-response information for non-carcinogenic chemicals that can be extrapolated to humans by applying safety factors. In most cases safety factors of 100 to 1,000 are applied to a laboratory derived No-Observed-Adverse-Effect Level (NOAEL; the highest concentration in a toxicity test where no chronic health effects were observed or measured) to account for interspecies extrapolation and protection of the most susceptible in a population (i.e., children and elderly). Therefore, TRVs have large margins of safety to ensure that the toxicity or risk of a substance to people is not underestimated.

For carcinogenic chemicals, dose-response information from laboratory studies is used to define cancer risk estimates to humans. Data from toxicity tests are used to determine the potential increase in cancer risk as a result of exposure to a cancer-causing substance (e.g., arsenic) called a slope factor (Health Canada 2003). The slope factor is used to calculate the cancer risk per 100,000 people due to exposure to cancer-causing substances. A cancer risk of 1 in 100,000 is considered to be "essentially negligible" by Health Canada (2003). The Canadian lifetime probability of developing cancer due to such as genetics, family history, diet, lifestyle and environmental pollutants is 4 in 10 or 40,000 in 100,000 (Health Canada 2003).

5.1.7 Risk Characterization

Risk estimates were calculated as the exposure ratio (ER), which is a ratio of the estimated exposure of metals and cyanide to the toxicity benchmarks, as follows:

$$ER = \frac{\text{Estimated Exposure}}{\text{Toxicity Benchmark}}$$

The resulting ER must be interpreted according to the assessment endpoints as described above.

The ER indicates whether the amount of a substance taken in by people or animals is greater than the amount of the substance below which there would be no health effect or no unacceptable risk of cancer. If the ER is greater than 1, then the amount taken in is greater than the threshold amount for which there are no health effects. This does not mean that there will be health effects; rather that there is a potential risk. Further consideration may be necessary to reduce uncertainty in the risk assessment, especially if the ERs are only slightly greater than 1, since making risk management decisions based on slight exceedances may result in unnecessary remediation action. If the ER is less than 1, then we can be certain that no health effects or unacceptable risks would occur.

In some cases, it is necessary to reduce the acceptable ER value since other sources of exposure need to be considered. For example, since the earth's crust is made up of metals, they are all around us. They are in the food we eat, the air we breathe and the water we drink. Therefore, the ER calculated from exposure in the study area must be adjusted to consider exposure from other sources. For this assessment the acceptable risk threshold for the human health risk assessment was an ER of 0.2 because it is assumed that people are exposed to metals from multiple sources.

For wildlife, the acceptable risk threshold is an ER of 1 since the risk assessment conservatively assumed wildlife obtained all of their food, water and soil from the Lupin Gold Mine. No other significant exposure sources would occur while wildlife are in the vicinity of the mine site.

5.2 How Sure Are We?

5.2.1 Applying Layers of Safety

In this risk assessment, exposures and benchmarks were estimated from available information about how exposure might take place and the potential health effects that could result. There is always uncertainty associated with these estimations, depending on the quality, quantity and variability associated with the available data. When information is uncertain, it is standard practice in a risk assessment to make assumptions that are biased towards safety, so that even if there is uncertainty, human and wildlife health will still be protected. Every effort was made to ensure that assumptions were specific to the Lupin Gold Mine.

There are several layers of safety applied in this study. For example, maximum concentrations were used in the risk assessment to estimate exposure. This assumption accounts for the potential variability in concentrations in soil, sand, sediment, water and vegetation. Conservative assumptions regarding the amount of time that wildlife spent near the mine site were also applied to the risk assessment. In addition, it was assumed that people ate caribou meat every day (i.e., 365 days per year) from caribou that were exposed to maximum concentrations from the mine site for 37 days per year.

There is also uncertainty associated with estimating toxicity benchmarks. Extrapolating from animal studies in the laboratory to the possible effects that may result from exposure to metals from the study area is uncertain. To add a layer of safety, for human health risk assessments it is a standard practice to assume that people are more sensitive to the toxic effects of a substance than laboratory animals. Therefore, the toxicity benchmark for human health is set at a much lower level than the animal benchmark (typically 100 to 1,000 times lower). This large margin of safety ensures that doses less than the toxicity benchmarks are safe and that exposure slightly greater than the benchmarks are extremely unlikely to cause adverse health effects.

All of these layers of safety ensure that risks due to exposure to metals and cyanide from the mine site have not been underestimated.

5.3 Is It Acceptable?

5.3.1 Acceptability of Guidelines and Toxicity Benchmarks

The risk assessment approach, guidelines and toxicity benchmarks used in this risk assessment have been determined by regulatory agencies to be acceptable based on a combination of scientific information and public acceptability. Science provides the understanding of the consequences of exposure. Public opinion has determined the level of protection that must be built into the guidelines and toxicity benchmarks.

6. RISK ASSESSMENT RESULTS

6.1 Wildlife Health Risk Assessment Results

ERs for wildlife receptors for all COCs are presented in Figure 4. ERs were less than 1 for caribou, grizzly bears, wolverines, foxes, wolves and arctic hare for all COCs. Therefore, no risks to individual animals or populations of these receptors are expected.

ERs were also less than 1 for exposure to barium, boron, chromium, copper, lead, manganese, molybdenum, nickel, selenium, silver, strontium, thallium, and vanadium for all receptors. Therefore, no risks to individual animals or populations are expected for exposure to these metals for all receptors.

ERs for maximum concentrations of aluminum, arsenic, cobalt, zinc and cyanide were greater than 1 from some receptors. These results are described in more detail below. The results are presented and discussed in terms of risks to individual animals. This represents the primary measurement endpoint. If risks to individuals were predicted, then risks to populations were discussed in terms of the secondary measurement endpoint (i.e., potential to affect birth or death rate by greater than 20%).

Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations

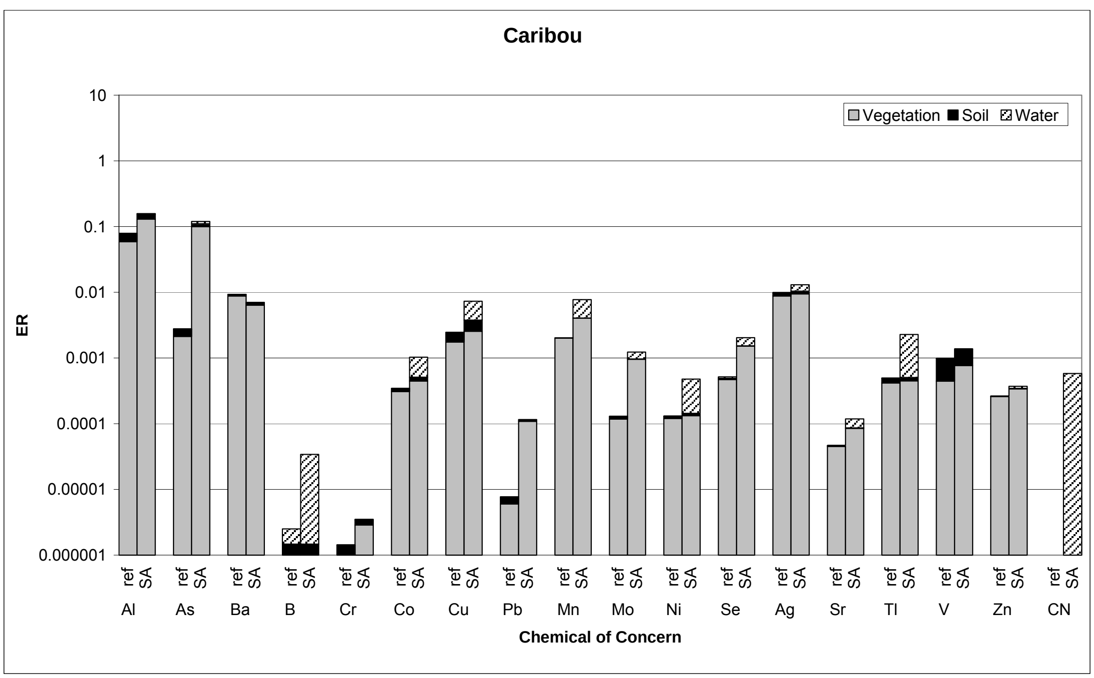
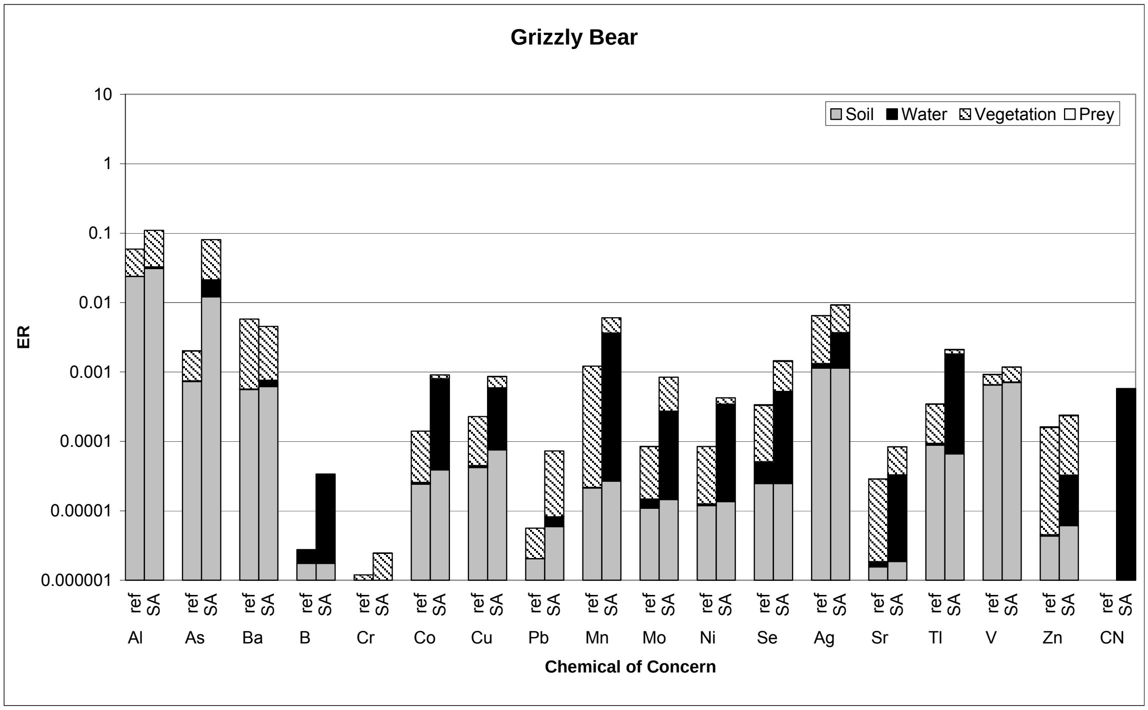


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



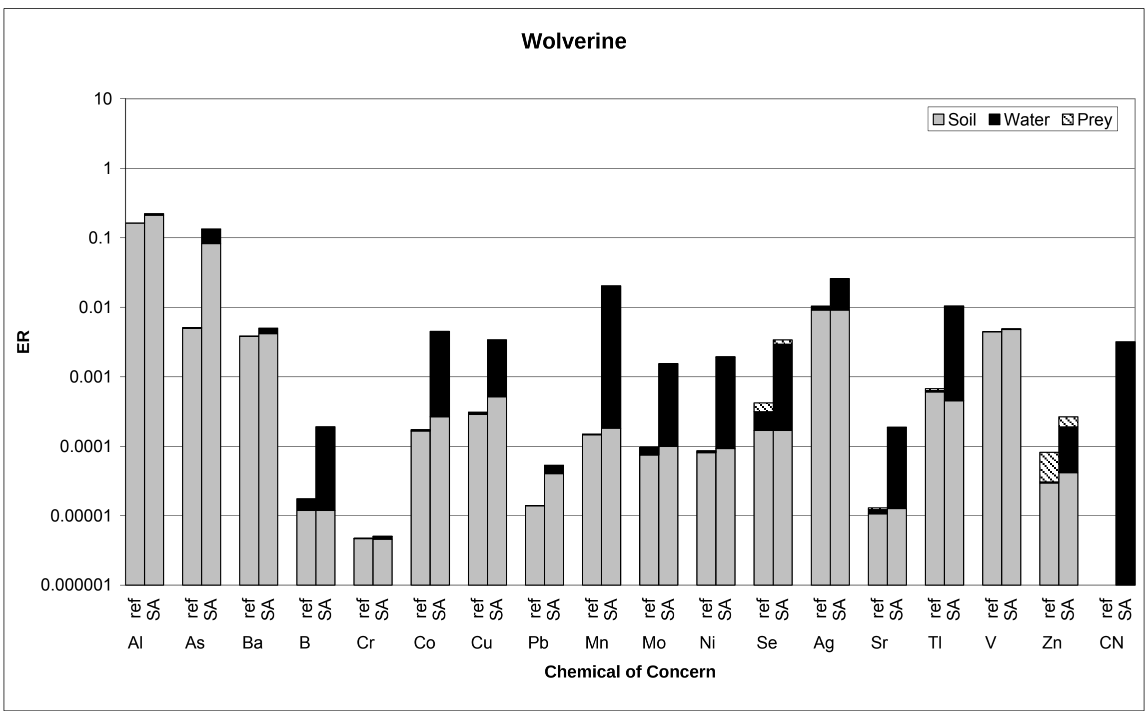
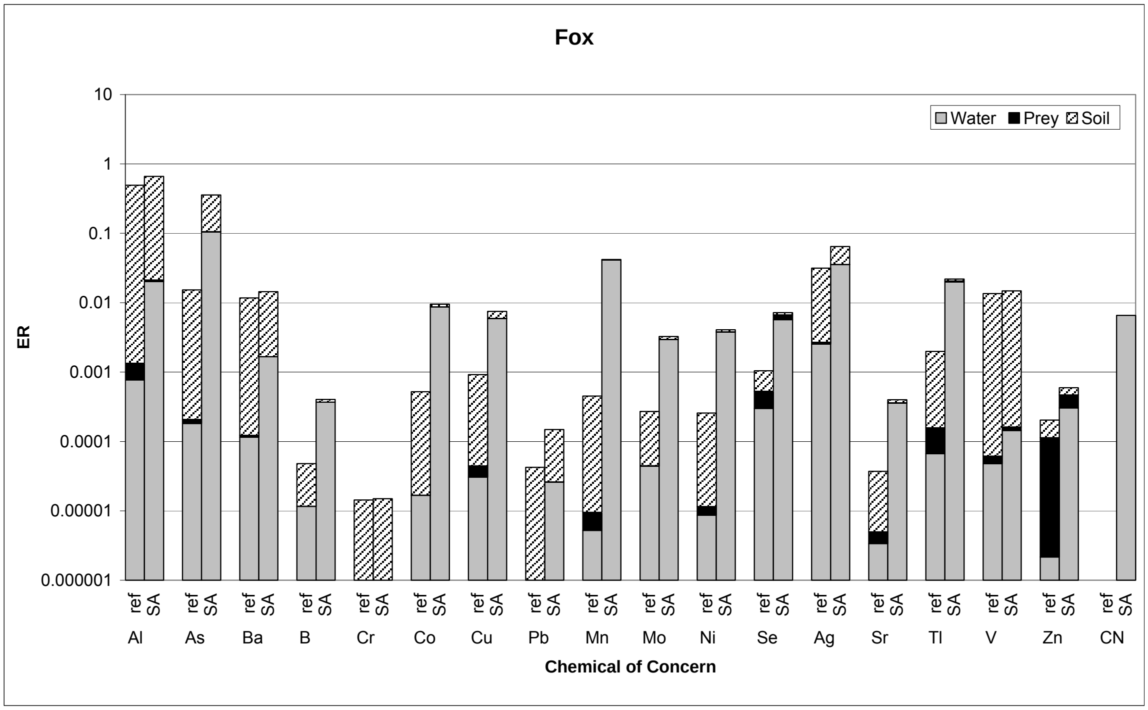


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



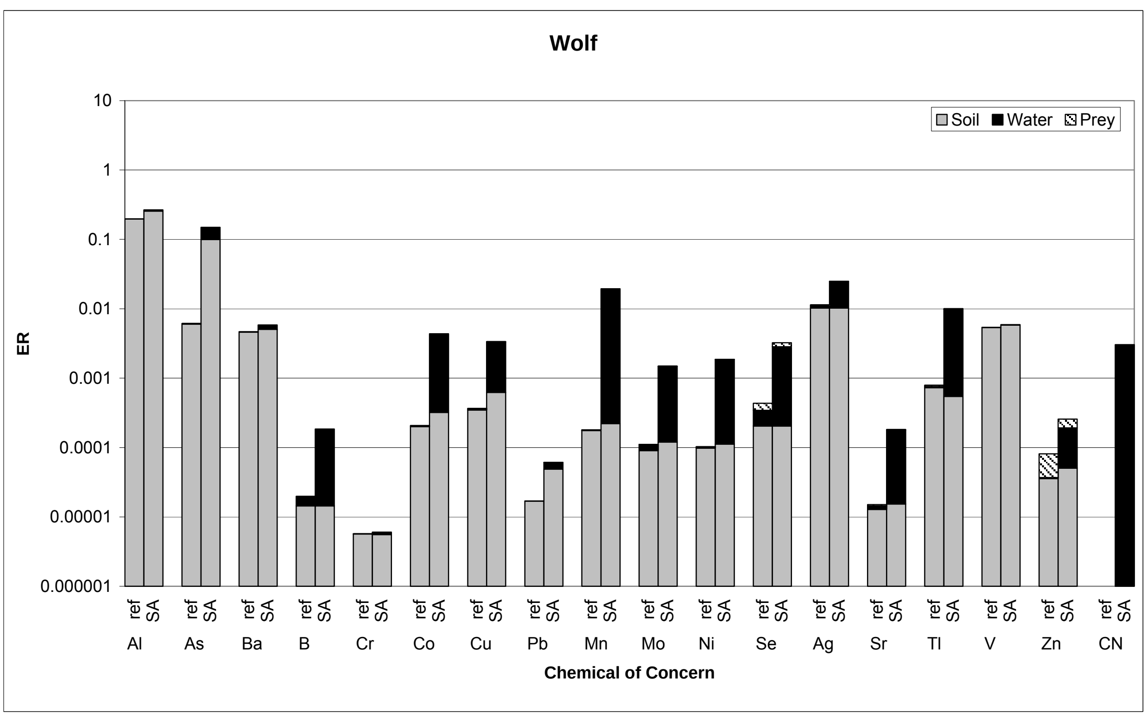
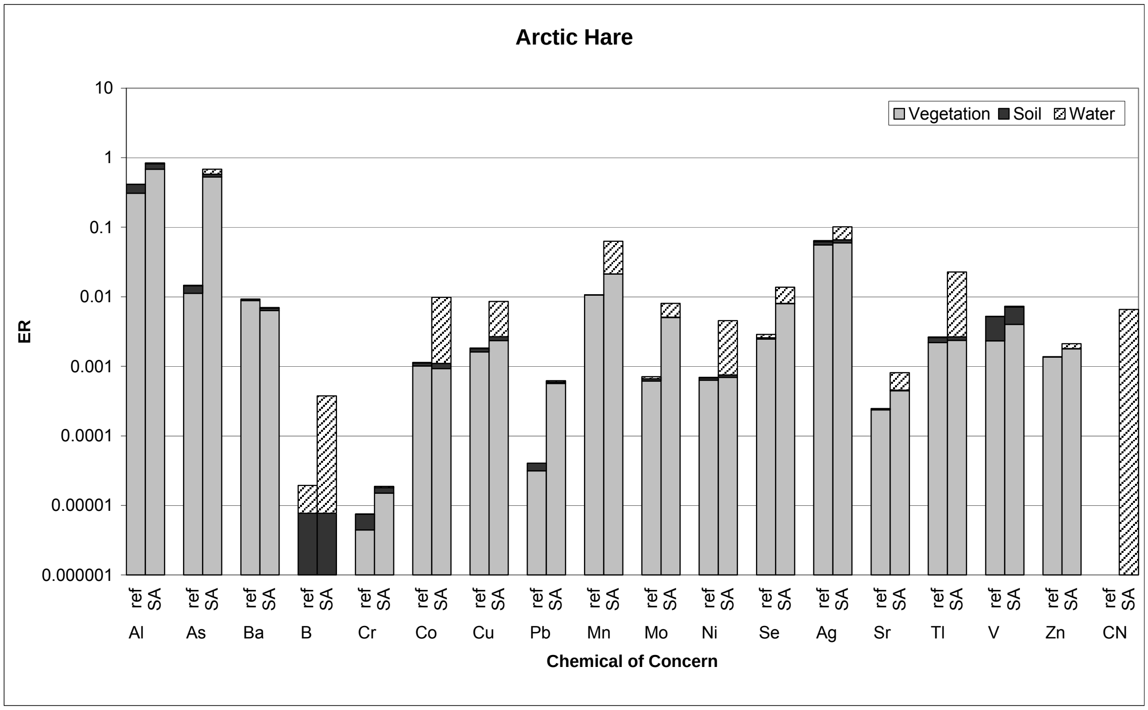


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



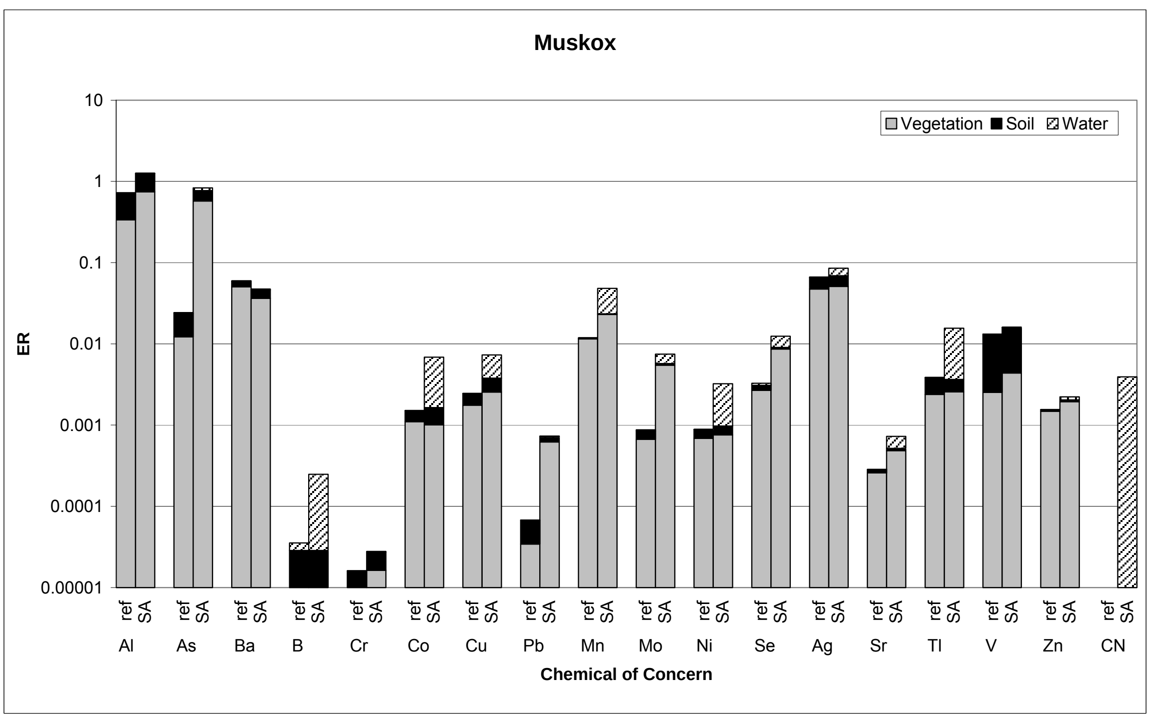
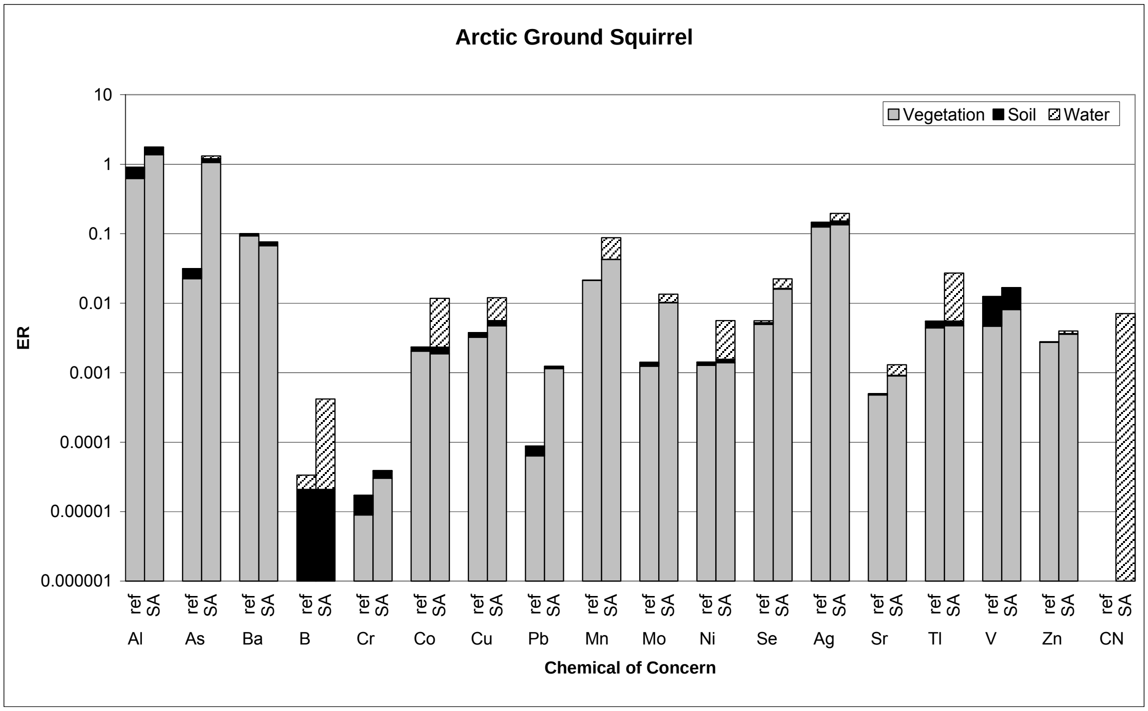


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



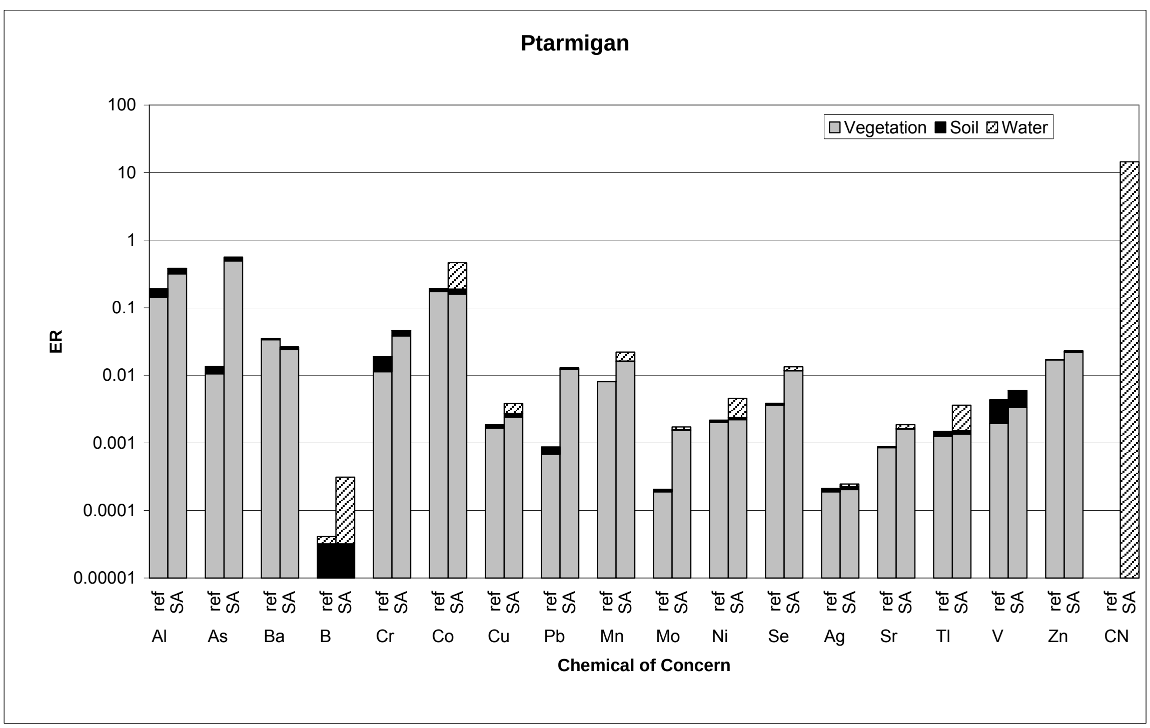
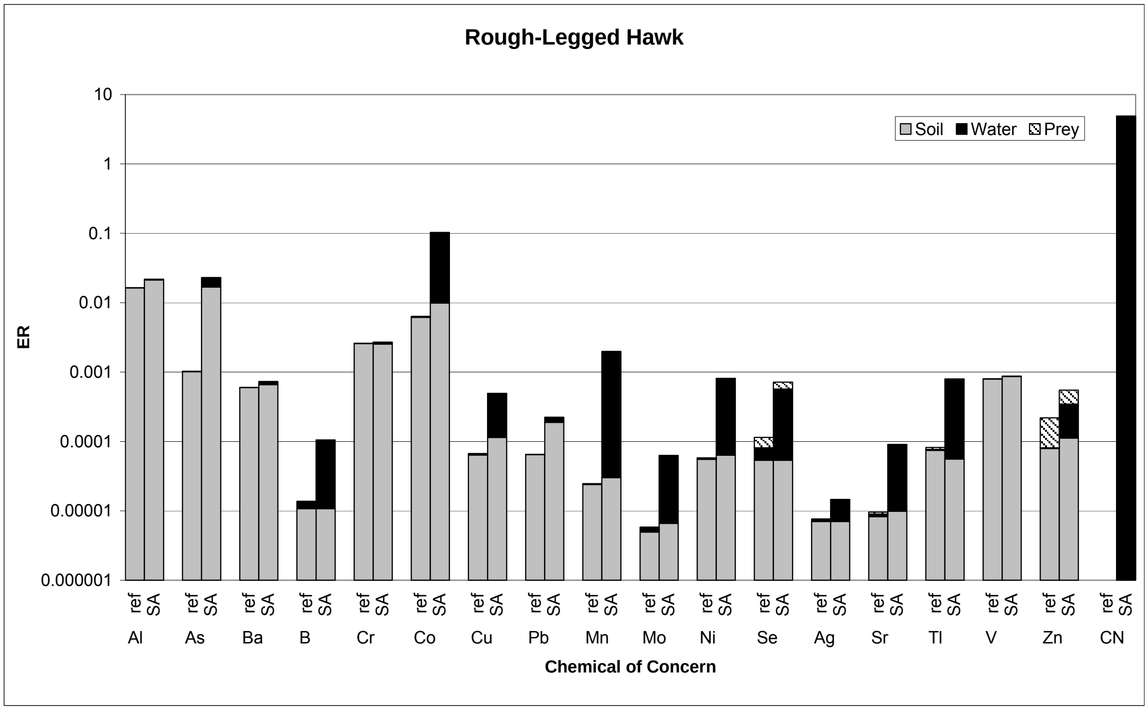


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



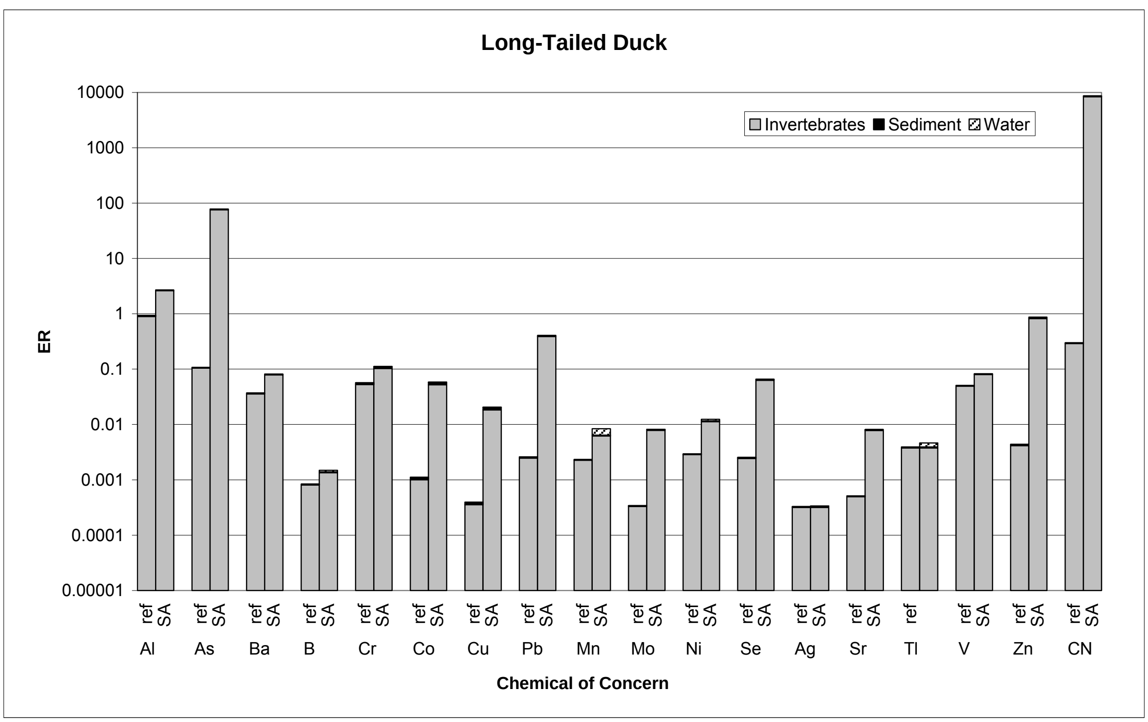
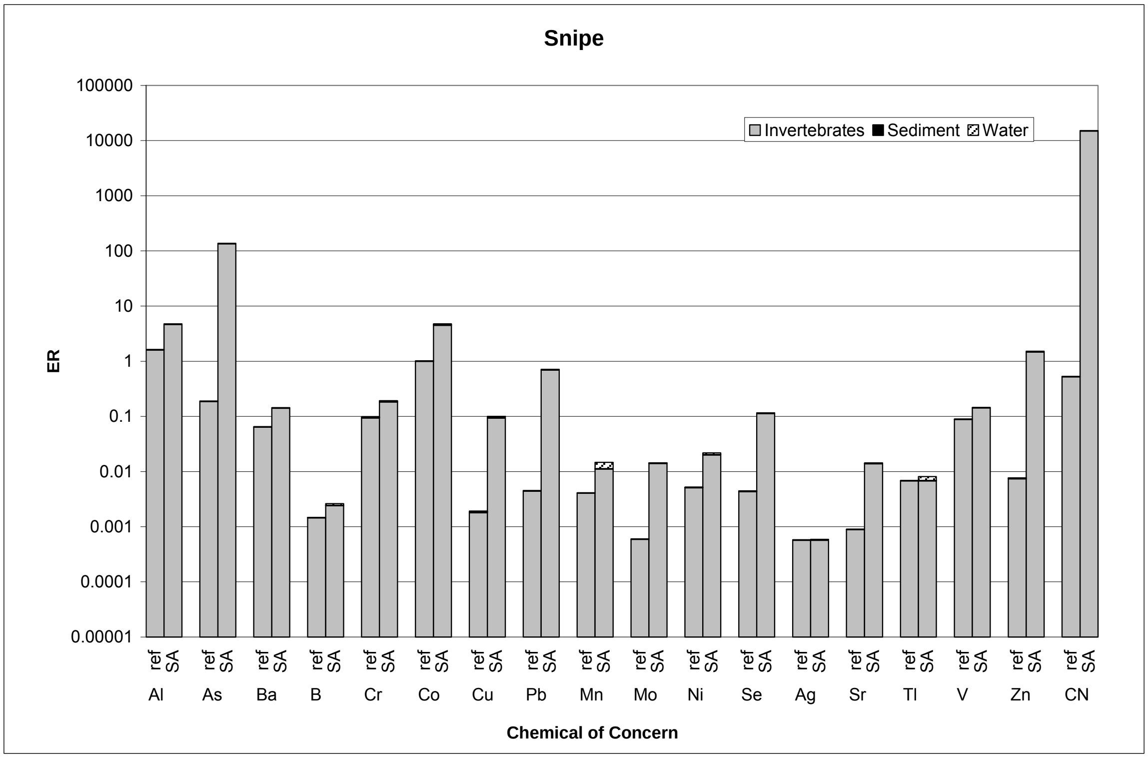


Figure 4
Exposure Ratios for Wildlife Receptors Showing the Relative Contribution of Risk from Exposure Sources, and Assuming Exposure to Maximum Concentrations (continued)



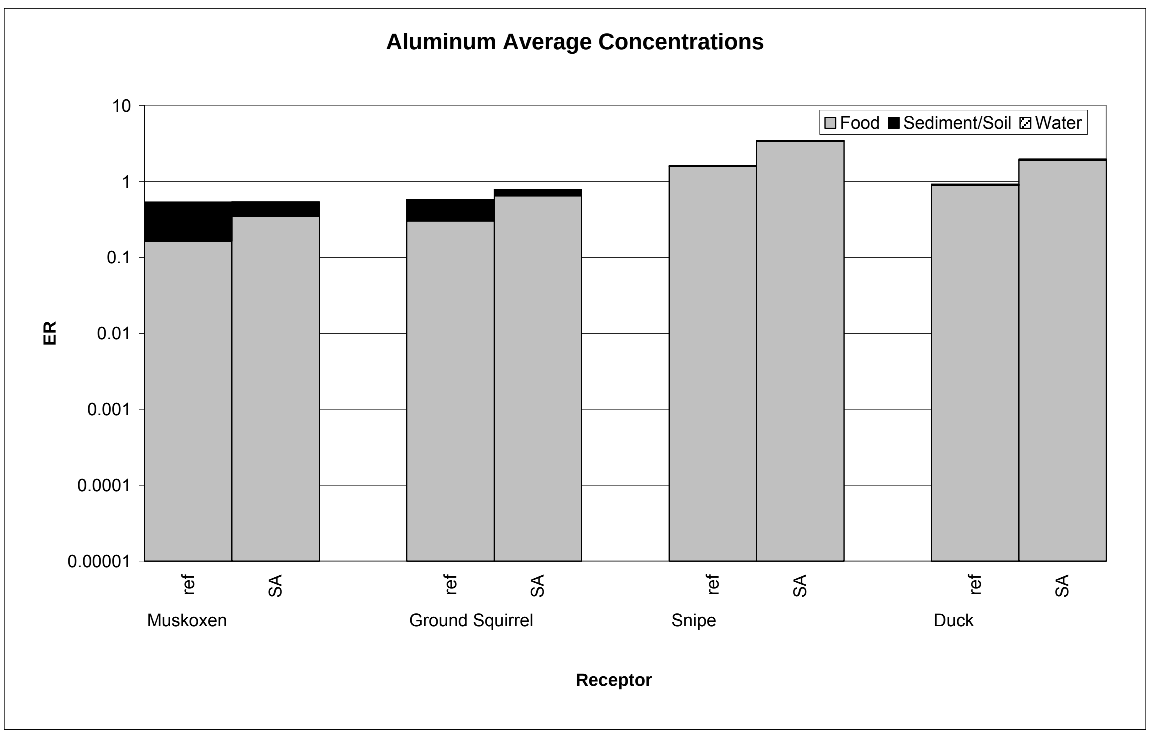
ref = reference area	SA = study area	
Al = aluminum	Cu = copper	Ag = silver
As = arsenic	Pb = lead	Sr = strontium
Ba = barium	Mn = manganese	Tl = thallium
B = boron	Mo = molybdenum	V = vanadium
Cr = chromium	Ni = nickel	Zn = zinc
Co = cobalt	Se = selenium	CN = cyanide

6.1.1 Aluminum

ERs were marginally greater than 1 in the study area for muskox, arctic ground squirrel, snipe and long-tailed duck based on maximum concentrations. ERs in the study area were only slightly higher than ERs calculated for exposure to maximum concentrations of aluminum in the reference area (Figure 4). The main exposure pathway contributing to ERs greater than 1 is vegetation ingestion for muskox and arctic squirrel, and benthic invertebrate ingestion for snipe and long-tailed duck.

For comparison, ERs for muskox, arctic ground squirrel, snipe and long-tailed duck were calculated using average concentrations of aluminum measured in samples from the study area and reference area. ERs were less than 1 for muskox and arctic ground squirrel and ERs for the study area and reference area are very similar (Figure 5). ERs are marginally greater than 1 for snipe and long-tailed duck based on average concentrations of aluminum. The predominant exposure pathway is invertebrate ingestion. Invertebrate concentrations of aluminum were estimated from literature uptake factors. However, aluminum is one of the most common elements of the earth's crust and is often at relatively high concentrations in sediments and soils. Most naturally occurring aluminum compounds are insoluble and not available for uptake in invertebrates and subsequently wildlife. Therefore, it is likely that aluminum concentrations were substantially overestimated.

Figure 5
ERs for Muskoxen, Arctic Ground Squirrel, Snipe and Long-Tailed Duck Based on Average Concentrations of Aluminum



Aluminum is not likely to cause adverse health effects for any individual wildlife receptor for the following reasons:

- the differences between the study area and reference area ERs are small; therefore, measured concentrations are likely naturally occurring;
- it was assumed that 100% of aluminum measured in sediment was 100% available for uptake to invertebrates and birds; and,
- ERs are only marginally greater than 1 for maximum exposure by muskox and arctic ground squirrel and less than 1 for average exposure. ERs are only marginally greater than 1 for maximum and average exposure by snipe and long-tailed duck.

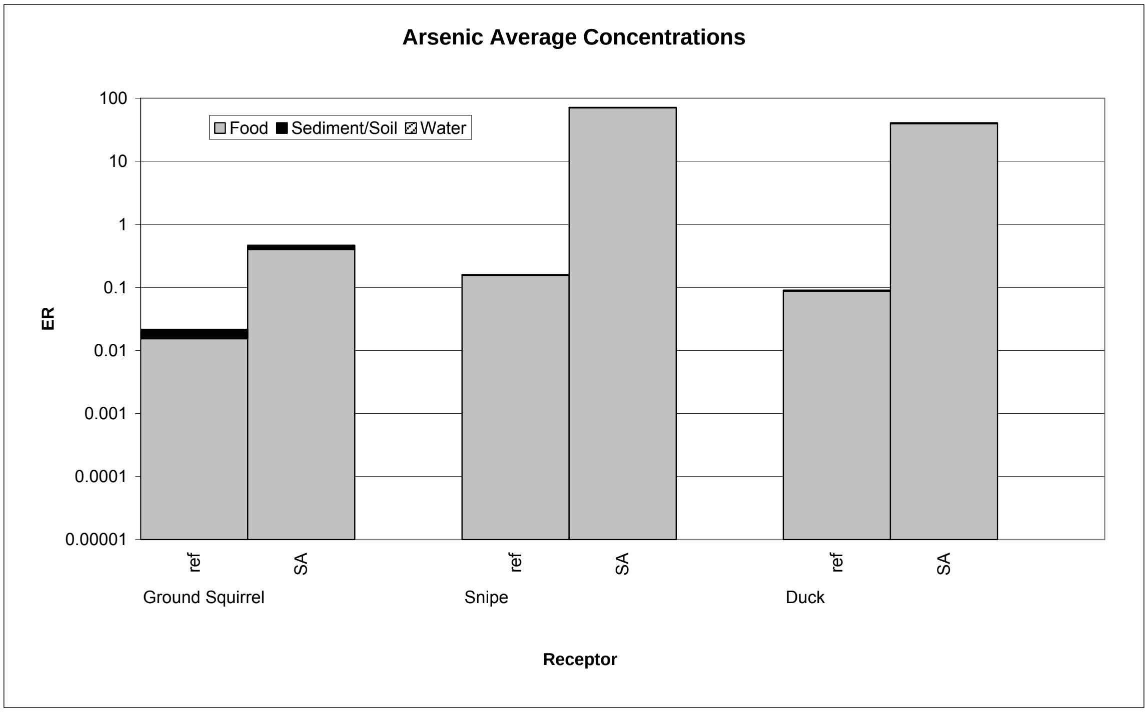
6.1.2 Arsenic

ERs estimated for maximum arsenic exposure were greater than 1 for arctic ground squirrel, snipe and long-tailed duck for exposure in the study area (Figure 4). ERs for arctic ground squirrel were only marginally greater than 1 (i.e., 1.1); therefore, risks to arctic ground squirrels are not expected to occur due to the conservative assumptions used in the risk assessment (e.g., exposure to maximum concentrations every day).

ERs for long-tailed duck and snipe exposure to arsenic were much greater than 1 (Figure 4). The predominant exposure pathway was invertebrate ingestion. Benthic invertebrate arsenic concentrations were estimated based on literature uptake values, which may have resulted in an overestimate of exposure. It is also not known whether substantial numbers of invertebrates inhabit the ponds on site. It is likely that invertebrate abundance is not sufficient to fully support the dietary needs of long-tailed ducks and snipe.

For comparison purposes, ERs for arctic ground squirrel, snipe and long-tailed duck were calculated using average concentrations of arsenic measured in samples from the study area and reference area. Based on average concentrations, ERs were less than 1 for arctic ground squirrel but remained greater than 1 for snipe and long-tailed duck (Figure 6).

Figure 6
ERs for Arctic Ground Squirrel, Snipe and Long-Tailed Duck Based on Average Concentrations of Arsenic

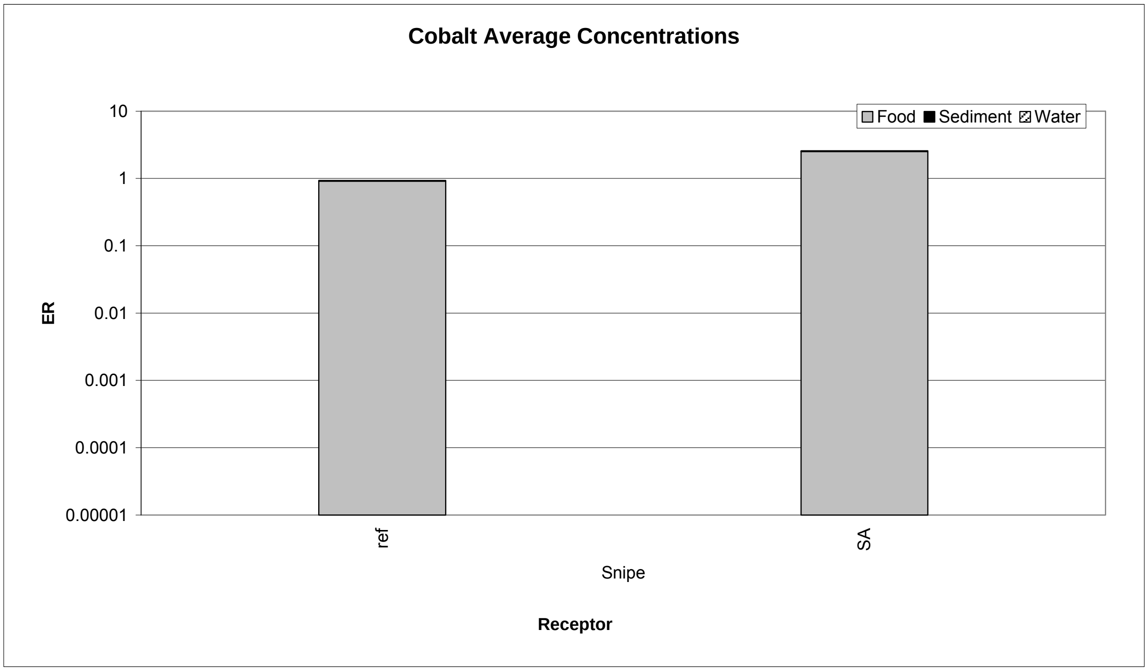


6.1.3 Cobalt

ERs were greater than 1 for snipe exposure to cobalt and benthic invertebrate ingestion was the predominant exposure pathway (Figure 4). Literature values for uptake were used to estimate benthic invertebrate concentrations from sediment data and as described above, this may have resulted in an overestimate of concentrations.

For comparison purposes, ERs for snipe were calculated using average concentrations of cobalt measured in samples from the study area and reference area. The ER based on average cobalt concentrations was marginally greater than 1 in the study area, but the majority of the exposure is expected to be due to background concentrations since the difference between ERs in the study area and reference area are minimal (Figure 7). Because of the conservative assumptions used in the risk assessment and minimal difference between the study and reference areas, adverse health effects are not expected for snipe exposure to cobalt.

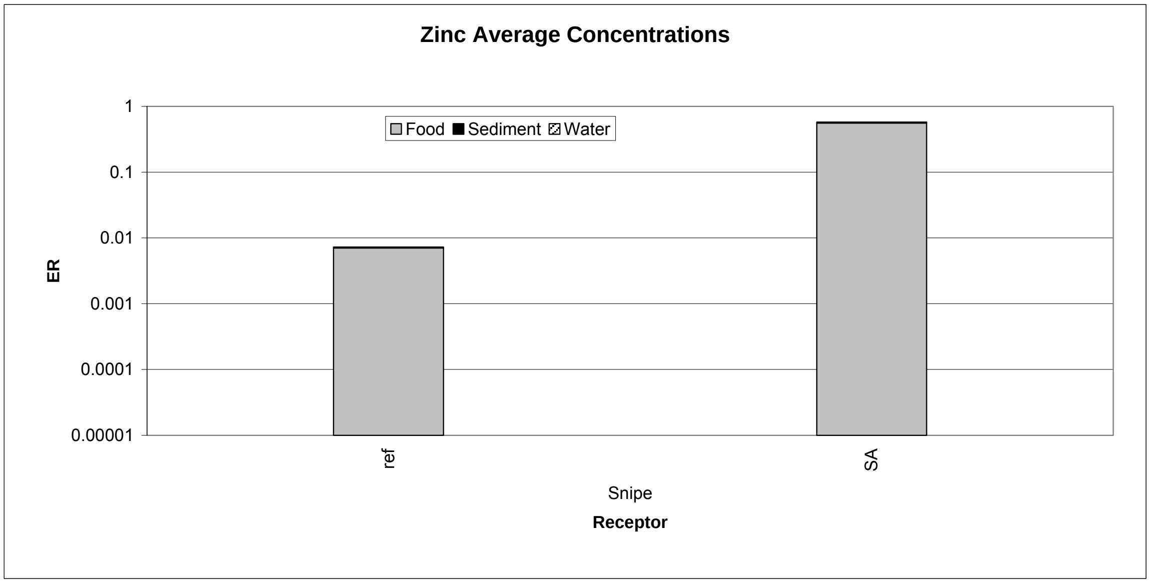
Figure 7
ERs for Snipe Based on Average Concentrations of Cobalt



6.1.4 Zinc

Exposure for snipe to maximum concentrations of zinc was only marginally greater than 1 in the study area (i.e., 1.5). The predominant exposure pathway is benthic invertebrate ingestion, which as described above is based on estimated benthic invertebrate concentrations using literature values. ERs calculated using average zinc concentrations were less than 1 (Figure 8). It is unlikely that adverse health effects would be caused by exposure to zinc because ERs were only marginally greater than 1 for maximum concentrations and were less than 1 based on average concentrations.

Figure 8
ERs for Snipe Based on Average Concentrations of Zinc

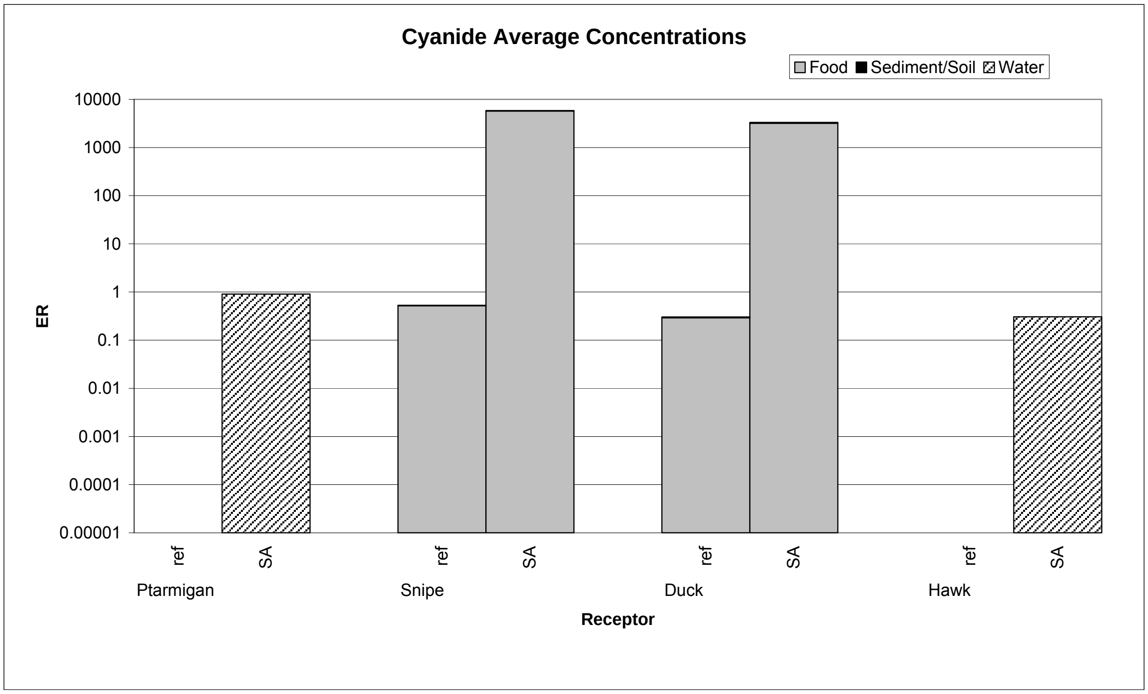


6.1.5 Cyanide

Estimated exposures to cyanide resulted in ERs much greater than 1 for long-tailed duck and snipe, and ERs slightly greater than 1 for ptarmigan and rough-legged hawk (Figure 4). The predominant exposure pathway is invertebrate ingestion; however, ERs for the sediment ingestion and water ingestion pathways were also much greater than 1 for long-tailed duck and snipe. Water ingestion is the predominant pathway for ptarmigan and rough-legged hawk.

ERs were also calculated based on average cyanide concentrations for long-tailed duck, snipe, ptarmigan and rough-legged hawk. ERs were less than 1 for ptarmigan and rough-legged hawk, but were greater than 1 for long-tailed duck and snipe (Figure 9).

Figure 9
ERs for Ptarmigan, Hawk, Snipe and Long-Tailed Duck Based on Average Concentrations of Cyanide



6.2 Risks to Wildlife Receptor Populations

The risks to wildlife receptors calculated from both maximum media concentrations and average media concentrations are presented in Table 4.

Table 4
Summary of Risks to Shorebirds and Waterfowl based on Maximum and Average Concentrations in the Study Area

Receptor	Contaminant of Concern	Total ER	
		Maximum Concentrations	Average Concentrations
Snipe	Arsenic	138	72
	Cyanide	15,173	5,822
Duck	Arsenic	78	41
	Cyanide	8,639	3,315

Population-level risks for migratory animals such as snipe and long-tailed duck would require a sufficient number of individuals to either have lower survivorship or lower reproductive capability due to exposure to the Lupin site to cause a decline in abundance and population persistence. The Lupin area is on the path of a major bird migratory route; therefore, many individuals may have short-duration exposure to the site. However, it is likely that very few individuals or breeding pairs would spend the entire breeding season at the site. Therefore, it is unlikely that sufficient numbers of individuals would be affected to pose a risk to populations.

6.3 Human Health Risk Assessment Results

ERs were less than 0.2 for all COCs for both toddler and adult ingestion of caribou meat, except for arsenic. ERs for maximum exposure to arsenic (non-carcinogenic effects) were marginally greater than 0.2 (i.e., 0.3 for both toddlers and adults) (Figure 10). Since arsenic is a carcinogen, a lifetime cancer risk due to arsenic exposure was also calculated. The lifetime cancer risk due to maximum concentrations of arsenic due to ingestion of caribou is 14 in 100,000. These calculations were based on maximum arsenic exposure in water, soil and vegetation by caribou and ingestion of these caribou by people everyday for a lifetime. This is a highly improbable scenario.

The cancer risks calculated for the reference areas and Study Area were compared with cancer risks calculated for the Canadian Drinking Water Quality Guideline and lifetime probability of getting cancer from all sources (such as, family history, genetics, lifestyle) (Figure 11). The lifetime probability of getting cancer from all sources is 40,000 in 100,000 (Health Canada 2003a). Since arsenic is naturally occurring, background water sources (surface water and groundwater) typically have concentrations of arsenic that have a greater than 1 in 100,000 cancer risk. Health Canada accepted a cancer risk for arsenic of 147 in 100,000 in the derivation of the drinking water quality guideline (Health Canada 2003b). The cancer risk estimated in the study area of 14 in 100,000 would not be considered measurable, and would be considered insignificant compared to the cancer risk associated with the Canadian Drinking Water Quality Guideline (Health Canada 2003b) and the cancer incidence from all causes in Canada (Health Canada 2003a).

Figure 10
ERs for Toddler and Adult Based on Maximum Arsenic Concentrations

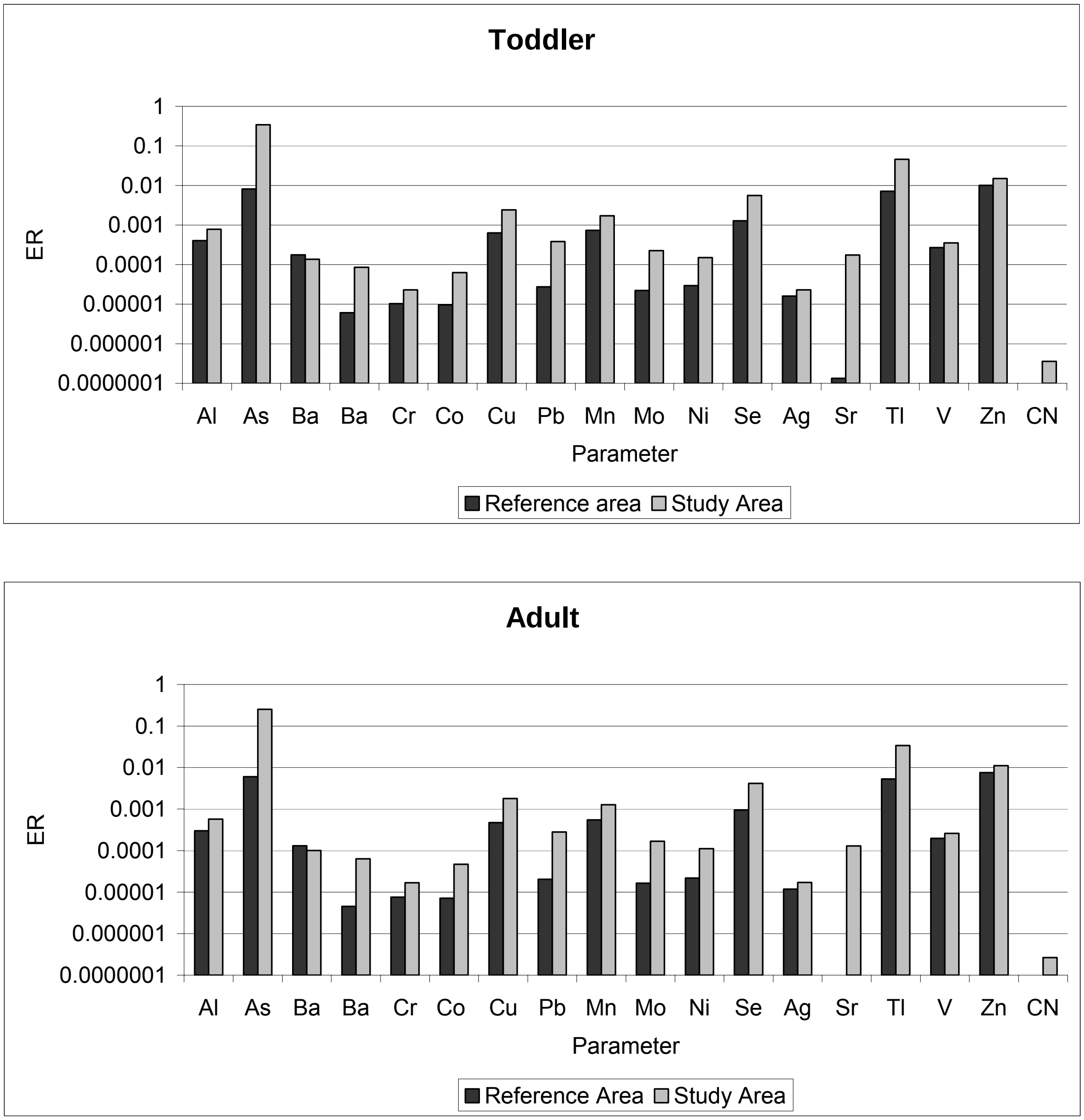
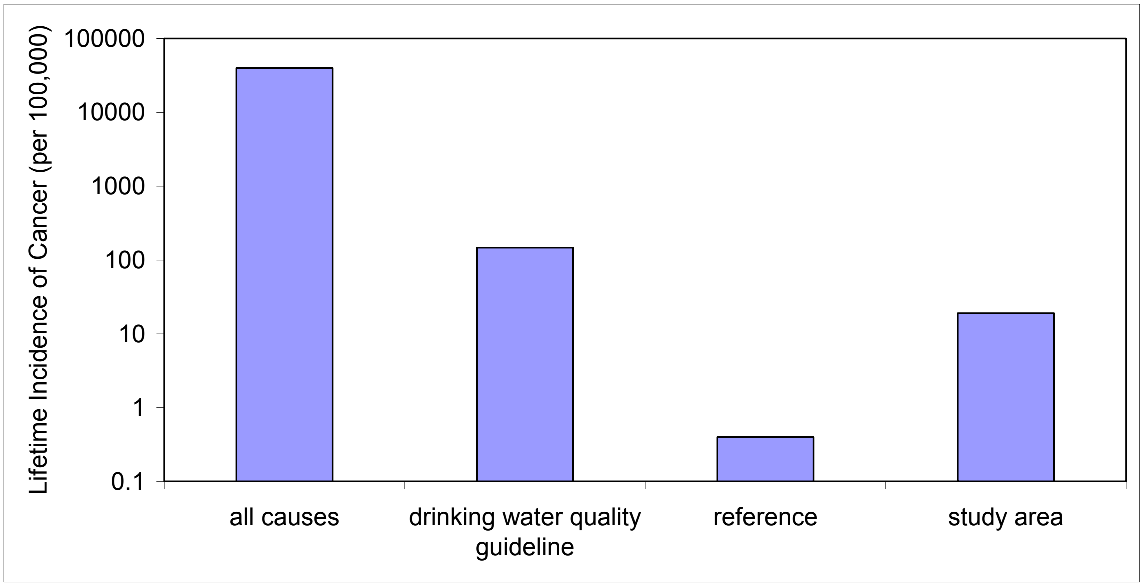


Figure 11
Lifetime Cancer Risks Due to All Causes, Drinking Water Quality Guideline and Maximum Arsenic Exposure in the Study Area and Reference Area



6.4 Uncertainty (How Sure Are We?)

There are several sources of uncertainty in the wildlife and human health risk assessment that may have resulted in an overestimate of potential risks.

- Amount of time spent by animals (particularly birds and caribou) in the vicinity of the TCA;
- Presence of adequate numbers of benthic invertebrates in the TCA to support shorebird and waterfowl diets;
- Availability for uptake and speciation (which affects toxicity) of metals and cyanide;
- Invertebrate uptake of metals and cyanide from sediment;
- Contribution of wind-blown tailings to vegetation metal concentrations versus direct uptake from soil (current plant concentrations may overestimate uptake from soil once all tailings are covered);
- Uptake of arsenic in caribou tissues;
- Frequency that people would consume caribou that have spent considerable of time at the Lupin TCA;

- Understanding of toxicity potential for wildlife (since toxicity benchmarks were based on a limited number of studies using laboratory animals such as rats and mice).

In addition to these areas of uncertainty, the characterization of risks to populations of receptors with predicted ERs greater than 1 (snipe and long-tailed duck) is uncertain because:

- The number of birds spending the entire breeding season in the area is unknown;
- Estimates of the total population of birds that may use the Lupin region either as a stop-over or for breeding is unknown;
- Quantitative estimates of the amount of change in survivorship or reproduction required to pose a risk to population persistence were not part of the scope of work for this screening-level assessment.

7. CONCLUSIONS

7.1 Human Health

For the human health risk assessment, for all of the metals evaluated in the assessment, estimated exposure was less than the toxicity benchmarks, with the exception of arsenic. It is very unlikely that the scenario used to estimate human exposure to arsenic via caribou ingestion would be realized. In addition, potential ERs of 0.3 for non-carcinogenic effects and 14 in 100,000 for carcinogenic effects are only slightly above 0.2 and 1 in 100,000; the levels for which no effects are expected. It is very unlikely that health effects would be observed based on these assumptions. Therefore, there is no risk to health due to the ingestion of caribou meat. Conservative assumptions and many layers of safety were used to estimate exposure and to derive toxicity benchmarks. This means that there is a high degree of certainty that risks have not been underestimated and that all members of a family would be safe from exposure to metals from the study area.

7.2 Wildlife Health

Based on the results of this preliminary risk assessment, there is a potential for risk to individual shorebirds and waterfowl due to arsenic and cyanide exposure. Risks are not expected due to any other COCs or for any other receptors. Conservative assumptions and many layers of safety were applied to the wildlife health risk assessment. This means that there is a high degree of certainty that risks have not been underestimated. As stated in Section 6.3, there are several assumptions that were made in the risk assessment that might have lead to an overestimation of risks for shorebirds and waterfowl. Furthermore, risks to populations of shorebirds and waterfowl are unlikely. However, the characterization of risks to populations is uncertain.

7.3 What Does This Mean for the Lupin Closure Plan?

The closure plan for the Lupin TCA includes two major features; covering exposed tailings with 1 m of esker sand and constructing a spillway between Pond 2 and the receiving environment and keeping water and sediment within Ponds 1 and 2.

No wildlife or human health risks are expected due to placement of 1 m of esker sand over exposed tailings.

The exposure pathways related to covering exposed tailings with esker sand are direct soil ingestion and ingestion of plants growing on the tailings areas. This risk assessment shows that risks from sand-covered tailings are acceptable, both for humans and wildlife. Furthermore, exposure via water from within the capped tailings will not be a concern. This is because, based on the results of the engineering feasibility of covering exposed tailings with esker sand, it is not expected that excessive water will seep into the ponds. Nor is it expected that water will move upward into the root zone of plants growing at the surface of the esker sand (Golder 2004). Therefore, water quality is not expected to worsen in the future.

Risks to individual shorebirds and waterfowl were predicted due primarily to exposure to arsenic and cyanide in invertebrates living in Ponds 1 and 2. This leads to the risk management questions:

- Should ponds 1 and 2 remain as features in the reclaimed landscape? and,
- If ponds 1 and 2 remain, should measures be taken to reduce exposure to arsenic and cyanide via invertebrates in contact with sediments?

These two questions cannot be answered with confidence because of the uncertainties in the risk assessment. The risks are very likely to be greatly over-estimated. Therefore, it would not be advisable to proceed to risk management since there may be a large mis-match between the cost of remediation and the actual risk reduction achieved. Therefore, it is recommended that uncertainties in the assessment of risk to waterfowl and shorebirds be reduced. The following two steps should be considered as preliminary steps to reduce uncertainty:

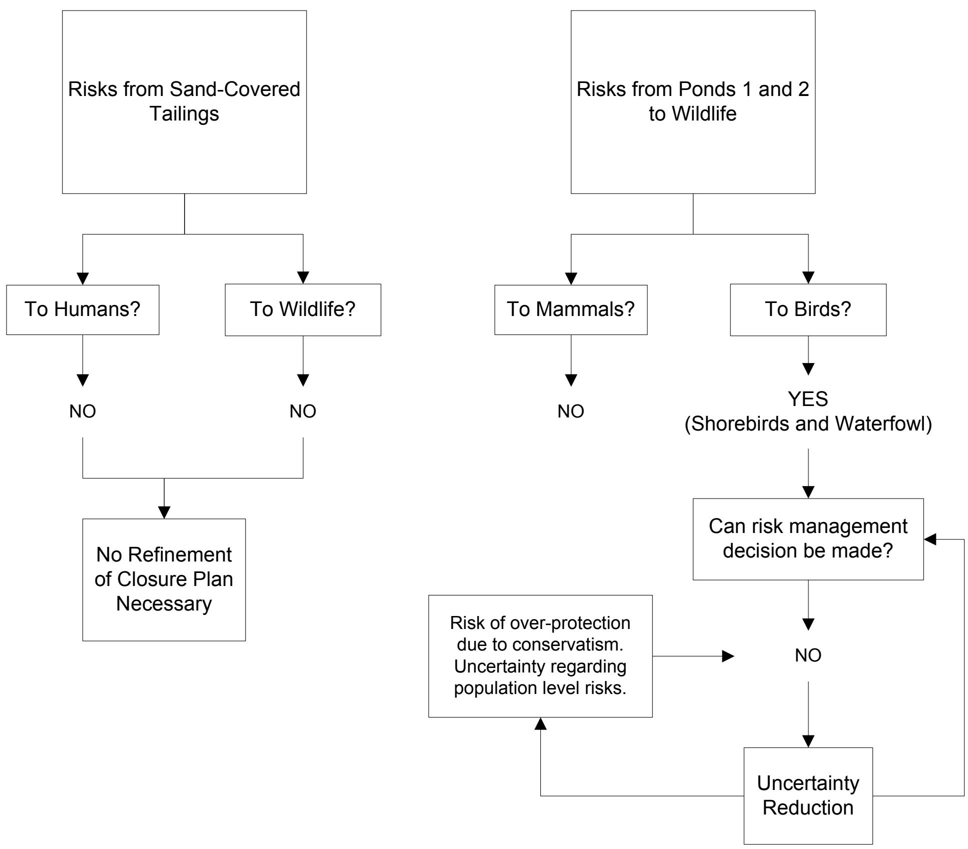
(1) Sensitivity analysis of the exposure model to reveal which parameters “drive” the risk estimates; and,

(2) Collection of information from the Canadian Wildlife Service and other sources regarding migratory bird populations to better estimate the time that birds may actually spend during the breeding season in the area.

Completion of steps (1) and (2), will allow a re-examination of the level of conservatism in the exposure models, and will also allow a more confident characterization of risks to populations. If the combination of confirmation of highly-conservative risks to individuals plus a more confident prediction of no risks to populations results in a conclusion that risk management is not required, then no further work will be necessary. However, if risks to populations cannot be ruled out and/or if regulatory acceptance of risks to individuals (despite the lack of risks to populations) is not forthcoming, then proceeding with further reduction of uncertainty may be necessary. Further reduction of uncertainty would involve proceeding with additional data collection.

Results of this assessment can be illustrated by the following flow-chart (Figure 12).

Figure 12
Summary of Risk Assessment Results and Recommendations



8. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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APPENDIX I

DATA USED IN RISK ASSESSMENT

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I DATA USED IN THE RISK ASSESSMENT

I.1 Introduction

Chemical data have been obtained for water and sediment samples, collected from the Lupin Mine Site receiving water bodies directly outside of the study area and from reference areas used in previous studies undertaken by Kinross Gold Corporation (Kinross). In addition, soil, sediment and vegetation samples were collected from the study area and from reference locations for the purposes of this assessment. These data were reviewed and evaluated in the risk assessment and are summarized in this appendix.

The risk assessment required information on metal concentrations in the following parts of the food chain:

- reference water, soil, sand, sediment and native plant species;
- sediment from ponds within the study area and the immediate receiving environment;
- soil from areas impacted by wind-blown tailings, and esker sand covering tailings containment cells;
- plants from areas impacted by wind-blown tailings and from the esker sand cover;
- water within the study area (pond 1, pond 2, cells 1, cell 4) and receiving environment;
- lake trout muscle and liver tissue from the study area (calculated), and receiving environment (calculated); and
- caribou meat tissue (calculated based on uptake from food, water, and soil).

I.2 Soil

In August, 2004, environmental technicians from Kinross collected soil samples from three locations:

- esker borrow area (reference location) approximately 3 km south-east of the Study Area;
- cell 1 esker sand covering; and
- an area potentially impacted by wind-blown tailings.

Soil concentrations used in the risk assessment are presented in Tables I-1 and I-2, for the reference areas and the Study Area, respectively.

Table I-1
Soil Concentrations from Samples Collected from the Reference Area (Esker Borrow Area)

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)								
		27-Aug-04		29-Aug-04						
		EB 5-1	EB 5-2	EB 5-3	EB 5-4	EB 5-5	EB 5-6	Minimum	Maximum	Mean[(a)]
Aluminum	50	4,640	4,860	4,550	4,810	4,250	4,800	4,250	4,860	4,652
Antimony	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	0.1	5.9	4.4	7.8	6.9	9.7	6.5	4.4	9.7	6.9
Barium	0.5	30.1	35.3	25.7	29.4	27.7	34.8	25.7	35.3	30.5
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	2	<2	<2	2	<2	<2	<2	<2	2	<2
Cadmium	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	0.2	18.4	20.9	18.8	18.3	17.6	23.0	17.6	23.0	19.5
Cobalt	0.1	3.0	3.5	2.2	2.9	2.1	3.2	2.1	3.5	2.8
Copper	0.5	8.2	7.1	5.2	7.6	5.9	8.3	5.2	8.3	7.1
Iron	200	7,000	7,900	6,800	7,500	5,800	7,900	5,800	7,900	7,150
Lead	0.5	1.4	1.3	1.8	1.3	2.0	1.4	1.3	2.0	1.5
Manganese	1	67	74	57	73	49	70	49	74	65
Mercury	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	0.1	0.1	0.1	0.2	0.1	0.3	0.1	0.1	0.3	0.2
Nickel	0.5	9.9	11.6	7.8	10.1	7.5	11.4	7.5	11.6	9.7
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1	4	4	4	5	5	3	3	5	4
Thallium	0.05	0.05	0.07	0.05	0.06	0.05	0.08	0.05	0.08	0.06
Tin	2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Titanium	1	284	343	386	277	334	334	277	386	326
Uranium	0.05	0.48	0.44	0.46	0.43	0.65	0.58	0.43	0.65	0.51
Vanadium	0.2	13.5	15.4	16.4	13.0	12.9	14.8	12.9	16.4	14.3
Zinc	5	16	17	14	17	14	17	14	17	16

(a) Calculations were based on half detection limits for parameters that were less than analytical detection limits.

Table I-2
Soil Concentrations from Samples Collected from the Study Area (Cell 1 and Wind Blown Tailings Area)

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)													
		Cell 1						Wind-Blown Tailings Area							
		27-Aug-04						27-Aug-04	29-Aug-04	30-Aug-04					
		Cell 1-5-1	Cell 1-5-2	Cell 1-5-3	Cell 1-5-4	Cell 1-5-5	Cell 1-5-6	WT 5-1	WT 5-2	WT 5-3	WT 5-4	WT 5-5	Minimum	Maximum	Mean[(a)]
Aluminum	50 - 100	50	50	50	50	50	50	4,380	4,950	5,750	4,330	6,310	<100	6,310	2,365
Antimony	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	0.1	144.0	34.0	20.2	28.8	43.4	21.0	50.1	142.0	40.0	161.0	118.0	20.2	161.0	73.0
Barium	0.5	29.5	38.1	37.3	38.8	30.2	33.0	30.7	24.9	21.8	20.4	19.3	19.3	38.8	29.5
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	1 - 2	2	2	1	2	1	2	1	1	1	1	1	1	2	1
Cadmium	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	0.2	18.6	22.0	21.6	17.7	22.6	19.7	18.5	19.0	21.7	13.5	16.9	13.5	22.6	19.3
Cobalt	0.1	2.9	5.6	3.8	3.5	3.1	3.1	2.8	2.9	4.3	2.1	3.3	2.1	5.6	3.4
Copper	0.5	8.5	10.5	9.4	7.4	7.1	7.2	10.6	8.5	14.2	9.5	14.9	7.1	14.9	9.8
Iron	200	8,900	9,100	9,700	7,600	8,500	8,400	7,100	10,600	9,300	7,600	12,000	7,100	12,000	8,982
Lead	0.5	3.9	2.2	1.8	2.5	2.7	2.4	3.7	4.2	3.8	5.8	4.3	1.8	5.8	3.4
Manganese	1	63	93	90	87	74	73	63	71	70	57	80	57	93	75
Mercury	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.11	<0.05	0.11	<0.05
Molybdenum	0.1	0.2	0.3	0.1	0.4	0.2	0.3	0.2	0.2	0.3	0.3	0.4	0.1	0.4	0.3
Nickel	0.5	9.6	11.6	12.6	9.0	10.3	9.6	10.3	9.7	13.3	7.7	9.4	7.7	13.3	10.3
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1 - 2	<2	<2	<2	<2	<2	<2	6	4	6	6	6	<2	6	3
Thallium	0.05	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	0.06	<0.05	<0.05	<0.05	0.05	<0.05	0.06	<0.05
Tin	0.05 - 2	0.54	0.62	0.46	0.56	0.70	0.73	1	1	1	1	1	0.46	1.0	0.8
Titanium	1	6	5	5	7	5	5	335	377	420	306	378	5	420	168
Uranium	0.05	0.05	0.08	0.08	0.025	0.06	0.06	0.78	0.64	1.07	0.80	0.96	0.03	1.07	0.42
Vanadium	0.2	15.4	17.4	17.8	14.9	16.8	17.0	13.0	16.5	16.4	12.5	14.6	12.5	17.8	15.7
Zinc	5	17	19	22	24	18	18	16	18	19	13	17	13	24	18

(a) Calculations based on half detection limits for parameters that were less than analytical detection limits.

(b) Not analyzed.

I.3 Sediment

In August 2004, environmental technicians from Kinross collected sediment samples from Pond 1 and Pond 2 (study area), Boomerang Lake (receiving environment), and Shallow Bay (reference location).

Sediment concentrations used in the risk assessment are presented in Tables I-3, I-4, and I-5 for the reference area, study area, and receiving environment, respectively.

Table I-3
Sediment Concentrations from Samples Collected from the Reference Area (Shallow Bay)

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)				
		29-Aug-04		Minimum	Maximum	Mean[(a)]
		Ref-sed 1	Ref-sed 2			
Aluminum	50	5,810	5,880	5,810	5,880	5,845
Antimony	0.1	<0.1	<0.1	<.01	<0.1	<0.1
Arsenic	0.1	22.1	14.9	14.9	22.1	18.5
Barium	0.5	45.6	46.9	45.6	46.9	46.3
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	2	3	3	3	3	3
Cadmium	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	0.2	22.7	23.9	22.7	23.9	23.3
Cobalt	0.1	5.3	6.3	5.3	6.3	5.8
Copper	0.5	8.7	8.1	8.1	8.7	8.4
Iron	200	12,900	10,700	10,700	12,900	11,800
Lead	0.5	2.2	2.4	2.2	2.4	2.3
Manganese	1	135	139	135	139	137
Mercury	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	0.1	0.4	0.3	0.3	0.4	0.4
Nickel	0.5	11.5	13.2	11.5	13.2	12.4
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1	5	6	5	6	6
Thallium	0.05	0.09	0.08	0.08	0.09	0.09
Tin	2	<2	<2	<2	<2	<2
Titanium	1	476	481	476	481	479
Uranium	0.05	0.78	0.88	0.78	0.88	0.83
Vanadium	0.2	19.5	20.2	19.5	20.2	19.9
Zinc	5	28	31	28	31	30
Cyanide	0.1	0.3	0.3	0.3	0.3	0.3

(a) Calculations based on half detection limits for parameters that were less than analytical detection limits.

Table I-4
Sediment Concentrations from Samples Collected from the Study Area (Pond 1 and Pond 2)

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)									
		Pond 1						Pond 2			
		28-Aug-04						28-Aug-04			
		P1-sed 1	P1-sed 2	P1-sed 3	P1-sed 4	P1-sed 5	P1-sed 6	P2-sed2	Minimum	Maximum	Mean[(a)]
Aluminum	50	8,840	17,100	6,120	17,000	16,600	15,000	7,170	6,120	17,100	12,547
Antimony	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1	<0.1
Arsenic	0.1	3,840	10,100	2,240	9,560	16,000	14,800	1,870	1,870	16,000	8,344
Barium	0.5	59.2	102	41.3	93.3	103	79.9	36.2	36.2	103.0	73.6
Beryllium	0.2	0.3	0.4	0.2	0.5	0.4	0.4	0.3	0.2	0.5	0.4
Boron	2	3	5	3	4	5	4	2	2	5	4
Cadmium	0.1	0.2	0.4	0.1	0.2	0.4	0.3	0.2	0.1	0.4	0.3
Chromium	0.2	28.1	44.5	20.9	46.7	42.3	43.1	22.9	20.9	46.7	35.5
Cobalt	0.1	11.4	15.8	8.9	15.4	17.1	14.5	28.5	8.9	28.5	15.9
Copper	0.5	331	387	234	444	414	451	210	210	451	353
Iron	200	36,500	92,300	24,100	94,900	100,000	117,000	28,600	24,100	117,000	70,486
Lead	0.5	60.2	235	33.8	287	377	214	46	33.8	377.0	179.0
Manganese	1	126	245	90	188	270	204	382	90	382	215
Mercury	0.05	0.13	<0.05	0.08	<0.05	0.05	0.06	0.11	<0.05	0.13	0.07
Molybdenum	0.1	2.2	2.5	1.7	9.5	4.9	4.2	7.7	1.7	9.5	4.7
Nickel	0.5	48.1	51.4	40.1	49	52	51.3	31	31.0	52.0	46.1
Selenium	0.2	1	2	0.5	1.4	2.6	2.1	0.8	0.5	2.6	1.5
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1	33	82	24	70	94	81	19	19	94	58
Thallium	0.05	0.09	0.07	0.07	0.07	0.07	0.07	0.09	0.07	0.09	0.08
Tin	2	<2	2	<2	2	2	3	<2	<2	3	<2
Titanium	1	324	404	299	409	383	318	323	299	409	351
Uranium	0.05	1.12	1.1	0.98	1.25	1.57	1.2	1.41	0.98	1.57	1.23
Vanadium	0.2	19.1	31.1	14.9	32.8	29.9	26.6	17.1	14.9	32.8	24.5
Zinc	5	536	5,190	338	1,820	6,140	1,930	472	338	6,140	2,347
Cyanide	0.1	635	5,500	717	3,660	8,580	3,050	914	635	8,580	3,294

(a) Calculations were based on half the detection limit for values that were less than analytical detection limits.

Table I-5
Sediment Concentrations from Samples Collected from Boomerang Lake

Parameter	Detection Limit (mg/kg)	Concentration (mg/kg)					
		28-Aug-04			Minimum	Maximum	Mean[(a)]
		B-sed 1	B-sed 2-1	B-sed 2-2			
Aluminum	50	6,390	10,700	14,600	6,390	14,600	10,563
Antimony	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Arsenic	0.1	71.6	539	6,590	71.6	6,590	2,400
Barium	0.5	43.7	61	72.1	43.7	72.1	58.9
Beryllium	0.2	<0.2	0.6	0.6	<0.2	0.6	0.4
Boron	2	2	6	9	2	9	6
Cadmium	0.1	<0.1	0.4	0.4	<0.1	0.4	0.3
Chromium	0.2	24.5	40.8	41.3	24.5	41.3	35.5
Cobalt	0.1	6.2	27.9	19.7	6.2	27.9	17.9
Copper	0.5	12.9	83.8	298.0	12.9	298.0	131.6
Iron	200	11,400	34,500	73,300	11,400	73,300	39,733
Lead	0.5	3.1	15.1	107	3.1	107.0	41.7
Manganese	1	107	213	283	107	283	201
Mercury	0.05	<0.05	0.07	0.28	0.07	0.28	0.18
Molybdenum	0.1	0.5	1.4	8.8	0.5	8.8	3.6
Nickel	0.5	15.2	64.6	57.3	15.2	64.6	45.7
Selenium	0.2	<0.2	0.6	1.3	<0.2	1.3	0.7
Silver	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Strontium	1	4	15	48	4	48	22
Thallium	0.05	0.11	0.14	0.09	0.09	0.14	0.11
Tin	2	<2	<2	2	<2	2	<2
Titanium	1	357	520	376	357	520	418
Uranium	0.05	0.65	1.97	2.01	0.65	2.01	1.54
Vanadium	0.2	20.4	30.4	29.5	20.4	30.4	26.8
Zinc	5	30	185	1,340	30	1,340	518
Cyanide	0.1	24.4	34.7	0.6	0.6	34.7	19.9

(a) Calculations based on half detection limits for parameters that were less than analytical detection limits.

I.4 Vegetation

In August 2004, environmental technicians from Kinross collected vegetation samples from cell 1 and areas potentially impacted by wind-blown tailings (study area), and the Esker Borrow Area (reference area). Vegetation collected from the esker-Borrow area included birch species (*Betula sp*.), crowberry (*Empertrum nigrum*), bearberry (*Arctostaphylos uva-ursi*) and native grasses. A variety of grasses were collected from cell 1 and areas potentially impacted by wind-blown tailings.

Vegetation concentrations used in the risk assessment are presented in Table I-6 and Table I-7, for the reference area and study area, respectively.

Table I-6
Metal Concentrations in Vegetation Collected from the Esker Borrow Area (Reference Area)

Parameter	Detection Limit	Concentration (mg/kg - Dry Weight)							
		27-Aug-04		29-Aug-04			Minimum	Maximum	Mean[(a)]
		EB-1	EB-2	EB-3	EB-4	EB-5			
% Moisture	0.1	52	53	51	60	57	51	60	55
Aluminum	4	633	326	345	59	179	59	633	308
Antimony	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Arsenic	0.2	1.5	0.7	1.2	0.7	1	0.7	1.5	1.0
Barium	0.08	29.4	3.92	13.2	9.4	10.1	3.92	29.4	13.20
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NC[(c)]	NC[(c)]	NC[(c)]
Cadmium	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chromium	0.2	1.5	0.9	0.8	0.6	0.9	0.6	1.5	0.9
Cobalt	0.08	0.93	1.47	0.48	0.32	0.25	0.25	1.47	0.69
Copper	0.08	3.19	3.2	2.1	2.1	3.08	2.1	3.2	2.73
Iron	2	293	176	162	45	104	45	293	156
Lead	0.04	0.31	0.12	0.2	0.04	0.1	0.04	0.31	0.15
Manganese	0.04	113	310	119	369	271	113	369	236
Mercury	0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Molybdenum	0.04	<0.04	<0.04	0.07	0.17	0.11	<0.04	0.17	0.08
Nickel	0.08	4.44	5.19	6.22	4.81	3.33	3.33	6.22	4.80
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Silver	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Strontium	0.04	7.66	2.73	6.73	3.13	3.91	2.73	7.66	4.83
Thallium	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Tin	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Titanium	0.05	18.2	10.6	10.6	2.13	4.3	2.13	18.2	9.17
Uranium	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NC[(c)]	NC[(c)]	NC[(c)]
Vanadium	0.08	0.59	0.35	0.28	0.11	0.18	0.11	0.59	0.30
Zinc	0.2	53.5	26.9	29.2	19.7	19.5	19.5	53.5	29.8

[(a)]Calculations were based on half the detection limit for values that were below analytical detection limits.
[(b)]Data not analyzed.
[(c)]Not calculated.

Table I-7
Metal Concentrations in Vegetation Collected from the Study Area (Cell 1 and Wind-blown Tailings Area)

Parameter	Detection Limit	Concentration (mg/kg Dry Weight)												
		27-Aug-04						29-Aug-04	30-Aug-04			Minimum	Maximum	Mean[(a)]
		cell 1-1	cell 1-2	cell 1-3	cell 1-4	cell 1-5	WT-1	WT-2	WT-3	WT-4	WT-5			
% Moisture	0.1	58	44	61	50	51	49	49	53	48	53	44	61	51.6
Aluminum	4	1300	1170	488	298	654	717	798	385	427	360	298	1300	660
Antimony	0.04	<0.04	0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	0.04	<0.04	<0.04	0.05	<0.04
Arsenic	0.2	15.9	52.7	14.9	10.8	17.9	11.5	65.4	15.9	32.1	28.7	10.8	65.4	26.6
Barium	0.08	13.8	12	6.27	6.62	15.9	19.7	11	9.3	13.7	16.6	6.27	19.7	12.49
Beryllium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NC[(c)]	NC[(c)]	NC[(c)]
Cadmium	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chromium	0.2	3.7	4.7	1.6	1	1.7	2.8	3.3	1	1.2	1.1	1	4.7	2.2
Cobalt	0.08	0.51	0.81	0.44	0.42	0.26	1.11	0.94	1.25	1.13	1.18	0.26	1.25	0.81
Copper	0.08	3.49	4.32	3	1.9	2.63	3.35	3.89	2.67	3.63	2.83	1.9	4.32	3.17
Iron	2	813	1470	534	400	662	577	1840	576	1080	685	400	1840	864
Lead	0.04	0.68	2.36	0.69	0.89	0.77	1.37	5.21	1.56	2.7	2.02	0.68	5.21	1.83
Manganese	0.04	252	395	688	345	217	243	118	186	176	135	118	688	276
Mercury	0.01	0.01	0.02	<0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01	0.02	<0.01
Molybdenum	0.04	0.28	1.29	0.53	0.14	0.1	0.12	0.07	0.05	0.07	<0.04	0.05	1.29	0.29
Nickel	0.08	4.65	5.89	2.27	1.49	1.69	5.36	6.35	4.07	4.43	4.07	1.49	6.35	4.03
Selenium	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	<0.2	0.3	<0.2
Silver	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Strontium	0.04	10.8	13.4	6.93	4.08	7.6	10.3	11.2	6.29	11.3	8.19	4.08	13.4	9.01
Thallium	0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Tin	0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Titanium	0.05	31.9	27.6	13.1	10.1	23.2	22.9	22.6	10.2	10.7	9.93	9.93	31.9	18.22
Uranium	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NA[(b)]	NC[(c)]	NC[(c)]	NC[(c)]
Vanadium	0.08	0.95	0.93	0.39	0.31	0.57	0.71	0.81	0.35	0.4	0.32	0.31	0.95	0.57
Zinc	0.2	27.3	25.4	19.4	17.2	28.7	52.2	63.7	46.2	65.2	55.1	17.2	65.2	40.0

(a) Calculations based on half the detection limit for values that were below analytical detection limits.
(b) Data not analyzed.
(c) Not calculated.

Metal concentrations in plant tissue were provided in dry weight (mg/kg). Concentrations were converted to wet weight for use in exposure estimate calculations. Plant tissue in dry weight was converted to wet weight according to the following equation:

Concentration in wet weight = concentration in dry weight x (1- % moisture),
where % moisture was measured for each sample.

Vegetation concentrations (mg/kg wet weight) used in the risk assessment are presented in Table I-8.

Table I-8
Calculated Wet Weight Concentrations of Metals in Vegetation Collected from the Reference Area (Esker Borrow Area) and Study Area (Cell 1 and Wind-blown Tailings Area)[(a)]

Parameter[(b)]	Reference Vegetation			Study Area Vegetation		
	Maximum Dry Weight (mg/kg)	Moisture (%)	Wet Weight (mg/kg) (calculated)	Maximum Dry Weight (mg/kg)	Moisture (%)	Wet Weight (mg/kg) (calculated)
Aluminum	633	0.55	285	1300	0.516	629
Antimony	<0.02	0.55	<0.02	0.05	0.516	0.02
Arsenic	1.5	0.55	0.7	65.4	0.516	31.7
Barium	29.4	0.55	13.2	19.7	0.516	9.5
Beryllium	<0.2	0.55	<0.2	<0.2	0.516	<0.2
Cadmium	<0.08	0.55	<0.08	<0.08	0.516	<0.08
Chromium	1.5	0.55	0.7	4.7	0.516	2.3
Cobalt	1.47	0.55	0.66	1.25	0.516	0.61
Copper	3.2	0.55	1.4	4.32	0.516	2.09
Iron	293	0.55	132	1840	0.516	891
Lead	0.31	0.55	0.14	5.21	0.516	2.52
Manganese	369	0.55	166	688	0.516	333
Mercury	0.02	0.55	0.01	0.02	0.516	0.01
Molybdenum	0.17	0.55	0.08	1.29	0.516	0.62
Nickel	6.22	0.55	2.799	6.35	0.516	3.07
Selenium	<0.2	0.55	<0.2	0.3	0.516	0.1
Silver	<0.08	0.55	<0.08	<0.08	0.516	<0.08
Strontium	7.66	0.55	3.45	13.4	0.516	6.5
Thallium	<0.04	0.55	<0.04	<0.04	0.516	<0.04
Tin	<0.08	0.55	<0.08	<0.08	0.516	<0.08
Titanium	18.2	0.55	8.2	31.9	0.516	15.4
Vanadium	0.59	0.55	0.27	0.95	0.516	0.46
Zinc	53.5	0.55	24.1	65.2	0.516	31.6

[(a)]Calculations based on half the detection limit for values that were below analytical detection limits.
[(b)]Boron and Uranium wet weight concentration not calculated because vegetation concentrations not measured.

I.5 Surface Water

Surface water data were obtained from water quality monitoring programs undertaken by Kinross at the Lupin Mine site from 1990 to 2004. Water quality data were collected from pond 1, pond 2, cell 1, cell 4, the receiving environment (Boomerang Lake, Long Lake, Test Lake, Norma Lake, Lori Lake, Dam 1A Lake, Dam 1a Siphon, Seep Creek, Inner Sun Bay, Outer Sun Bay), and reference locations in South Bay. These data were provided by Kinross, but have not been reported in other publications.

Water quality data collected by Kinross for the reference area are presented in Table I-9. Water quality data collected by Kinross for the study area (Pond 1, Pond 2, Cell 1, and Cell 4) are presented in Table I-10, I-11, and Table I-12. A descriptive summary of water quality data in the study areas is presented in Table I-12. Water quality data collected by Kinross for the receiving environment are presented in Table I-13.

Table I-9
Water Concentrations of Samples Collected from the Reference Area (South Bay)

Parameter	Detection Limit (mg/L)	Concentration (mg/L)								
		1996						Minimum	Maximum	Mean[(a)]
		Lu-R1-1	Lu-R1-2	Lu-R1-3	Lu-R1-4	Lu-R1-5	Lu-R1-6			
Aluminum	0.01	0.12	0.13	0.12	0.12	0.12	0.10	0.10	0.13	0.12
Antimony	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Arsenic	0.002	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002	<0.002
Barium	0.005	<0.005	0.005	0.005	<0.005	<0.005	0.006	<0.005	0.006	<0.005
Beryllium	0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Boron	0.005	0.011	0.006	0.006	<0.005	0.005	0.009	<0.005	0.011	0.007
Cadmium	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Chromium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cobalt	0.001	0.001	0.001	0.001	0.001	<0.001	0.002	<0.001	0.002	0.001
Copper	0.002	0.005	0.002	0.003	<0.002	<0.002	<0.002	<0.002	0.005	0.002
Iron	0.02	0.17	0.16	0.17	0.16	0.16	0.15	0.15	0.17	0.16
Lead	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Manganese	0.002	0.009	0.008	0.009	0.008	0.008	0.015	0.008	0.015	0.010
Molybdenum	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Nickel	0.002	0.006	0.006	0.006	0.005	0.004	0.007	0.004	0.007	0.006
Selenium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Silver	0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Strontium	0.005	0.008	0.008	0.008	0.007	0.007	0.009	0.007	0.009	0.008
Thallium	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Tin	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Titanium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Uranium	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Zinc	0.002	<0.002	0.004	0.007	0.002	0.003	0.003	<0.002	0.007	0.003

(a) Calculations based on half detection limits for parameters that were less than analytical detection limits.

Table I-10
Water Concentrations of Samples Collected from Pond 1

Parameter	Detection Limit (mg/L)	Concentration (mg/L)														
		07-Jul-98	05-Oct-98	23-Aug-98	28-Mar-99	25-Jul-99	06-Sep-99	02-Mar-00	25-Apr-00	21-Jul-00	09-Nov-00	12-Apr-01	04-Aug-01		01-Sep-01	
		P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-104	P1-103	P1-104	P1-103	P1-104
Aluminum	0.005 - 0.009	0.073	0.223	0.081	0.091	0.123	0.184	0.023	0.081	0.065	0.070	0.052	0.078	0.093	0.094	0.098
Antimony	0.0002 - 0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Arsenic	0.0002 - 0.01	0.34	0.30	0.28	0.24	0.10	0.09	0.05	0.04	0.02	0.10	0.11	0.04	0.05	0.13	0.12
Barium	0.0002 - 0.001	0.0122	0.0143	0.0143	0.0182	0.0138	0.0134	0.0194	0.0257	0.0098	0.0164	0.0187	0.0109	0.0120	0.0119	0.0119
Beryllium	0.0001 - 0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Boron	0.002	0.115	0.139	0.130	0.170	0.087	0.089	0.118	0.137	0.057	0.084	0.138	0.064	0.066	0.089	0.087
Cadmium	0.00001 - 0.0006	<0.0005	<0.0005	0.0008	<0.0005	<0.0005	<0.0005	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Chromium	0.0005 - 0.0009	0.0010	<0.0008	0.0010	<0.0008	<0.0008	0.0228	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009
Cobalt	0.0008	0.0414	0.0506	0.0452	0.0649	0.0421	0.0451	0.0653	0.0693	0.0288	0.0411	0.0493	0.0312	0.0342	0.0391	0.0380
Copper	0.001	0.044	0.065	0.040	0.068	0.029	0.030	0.038	0.038	0.017	0.068	0.066	0.027	0.026	0.139	0.135
Iron	0.003 - 0.1	0.305	1.250	0.201	0.846	0.495	1.580	0.615	0.450	0.219	0.437	0.340	0.489	0.547	0.592	0.624
Lead	0.0001 - 0.002	0.003	<0.002	<0.002	<0.002	<0.002	0.021	0.004	0.004	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002
Manganese	0.0002 - 0.005	0.3270	0.4910	0.4310	0.6780	0.4570	0.4870	0.7640	0.8200	0.3510	0.5460	0.6840	0.3860	0.4260	0.3950	0.3910
Molybdenum	0.001	0.034	0.034	0.031	0.039	0.023	0.020	0.020	0.021	0.008	0.020	0.025	0.010	0.013	0.020	0.019
Nickel	0.0005 - 0.001	0.094	0.111	0.097	0.140	0.096	0.116	0.137	0.148	0.066	0.104	0.122	0.073	0.080	0.106	0.104
Selenium	0.0002 - 0.004	0.007	0.005	<0.004	<0.004	<0.004	<0.004	0.019	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Silver	0.0001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.002	<0.001
Strontium	0.0001 - 0.001	0.2130	0.2580	0.2270	0.3440	0.2070	0.2050	0.2890	0.3020	0.1410	0.3470	0.4650	0.2140	0.2330	0.3030	0.2970
Thallium	0.00005 - 0.004	<0.004	<0.004	<0.004	0.005	<0.004	0.005	0.008	0.01	<0.004	<0.004	<0.004	<0.004	<0.004	0.005	0.005
Tin	0.001 - 0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.005	0.005	<0.003	0.005	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Titanium	0.0004 - 0.0005	<0.0004	<0.0004	0.0004	<0.0004	<0.0004	0.0611	<0.0004	<0.0004	0.0012	<0.0004	<0.0004	<0.0004	0.0016	<0.0004	<0.0004
Uranium	0.0005	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
Vanadium	0.0001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc	0.0007 - 0.001	0.0512	0.1250	0.0702	0.1720	0.1080	0.1360	0.2300	0.2410	0.0989	0.1090	0.1230	0.0770	0.0847	0.0956	0.0970
Cyanide	0.001 - 0.002	NA[a]	0.022	0.021	0.045	NA[a]	0.020	NA[a]	NA[a]	0.058	1.030	0.288	NA[a]	0.183	NA[a]	1.870

Table I-10
Water Concentrations of Samples Collected from Pond 1 (continued)

Parameter	Detection Limit (mg/L)	Concentration (mg/L)															
		03-Feb-02	04-Feb-02	12-Apr-02	05-Jul-02		16-Jul-02			24-Jul-02			08-Aug-02	22-Apr-03	02-Aug-03	12-Oct-03	13-Jul-04
		P1-104	P1-104T	P1-104	P1-104	P1-104b	P1-104a	P1-104b	P1-104c	P1-104a	P1-104b	P1-104c	P1-104a	P1-104	P1-104	P1-104	P1-104
Aluminum	0.005 - 0.009	0.083	0.076	0.087	0.057	0.067	0.046	0.045	0.046	0.044	0.045	0.048	0.044	0.060	0.068	0.079	0.065
Antimony	0.0002 - 0.006	<0.006	<0.006	<0.005	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	0.0003	0.0007	0.0004	0.0003	0.0003
Arsenic	0.0002 - 0.01	0.10	0.09	0.11	0.0932	0.1000	0.0933	0.0939	0.0928	0.0891	0.0896	0.0921	0.0851	0.1610	0.0734	0.0583	0.0726
Barium	0.0002 - 0.001	0.0156	0.0149	0.0180	0.0140	0.0150	0.0130	0.0130	0.013	0.013	0.013	0.013	0.014	0.021	0.011	0.015	0.012
Beryllium	0.0001 - 0.0006	<0.0006	<0.0006	<0.0005	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Boron	0.002	0.100	0.101	0.175	0.077	0.083	0.084	0.083	0.083	0.081	0.082	0.082	0.083	0.179	0.088	0.102	0.076
Cadmium	0.00001 - 0.0006	<0.0006	<0.0006	<0.0005	0.00004	0.00007	0.00005	0.00005	0.00004	0.00005	0.00005	0.00005	0.00006	0.00007	0.00007	0.00014	0.00015
Chromium	0.0005 - 0.0009	<0.0009	<0.0009	<0.0008	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0007	0.0006	<0.0005	<0.0005
Cobalt	0.0008	0.0473	0.0453	0.0476	0.0314	0.0339	0.0343	0.0347	0.0342	0.0340	0.0341	0.0339	0.0361	0.0730	0.0415	0.0504	0.0351
Copper	0.001	0.051	0.045	0.045	0.030	0.032	0.028	0.028	0.028	0.025	0.025	0.026	0.026	0.083	0.043	0.027	0.150
Iron	0.003 - 0.1	0.342	0.292	0.316	0.326	0.295	0.267	0.272	0.269	0.224	0.245	0.280	0.393	0.4	0.4	0.3	0.5
Lead	0.0001 - 0.002	<0.002	<0.002	0.005	0.0026	0.0033	0.0018	0.0018	0.0018	0.0017	0.0016	0.0019	0.0069	0.0040	0.0010	0.0006	0.0007
Manganese	0.0002 - 0.005	0.5310	0.5030	0.5500	0.3360	0.3540	0.3640	0.4090	0.3630	0.3610	0.3660	0.3680	0.3750	0.6110	0.3540	0.4540	0.2770
Molybdenum	0.001	0.026	0.025	0.028	0.023	0.025	0.023	0.023	0.023	0.023	0.022	0.023	0.024	0.055	0.027	0.028	0.025
Nickel	0.0005 - 0.001	0.117	0.106	0.123	0.0672	0.0713	0.0680	0.0668	0.0664	0.0702	0.0692	0.0704	0.0790	0.1340	0.0825	0.0978	0.0847
Selenium	0.0002 - 0.004	<0.0002	0.0006	<0.0002	0.0004	0.0006	0.0003	0.0003	<0.0002	<0.0002	<0.0002	0.0003	0.0006	0.0008	0.0003	0.0006	0.0003
Silver	0.0001 - 0.001	<0.001	<0.001	0.001	0.0021	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0001
Strontium	0.0001 - 0.001	0.3880	0.3800	0.4180	0.3030	0.3310	0.323	0.323	0.323	0.325	0.318	0.326	0.334	0.547	0.286	0.339	0.490
Thallium	0.00005 - 0.004	<0.004	<0.004	0.004	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Tin	0.001 - 0.003	<0.003	<0.003	<0.003	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	<0.001	<0.001	<0.001	<0.001
Titanium	0.0004 - 0.0005	<0.0004	<0.0004	<0.0004	0.004	0.0045	0.0046	0.0045	0.0046	0.0046	0.0046	0.0045	0.0044	0.0089	0.0044	0.0061	0.0046
Uranium	0.0005	NA[(a)]	NA[(a)]	NA[(a)]	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0008	<0.0005	<0.0005	<0.0005
Vanadium	0.0001 - 0.001	<0.001	0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Zinc	0.0007 - 0.001	0.0917	0.0559	0.0839	0.0510	0.0630	0.052	0.052	0.057	0.050	0.052	0.056	0.093	0.096	0.047	0.064	0.284
Cyanide	0.001 - 0.002	0.680	NA[(a)]	0.270	0.390	0.270	0.024	0.022	0.022	0.022	0.022	0.022	0.022	1.700	0.036	0.026	0.720

(a) Not Analyzed.

Table I-11
Water Concentrations of Samples Collected from Pond 2

Parameter	Detection Limit (mg/L)	Concentration (mg/L)																						
		14-Apr-98	07-Jul-98	05-Oct-98	23-Aug-98	28-Mar-99		25-Jul-99	06-Sep-99	02-Mar-00		25-Apr-00	07-Jul-00	09-Nov-00	12-Apr-01		04-Aug-01		01-Sep-01		03-Feb-02	04-Feb-02	12-Apr-02	
		P2-102	P2-102	P2-102	P2-102	P2-102	P2-106	P2-102	P2-102	P2-102	P2-107	P2-107	P2-102	P2-102	P2-102	P2-107	P2-102	P2-107	P2-102	P2-107	P2-102	P2-102T	P2-102	P2-106
Aluminum	0.005 - 0.009	1.140	0.101	0.489	0.346	1.070	1.150	0.469	0.112	0.531	0.629	0.925	0.125	0.216	0.932	0.501	0.050	0.059	0.089	0.073	0.304	0.255	0.381	0.353
Antimony	0.0002 - 0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.005	<0.005
Arsenic	0.0002 - 0.01	0.04	0.02	0.03	0.04	0.02	0.05	0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02	0.02
Barium	0.0002 - 0.001	0.0304	0.0162	0.0189	0.0181	0.0257	0.0252	0.0172	0.0152	0.0226	0.0230	0.0433	0.0159	0.0200	0.0231	0.0217	0.0148	0.0147	0.0153	0.0143	0.0200	0.0189	0.0227	0.0229
Beryllium	0.0001 - 0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0005	<0.0005
Boron	0.002	0.348	0.156	0.171	0.168	0.239	0.231	0.131	0.121	0.165	0.173	0.199	0.136	0.121	0.195	0.179	0.115	0.114	0.116	0.108	0.146	0.137	0.209	0.206
Cadmium	0.00001 - 0.0006	0.0017	<0.0005	0.0022	0.0010	0.0007	0.0010	<0.0005	<0.0005	<0.0006	<0.0006	0.0007	<0.0006	0.0006	0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0005	<0.0005
Chromium	0.0005 - 0.0009	0.0093	0.0011	0.0016	0.0020	0.0009	0.0012	<0.0008	<0.0008	<0.0008	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0008	<0.0008
Cobalt	0.0008	0.1500	0.0658	0.0708	0.0650	0.1180	0.1100	0.0744	0.0682	0.1030	0.1020	0.1110	0.0659	0.0777	0.1130	0.1000	0.0654	0.0656	0.0648	0.0637	0.0853	0.0758	0.0887	0.0825
Copper	0.001	0.092	0.011	0.040	0.018	0.054	0.056	0.026	0.005	0.027	0.030	0.030	0.007	0.023	0.023	0.021	0.010	0.010	0.010	0.009	0.019	0.017	0.024	0.024
Iron	0.003 - 0.1	0.619	0.162	0.353	0.188	0.559	0.703	0.479	0.131	0.066	0.125	0.187	0.077	0.168	0.248	0.316	0.151	0.182	0.245	0.205	0.161	0.114	0.146	0.141
Lead	0.0001 - 0.002	0.007	<0.002	0.002	<0.002	<0.002	0.004	<0.002	0.006	0.004	<0.002	0.003	<0.002	0.003	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
Manganese	0.0002 - 0.005	2.95	1.26	1.32	1.25	2.37	2.18	1.49	1.27	1.99	1.9800	2.1600	1.32	1.60	2.49	2.15	1.37	1.37	1.32	1.29	1.74	1.61	1.89	1.77
Molybdenum	0.001	0.001	0.001	0.001	0.003	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.003
Nickel	0.0005 - 0.001	0.234	0.103	0.121	0.110	0.183	0.177	0.121	0.111	0.167	0.165	0.177	0.110	0.128	0.179	0.160	0.109	0.108	0.109	0.107	0.144	0.131	0.163	0.155
Selenium	0.0002 - 0.004	<0.003	<0.004	0.012	<0.004	<0.004	<0.004	<0.004	0.007	0.013	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.010	0.019	0.007	0.006	<0.0002	<0.0002	<0.0002	0.0006
Silver	0.0001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002
Strontium	0.0001 - 0.001	0.448	0.309	0.320	0.307	0.461	0.454	0.278	0.264	0.374	0.371	0.387	0.282	0.286	0.394	0.380	0.249	0.248	0.256	0.253	0.342	0.322	0.362	0.344
Thallium	0.00005 - 0.004	<0.004	<0.004	<0.004	<0.004	0.008	<0.004	<0.004	0.005	<0.004	<0.004	0.015	<0.004	<0.004	0.006	0.005	<0.004	<0.004	<0.004	0.007	<0.004	<0.004	0.007	0.008
Tin	0.001 - 0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Titanium	0.0004 - 0.0005	0.0006	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	0.0009	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004	<0.0004
Uranium	0.0005	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
Vanadium	0.0001 - 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001
Zinc	0.0007 - 0.001	0.532	0.225	0.291	0.239	0.50	0.475	0.318	0.278	0.449	0.454	0.049	0.245	0.326	0.496	0.427	0.248	0.248	0.243	0.238	0.353	0.253	0.378	0.352
Cyanide	0.001 - 0.002	0.006	NA[a]	0.061	0.031	0.052	0.037	NA[a]	0.028	NA[a]	NA[a]	NA[a]	0.014	0.012	0.006	0.012	0.173	0.187	0.087	NA[a]	0.058	NA[a]	0.018	0.018

Table I-11
Water Concentrations of Samples Collected from Pond 2 (continued)

Parameter	Detection Limit (mg/L)	Concentration (mg/L)																								
		05-Jul-02						08-Jul-02	16-Jul-02									22-Apr-03		02-Aug-03	12-Oct-03			13-Jul-04		
		P2-102	P2-102b	P2-106	P2-106b	P2-107	P2-107b	P2-102a	P2-102a	P2-102b	P2-102c	P2-106a	P2-106b	P2-106c	P2-107a	P2-107b	P2-107c	P2-102	P2-107	P2-102	P2-102	P2-105	P2-106	P2-106	P2-102	P2-105
Aluminum	0.005 - 0.009	0.073	0.070	0.078	0.082	0.070	0.072	0.074	0.051	0.050	0.059	0.054	0.057	0.055	0.051	0.052	0.052	1.020	0.430	0.059	0.114	0.117	0.115	0.080	0.073	0.120
Antimony	0.0002 - 0.006	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Arsenic	0.0002 - 0.01	0.0076	0.0074	0.0084	0.008	0.0078	0.0082	0.0072	0.0074	0.0073	0.0074	0.0073	0.0074	0.0079	0.0075	0.0078	0.0083	0.0341	0.0295	0.0415	0.0619	0.0625	0.0543	0.0131	0.0136	0.0312
Barium	0.0002 - 0.001	0.019	0.018	0.019	0.016	0.019	0.016	0.021	0.015	0.016	0.015	0.015	0.015	0.015	0.015	0.016	0.015	0.031	0.026	0.016	0.019	0.019	0.018	0.014	0.014	0.014
Beryllium	0.0001 - 0.0006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Boron	0.002	0.096	0.100	0.095	0.096	0.099	0.098	0.090	0.099	0.100	0.098	0.101	0.100	0.100	0.102	0.098	0.100	0.204	0.186	0.094	0.109	0.112	0.110	0.074	0.080	0.078
Cadmium	0.00001 - 0.0006	0.00022	0.00021	0.00021	0.00023	0.00021	0.00021	0.00019	0.00020	0.00021	0.00023	0.00020	0.00019	0.00021	0.00018	0.00023	0.00021	0.00053	0.00033	0.00023	0.00019	0.00019	0.00019	0.00019	0.00022	0.00017
Chromium	0.0005 - 0.0009	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0016	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0008	<0.0005	0.0005	0.0006	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Cobalt	0.0008	0.0569	0.0551	0.0550	0.0530	0.0562	0.0530	0.0520	0.0559	0.0571	0.0569	0.0565	0.0568	0.0568	0.0566	0.0570	0.0568	0.1280	0.0988	0.0449	0.0499	0.0502	0.0483	0.0449	0.0447	0.0439
Copper	0.001	0.008	0.008	0.007	0.007	0.008	0.008	0.008	0.010	0.007	0.008	0.010	0.008	0.009	0.008	0.007	0.009	0.029	0.019	0.004	0.007	0.006	0.005	0.028	0.027	0.050
Iron	0.003 - 0.1	0.009	0.051	0.059	0.060	0.077	0.094	0.056	0.299	0.123	0.101	0.204	0.159	0.109	0.113	0.132	0.123	0.4	0.4	0.2	0.4	0.4	0.4	0.1	0.1	0.4
Lead	0.0001 - 0.002	0.0004	0.0005	0.0005	0.0006	0.0006	0.0006	0.0005	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0005	0.0036	0.0027	0.0009	0.0010	0.0009	0.0008	0.0002	0.0002	0.0005
Manganese	0.0002 - 0.005	1.08	1.05	1.03	1.02	1.08	1.06	1.16	1.11	1.11	1.12	1.11	1.09	1.09	1.10	1.11	1.10	2.74	2.01	1.09	1.12	1.12	1.11	0.929	0.910	0.806
Molybdenum	0.001	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.003	0.002	0.004	0.004	0.003	0.005	0.005	0.009
Nickel	0.0005 - 0.001	0.0884	0.0843	0.0860	0.1010	0.0868	0.0818	0.0838	0.0806	0.0801	0.0795	0.0791	0.0797	0.0793	0.0811	0.0788	0.0807	0.2070	0.1550	0.0764	0.0907	0.0931	0.0909	0.0809	0.0809	0.0829
Selenium	0.0002 - 0.004	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	0.0002	0.0003	<0.0002	<0.0002	<0.0002	0.0002	0.0004	0.0005	<0.0002	<0.0002	0.0003
Silver	0.0001 - 0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.0001	<0.0001	<0.0001
Strontium	0.0001 - 0.001	0.2900	0.2790	0.2790	0.2680	0.2860	0.2720	0.2630	0.275	0.274	0.276	0.277	0.281	0.281	0.277	0.281	0.274	0.538	0.454	0.248	0.289	0.308	0.300	0.275	0.284	0.337
Thallium	0.00005 - 0.004	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Tin	0.001 - 0.003	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Titanium	0.0004 - 0.0005	0.0040	0.0038	0.0040	0.0039	0.0039	0.0040	0.0034	0.0041	0.0042	0.0043	0.0041	0.0041	0.0040	0.0043	0.0046	0.0044	0.0096	0.0075	0.0048	0.0057	0.0058	0.0056	0.0046	0.0044	0.0063
Uranium	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Vanadium	0.0001 - 0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
Zinc	0.0007 - 0.001	0.2030	0.1960	0.1960	0.1880	0.2000	0.1900	0.2030	0.1950	0.1950	0.198	0.196	0.197	0.198	0.199	0.204	0.208	0.560	0.397	0.153	0.178	0.187	0.175	0.184	0.186	0.204
Cyanide	0.001 - 0.002	0.078	0.082	0.082	0.090	0.084	0.092	0.084	<0.002	<0.002	<0.002	0.092	0.090	0.090	0.012	0.012	0.006	0.012	0.010	0.044	0.018	0.022	0.018	NA[(a)]	0.250	0.440

(a) Not Analyzed.

Table I-12
Water Concentrations of Samples Collected from Cell 1 and Cell 4

Parameter	Detection Limit (mg/L)	Concentration (mg/L)										
		23-Aug-98			01-Sep-01	07-Jul-02		03-Aug-02		02-Aug-03	13-Jul-04	
		Cell 4	Cell 4 u/s	Cell 4	Cell 4	cell 1 (ground)	cell 1 (surface)	cell 1-4	cell 1-5	Cell 4	Cell 1 pond	Cell 4 u/s
Aluminum	0.005 - 0.009	0.151	0.158	0.027	NA[(a)]	0.120	3.400	0.811	1.290	0.083	NA[(a)]	NA[(a)]
Antimony	0.0002 - 0.006	<0.005	<0.006	<0.006	NA[(a)]	<0.0002	<0.0002	0.0019	0.0004	0.0008	NA[(a)]	NA[(a)]
Arsenic	0.0002 - 0.01	1.15	0.40	0.17	NA[(a)]	0.0082	0.0549	0.0084	0.0121	0.4340	NA[(a)]	NA[(a)]
Barium	0.0002 - 0.001	0.0113	0.0131	0.0128	NA[(a)]	0.0870	0.0250	0.0220	0.0210	0.0160	NA[(a)]	NA[(a)]
Beryllium	0.0001 - 0.0006	<0.0005	<0.0006	<0.0006	NA[(a)]	<0.0001	0.0007	0.0006	0.0009	<0.0001	NA[(a)]	NA[(a)]
Boron	0.002	0.169	0.142	0.229	NA[(a)]	0.021	0.013	0.169	0.065	0.165	NA[(a)]	NA[(a)]
Cadmium	0.00001 - 0.0006	<0.0005	<0.0006	<0.0006	NA[(a)]	0.00012	0.00058	0.00296	0.00719	0.00004	NA[(a)]	NA[(a)]
Chromium	0.0005 - 0.0009	0.0010	<0.0009	<0.0009	NA[(a)]	0.0011	0.0007	<0.0005	<0.0005	0.0008	NA[(a)]	NA[(a)]
Cobalt	0.0008	0.0401	0.0454	0.0469	NA[(a)]	0.0396	0.0888	0.4600	1.0400	0.0514	NA[(a)]	NA[(a)]
Copper	0.001	0.346	0.389	0.227	NA[(a)]	0.019	0.051	0.167	0.206	0.961	NA[(a)]	NA[(a)]
Iron	0.003 - 0.1	1.010	0.776	3.400	NA[(a)]	1.500	2.310	0.129	0.007	0.4	NA[(a)]	NA[(a)]
Lead	0.0001 - 0.002	0.004	0.004	<0.002	NA[(a)]	0.0016	0.0014	0.0097	0.0124	0.0014	NA[(a)]	NA[(a)]
Manganese	0.0002 - 0.005	0.1170	5.4100	5.8900	NA[(a)]	1.1800	1.3700	5.5300	13.5000	0.1530	NA[(a)]	NA[(a)]
Molybdenum	0.001	0.058	0.041	0.027	NA[(a)]	<0.001	<0.001	0.002	<0.001	0.067	NA[(a)]	NA[(a)]
Nickel	0.0005 - 0.001	0.161	0.168	0.158	NA[(a)]	0.0047	0.1780	1.1500	3.0600	0.1950	NA[(a)]	NA[(a)]
Selenium	0.0002 - 0.004	<0.004	<0.004	0.007	NA[(a)]	<0.0002	0.0004	0.0015	0.0013	0.0022	NA[(a)]	NA[(a)]
Silver	0.0001 - 0.001	<0.001	<0.001	<0.001	NA[(a)]	0.0001	<0.0001	<0.0001	<0.0001	0.0013	NA[(a)]	NA[(a)]
Strontium	0.0001 - 0.001	0.3420	0.4630	0.4590	NA[(a)]	0.0550	0.2000	0.5160	0.9470	0.7400	NA[(a)]	NA[(a)]
Thallium	0.00005 - 0.004	<0.004	<0.004	<0.004	NA[(a)]	0.00009	0.00012	0.00014	0.00043	<0.00005	NA[(a)]	NA[(a)]
Tin	0.001 - 0.003	<0.003	<0.003	0.004	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	<0.001	NA[(a)]	NA[(a)]
Titanium	0.0004 - 0.0005	<0.0004	<0.0004	0.0318	NA[(a)]	0.0025	0.0041	0.0075	0.0111	0.0070	NA[(a)]	NA[(a)]
Uranium	0.0005	NA[(a)]	NA[(a)]	NA[(a)]	NA[(a)]	<0.0005	0.0014	<0.0005	0.0015	0.0009	NA[(a)]	NA[(a)]
Vanadium	0.0001 - 0.001	<0.001	<0.001	<0.001	NA[(a)]	0.001	<0.0001	<0.0001	<0.0001	<0.0001	NA[(a)]	NA[(a)]
Zinc	0.0007 - 0.001	0.1600	0.1360	0.0947	NA[(a)]	0.0240	0.1680	0.437	0.692	0.983	NA[(a)]	NA[(a)]
Cyanide	0.001 - 0.002	NA[(a)]	NA[(a)]	NA[(a)]	4.500	NA[(a)]	NA[(a)]	0.028	0.002	3.000	0.004	1.800

(a) Not Analyzed.

Table I-13
Descriptive Summary of Water Concentrations of Samples Collected from the Study Area (Pond 1, Pond 2, Cell 1 and Cell 4)

Parameter	Minimum	Maximum	Mean[(a)]
Aluminum	0.023	3.4	0.25
Antimony	0.0003	0.002	0.0005
Arsenic	0.0072	1.15	0.09
Barium	0.0098	0.087	0.018
Beryllium	<0.0001	0.0009	0.0002
Boron	0.013	0.348	0.122
Cadmium	0.00004	0.0072	0.0005
Chromium	<0.0005	0.0228	0.0008
Cobalt	0.029	1.04	0.076
Copper	0.004	0.961	0.055
Iron	0.007	3.4	0.4
Lead	0.0002	0.021	0.002
Manganese	0.117	13.5	1.34
Molybdenum	<0.001	0.067	0.012
Nickel	0.0047	3.06	0.156
Selenium	<0.0002	0.019	0.002
Silver	<0.0001	0.002	0.0004
Strontium	0.055	0.947	0.330
Thallium	<0.00005	0.015	0.002
Tin	<0.001	0.005	0.002
Titanium	<0.0004	0.061	0.0037
Uranium	<0.0005	0.0015	<0.0005
Vanadium	<0.0001	0.003	0.0004
Zinc	0.024	0.98	0.22
Cyanide	<0.002	4.5	0.28

(a) Calculations were based on half the detection limit for values that were less than analytical detection limits.

Table I-14
Water Concentrations of Samples Collected from the Receiving Environment

Parameter	Detection Limit (mg/L)	Concentration (mg/L)															
		07-Jul-00		18-Jul-00		08-Jul-01						03-Aug-01		16-Jul-02	17-Jul-02	24-Jul-02	25-Jul-02
		Long Lake	Test Lake	Dam 1a Siphon		Lori Lake	Boomerang Lake	Dam 1a Lake	Dam 2 Lake	Seep Creek	Inner Sun Bay	Outer Sun Bay		Dam 1a Siphon	Dam 1a Siphon	Dam 1a Siphon	Dam 1a Siphon
		SB2	SB5	925-10a	925-10b	WQ4	B-WQ5	WQ6	WQ7	WQ8	WQ9	925-25	925-99	925-10	925-10	925-10	925-10
Aluminum	0.005 - 0.009	0.063	0.085	NA[b]	NA[b]	0.079	0.048	0.042	0.203	0.064	0.064	0.018	0.019	NA[b]	NA[b]	NA[b]	NA[b]
Antimony	0.0002 - 0.006	<0.006	<0.006	NA[b]	NA[b]	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	NA[b]	NA[b]	NA[b]	NA[b]
Arsenic	0.0002 - 0.01	0.03	0.005	NA[b]	NA[b]	0.03	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	0.0075	0.0087	0.0073	0.0078
Barium	0.0002 - 0.001	0.0066	0.0042	NA[b]	NA[b]	0.0059	0.0113	0.0067	0.0184	0.0039	0.0056	0.0024	0.0024	NA[b]	NA[b]	NA[b]	NA[b]
Beryllium	0.0001 - 0.0006	<0.0006	<0.0006	NA[b]	NA[b]	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	NA[b]	NA[b]	NA[b]	NA[b]
Boron	0.002	0.017	<0.002	NA[b]	NA[b]	<0.002	<0.002	0.003	0.007	<0.002	<0.002	<0.002	0.003	NA[b]	NA[b]	NA[b]	NA[b]
Cadmium	0.00001 - 0.0006	<0.0006	<0.0006	NA[b]	NA[b]	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	NA[b]	NA[b]	NA[b]	NA[b]
Chromium	0.0005 - 0.0009	0.0011	<0.0009	NA[b]	NA[b]	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	<0.0009	NA[b]	NA[b]	NA[b]	NA[b]
Cobalt	0.0008	0.0012	0.0008	NA[b]	NA[b]	<0.0008	0.0044	0.0011	0.0277	<0.0008	0.0009	<0.0008	<0.0008	NA[b]	NA[b]	NA[b]	NA[b]
Copper	0.001	0.003	0.002	NA[b]	0.006	0.003	0.002	<0.001	0.008	<0.001	0.001	0.001	0.001	0.007	0.014	0.007	0.007
Iron	0.003 - 0.1	0.075	0.423	NA[b]	NA[b]	0.183	0.227	0.164	0.121	0.149	0.147	0.035	0.025	NA[b]	NA[b]	NA[b]	NA[b]
Lead	0.0001 - 0.002	0.003	<0.002	NA[b]	NA[b]	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	NA[b]	NA[b]	NA[b]	NA[b]
Manganese	0.0002 - 0.005	0.0104	0.0056	NA[b]	NA[b]	0.0040	0.1400	0.0180	0.5150	0.0044	0.0080	0.0052	0.0052	NA[b]	NA[b]	NA[b]	NA[b]
Molybdenum	0.001	0.001	<0.001	NA[b]	NA[b]	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	NA[b]	NA[b]	NA[b]	NA[b]
Nickel	0.0005 - 0.001	0.015	0.007	NA[b]	NA[b]	0.005	0.01	0.004	0.147	0.001	0.003	0.001	0.001	NA[b]	NA[b]	NA[b]	NA[b]
Selenium	0.0002 - 0.004	<0.004	0.006	NA[b]	NA[b]	<0.004	0.007	<0.004	<0.004	0.008	<0.004	<0.004	<0.004	NA[b]	NA[b]	NA[b]	NA[b]
Silver	0.0001 - 0.001	<0.001	<0.001	NA[b]	NA[b]	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	NA[b]	NA[b]	NA[b]	NA[b]
Strontium	0.0001 - 0.001	0.0169	0.0094	NA[b]	NA[b]	0.0188	0.0290	0.0182	0.0426	0.0124	0.0087	0.0056	0.0056	NA[b]	NA[b]	NA[b]	NA[b]
Thallium	0.00005 - 0.004	<0.004	<0.004	NA[b]	NA[b]	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	NA[b]	NA[b]	NA[b]	NA[b]
Tin	0.001 - 0.003	<0.003	<0.003	NA[b]	NA[b]	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	NA[b]	NA[b]	NA[b]	NA[b]
Titanium	0.0004 - 0.0005	0.0008	0.0008	NA[b]	NA[b]	0.0043	<0.0004	0.0037	0.0034	0.0036	0.0034	<0.0004	<0.0004	NA[b]	NA[b]	NA[b]	NA[b]
Uranium	0.0005	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]
Vanadium	0.0001 - 0.001	0.002	0.002	NA[b]	NA[b]	<0.001	<0.001	<0.001	0.002	0.002	<0.001	<0.001	<0.001	NA[b]	NA[b]	NA[b]	NA[b]
Zinc	0.0007 - 0.001	0.0196	0.0033	NA[b]	0.2430	0.0056	0.0057	0.0029	0.0610	0.0016	0.0047	0.0023	0.0031	0.1940	0.2060	0.1940	0.2010
Cyanide	0.001 - 0.002	0.001	0.001	0.014	0.016	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]	0.001	0.003	<0.002	0.006	0.104	0.096

Table I-14
Water Concentrations of Samples Collected from the Receiving Environment (continued)

Parameter	Detection Limit (mg/L)	Concentration (mg/L)											
		03-Aug-02				07-Aug-02	08-Aug-02	12-Oct-03		13-Jul-04			
		Dam 1a Siphon	Norma Lake	Boomerang Lake	Dam 2 Lake	Dam 1a Siphon	Dam 1a Siphon	Boomerang Lake	Dam 2 Lake	Dam 1a Siphon			
		925-10	WQ1	B-WQ5	WQ7	925-10	925-10	B-WQ5	WQ7	925-10	Minimum	Maximum	Mean(a)
Aluminum	0.005 - 0.009	NA(b)	0.011	0.018	0.124	NA(b)	NA(b)	0.06	0.385	0.223	0.011	0.385	0.092
Antimony	0.0002 - 0.006	NA(b)	<0.0002	<0.0002	<0.0002	NA(b)	NA(b)	<0.0002	<0.0002	<0.0002	<0.0002	<0.006	<0.006
Arsenic	0.0002 - 0.01	0.0099	0.0179	0.0045	0.0036	0.0132	0.0123	0.0071	0.0017	0.0072	0.0017	0.03	0.01
Barium	0.0002 - 0.001	NA(b)	0.0050	0.0080	0.019	NA(b)	NA(b)	0.008	0.020	0.024	0.0024	0.0240	0.0094
Beryllium	0.0001 - 0.0006	NA(b)	<0.0001	<0.0001	0.0002	NA(b)	NA(b)	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	0.0002
Boron	0.002	NA(b)	0.003	0.006	0.008	NA(b)	NA(b)	0.0040	0.010	0.009	<0.002	0.017	0.005
Cadmium	0.00001 - 0.0006	NA(b)	<0.00001	<0.00001	0.00013	NA(b)	NA(b)	0.00006	0.00023	0.00025	<0.00001	0.0003	0.0002
Chromium	0.0005 - 0.0009	NA(b)	<0.0005	<0.0005	<0.0005	NA(b)	NA(b)	<0.0005	<0.0005	<0.0005	<0.0005	0.0011	<0.0005
Cobalt	0.0008	NA(b)	0.0001	0.0005	0.0167	NA(b)	NA(b)	0.0018	0.0407	0.046	0.0001	0.0460	0.0111
Copper	0.001	0.006	0.001	0.002	0.008	0.006	0.007	0.003	0.016	0.009	0.001	0.016	0.005
Iron	0.003 - 0.1	NA(b)	0.030	0.083	0.034	NA(b)	NA(b)	0.1	<0.1	0.7	0.025	0.7	0.2
Lead	0.0001 - 0.002	NA(b)	<0.0001	<0.0001	<0.0001	NA(b)	NA(b)	0.0009	0.0002	0.0002	<0.0001	0.003	0.001
Manganese	0.0002 - 0.005	NA(b)	0.0022	0.0146	0.3090	NA(b)	NA(b)	0.016	0.412	0.566	0.0022	0.5660	0.1207
Molybdenum	0.001	NA(b)	<0.001	<0.001	<0.001	NA(b)	NA(b)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
Nickel	0.0005 - 0.001	NA(b)	0.0069	0.0034	0.126	NA(b)	NA(b)	0.0076	0.205	0.0867	0.0010	0.205	0.037
Selenium	0.0002 - 0.004	NA(b)	<0.0002	<0.0002	<0.0002	NA(b)	NA(b)	<0.0002	<0.0002	<0.0002	<0.0002	0.008	0.002
Silver	0.0001 - 0.001	NA(b)	<0.0001	<0.0001	<0.0001	NA(b)	NA(b)	<0.0001	<0.0001	<0.0001	<0.0001	<0.001	<0.001
Strontium	0.0001 - 0.001	NA(b)	0.0110	0.0330	0.0430	NA(b)	NA(b)	0.039	0.0570	0.0730	0.0056	0.0730	0.0272
Thallium	0.00005 - 0.004	NA(b)	<0.00005	<0.00005	<0.00005	NA(b)	NA(b)	<0.00005	<0.00005	<0.00005	<0.00005	<0.004	<0.004
Tin	0.001 - 0.003	NA(b)	NA(b)	NA(b)	NA(b)	NA(b)	NA(b)	<0.001	<0.001	<0.001	<0.001	<0.003	<0.003
Titanium	0.0004 - 0.0005	NA(b)	<0.0005	0.0008	0.0008	NA(b)	NA(b)	0.0026	0.0014	0.0015	<0.0004	0.0043	0.0018
Uranium	0.0005	NA(b)	<0.0005	<0.0005	<0.0005	NA(b)	NA(b)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Vanadium	0.0001 - 0.001	NA(b)	<0.0001	<0.0001	<0.0001	NA(b)	NA(b)	0.0001	<0.0001	<0.0001	<0.0001	0.002	0.0007
Zinc	0.0007 - 0.001	0.2000	0.005	0.004	0.054	0.201	0.247	0.006	0.087	0.283	0.0016	0.283	0.090
Cyanide	0.001 - 0.002	0.060	<0.002	<0.002	<0.002	0.092	0.092	0.001	0.002	NA(b)	<0.002	0.104	0.027

(a) Calculations based on half the detection limit for values that were less than analytical detection limits.

(b) Not analyzed.

I.6 Caribou Tissue Concentrations

Caribou tissue concentrations (i.e., caribou meat) were calculated based on uptake of chemicals from soil, water and vegetation into animal tissue. Empirical data on concentrations of metals in meat from caribou were not available for the Lupin mine area; therefore, meat tissue concentrations were calculated from soil, vegetation and water data. These calculations are based on metal-specific biotransfer factors (BTF) for beef obtained from an on-line database (RAIS 2004), which were corrected to account for the differences in lipid content for beef and caribou. Meat concentrations were calculated using exposure equations presented in Table I-15.

Table I-15
Meat Uptake Equations

Total Uptake from soil, food, and water (C_{meat}) = $C_{meatsoil}$ + $C_{meatvegetation}$ + $C_{meatwater}$	
Pathway	**Equation and Equation Parameters**
soil ingestion	$C_{meatsoil}$ = BTF x C_{soil} x IR_{soil} x fw x LCF
	BTF = Biotransfer Factor (day/kg) IR_{soil} = soil ingestion rate for caribou (0.03 kg/day) (Beyer et al. 1996) C_{soil} = maximum concentration in Study Area soil (mg/kg) fw = fraction of daily consumption from site (assumed 1; unitless) LCF = lipid conversion factor (caribou lipid content/beef lipid content; unitless) (USDA 2004)
vegetation ingestion	$C_{meatvegetation}$ = BTF x $C_{vegetation}$ x $IR_{vegetation}$ x fw x LCF
	BTF = Biotransfer Factor (day/kg) $IR_{vegetation}$ = vegetation ingestion rate for caribou (1.6 kg/day) (U.S. EPA 1993) $C_{vegetation}$ = maximum concentration in Study Area vegetation (mg/kg) fw = fraction of daily consumption from site (assumed 1; unitless) LCF = lipid conversion factor (caribou lipid content/beef lipid content; unitless) (USDA 2004)
water ingestion	$C_{meatwater}$ = BTF x C_{water} x IR_{water} x fw X LCF
	BTF = Biotransfer Factor (day/kg) IR_{water} = water ingestion rate for caribou (6.7 L/day) (U.S. EPA 1993) C_{water} = maximum concentration in Study Area water (mg/L) fw = fraction of daily consumption from site (assumed 1; unitless) LCF = lipid conversion factor (caribou lipid content/beef lipid content; unitless) (USDA 2004)

Predicted caribou meat metal concentrations for the study area are presented in Tables I-16, I-17, and Table I-18 for soil, vegetation, and water ingestion, respectively. Total predicted caribou meat metal concentrations from ingestion of all media are presented in Table I-19.

Table I-16
Caribou Meat Concentrations Based on Soil Ingestion

Parameter[(a)]	BTF (day/kg)[(b)]	Soil Concentration (mg/kg)	Soil Ingestion Rate (kg/day)	fw (unitless)	Lipid Content (caribou - %)	Lipid Content (beef - %)	Lipid Conversion Factor	Meat Concentration (mg/kg) (calculated)[(c)]
Aluminum	0.0015	6310	0.05	1	3.36	22.55	0.15	0.07
Antimony	0.00004	0.05	0.05	1	3.36	22.55	0.15	0.00000001
Arsenic	0.0020	161	0.05	1	3.36	22.55	0.15	0.002
Barium	0.00020	38.8	0.05	1	3.36	22.55	0.15	0.00006
Boron	0.00080	2	0.05	1	3.36	22.55	0.15	0.00001
Cadmium	0.00040	<0.1	0.05	1	3.36	22.55	0.15	0.00000015
Chromium	0.0090	22.6	0.05	1	3.36	22.55	0.15	0.0015
Cobalt	0.00010	5.6	0.05	1	3.36	22.55	0.15	0.000004
Copper	0.0090	14.9	0.05	1	3.36	22.55	0.15	0.0010
Lead	0.00040	5.8	0.05	1	3.36	22.55	0.15	0.00002
Manganese	0.00050	93	0.05	1	3.36	22.55	0.15	0.0003
Mercury	0.010	0.11	0.05	1	3.36	22.55	0.15	0.000008
Molybdenum	0.0010	0.4	0.05	1	3.36	22.55	0.15	0.000003
Nickel	0.0050	13.3	0.05	1	3.36	22.55	0.15	0.0005
Selenium	0.10	<0.2	0.05	1	3.36	22.55	0.15	0.00007
Silver	0.0030	<0.2	0.05	1	3.36	22.55	0.15	0.000002
Strontium	0.0080	6	0.05	1	3.36	22.55	0.15	0.0004
Thallium	0.040	0.06	0.05	1	3.36	22.55	0.15	0.00002
Vanadium	0.0025	17.8	0.05	1	3.36	22.55	0.15	0.0003
Zinc	0.10	24	0.05	1	3.36	22.55	0.15	0.02

(a) Meat concentration of cyanide not calculated, because cyanide is not expected in soil.
(b) RAIS 2004.
(c) Calculations were based on half detection limits for values that were less than analytical detection limits.

Table I-17
Caribou Meat Concentrations Based on Vegetation Ingestion

Parameter[b]	BTF (d/kg)[a]	Vegetation Concentration (mg/kg)	Vegetation Ingestion Rate (kg/day)	fw (unitless)	Lipid Content (caribou - %)	Lipid Content (beef - %)	Lipid Conversion Factor	Meat Concentration (mg/kg) (calculated)[c]
Aluminum	0.0015	629	1.6	1	3.36	22.55	0.15	0.2
Antimony	0.00004	0.024	1.6	1	3.36	22.55	0.15	0.0000002
Arsenic	0.0020	31.7	1.6	1	3.36	22.55	0.15	0.02
Barium	0.00020	9.5	1.6	1	3.36	22.55	0.15	0.0005
Cadmium	0.00040	<0.08	1.6	1	3.36	22.55	0.15	0.000002
Chromium	0.0090	2.3	1.6	1	3.36	22.55	0.15	0.005
Cobalt	0.00010	0.61	1.6	1	3.36	22.55	0.15	0.00001
Copper	0.0090	2.09	1.6	1	3.36	22.55	0.15	0.004
Lead	0.00040	2.52	1.6	1	3.36	22.55	0.15	0.0002
Manganese	0.00050	333	1.6	1	3.36	22.55	0.15	0.04
Mercury	0.010	0.01	1.6	1	3.36	22.55	0.15	0.00002
Molybdenum	0.0010	0.62	1.6	1	3.36	22.55	0.15	0.0001
Nickel	0.0050	3.07	1.6	1	3.36	22.55	0.15	0.004
Selenium	0.10	0.1	1.6	1	3.36	22.55	0.15	0.003
Silver	0.0030	<0.08	1.6	1	3.36	22.55	0.15	0.00001
Strontium	0.0080	6.5	1.6	1	3.36	22.55	0.15	0.01
Thallium	0.040	<0.04	1.6	1	3.36	22.55	0.15	0.00009
Vanadium	0.0025	0.46	1.6	1	3.36	22.55	0.15	0.0003
Zinc	0.10	31.56	1.6	1	3.36	22.55	0.15	0.8

(a) RAIS 2004.
(b) Boron and cyanide meat concentration from vegetation ingestion not calculated because not analyzed in vegetation.
(c) Calculations based on half the detection limit for values below analytical detection limits.

Table I-18
Caribou Meat Concentrations Based on Water Ingestion

Parameter	BTF (d/kg)[a]	Water Concentration (mg/L)	Water Ingestion Rate (L/day)	fw (unitless)	Lipid Content (caribou - %)	Lipid Content (beef - %)	Lipid Conversion Factor	Meat Concentration (mg/kg) (calculated)
Aluminum	0.0015	3.4	6.7	1	3.36	22.55	0.15	0.005
Antimony	0.00004	0.0019	6.7	1	3.36	22.55	0.15	0.00000008
Arsenic	0.0020	1.15	6.7	1	3.36	22.55	0.15	0.002
Barium	0.00020	0.087	6.7	1	3.36	22.55	0.15	0.00002
Boron	0.00080	0.348	6.7	1	3.36	22.55	0.15	0.0003
Cadmium	0.00040	0.0072	6.7	1	3.36	22.55	0.15	0.000003
Chromium	0.0090	0.0228	6.7	1	3.36	22.55	0.15	0.0002
Cobalt	0.00010	1.04	6.7	1	3.36	22.55	0.15	0.0001
Copper	0.0090	0.961	6.7	1	3.36	22.55	0.15	0.009
Lead	0.00040	0.021	6.7	1	3.36	22.55	0.15	0.00001
Manganese	0.00050	13.5	6.7	1	3.36	22.55	0.15	0.007
Mercury	0.010	NA[b]	6.7	1	3.36	22.55	0.15	NC[c]
Molybdenum	0.0010	0.067	6.7	1	3.36	22.55	0.15	0.0001
Nickel	0.0050	3.06	6.7	1	3.36	22.55	0.15	0.02
Selenium	0.10	0.019	6.7	1	3.36	22.55	0.15	0.002
Silver	0.0030	0.0021	6.7	1	3.36	22.55	0.15	0.00001
Strontium	0.0080	0.947	6.7	1	3.36	22.55	0.15	0.008
Thallium	0.040	0.015	6.7	1	3.36	22.55	0.15	0.0006
Vanadium	0.0025	0.003	6.7	1	3.36	22.55	0.15	0.00001
Zinc	0.10	0.983	6.7	1	3.36	22.55	0.15	0.10
Cyanide	0.00000031	4.5	6.7	1	3.36	22.55	0.15	0.000001

[a]RAIS 2004.
[b]Not analyzed.
[c]Not calculated because mercury not analyzed in water.

Table I-19
Total Caribou Meat Concentrations

Parameter	Meat Concentration (mg/kg) (calculated)			
	Soil	Water	Vegetation	Total
Aluminum	0.07	0.005	0.2	0.3
Antimony	0.00000001	0.00000008	0.0000002	0.0000003
Arsenic	0.002	0.002	0.02	0.02
Barium	0.00006	0.00002	0.0005	0.0005
Boron	0.00001	0.0003	NC[a]	0.0003[b]
Cadmium	0.0000001	0.000003	0.000002	0.000005
Chromium	0.002	0.0002	0.005	0.007
Cobalt	0.000004	0.0001	0.00001	0.0001
Copper	0.001	0.009	0.004	0.01
Lead	0.00002	0.000008	0.0002	0.0003
Manganese	0.0003	0.007	0.04	0.05
Mercury	0.000008	NC[a]	0.00002	0.00003[c]
Molybdenum	0.000003	0.00007	0.0001	0.0002
Nickel	0.0005	0.02	0.004	0.02
Selenium	0.00007	0.002	0.003	0.005
Silver	0.000002	0.000006	0.00001	0.00002
Strontium	0.0004	0.008	0.01	0.02
Thallium	0.00002	0.0006	0.00009	0.0007
Vanadium	0.0003	0.000007	0.0003	0.0006
Zinc	0.02	0.10	0.8	0.9
Cyanide	NC[a]	0.000001	NC[a]	0.000001[d]

[a] Not calculated because media concentration not available.
[b] Based on soil and water ingestion only; vegetation concentration not available.
[c] Based on soil and vegetation ingestion only; water concentration not available.
[d] Based on water ingestion only; soil and vegetation concentrations not available.

I.7 Benthic Invertebrate Concentrations

Body burdens of metals in benthic invertebrates have not previously been reported for receiving environment water bodies or the study area at the Lupin mine site. However, wild waterfowl have been observed using these water bodies as feeding areas. Therefore, it was necessary to estimate the concentrations of metals in invertebrates from these areas, as they would provide a major food source for waterfowl.

Site-specific bioconcentration factors (BCFs) could not be calculated for the Lupin mine site because reference data were not available for benthic invertebrate metal concentrations. Thus, literature-based BCFs (U.S. EPA 1999) were used for calculation of predicted invertebrate whole-body concentrations in the study area and receiving environment. In cases where a literature-based BCF was not available, a conservative BCF of 1 was used as an alternative. Sediment to benthic invertebrate BCFs for each parameter were used to calculate predicted invertebrate whole-body concentrations for the study area (Pond 1 and Pond 2) and receiving environment (Boomerang Lake) based on the equation:

Predicted Benthic Invertebrate Whole Body Concentration (mg/kg) =
BCF (L/kg) x Maximum Sediment Concentration (mg/L)

Sediment data used to calculate invertebrate tissue metal concentrations for the study area and receiving environment are shown in Table I-4 and Table I-5, respectively. Predicted invertebrate whole-body metal concentrations are presented in Table I-20.

Table I-20
Predicted Invertebrate Whole-Body Metal Concentration in the Study Area and in the Receiving Environment[(a)]

Parameter	BCF[(b)]	Study Area		Receiving Environment	
		Maximum Sediment Concentration (mg/kg)	Invertebrate Concentration (mg/kg) (calculated)	Maximum Sediment Concentration (mg/kg)	Invertebrate Concentration (mg/kg) (calculated)
Aluminum	0.90	17100	15390	14600	13140
Arsenic	0.90	16000	14400	6590.0	5931
Barium	0.90	103	92.7	72.1	64.89
Boron	1	5	5	9	9
Chromium	0.39	46.7	18.213	41.3	16.107
Cobalt	1	28.5	28.5	27.9	27.9
Copper	0.30	451	135.3	298.0	89.4
Lead	0.63	377	237.51	107.0	67.41
Manganese	1	382	382	283	283
Mercury	0.068	0.13	0.00884	0.28	0.01904
Molybdenum	1	9.5	9.5	8.8	8.8
Nickel	0.90	52	46.8	64.6	58.14
Selenium	0.90	2.6	2.34	1.3	1.17
Silver	0.90	<0.2	0.09	<0.2	0.09
Strontium	1	94	94	48	48
Thallium	0.90	0.09	0.081	0.14	0.126
Vanadium	1	32.8	32.8	30.4	30.4
Zinc	0.57	6140	3499.8	1340	763.8
Cyanide	0.90	8580	7722	34.7	31.23

[(a)] Mean concentrations were used; calculations were based on half detection limits for values that were below analytical detection limits.
[(b)] U.S. EPA 1999. If no BCF was available, a conservative value of 1 was used.

I.8 References

RAIS (Risk Assessment Information System). 2004. Available On-line at http://risk.lsd.ornl.gov/cgi-bin/tox/TOX_9801. Accessed in September, 2004.

U.S. EPA (United States Environmental Protection Agency). 1993. Wildlife Exposure Factors Handbook. Volume I of II. EPA/600/R-93/187a.

U.S. EPA (United States Environmental Protection Agency). 1999. Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities. Volume 3A and 3B. EPA530-D-99-001C.

APPENDIX II

RISK ASSESSMENT APPROACH

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1. INTRODUCTION

Appendix II presents the detailed methods used for the human and wildlife risk assessments.

1.1 Risk Assessment Guidance

In Canada and the United States, risk assessment has been accepted by various levels of federal and regional governments as a valid method to guide risk management decisions. The risk assessment methodology for this assessment is based on the following provincial and federal guidance documents:

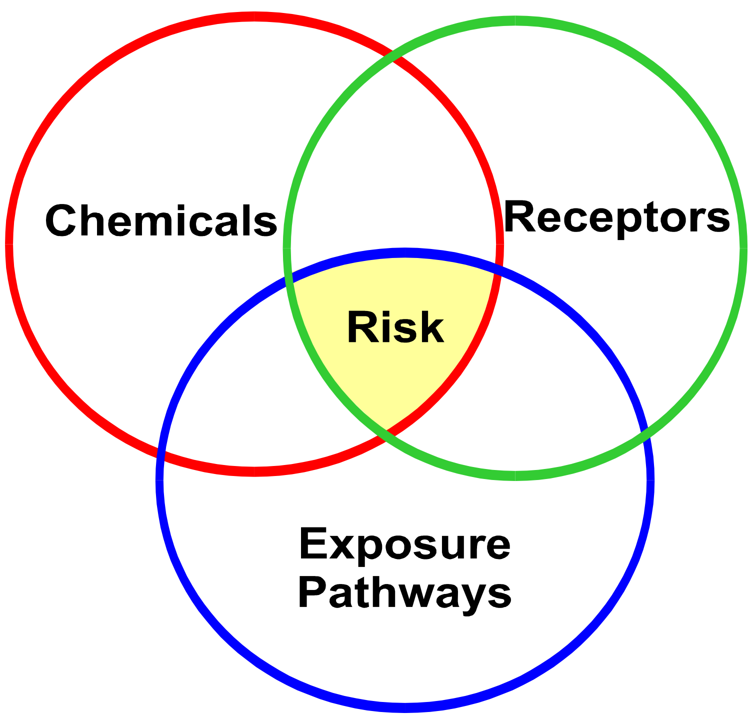
- CCME. A Framework for Ecological Risk Assessment. General Guidance. (1996).
- Health Canada. Federal Contaminated Site Risk Assessment in Canada. Version 1.1. (2003).
- Health Canada. Human Health Risk Assessment for Priority Substances. (1994).
- Health Canada. Human Health Risk Assessment of Chemicals from Contaminated Sites. Prepared by Golder Associates Ltd. and Cantox Inc. (not published 1995).
- United States Environmental Protection Agency (U.S. EPA). Guidelines for Ecological Risk Assessment (U.S. EPA 1998).

2. RISK ASSESSMENT APPROACH

2.1 Risk Assessment Framework

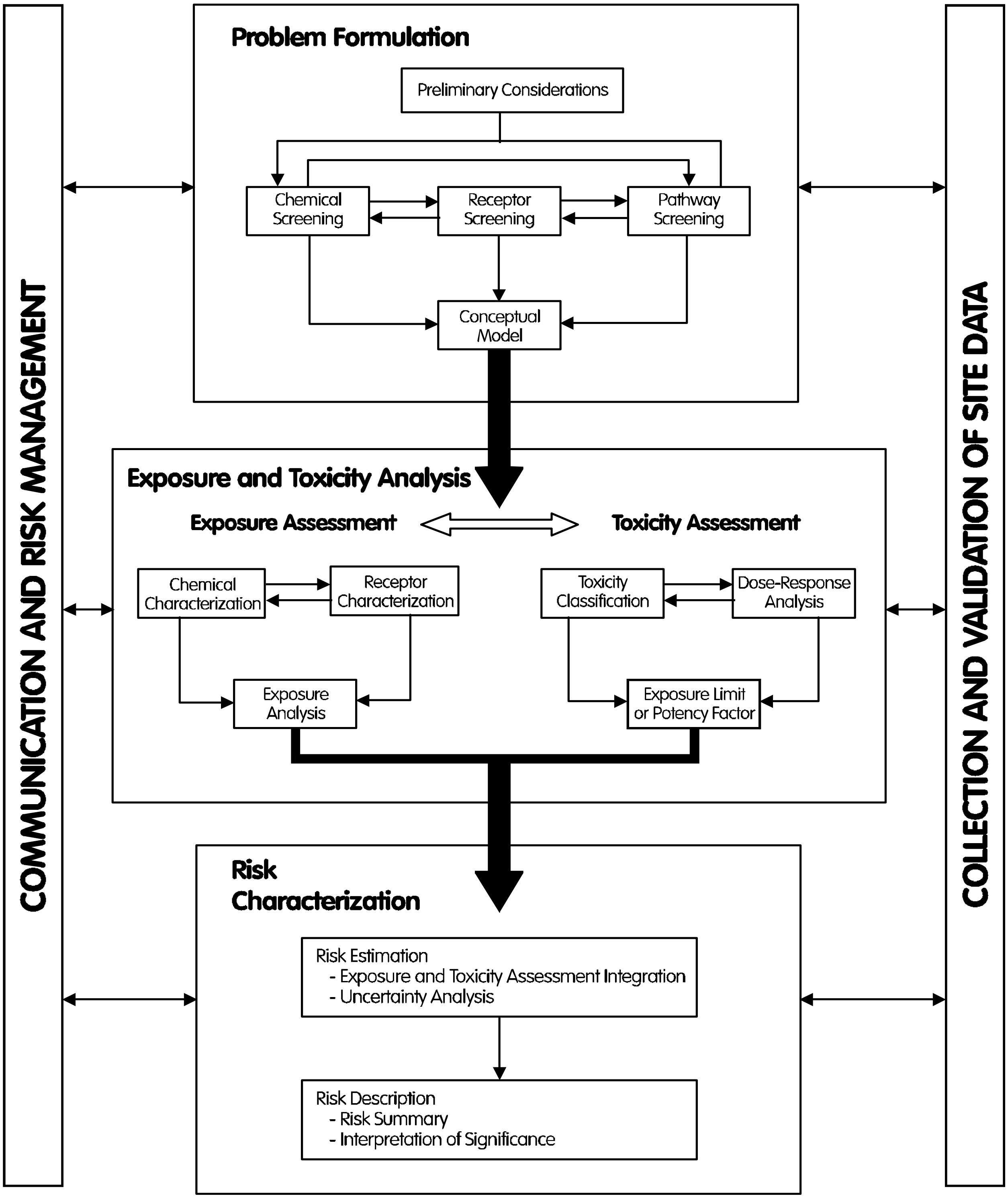
The potential for a risk to arise from exposure to chemicals is predicated on the co-existence of three elements including: i) chemicals must be present; ii) receptors (i.e., people or animals) must be present; and iii) exposure pathways must exist between the source of the chemicals and the receptors (Figure II-1). In the absence of any one of the three elements outlined in Figure II-1, risks cannot occur. The presence of all three elements, however, does not necessarily indicate an unacceptable risk. In such situations, risk assessment involves addressing both the magnitude and uncertainty associated with potential health risks.

Figure II-1
Three Elements of Risk



This risk assessment followed a widely recognized framework, as illustrated in Figure II-2 (Health Canada [unpublished] 1995). The framework progresses from a qualitative initial phase (Problem Formulation) through Exposure and Toxicity Analysis, and culminates in quantitative Risk Characterization.

Figure II-2
Risk Assessment Framework



Source: Health Canada [unpublished] 1995.

2.1.1 Problem Formulation

The objective of the problem formulation stage is to develop a focused understanding of how the closure plan for the Lupin Mine might affect the health of ecological receptors that spend time near the mine site and the health of people that may consume game (i.e., caribou) that have been exposed to metals from the mine site. This is achieved by the following:

- considering the attributes of the Lupin mine site;
- identifying the ecological receptors that are expected to access the area;
- focusing on the metals that may be hazardous; and
- identifying the plausible exposure pathways between metals and receptors.

The problem formulation helps to focus the risk assessment on the substances, receptors and exposure pathways of greatest concern (i.e., metals with the greatest toxic potential; receptors with the greatest likelihood of being exposed; and exposure pathways that account for the majority of exposure to metals). If unacceptable health risks are not predicted for these, it is unlikely that there will be unacceptable health risks for other metals, receptors or exposure pathways.

The three main components of problem formulation are:

1. Receptor screening: The objective of the receptor screening process is to select a representative set of receptors that may be exposed to metals in soil, water and food from the Lupin mine site. For the human health risk assessment, a toddler is typically evaluated as the most susceptible receptor. For the ecological risk assessment, representative receptors are those that would be most exposed and/or susceptible, that play a key role in the ecological food web and that have sufficient characterization data to facilitate calculations of exposure and health risks. Species lists compiled by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002; SARA 2002) were also consulted to determine whether any local species have been designated as sensitive or threatened.

2. Chemical screening: The objective of chemical screening is to focus on the chemicals of greatest concern. Only metals and cyanide were evaluated because other potential chemicals of concern (e.g., organic compounds) are not associated with mine tailings.

Substances were not evaluated in the risk assessment if concentrations in the study area were equivalent to or less than reference concentrations; if concentrations from the mine site were less than applicable guidelines/criteria; and/or the substances were identified as essential nutrients or were fundamentally not toxic. The remaining substances, which have the potential to contribute to increased health risks, were evaluated in the risk assessment.

3. Exposure pathway screening: The objective of exposure pathway screening is to determine all of the potential routes by which ecological receptors and people could be exposed to metals in soil, sediment, water and food from the Lupin mine site. A list of plausible exposure pathways was developed. The list was then evaluated to determine whether each pathway would be operable for each receptor. For example, the soil ingestion exposure pathway is operable for all ecological receptors, but vegetation ingestion is only operable for wildlife species that are herbivorous or omnivorous.

2.1.2 Exposure Assessment

Exposure assessment is the process of estimating the exposure of a substance to a human or ecological receptor under a given exposure scenario. An exposure assessment is conducted for each chemical of concern identified in the problem formulation. For humans and wildlife, exposure is determined as a dose. This value is called the estimated daily intake (EDI) and is typically expressed as mg of a chemical per kg of body weight per day (mg/kg-day). The EDI is calculated from site-specific concentrations of metals in soil/sediment, water and food (vegetation for herbivorous wildlife receptors and caribou meat for people and carnivorous wildlife), the amount of time a receptor spends near the mine site and receptor-specific parameters, such as body weight, ingestion rates and dietary preferences.

2.1.3 Toxicity Assessment

Toxicity assessment involves identification of the potentially toxic effects of chemicals and determination of the amount of chemicals that a receptor can be exposed to without experiencing unacceptable effects. This value is called the toxicity reference value (TRV) or toxicity benchmark. For humans and wildlife, the TRV is expressed as mg of a chemical per kg of body weight per day (mg/kg-day) and is referred to as the tolerable daily intake (TDI). The toxicity assessment provides the basis for evaluating what is an acceptable exposure and what level of exposure may adversely affect human and ecological health.

2.1.4 Risk Characterization

In the risk characterization step, information from the exposure and toxicity assessments are combined to determine if a potential risk exists. Risks may be estimated qualitatively based on scientific judgement for a screening level risk assessment, or quantitatively using exposure ratios for a more detailed risk assessment (CCME 1996). Exposure ratios (ERs) for chemicals of concern are calculated as the ratio of the estimated exposure (based on the exposure assessment) to the TRV (based on the toxicity assessment), according to the following equations:

Humans and Wildlife: ER = estimated exposure ÷ TRV; based on dose or daily intake.

The ER indicates whether the amount of a substance taken in by people or animals is greater than the amount of the substance below which there would be no health effect or no unacceptable risk of cancer. If the ER is greater than 1, then the amount taken in is greater than the threshold amount for which there are no health effects. This does not mean that there will be health effects but that further consideration is necessary. If the ER is less than 1, then we can be certain that no health effects or unacceptable risks would occur.

It is important to note that ER values greater than 1 do not necessarily indicate that health effects will occur because of the layers of safety incorporated into the assessment. Thus, when an ER is greater than 1, it is important to consider the conservative assumptions upon which the assessment is based in combination with the degree of exceedence when determining the magnitude of risk.

2.2 Structure of the Appendix

The remainder of this appendix describes the methods and assumptions used in the risk assessment. The first step in the Problem Formulation, chemical screening, is presented in Section 3. The remainder of the appendix presents the rest of the steps in the assessments for wildlife health (Section 4) and human health (Section 5). These steps include receptor and exposure pathway screening, exposure assessment, toxicity assessment and risk characterization.

3. CHEMICAL SCREENING FOR WILDLIFE AND HUMAN HEALTH RISK ASSESSMENTS

The wildlife health risk assessment focused on substances that have been identified as chemicals of concern in water, soil, sediment, and vegetation from the Lupin mine. A chemical screening process was used to identify chemicals of concern for all receptors. Concentrations of substances (presented in Appendix I) in water, sediments, soil, and vegetation were used for the chemical screening process. The chemical screening process is presented in Figure II-3, and described below. The chemicals of concern identified for the human health risk assessment were the same as the chemicals identified for the wildlife risk assessment, because the only applicable human health exposure pathway is the consumption of game meat (e.g., caribou).

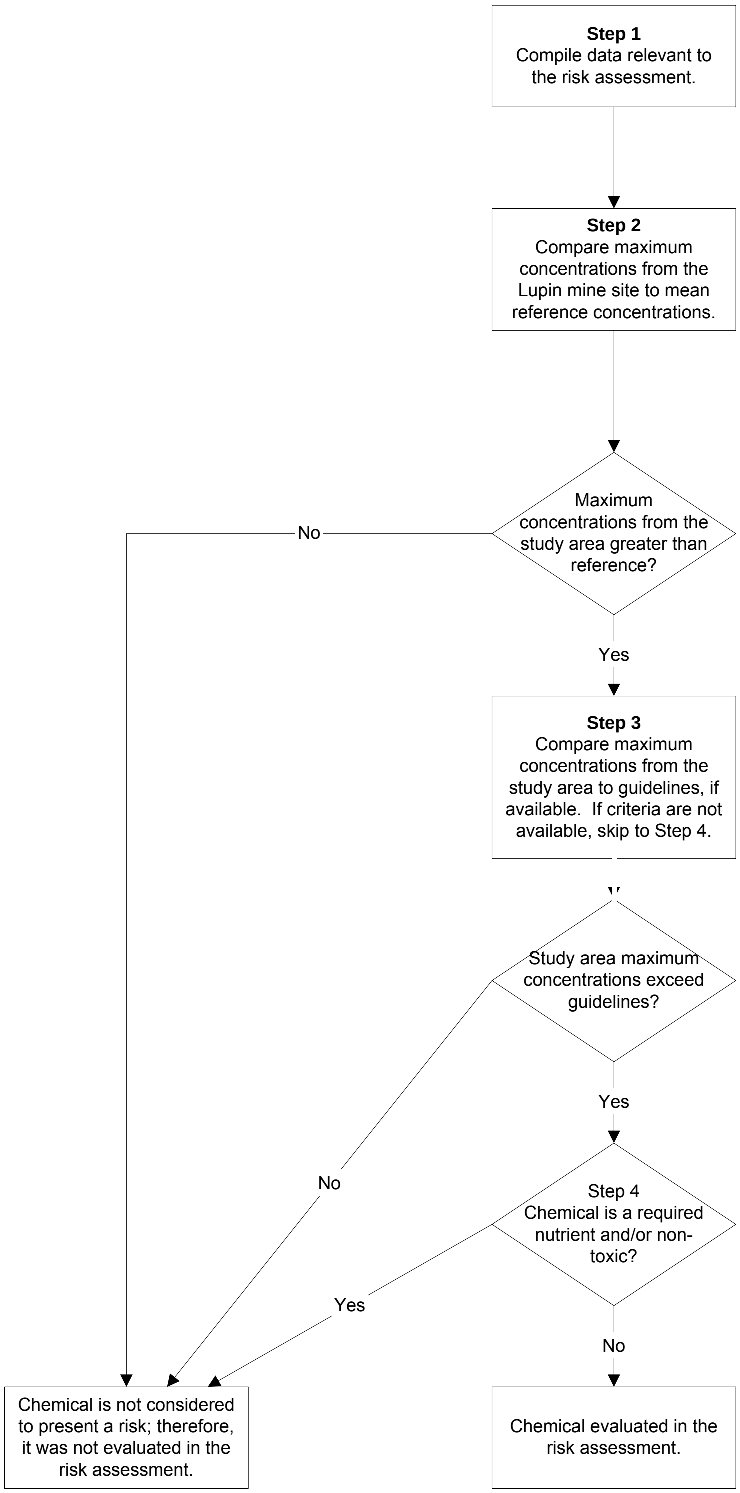
Step 1: Compile Relevant Data

Data used in the screening process are presented in Appendix I. Water, soil, sediment, and vegetation data used in the screening process of the risk assessment are presented in Appendix I, Sections 1.5, 1.2, 1.3, and 1.4, respectively.

Step 2: Comparison to Concentrations in the Reference Area

In Step 2 of the chemical screening process, maximum concentrations measured in the study area were compared with average concentrations measured in the reference area. The purpose of this step of the risk assessment is to identify metals that are present at greater concentrations in the study area than are typically present in the environment. Parameters that were present in the study area at concentrations that are greater than in the reference area are carried forward to the next step of the risk assessment.

Figure II-3
Chemical Screening Process



Step 3: Comparison to Guidelines

Step 3 of the screening process compares maximum concentrations in the study area with applicable regulatory guidelines for water, soil, and sediment. The guidelines used for screening process are presented in Table II-1. Parameters that do not exceed the guidelines were not evaluated further. The CCME guidelines are derived using a conservative risk-based approach; therefore, concentrations that are less than the guidelines are considered to be safe for wildlife (CCME 1999).

Table II-1
Guidelines Used for the Screening Step of the Wildlife and Human Health Risk Assessments

Media	Wildlife Health [a]
Water	Canadian Water Quality Guideline for the Protection of Agricultural Uses (CCME 1999)
Soil	Canadian Soil Quality Guidelines for Agricultural Uses (CCME 1999)
Sediment	Canadian Soil Quality Guidelines for Agricultural Uses (CCME 1999)

[a] Chemicals of concern identified for wildlife health were also used for the human health assessment because caribou meat ingestion was the only pathway evaluated for human health.

Step 4: Essential Nutrients and Fundamentally Non-toxic Substances

Two substances, tin and titanium, were considered fundamentally non-toxic to wildlife and human health based on their inert nature, as discussed below.

Tin

Tin is present in the earth's crust at concentrations up to 3 mg/kg (Toxnet 2004). Tin is poorly absorbed following oral exposure. Less than 5% of ingested tin is absorbed into the bloodstream (Hiles 1974; ATSDR 1992). Chronic health effects due to exposure to tin at environmental concentrations are not likely to occur due to poor absorption and lack of toxicity. Following absorption, most tin is excreted by the body since it has poor ability to bind to tissues (Hiles 1974). Therefore, since tin is poorly absorbed and does not cause health effects at environmental concentrations, it was considered fundamentally non-toxic and was not evaluated further in the human and wildlife health risk assessments.

Titanium

Titanium is the ninth most abundant element in the earth's crust and is widely distributed. It is commonly used in industry because of its corrosion-resistant and toxicologically inert properties (WHO 1982; TOXNET 2004). Titanium is commonly used in the cosmetic industry and is used in the construction of surgical implants (WHO 1982). Chronic toxicity studies reviewed by the World Health Organization (WHO 1982) indicate that long term exposure to titanium does not result in adverse health effects. Two long-term studies of rats exposed to titanium in drinking water showed no differences in survival or microscopic cellular changes between exposed and control animals (WHO 1982). Occupational exposures to titanium dusts indicate that no health effects are associated with titanium inhalation exposure (WHO 1982; TOXNET 2004). Due to the lack of toxicity associated with titanium exposure and the general acceptance of its inert properties, titanium was considered fundamentally non-toxic and was not evaluated further in the human and wildlife health risk assessments.

The chemical screening (steps 2 through 4) for the Lupin mine site is presented below. The screening process focused on each media separately, for the human health and wildlife health risk assessments.

3.1 Water

3.1.1 Step 2: Comparison to Water Concentrations in the Reference Area

Maximum concentrations measured in the study area were compared with average concentrations measured in the reference area (South Bay). If concentrations from the study area were greater than concentrations from the reference area, these parameters were carried forward to Step 3 of the chemical screening process. Comparisons are presented in Table II-2.

Table II-2
Comparison of Metal Concentration in Water from the Study Area (Pond 1, Pond 2, Cell 1, and Cell 4) to Concentrations in the Reference Area (South Bay)

Parameter	Concentration (mg/L)	
	Reference Area Average Concentration	Study Area Maximum Concentration
Aluminum	0.118	3.4
Antimony	<0.002	0.0019
Arsenic	<0.002	1.2
Barium	<0.005	0.09
Beryllium	<0.005	0.0009
Boron	0.007	0.4
Cadmium	<0.0005	0.007
Chromium	<0.002	0.02
Cobalt	0.0011	1.04
Copper	0.002	0.96
Iron	0.16	3.4
Lead	<0.0001	0.02
Manganese	0.0095	13.5
Molybdenum	<0.002	0.07
Nickel	0.006	3.1
Selenium	<0.002	0.02
Silver	<0.0003	0.002
Strontium	0.008	0.9
Thallium	<0.0001	0.02
Tin	<0.002	0.005
Titanium	<0.002	0.06
Uranium	<0.0001	0.002
Vanadium	<0.002	0.003
Zinc	0.0033	0.98
Cyanide	Not Analyzed in Water	4.5

Note: Shading indicates concentration is greater than in the reference area.

3.1.2 Steps 3 and 4: Comparison to Water Quality Guidelines and Identification of Non-toxic Substances

The next step in the screening process compared parameters retained from Step 2 to applicable regulatory criteria (Table II-1). There are no water quality guidelines for the protection of wildlife; therefore, CCME water quality guidelines for the protection of agricultural uses (livestock) were used as a surrogate for wildlife health. The use of agricultural guidelines as a surrogate for wildlife is considered applicable since the guidelines consider mammalian and avian toxicity studies

(CCME 1999). If the maximum concentration for a parameter from the study area exceeded regulatory criteria, then the parameter was carried forward to Step 4 of the screening process. In addition, if regulatory criteria were not available, metals from Step 3 were retained and evaluated in Step 4 of the screening process. In step 4, metals identified as essential elements or non-toxic substances (described above in Section 3.0) were not evaluated further in the risk assessment.

Maximum water concentrations in the study area compared with regulatory guidelines, and those metals identified as non-toxic for wildlife (and human) health are presented in Table II-3.

Table II-3
Water Concentrations from the Study Area (Pond 1, Pond 2, Cell 1, and Cell 4) compared with Canadian Water Quality Guidelines for the Protection of Agricultural Land Uses

Parameter	Concentration (mg/L)		Evaluation for the Risk Assessment
	CWQG for the Protection of Agricultural Water Uses[(a)]	Study Area Maximum	
Aluminum	5	3.4	Less than guideline; Not evaluated
Arsenic	0.025	1.2	Exceeds guideline; Evaluated
Barium	No guideline	0.09	No guideline; Evaluated
Boron	5	0.3	Less than guideline; Not evaluated
Cadmium	0.08	0.007	Less than guideline; Not evaluated
Chromium	0.05[(b)]	0.02	Less than guideline; Not evaluated
Cobalt	1	1.04	Exceeds guideline; Evaluated
Copper	0.5	0.96	Exceeds guideline; Evaluated
Iron	No guideline	3.4	Non-toxic; Not evaluated
Lead	0.1	0.02	Less than guideline; Not evaluated
Manganese	No guideline	13.5	No guideline; Evaluated
Molybdenum	0.5	0.07	Less than guideline; Not evaluated
Nickel	1	3.1	Exceeds guideline; Evaluated
Selenium	0.050	0.02	Less than guideline; Not evaluated
Silver	No guideline	0.002	No guideline; Evaluated
Strontium	No guideline	0.9	No guideline; Evaluated
Thallium	No guideline	0.015	No guideline; Evaluated
Tin	No guideline	0.005	Non-toxic; Not evaluated
Titanium	No guideline	0.06	Non-toxic; Not evaluated
Uranium	0.2	0.002	Less than guideline; Not evaluated
Vanadium	0.1	0.003	Less than guideline; Not evaluated
Zinc	50	0.98	Less than guideline; Not evaluated
Cyanide	No guideline	4.5	No guideline; Evaluated

(a) CCME Agricultural Use Guidelines (CCME 1999).
(b) Interim guideline.
Note: Shading indicates concentration is greater than guideline or no guideline available and the substance was evaluated because the metal has the potential to cause health effects.

3.1.3 Chemicals of Concern in Water

Metals that are present in water from the study area in concentrations greater than in the reference locations, that exceed applicable regulatory guidelines or for which no guidelines are available, and that are not essential nutrients were evaluated in the risk assessment. The chemicals of concern identified in water and evaluated in the risk assessment are presented in Table II-4.

Table II-4
Parameters Identified as Chemicals of Concern in Water

Parameter	Wildlife (and Human) Health Risk Assessment
Arsenic	√
Barium	√
Cobalt	√
Copper	√
Manganese	√
Nickel	√
Silver	√
Strontium	√
Thallium	√
Cyanide	√

3.2 Soil

3.2.1 Step 2: Comparison to Soil Concentrations in the Reference Area

Maximum metals concentrations measured in soil covering cell 1 and soil from areas expected to be impacted by wind blown tailings were compared with average metal concentrations measured in the reference area (esker borrow area). Parameters measured in the study area that were present at concentrations that were greater than the reference area were carried forward to Step 3 of the chemical screening process (Table II-5).

Table II-5
Comparison of Metal Concentration in Soil from the Study Area to Concentrations in the Reference Area

Parameter	Concentration (mg/kg)	
	Reference Area Average Concentration	Study Area Maximum Concentration
Aluminum	4,652	6,310
Antimony	<0.1	<0.1
Arsenic	6.9	161
Barium	30.5	38.8
Beryllium	<0.2	<0.2
Boron	<2	2
Cadmium	<0.1	<0.1
Chromium	19.5	22.6
Cobalt	2.8	5.6
Copper	7.1	14.9
Iron	7,150	12,000
Lead	1.5	5.8
Manganese	65	93
Mercury	<0.05	0.11
Molybdenum	0.2	0.4
Nickel	9.7	13.3
Selenium	<0.2	<0.2
Silver	<0.2	<0.2
Strontium	4	6
Thallium	0.06	0.06
Tin	<2	1
Titanium	326	420
Uranium	0.51	1.07
Vanadium	14.3	17.8
Zinc	16	24

Note: Shading indicates concentration is greater than reference area concentration.

3.2.2 Steps 3 and 4: Comparison to Soil Quality Guidelines and Non-toxic Substances

The next step in the screening process compared metals in soil retained from Step 2 to applicable regulatory criteria (Table II-1). There are no soil quality guidelines for the protection of wildlife; therefore, CCME soil quality guidelines for the protection of agricultural uses (livestock) were used as a surrogate for wildlife health. The use of agricultural guidelines as a surrogate for wildlife is considered applicable since the guidelines consider mammalian and avian toxicity studies (CCME 1999). For some parameters, no Canadian soil quality guideline was available, so the Canadian interim soil remediation criteria (CCME 1999) were used. Parameters that had concentrations in the study area that were greater than regulatory guidelines were retained and evaluated in the risk assessment. Parameters for which guidelines were not available were evaluated for their potential to cause health effects and those that were deemed to be essential nutrients or non-toxic (described in Section 3.0) were not evaluated further in the risk assessment.

Maximum soil concentrations in the study area compared with regulatory guidelines and identification of essential nutrients are presented in Table II-6.

Table II-6
Soil Concentrations from the Study Area (cell 1 and wind blown tailings area) Compared with Canadian Soil Quality Guidelines for Agricultural Land Uses

Parameter	Concentration (mg/kg)		Evaluation for the Risk Assessment
	CSQG for Agricultural Use[(a)]	Study Area Maximum Concentration	
Aluminum	No guideline	6,310	No guideline; Evaluated
Arsenic	12	161	Exceeds guideline; Evaluated
Barium	750[(b)]	38.8	Less than guideline; Not evaluated
Boron	No guideline	2	No guideline; Evaluated
Chromium	64	22.6	Less than guideline; Not evaluated
Cobalt	40[(b)]	5.6	Less than guideline; Not evaluated
Copper	63	14.9	Less than guideline; Not evaluated
Iron	No guideline	12,000	Non-toxic; Not evaluated
Lead	70	5.8	Less than guideline; Not evaluated
Manganese	No guideline	93	Exceeds guideline; Evaluated
Mercury	6.6	0.11	Less than guideline; Not evaluated
Molybdenum	5.0	0.4	Less than guideline; Not evaluated
Nickel	50	13.3	Less than guideline; Not evaluated
Strontium	No guideline	6	No Guideline; Evaluated
Titanium	No guideline	420	Non-toxic; Not evaluated
Uranium	10	1.07	Less than guideline; Not evaluated
Vanadium	130	17.8	Less than guideline; Not evaluated
Zinc	200	24	Less than guideline; Not evaluated

(a) CCME Soil Quality Guidelines for Agricultural Land Use (CCME 1999).
(b) CCME Interim Soil Remediation Criteria (CCME 1999).
Note: Shading indicates concentration is greater than guideline, no guideline is available, and evaluated in the risk assessment because of the potential to cause health effects.

3.2.3 Chemicals of Concern in Soil

Metals that are present in soil from the study area in concentrations greater than in the reference locations, that exceed applicable regulatory guidelines or for which no guidelines are available, and that are not essential nutrients were evaluated in the risk assessment. The following chemicals of concern were identified for the soil pathway and evaluated in the wildlife (and human) heath risk assessments are:

- Aluminum;
- arsenic;
- boron;
- manganese; and,
- strontium.

3.3 Sediment

3.3.1 Step 2: Comparison to Sediment Concentrations in the Reference Area

Metals concentrations measured in sediment collected from the study area were compared with metal concentrations measured in the reference area. For each metal, the maximum concentration from the study area (pond 1 and pond 2) was compared to the average reference concentration (Shallow Bay). Parameters that were in the study area at concentrations that were greater than concentrations from the reference area, were carried forward to Step 3 of the chemical screening process (Table II-7).

Table II-7
Sediment Concentrations from the Study Area (pond 1 and pond 2) Compared with Concentrations in the Reference Area (Shallow Bay)

Parameter	Concentration (mg/kg)	
	Reference Area Average Concentration	Study Area Maximum Concentration
Aluminum	5,845	17,100
Antimony	<0.1	0.1
Arsenic	18.5	16,000
Barium	46.25	103
Beryllium	<0.2	0.5
Boron	3	5
Cadmium	<0.1	0.4
Chromium	23.3	46.7
Cobalt	5.8	28.5
Copper	8.4	451
Iron	11,800	117,000
Lead	2.3	377
Manganese	137	382
Mercury	<0.05	0.13
Molybdenum	0.35	9.5
Nickel	12.35	52
Selenium	<0.2	2.6
Silver	<0.2	<0.2
Strontium	5.5	94
Thallium	0.09	0.09
Tin	<2	3
Titanium	479	409
Uranium	0.83	1.57
Vanadium	19.85	32.8
Zinc	29.5	6,140
Cyanide	0.3	8,580

Note: Shading indicates concentration is greater than reference area concentration.

3.3.2 Steps 3 and 4: Comparison to Sediment Quality Guidelines and Non-toxic Substances

The next step in the screening process compared metals in sediment retained from Step 2 to applicable regulatory criteria (Table II-1). There are no sediment quality guidelines for the protection of wildlife (shorebirds and waterfowl); therefore, CCME soil quality guidelines for the protection of agricultural uses were used as a surrogate for wildlife health. The use of agricultural guidelines as a surrogate for wildlife is considered applicable since the guidelines consider mammalian and avian toxicity studies (CCME 1999). The Canadian Interim Soil Remediation Criteria (CCME 1999) were used if a CCME guideline was not available. Parameters with concentrations in the study area that exceeded regulatory guidelines were evaluated in the risk assessment. If a regulatory guideline was not available the substance was evaluated for potential to cause health effects. Metals identified as essential elements or non-toxic substances (described above in Section 3.0) were not evaluated further in the risk assessment.

Maximum sediment concentrations in the study area compared with regulatory guidelines and identification of non-toxic substances are presented in Table II-8 for wildlife.

Table II-8
Sediment Concentrations from the Study Area (pond 1 and pond 2) Compared with Canadian Soil Quality Guidelines for Agricultural Land Uses

Parameter	Concentration (mg/kg)		Evaluation for Risk Assessment
	CSQG for Agricultural Use[a]	Study Area Maximum Concentration	
Aluminum	No guideline	17,100	No guideline; Evaluated
Antimony	13[b]	0.1	Less than guideline; Not evaluated
Arsenic	12	16,000	Exceeds guideline; Evaluated
Barium	750[b]	103	Less than guideline; Not evaluated
Beryllium	1.2[b]	0.5	Less than guideline; Not evaluated
Boron	1.5[b]	5	Exceeds guideline; Evaluated
Cadmium	1.4	0.4	Less than guideline; Not evaluated
Chromium	64	46.7	Less than guideline; Not evaluated
Cobalt	40[b]	28.5	Less than guideline; Not evaluated
Copper	63	451	Exceeds guideline; Evaluated
Iron	No guideline	117,000	Non-toxic; Not evaluated
Lead	70	377	Exceeds guideline; Evaluated
Manganese	No guideline	382	No guideline; Evaluated
Mercury	6.6	0.13	Less than guideline; Not evaluated
Molybdenum	5.0	9.5	Exceeds guideline; Evaluated
Nickel	50	52	Exceeds guideline; Evaluated
Selenium	1	2.6	Exceeds guideline; Evaluated
Strontium	No guideline	94	No guideline; Evaluated
Tin	No guideline	3	Non-toxic; Not evaluated
Uranium	10	1.57	Less than guideline; Not evaluated
Vanadium	130	32.8	Less than guideline; Not evaluated
Zinc	200	6,140	Exceeds guideline; Evaluated
Cyanide	0.9	8,580	Exceeds guideline; Evaluated

[a] CCME Soil Quality Guidelines for Agricultural Land Use (CCME 1999).
[b] CCME Interim Soil Remediation Criteria (CCME 1999).
Note: Shading indicates concentration is greater than guideline or no guideline is available and the parameter was evaluated in the risk assessment due to the potential to cause health effects.

3.3.3 Chemicals of Concern in Sediment

Metals that are present in sediment in the study area at concentrations greater than measured in the reference area, that exceed applicable regulatory guidelines or for which no guidelines are available, and metals that were not essential nutrients were evaluated in the wildlife health risk assessment. The chemicals of concern identified in sediment and evaluated in the risk assessment are presented in Table II-9.

Table II-9
Parameters Identified as Chemicals of Concern in Sediment

Parameter	Wildlife Health Risk Assessment
Aluminum	√
Arsenic	√
Boron	√
Copper	√
Lead	√
Manganese	√
Molybdenum	√
Nickel	√
Selenium	√
Strontium	√
Zinc	√
Cyanide	√

3.4 Vegetation

3.4.1 Step 2: Comparison to Concentrations in Vegetation from the Reference Area

Metals concentrations measured in vegetation collected from the study area were compared with metal concentrations measured in the reference area. For each metal, the maximum concentration from the study area (cell 1 cover and wind blown tailings area) was compared to the mean reference concentrations (esker borrow area). If metal concentrations from the study area were greater than concentrations from the reference site, these metals were carried forward to Step 3 of the chemical screening process. Comparisons are presented in Table II-10.

Table II-10
Maximum Concentrations of Parameters in Vegetation from the Study Area (pond 1 and pond 2) Compared with Average Concentrations in the Reference Area (esker borrow area)

Parameter	Concentration (mg/kg) (Wet Weight)	
	Reference Area Average Concentration	Study Area Maximum Concentration
Aluminum	139	629
Antimony	<0.04	0.02
Arsenic	0.5	31.7
Barium	5.94	9.53
Beryllium	<0.2	<0.2
Cadmium	<0.08	<0.08
Chromium	0.4	2.3
Cobalt	0.31	0.61
Copper	1.23	2.09
Iron	70	891
Lead	0.07	2.52
Manganese	106	333
Mercury	<0.01	<0.01
Molybdenum	0.04	0.62
Nickel	2.16	3.07
Selenium	<0.2	<0.2
Silver	<0.08	<0.08
Strontium	2.17	6.49
Thallium	<0.04	<0.04
Tin	<0.08	<0.08
Titanium	4.12	15.44
Vanadium	0.14	0.46
Zinc	13.4	31.6

Note: Shading indicates that concentration in the study area is greater than in the reference area.

3.4.2 Steps 3 and 4: Comparison to Guidelines and Non-toxic Substances

There are no guidelines available for acceptable concentrations of metals in vegetation for human or wildlife health. Therefore, all metal concentrations that were higher in the study area than reference area were carried forward to step 4 of the screening process. In step 4, metals identified as essential elements or non-toxic substances (described above in Section 3.0) were not evaluated further in the risk assessment. The substances that were considered non-toxic for vegetation and not evaluated for vegetation were tin and titanium.

3.4.3 Chemicals of Concern in Vegetation

Metals that were present in vegetation from the study area in concentrations greater than in the reference locations, for which no guidelines are available, and were not essential nutrients were evaluated in the human and wildlife health risk assessments. The chemicals of concern identified in vegetation and evaluated in the risk assessment are:

- aluminum
- arsenic
- barium
- chromium
- cobalt
- copper
- lead
- manganese
- molybdenum
- nickel
- strontium
- vanadium
- zinc

3.5 Final List of Chemicals of Concern

Parameters that are present in the study area in concentrations greater than in the reference locations, that exceed applicable regulatory guidelines or for which no guidelines are available, and that are not essential nutrients or essentially non-toxic were evaluated in the risk assessment. The final chemicals of concern for the wildlife (and human) health risk assessments are presented in Table II-11. Although a metal may have only been identified as a chemical of concern in one media (water, soil, sediment, or vegetation), it was evaluated in all media in the risk assessment to determine total exposure.

Table II-11
Metals Evaluated in the Wildlife (and Human) Health Risk Assessment

Parameter	Water	Soil	Sediment	Vegetation
Aluminum		√	√	√
Arsenic	√	√	√	√
Barium	√			√
Boron		√	√	
Chromium				√
Cobalt	√			√
Copper	√		√	√
Lead			√	√
Manganese	√	√	√	√
Molybdenum			√	√
Nickel	√		√	√
Selenium			√	
Silver	√			
Strontium	√	√	√	√
Thallium	√			
Vanadium				√
Zinc			√	√
Cyanide	√		√	

4. WILDLIFE HEALTH RISK ASSESSMENT

4.1 Problem Formulation

4.1.1 Ecological Receptor Screening

There are many wildlife species that could be present in the tundra environment in the vicinity of the Lupin mine site. However, it is not practical to evaluate all species. Receptors selected for the risk assessment were considered to be representative of the local ecosystem. Representative receptors are those that have the greatest potential for exposure, that play a key role in the food web, and that have sufficient characterization data to facilitate calculations of exposure and health risks. Receptors were also selected to include animals that are considered to be vulnerable by COSEWIC (2002) and SARA (2002). According to CCME (1996), species identified as endangered, threatened or of special concern should be considered in the risk assessment. The short-listed wildlife receptors are defined as resources or environmental features with the following characteristics:

- are important to human populations (i.e., used as a food source);
- have economic and/or social value (i.e., animals that are trapped for furs, recreational value);
- have intrinsic ecological significance (i.e., endangered species, key species in the food web); and
- serve as a baseline from which the impacts can be evaluated (CCME 1996).

The risk assessment focused on birds and mammals that are herbivorous or that prey on herbivores in the vicinity of the Lupin mine site. Selection rationale for the wildlife receptors within the bird and mammal groups is presented in Table II-12.

Table II-12
Valued Ecosystem Components Evaluated in the Risk Assessment

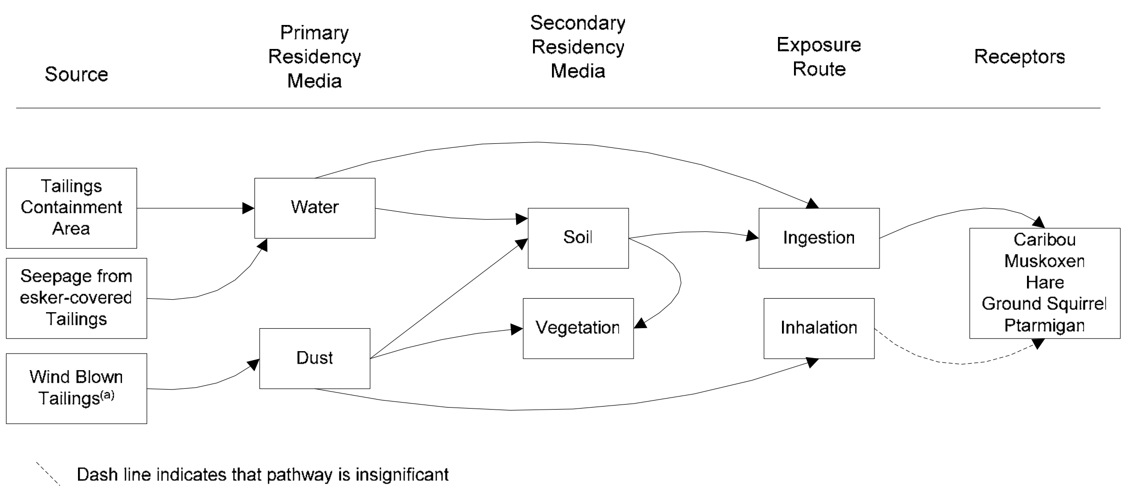
Classification	Common Name	Scientific Name	Rationale
Large Carnivorous/ Omnivorous Mammal	Grizzly Bear	*Ursus arctos horribilis*	The grizzly bear is a socially important species and represents an omnivorous receptor. Grizzly bear may feed on vegetation and prey that have been exposed to metals from the Lupin mine site. Grizzly bears are listed as species of special concern by COSEWIC. Therefore, Grizzly bears were evaluated in the risk assessment.
	Wolf	*Canis lupus*	The wolf is a primary predator of caribou and is considered to be one of the species at the top of the food chain. Wolves have been observed near the Lupin mine site. Therefore, due to their position in the food web and their presence near the mine, wolves were evaluated in the risk assessment.
Small carnivore	Wolverine	*Gulo gulo*	The wolverine is a carnivore. It is primarily a scavenger rather than a hunter and is usually dependent on other carnivores, such as wolves, to kill the animals for it to eat. Some individual wolverines can become good hunters and can kill young and adult ungulates, such as caribou, if the prey is in poor physical condition or if the wolverine has manoeuvred it into a disadvantaged position. Wolverines are listed as species of special concern by COSEWIC. Therefore, due to its COSEWIC classification and position in the food chain, wolverines were evaluated in the risk assessment.
	Fox	*Vulpes vulpes*	Foxes (both red and arctic) are primary predators of arctic ground squirrels and arctic hare. They have a relatively small home range and could spend a considerable amount of time in the vicinity of the Lupin mine site. Although Arctic or Red fox are not listed by COSEWIC, their role in the food chain is important. Thus, the fox was evaluated in the risk assessment.
Large Herbivores	Caribou	*Rangifer tarandus*	Caribou are an ecologically important species in the north. They are an important prey item for wolves and grizzlies and are an important food item for people. Thousands of caribou can pass through or near the Lupin mine while travelling to and from their calving grounds. Due to their importance as a food item for both people and wildlife, caribou were evaluated in the risk assessmen.
	Muskoxen	*Ovibos moschatus*	Muskoxen are arctic dwelling animals with relatively small home ranges. Muskoxen are slow-moving animals that must dig through snow to consume vegetation. They are also important prey items for wolves. Muskoxen have been observed occasionally near Lupin. Therefore, muskoxen were evaluated in the risk assessment.
Small Herbivores	Arctic hare	*Lepus arcticus*	Arctic hare are important prey items for carnivorous wildlife such as wolves and grizzly bears. Therefore, hare were evaluated in the risk assessment to represent all small herbivores in the study area.
	Arctic ground squirrel	*Spermophilus parryii*	Arctic ground squirrels are small herbivores and are important prey items for carnivores such as foxes. Ground squirrels are also trapped by local Inuit residents. Therefore, ground squirrels were evaluated in the risk assessment to represent small herbivores in the area.
Birds	Ptarmigan	*Lagopus lagopus*	Ptarmigan are important prey items for carnivorous wildlife such as wolves. In addition, they are one of few species of birds that have a small home range. Therefore, ptarmigan were evaluated in the risk assessment to represent small avian herbivores in the study area.
	Rough legged hawk	*Buteo lagopus*	Raptors and birds of prey are socially important species. Furthermore, their food source includes rodents such as the arctic ground squirrel. Several species of hawks have been observed surrounding the Lupin mine site. Therefore, the rough-legged hawk was evaluated as representative of raptors.
	Snipe	*Gallinago gallinago*	The snipe is a common shorebird in northern regions. Shorebirds consume sediment-dwelling invertebrates, so were chosen to represent this part of the food chain.
	Duck	*Clangula hyemalis*	The long-tailed duck is a common seabird that breeds in the area of the Lupin mine. During the breeding season, long-tailed ducks ingest aquatic and benthic invertebrates and sediments when foraging for food. Therefore, the long-tailed duck was chosen to represent waterfowl that might choose to forage for food on the Lupin mine site.

4.1.2 Wildlife Exposure Pathway Screening

Exposure pathways are the means by which a substance comes into contact with receptors and are largely dependent on the physical-chemical properties of the substances, the environment in which the receptor lives and the likely receptor behaviour. The results of the exposure pathway screening are summarized in the Conceptual Exposure Model, which details the source of the metal, the release mechanisms, environmental transport and residency media, exposure routes and receptors. The conceptual exposure models for herbivores, grizzly bears, carnivores, and waterfowl are presented in Figures II-4, II-5, II-6, and II-7, respectively.

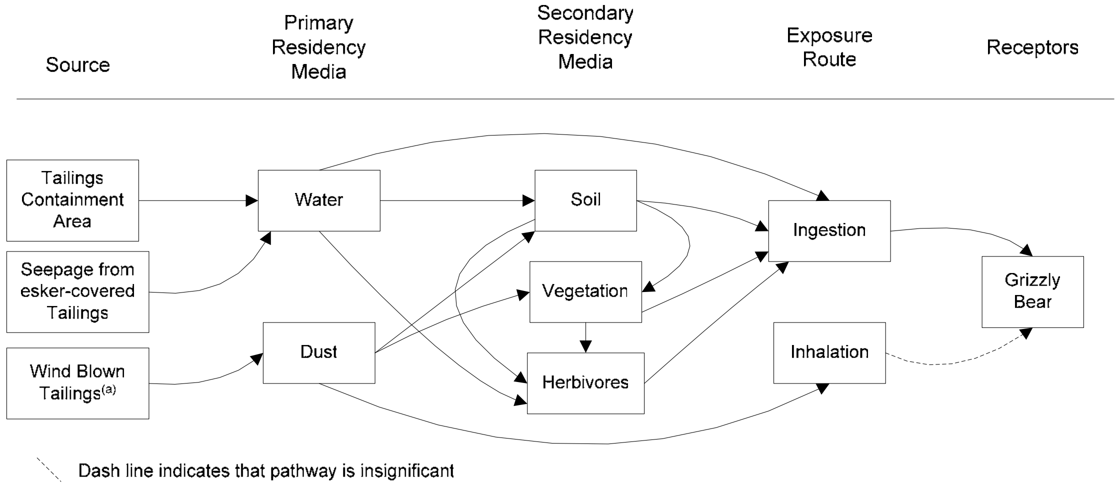
Wildlife Receptors may be exposed to metals through direct and indirect pathways. Direct pathways are those in which the receptor comes into direct contact with the source of metals and include soil and water ingestion. Indirect exposure pathways are those in which the exposure results from a secondary source (i.e., food chain). Ingestion of vegetation and prey would be examples of indirect exposure pathways.

Figure II-4
Herbivore Exposure Pathway



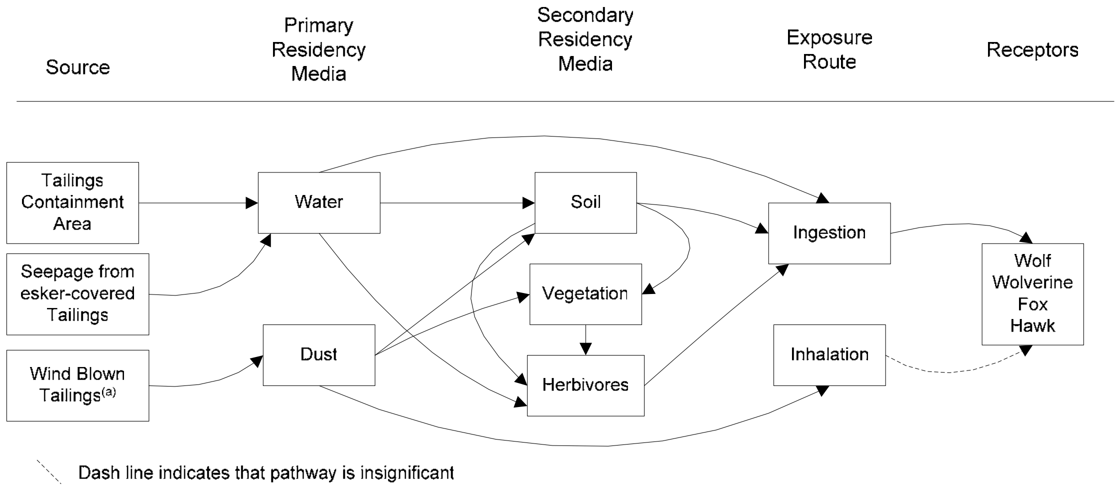
(a)Exposed tailings will be covered as part of closure plan.

Figure II-5
Grizzly Bear Exposure Pathway



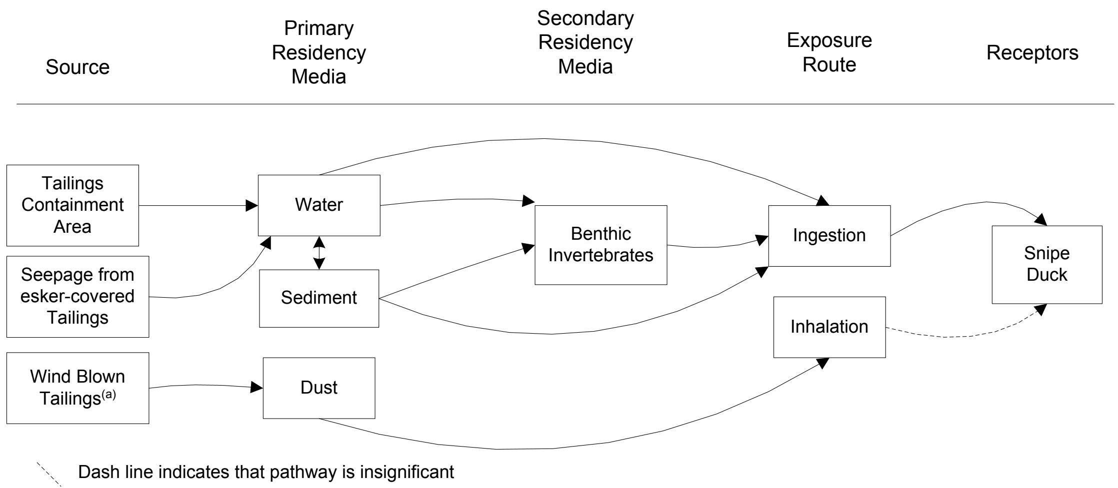
[a]Exposed tailings will be covered as part of closure plan.

Figure II-6
Carnivore Exposure Pathway



[a]Exposed tailings will be covered as part of closure plan.

Figure II-7
Waterfowl and Shorebird Exposure Pathway



(a)Exposed tailings will be covered as part of closure plan.

Dietary assumptions and exposure pathways for each receptor are presented in Table II-13 and described in the following paragraphs.

Table II-13
Dietary Preferences of the Wildlife Receptors

Species	Diet Preference[a]	Soil/Sediment Ingestion	Water Ingestion
Caribou	100% vegetation	Soil	Evaluated for all VECs
Muskoxen	100% vegetation	Soil	
Grizzly Bear	50% vegetation 50% caribou[b]	Soil	
Wolf	100% mammal	Soil	
Fox	100% mammal	Soil	
Wolverine	100% mammal	Soil	
Arctic Ground Squirrel	100% vegetation	Soil	
Hare	100% vegetation	Soil	
Ptarmigan	100% vegetation	Soil	
Hawk	100% mammal	Soil	
Duck	100% invertebrates	Sediment	
Snipe	100% invertebrates	Sediment	

(a) CWS 2003.
(b) Gau and Case 1998.

Ingestion of Soil

All wildlife may ingest soil either inadvertently when ingesting vegetation or grooming or purposely (Beyer et al. 1994). There are two sources of metals in soil; wind blown tailings dust and seepage upwards to esker sand from the reclaimed tailings areas. Direct ingestion of exposed tailings was not evaluated in the risk assessment because exposed tailings will be covered in the near future. Ingestion of soil was evaluated for all receptors in the risk assessment.

Ingestion of Sediment

Wildlife that are commonly found in an aquatic habitat may ingest sediment, similar to those that ingest soil while feeding, grooming, or purposely. Both waterfowl and shorebirds may ingest sediment by this pathway. Therefore, sediment ingestion was evaluated for both the duck and the Snipe.

Ingestion of Vegetation

Vegetation may take up metals from soil. Grasses growing on soil at the Lupin mine site are assumed to be consumed by all herbivorous wildlife. The pathway of vegetation ingestion was evaluated for ground squirrel, hare, ptarmigan, caribou, muskoxen and grizzly bears.

Ingestion of Water

There will be standing water in the holding ponds on the Lupin mine site area. All wildlife may use this water as a drinking water source while in the vicinity of the Lupin mine site. Therefore, ingestion of water was evaluated for all receptors in the risk assessment.

Ingestion of Invertebrates

Benthic or aquatic invertebrates take up substances from sediment. Therefore, wildlife such as ducks and snipe, may be exposed to chemicals of concern by eating invertebrates. It was assumed that the diet of waterfowl and shorebirds was composed of 100% invertebrates. Therefore, ingestion of invertebrates was evaluated for the duck and the snipe in the risk assessment.

Ingestion of Mammalian Prey

Predatory animals will consume herbivores that have consumed water, soil and vegetation from the Lupin mine site. Since herbivorous prey species may accumulate metals into their tissue, predatory animals may subsequently be exposed to metals. Therefore, the pathway of prey ingestion was evaluated for grizzly bears, wolves, foxes, wolverine, and hawks.

Inhalation of Air

The air inhalation pathway was not evaluated because none of the metals are volatile chemicals and because inhalation of airborne particles that may be composed of metals is an insignificant pathway when compared to the soil, food and water ingestion pathways.

4.2 Exposure Assessment

4.2.1 Spatial and Temporal Boundaries

The footprint of the Lupin mine is 10.4 km^2 and the tailings containment area itself is 7.8 km^2. Animals with relatively small home ranges (i.e., arctic hare, arctic ground squirrel and fox) were assumed to obtain 100% of their food and water from the vicinity of the Lupin tailings containment area. Although the arctic ground squirrel hibernates for 5 months per year, it was assumed that 100% its food and water is from the Lupin mine site during its 210-day active period (7 months). For animals that are migratory or have large home ranges, the area of the Lupin mine site is not enough area to fulfil all of the basic needs (such as food and shelter). Therefore, estimates of exposure time were based on reports on wildlife movement, literature descriptions of home ranges and communication with wildlife biologists.

4.2.2 Grizzly Bear

Studies of collared grizzly bears near an active diamond mine indicated that one bear spent 10% of its active, non-hibernating season (approximately six months extending from May to October) within 1 km of the mine (R. Gau, RWED, personal communication,). Assuming that the Lupin mine would be more attractive to a grizzly bear once it has closed and human activity is absent it was assumed for the purposes of the risk assessment that a grizzly bear spent 10% of its six active months per year at the Lupin mine, or approximately 18 days. This is considered to be a conservative estimate, as the Lupin mine represents approximately 0.005% of the home range of an adult female grizzly bear (estimated at 2,074 km^2, McLoughlin et al. 1999).

4.2.3 Wolf

Barren-ground wolves of the central Canadian arctic rely heavily on Bathurst caribou, and their seasonal movements reflect this. Studies of wolves preying on Bathurst caribou indicate that wolves select den sites that are in an optimal position to encounter caribou returning from the calving ground when the nutritional demands of their pups is the greatest (Heard and Williams 1992). Barren-ground wolves generally spend the summer north of the treeline, and during this time show territorial behaviour, centred on the pack's den. During the winter, these wolves follow the caribou herds and do not exhibit territorial behaviour (Walton et al. 2001). Although their winter range (November to April) may overlap with the Lupin mine (Cluff 2001), the much larger size of the winter range (approximately 45,000 km^2 for males in the winter versus 2,000 km^2 for males in the summer, Walton et al. 2001) and the nomadic behaviour of wolves during the winter indicate that it is unlikely for a wolf to remain in contact with the Lupin mine for any length of time during the winter.

During the summer, males have a slightly larger home range than females (approximately 2,000 km^2 versus 1,100 km^2) (Walton et al. 2001). Summer denning extends from approximately May to October. Wolf movements during this time can be described as being concentrated in an area around the den (approximately 400 km^2, D. Cluff, RWED personal communication,) with occasional long-distance caribou hunting excursions during June and July if necessary.

For the purposes of the risk assessment, it was assumed that a pack of wolves denned within the footprint of the Lupin mine site for the summer season (May to October), that the individual from this pack did not leave the mine footprint during these six months. Although wolves rely on hunting excursions away from the den to provide enough food at the den, it was assumed that caribou (and other prey items) were readily available near the Lupin mine and hunting excursions were not necessary. Assuming that the Lupin mine attracts caribou and that the wolf's diet was supplemented by other species present at the mine site (such as arctic hare and arctic ground squirrel) it was conservatively assumed that the wolf obtained 50% of its food from the Lupin mine.

4.2.4 Wolverine

Wolverine, members of the weasel family, are small carnivores and frequent scavengers. Studies of wolverine in the Slave Geological Province identified caribou, muskox, arctic ground squirrel, microtines (lemmings and voles) and ptarmigan as the principal prey of the wolverine in this area (Mulders 2000).

The home range of adult female wolverine in the Slave Geological Province was estimated by Mulders (2000) at 126 km^2. The footprint of the Lupin mine represents approximately 0.08% of this home range. Unlike other carnivores, wolverine do not hibernate or migrate; thus, wolverine are likely to be present around the Lupin mine for a greater portion of the year. Like a grizzly bear, a wolverine obtains all of its food from within a distinct territory. Therefore, it was conservatively assumed that a wolverine would spend 50% of its time (183 days) at the Lupin mine.

4.2.5 Bathurst Caribou

Satellite telemetry data for 31 female caribou from the Bathurst herd were used to develop seasonal ranges of the herd (Gunn et al. 2002). Movements tracked from April 1996 to December 2001 were used to estimate the amount of time the Bathurst herd seasonal range could overlap with the Lupin mine. This data showed that the Lupin mine is located within the seasonal home range of the Bathurst herd during the summer, fall, rut and spring migration, for a total of approximately 187 days per year. Straight-line movement rates, compiled using the same satellite collar data by week by Gunn et al. (2002) indicate that caribou are constantly moving. Daily movement rates range from approximately 2 to 23 km/day (averaged by week). This suggests that the actual time that caribou would be present at the Lupin mine would be much less.

Use of mine sites by caribou was documented at the Lupin mine (Muller and Gunn 1996; Gunn 1998). These studies indicated that caribou will use disturbed areas and structures at an active mine (including tailings ponds, roads, airstrips, and buildings) for shade, to avoid mosquitoes, and to avoid predators. Based on these factors, a conservative estimate of 10% of the year (approximately 37 days) was used in the risk assessment to represent the time spent by caribou at the Lupin mine site.

4.2.6 Muskox

Muskox are not known to migrate; however, small seasonal movements have been documented (Gunn and Fournier 2000). Little research has been conducted on the home range or movement patterns of muskox in Canada, and no surveys have been conducted to document muskox numbers near the Lupin mine. It is expected that muskox will recolonize their former ranges, which may include the Lupin mine area (Fournier and Gunn 1998).

Assuming that muskox in the Contwoyto area do not migrate, a muskox may spend a considerable amount of the year at the Lupin mine. For the purposes of the risk assessment, it was assumed that a muskox may be present at the Lupin mine for 8 months, or 240 days. This is a substantial overestimate since although muskox are sedentary, their forage area is likely to be greater than mine site area.

4.2.7 Birds

Baseline data for the Diavik Diamond Mine Project, collected from 1995 to 1997, was used to estimate the amount of time that birds would spend in the vicinity of the Lupin mine (DDMI 1998). The Diavik mine, located on an island in Lac de Gras, is approximately 140 km to the south of the Lupin mine.

Baseline reports from the Diavik project were reviewed to identify the dates of earliest occurrence and latest occurrence (regardless of year) for each of the receptor bird species. These dates were used to determine the maximum number of days each species may be in the region of the Lupin mine. Since the Lupin mine is north of the Diavik mine, migratory birds probably spend less time in the Lupin area than suggested by the Diavik data. The time span between the observation of the earliest spring arrival and last fall departure were used as a conservative estimate of the exposure time of each species, except for ptarmigan, which were assumed to be at the site all year (Table II-14, DDMI 1998). Though many willow ptarmigan return south of the treeline for the winter months (Godfrey 1986), some stay above the treeline for the entire winter. Therefore, for the purposes of the risk assessment, it was assumed that willow ptarmigan could be get 100% of their food and water from the vicinity of the Lupin mine.

Table II-14
Estimated Residency Period of Bird Species at the Lupin Mine, Based on Studies at Lac de Gras, 1995 to 1997 (DDMI 1998)

Bird Species	First Occurrence (year observed)	Last Occurrence (year observed)	Maximum Number of Days Present
Willow ptarmigan	26 April (1996)	At least 29 October[a]	219[b]
Rough-legged hawk	5 May (1997)	17 October (1996)	166
Wilson's Snipe	31 May (1996)	3 September (1995)	96
Long-tailed duck	22 May (1997)	24 October (1996)	156

(a) Willow ptarmigan were still present in the study area when field studies were completed.
(b) Based on an estimated presence in the area until 30 November.

4.2.8 Summary

The estimated exposure time for the wildlife receptors is summarized in Table II-15. These estimates are not intended to be a precise representation of each species' behaviour near the mine; rather they are intended to represent a worst-case scenario. Due to the small size of the Lupin mine (10.4 km^2) relative to the home range of some barren-ground species, it is very unlikely that animals would spend a significant period of time in the vicinity of the Lupin mine.

Table II-15
Estimated Maximum Exposure Time for Wildlife Receptors

Species	Estimated Exposure (days)	Percent of Year at the Lupin Mine Site
Grizzly bear	18	10
Wolf	90	50
Wolverine	164	50
Red fox	365	100
Caribou	37	10
Muskox	240	66
Arctic hare	365	100
Arctic ground squirrel	210	100
Willow ptarmigan	365	100
Rough-legged hawk	166	45
Wilson's Snipe	96	26
Long-tailed duck	156	43

4.2.9 Exposure Estimate Equations

Exposure estimate equations used for the wildlife health exposure assessments are presented in Table II-16. Exposure was calculated based on maximum metal concentrations in soil, sediment, water and food.

Table II-16
Wildlife Exposure Equations

Pathway	Equation and Equation Parameters
Soil/Sediment ingestion	$EDI_{soil} = \frac{IR \times C_{soil} \times ET}{BW}$
	EDI_{soil} = exposure due to ingestion of soil (mg metal/kg body weight - day) IR = ingestion rate (kg/day) C_{soil} = metal concentration in soil (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Vegetation ingestion	$EDI_{veg} = \frac{IR \times C_{veg} \times ET}{BW}$
	EDI_{veg} = exposure due to ingestion of vegetation (mg metal/kg body weight - day) IR = ingestion rate from LLCF in wet weight (kg/day) C_{veg} = metal concentration in vegetation in wet weight (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Prey/invertebrate ingestion	$EDI_{prey} = \frac{IR_{prey} \times C_{prey} \times ET}{BW}$
	EDI_{prey} = exposure due to ingestion of prey (mg metal/kg body weight-day) IR_{prey} = food ingestion rate (kg/day) C_{prey} = concentration in prey (mg/kg) ET = exposure time (days/year) BW = receptor body weight (kg)
Water ingestion	$EDI_{water} = \frac{IR_{water} \times C_{water} \times ET}{BW}$
	EDI_{water} = exposure due to ingestion of water (mg metal/kg body weight-day) IR_{water} = water ingestion rate (L/day) C_{water} = concentration in water (mg/L) ET = exposure time (days/year) BW = receptor body weight (kg)

4.2.10 Wildlife Exposure Parameters

Details on the body weights, food, water, sediment, and soil ingestion rates, dietary compositions and time spent near the Lupin mine site for wildlife receptors are presented in Table II-17.

Table II-17
Wildlife Parameters Used in the Risk Assessment

Receptor	Body weight (kg)	Food Ingestion rate (kg/day)[a]	Water Ingestion Rate (L/day)[a]	Soil Ingestion Rate[b]
Muskoxen	280[c]	5.3	15.8	0.4[g]
Caribou	108[c]	2.6	6.7	0.05[h]
Grizzly bears	139[d]	4.0	8.4	0.08[h]
Wolverine	10[d]	0.5	0.8	0.009[h]
Fox	5.0[e]	0.3	0.4	0.007[i]
Wolves	34[c]	1.3	2.4	0.04[i]
Hare	4.81[d]	0.1	0.4	0.001[h]
Arctic ground squirrel	0.750[d]	0.03	0.08	0.0007[j]
Ptarmigan	0.559[f]	0.04	0.04	0.0008[h]
Rough legged hawk	0.956[f]	0.06	0.06	0.001[h]
Snipe	0.1220[f]	0.015	0.014	0.0003[h]
Duck	0.873[f]	0.05	0.05	0.002[k]

[a] U.S. EPA 1993.
[b] Sediment ingestion rate for snipe and duck.
[c] Silva and Downing 1995; RWED 2004.
[d] Silva and Downing 1995.
[e] RWED 2004.
[f] Dunning 1993.
[g] Assumed 6.8% of food ingestion; surrogate bison; Beyer et al. 1994.
[h] Assumed 2% of food ingestion; Beyer et al. 1994.
[i] Assumed 2.8% of food ingestion; surrogate red fox; Beyer et al. 1994.
[j] Assumed 2.7% of food ingestion; surrogate white-tailed prairie dog; Beyer et al. 1994.
[k] Assumed 3.3% of food ingestion; surrogate mallard; Beyer et al. 1994.

4.3 Bioavailability

Bioavailability (also referred to as absorption efficiency) is a measure of the amount of a chemical that is absorbed and retained within the body. Consideration of bioavailability may be important under the following circumstances (Health Canada 1995; U.S. EPA 1989):

- if the medium of exposure is different than the medium on which the TRV is based (e.g., exposure is from soil, but the TRV is based on exposure from water);
- if the route of exposure is different than the routes of exposure in the study used to derive the TRV (e.g., oral route of exposure, but based on an inhalation study); and
- the TRV derived by the regulatory agency has been adjusted for bioavailability.

In the wildlife health assessment, exposure estimates were not adjusted for bioavailability because in the majority of cases, TRVs were expressed as the administered dose (i.e., amount taken into the body), rather than the absorbed dose (i.e., amount absorbed and retained in the body), and the toxicity reference value was based on the same route of exposure as that being evaluated and/or because bioavailability rates were not available. The lack of adjustment for bioavailability may introduce additional conservatism if the form of the metal administered in laboratory toxicity tests is more soluble than the form of the metal in soil, plants and caribou meat. For example, metals are often introduced to water or food as metal salts during laboratory tests. Metal salts are more readily taken up into the body once administered. Therefore, a given concentration of metal salts may cause effects at lower thresholds than would have occurred had the metals been administered in more environmentally-realistic forms such as a mixture of salts, metal-organic complexes, and particulates.

4.4 Toxicity Assessment

Toxicity Reference Values (TRV) (or toxicity benchmarks) used in the wildlife health assessment are based on laboratory toxicity studies. Toxicity test species should ideally be the same species being evaluated in the risk assessment, but this is rarely possible. Most often, toxicity studies are conducted with rats and mice. Laboratory toxicity studies conducted using rats, mice, mallard ducks or other captive species provide dose-response information that can be extrapolated to wildlife. TRVs for the wildlife health assessment were obtained from Sample et al. (1996), unless otherwise noted. The Low-Observed-Adverse-Effect Level (LOAEL) for sublethal effects was selected for each metal, where available. The LOAELs from laboratory studies were extrapolated, incorporating differences in physiology between large and small animals according to the allometric method described in Sample and Arenal (1999). If a LOAEL was not available or inappropriate (i.e., based on mortality), a No-Observed-Adverse-Effect-Level (NOAEL) was used. The allometric method is based on the observation that many biological properties vary with body weight (Sample and Arenal 1999).

The equation used to calculate a TRV specific for mammals is based on the allometric scaling from toxicity laboratory studies is as follows:

$A_w = A_t (BW_t/BW_w)^{1-0.94}$

Where:

A_w = toxicity value for mammals

A_t = toxicity value for test species

BW_t = body weight for the test species

BW_w = body weight for mammals

A similar scaling process was done for birds. The equation used to calculate a TRV specific for birds is based on the allometric scaling from toxicity laboratory studies is as follows:

$A_w = A_t (BW_t/BW_w)^{1-1.2}$

Where:

A_w = toxicity value for birds

A_t = toxicity value for test species

BW_t = body weight for the test species

BW_w = body weight for birds

The mammalian and avian wildlife TRVs used in the wildlife health risk assessment are presented in Table II-18 and II-19, respectively.

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Muskoxen							
Aluminum	mouse	0.03	reproduction	19.3	280	11.2	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	280	0.73	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	280	3.5	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	280	63	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[a]	280	1,833	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	280	8	NAS 1980
Copper	mink	1	reproduction	15.1	280	10.8	Sample et al. 1996
Lead	rat	0.35	reproduction	80	280	54	Sample et al. 1996

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Manganese	rat	0.35	reproduction	284	280	190	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	280	1.5	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	280	54	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	280	0.22	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[a]	280	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[a]	280	176	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	280	0.05	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	280	1.4	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	280	214	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[a]	280	45.3	Sample et al. 1996
Caribou							
Aluminum	mouse	0.03	reproduction	19.3	108	11.8	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	108	0.77	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	108	3.7	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	108	66	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[a]	108	1,941	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	108	8	NAS 1980
Copper	mink	1	reproduction	15.1	108	11.4	Sample et al. 1996
Lead	rat	0.35	reproduction	80	108	57	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	108	201	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	108	1.6	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	108	57	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	108	0.23	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[a]	108	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[a]	108	186	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	108	0.053	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	108	1.5	Sample et al. 1997
Zinc	rat	0.35	reproduction	320	108	227	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[a]	108	48.0	Sample et al. 1996
Grizzly Bear							
Aluminum	mouse	0.03	reproduction	19.3	139	11.6	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	139	0.76	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	139	3.6	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	139	65	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[a]	139	1,911	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	139	8	NAS 1980

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Copper	mink	1	reproduction	15.1	139	11.3	Sample et al. 1996
Lead	rat	0.35	reproduction	80	139	56	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	139	198	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	139	1.6	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	139	56	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	139	0.23	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[a]	139	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[a]	139	184	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	139	0.052	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	139	1.4	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	139	223	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[a]	139	47.3	Sample et al. 1996
Wolverine							
Aluminum	mouse	0.03	reproduction	19.3	10	13.6	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	10	0.89	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	10	4.2	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	10	77	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[a]	10	2,237	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	10	10	NAS 1980
Copper	mink	1	reproduction	15.1	10	13.2	Sample et al. 1996
Lead	rat	0.35	reproduction	80	10	65	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	10	232	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	10	1.8	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	10	65	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	10	0.27	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[a]	10	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[a]	10	215	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	10	0.061	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	10	1.7	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	10	262	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[a]	10	55.3	Sample et al. 1996
Fox							
Aluminum	mouse	0.03	reproduction	19.3	5.0	14.2	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	5.0	0.93	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	5.0	4.4	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	5.0	80	Sample et al. 1996

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	5.0	2,333	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	5.0	10	NAS 1980
Copper	mink	1	reproduction	15.1	5.0	13.7	Sample et al. 1996
Lead	rat	0.35	reproduction	80	5.0	68	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	5.0	242	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	5.0	1.9	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	5.0	68	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	5.0	0.28	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	5.0	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	5.0	224	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	5.0	0.06	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	5.0	1.8	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	5.0	273	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	5.0	57.7	Sample et al. 1996
Wolf							
Aluminum	mouse	0.03	reproduction	19.3	34	12.7	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	34	0.83	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	34	3.9	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	34	71	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[(a)]	34	2,079	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	34	9	NAS 1980
Copper	mink	1	reproduction	15.1	34	12.2	Sample et al. 1996
Lead	rat	0.35	reproduction	80	34	61	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	34	216	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	34	1.7	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	34	61	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	34	0.25	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[(a)]	34	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[(a)]	34	200	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	34	0.056	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	34	1.6	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	34	243	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[(a)]	34	51.4	Sample et al. 1996
Hare							
Aluminum	mouse	0.03	reproduction	19.3	4.81	14.2	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	4.81	0.93	Sample et al. 1996

Table II-18
Mammalian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Barium	rat	0.435	growth, hypertension	5.1	4.81	4.4	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	4.81	80	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[a]	4.81	2,339	Sample et al. 1997
Cobalt	pig	225	clinical effects	8	4.81	10	NAS 1980
Copper	mink	1	reproduction	15.1	4.81	13.8	Sample et al. 1996
Lead	rat	0.35	reproduction	80	4.81	68	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	4.81	243	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	4.81	1.9	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	4.81	68	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	4.81	0.28	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[a]	4.81	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[a]	4.81	225	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	4.81	0.063	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	4.81	1.8	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	4.81	273	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[a]	4.81	57.8	Sample et al. 1996
Arctic Ground Squirrel							
Aluminum	mouse	0.03	reproduction	19.3	0.750	15.9	Sample et al. 1996
Arsenic	mouse	0.03	reproduction	1.26	0.750	1.0	Sample et al. 1996
Barium	rat	0.435	growth, hypertension	5.1	0.750	4.9	Sample et al. 1996
Boron	rat	0.35	reproduction	93.6	0.750	89	Sample et al. 1996
Chromium	rat	0.35	reproduction, longevity	2,737[a]	0.750	2,615	Sample et al. 1996
Cobalt	pig	225	clinical effects	8	0.750	11	NAS 1980
Copper	mink	1	reproduction	15.1	0.750	15.4	Sample et al. 1996
Lead	rat	0.35	reproduction	80	0.750	76	Sample et al. 1996
Manganese	rat	0.35	reproduction	284	0.750	271	Sample et al. 1996
Molybdenum	mouse	0.03	reproduction	2.6	0.750	2.1	Sample et al. 1996
Nickel	rat	0.35	reproduction	80	0.750	76	Sample et al. 1996
Selenium	rat	0.35	reproduction	0.33	0.750	0.32	Sample et al. 1996
Silver	human	70.7	skin discoloration	0.005[a]	0.750	0.005	IRIS 2004
Strontium	rat	0.35	body weight, bone changes	263[a]	0.750	251	Sample et al. 1996
Thallium	rat	0.365	reproduction	0.074	0.750	0.07	Sample et al. 1996
Vanadium	rat	0.26	reproduction	2.1	0.750	1.97	Sample et al. 1996
Zinc	rat	0.35	reproduction	320	0.750	306	Sample et al. 1996
Cyanide	rat	0.273	reproduction	68.7[a]	0.750	64.7	Sample et al. 1996

[a]Values is a NOAEL; no LOAEL value available.

Table II-19
Avian Toxicity Reference Values Used in the Wildlife Health Assessment

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Ptarmigan							
Aluminum	ringed dove	0.155	reproduction	109.7[(a)]	0.559	141.8	Sample et al. 1996.
Arsenic	mallard duck	1	mortality	5.14[(b)]	0.559	4.57	Sample et al. 1996.
Barium	chicken	0.121	mortality	20.8[(b)]	0.559	28.2	Sample et al. 1996.
Boron	mallard duck	1	reproduction	100	0.559	89	Sample et al. 1996.
Chromium	black duck	1.25	reproduction	5	0.559	4.3	Sample et al. 1996.
Cobalt	chicken	1.5	Clinical effects	0.33[(a)]	0.559	0.27	NAS 1980.
Copper	chicken	0.534	growth, mortality	61.7	0.559	62	Sample et al. 1996.
Lead	Japanese Quail	0.150	reproduction	11.3	0.559	14.7	Sample et al. 1996.
Manganese	Japanese quail	0.072	growth, behaviour	977[(a)]	0.559	1,472	Sample et al. 1996.
Molybdenum	chicken	1.5	reproduction	35.3	0.559	29	Sample et al. 1996.
Nickel	mallard duck	0.782	mortality, growth, behaviour	107	0.559	100	Sample et al. 1996.
Selenium	mallard duck	1	reproduction	1	0.559	0.9	Sample et al. 1996.
Silver	turkey	0.5	growth, hematological effects	6.66	0.559	6.8	Jensen et al. 1974.
Strontium	chicken	1.5	Clinical Effects	353.3	0.559	290	NAS 1980.
Thallium	European starling	0.0823[(c)]	mortality	0.35[(b)]	0.559	0.51	U.S. EPA 1999.
Vanadium	mallard duck	1.17	mortality, body weight, blood chemistry	11.4[(a)]	0.559	9.83	Sample et al. 1996.
Zinc	chicken	1.935	reproduction	131	0.559	102.2	Sample et al. 1996.
Cyanide	mallard duck	1	ATP production	0.025[(a)]	0.559	0.022	Ma and Pritsos 1997.
Hawk							
Aluminum	ringed dove	0.155	reproduction	109.7[(a)]	0.956	157.8	Sample et al. 1996.
Arsenic	mallard duck	1	mortality	5.14[(b)]	0.956	5.09	Sample et al. 1996.
Barium	chicken	0.121	mortality	20.8[(b)]	0.956	31.4	Sample et al. 1996.
Boron	mallard duck	1	reproduction	100	0.956	99.1	Sample et al. 1996.
Chromium	black duck	1.25	reproduction	5	0.956	4.7	Sample et al. 1996.
Cobalt	chicken	1.5	Clinical effects	0.33[(a)]	0.956	0.30	NAS 1980.
Copper	chicken	0.534	growth, mortality	61.7	0.956	69	Sample et al. 1996.
Lead	Japanese Quail	0.150	reproduction	11.3	0.956	16.4	Sample et al. 1996.
Manganese	Japanese quail	0.072	growth, behaviour	977[(a)]	0.956	1,639	Sample et al. 1996.
Molybdenum	chicken	1.5	reproduction	35.3	0.956	32.3	Sample et al. 1996.

Table II-19
Avian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Nickel	mallard duck	0.782	mortality, growth, behaviour	107	0.956	111.4	Sample et al. 1996.
Selenium	mallard duck	1	reproduction	1	0.956	1.0	Sample et al. 1996.
Silver	turkey	0.5	growth, hematological effects	6.66	0.956	7.6	Jensen et al. 1974.
Strontium	chicken	1.5	Clinical Effects	353.3	0.956	323	NAS 1980.
Thallium	European starling	0.0823[c]	mortality	0.35[b]	0.956	0.57	U.S. EPA 1999.
Vanadium	mallard duck	1.17	mortality, body weight, blood chemistry	11.4[a]	0.956	10.95	Sample et al. 1996.
Zinc	chicken	1.935	reproduction	131	0.956	113.8	Sample et al. 1996.
Cyanide	mallard duck	1	ATP production	0.025[a]	0.956	0.025	Ma and Pritsos 1997.
Snipe							
Aluminum	ringed dove	0.155	reproduction	109.7[a]	0.1220	104.6	Sample et al. 1996.
Arsenic	mallard duck	1	mortality	5.14[b]	0.1220	3.37	Sample et al. 1996.
Barium	chicken	0.121	mortality	20.8[b]	0.1220	20.8	Sample et al. 1996.
Boron	mallard duck	1	reproduction	100	0.1220	65.7	Sample et al. 1996.
Chromium	black duck	1.25	reproduction	5	0.1220	3.1	Sample et al. 1996.
Cobalt	chicken	1.5	Clinical effects	0.33[a]	0.1220	0.20	NAS 1980.
Copper	chicken	0.534	growth, mortality	61.7	0.1220	46	Sample et al. 1996.
Lead	Japanese Quail	0.150	reproduction	11.3	0.1220	10.84	Sample et al. 1996.
Manganese	Japanese quail	0.072	growth, behaviour	977[a]	0.1220	1,086	Sample et al. 1996.
Molybdenum	chicken	1.5	reproduction	35.3	0.1220	21.4	Sample et al. 1996.
Nickel	mallard duck	0.782	mortality, growth, behaviour	107	0.1220	73.8	Sample et al. 1996.
Selenium	mallard duck	1	reproduction	1	0.1220	0.7	Sample et al. 1996.
Silver	turkey	0.5	growth, hematological effects	6.66	0.1220	5.0	Jensen et al. 1974.
Strontium	chicken	1.5	Clinical Effects	353.3	0.1220	214	NAS 1980.
Thallium	European starling	0.0823[c]	mortality	0.35[b]	0.1220	0.38	U.S. EPA 1999.
Vanadium	mallard duck	1.17	mortality, body weight, blood chemistry	11.4[a]	0.1220	7.25	Sample et al. 1996.
Zinc	chicken	1.935	reproduction	131	0.1220	75.4	Sample et al. 1996.
Cyanide	mallard duck	1	ATP production	0.025[a]	0.1220	0.016	Ma and Pritsos 1997.

Table II-19
Avian Toxicity Reference Values Used in the Wildlife Health Assessment (continued)

Parameter	Test Species	Test Species Body Weight (kg)	Toxicity Endpoint	Test Species LOAEL (mg/kg-day)	Wildlife Body Weight (kg)	Estimated Chronic Wildlife LOAEL	Reference
Duck							
Aluminum	ringed dove	0.155	reproduction	109.7[a]	5.847	226.7	Sample et al. 1996.
Arsenic	mallard duck	1	mortality	5.14[b]	5.847	7.32	Sample et al. 1996.
Barium	chicken	0.121	mortality	20.8[b]	5.847	45.2	Sample et al. 1996.
Boron	mallard duck	1	reproduction	100	5.847	142.4	Sample et al. 1996.
Chromium	black duck	1.25	reproduction	5	5.847	6.8	Sample et al. 1996.
Cobalt	chicken	1.5	Clinical effects	0.33[a]	5.847	0.43	NAS 1980.
Copper	chicken	0.534	growth, mortality	61.7	5.847	100	Sample et al. 1996.
Lead	Japanese Quail	0.150	reproduction	11.3	5.847	23.5	Sample et al. 1996.
Manganese	Japanese quail	0.072	growth, behaviour	977[a]	5.847	2,354	Sample et al. 1996.
Molybdenum	chicken	1.5	reproduction	35.3	5.847	46.3	Sample et al. 1996.
Nickel	mallard duck	0.782	mortality, growth, behaviour	107	5.847	160	Sample et al. 1996.
Selenium	mallard duck	1	reproduction	1	5.847	1.4	Sample et al. 1996.
Silver	turkey	0.5	growth, hematological effects	6.66	5.847	10.9	Jensen et al. 1974.
Strontium	chicken	1.5	Clinical Effects	353.3	5.847	464	NAS 1980.
Thallium	European starling	0.0823[c]	mortality	0.35[b]	5.847	0.82	U.S. EPA 1999.
Vanadium	mallard duck	1.17	mortality, body weight, blood chemistry	11.4[a]	5.847	15.73	Sample et al. 1996.
Zinc	chicken	1.935	reproduction	131	5.847	163.4	Sample et al. 1996.
Cyanide	mallard duck	1	ATP production	0.025[a]	5.847	0.036	Ma and Pritsos 1997.

(a) Value is a NOAEL; no LOAEL was available.
(b) Value is a NOAEL; LOAEL was not used because it was based on mortality.
(c) Dunning 1993.

4.4.1.1 Toxicity Profiles for Mammals

Aluminum

No specific data were identified regarding the oral toxicity of aluminum to mammalian wildlife. A LOAEL of 19.3 mg/kg-day was reported for effects on reproduction (i.e., number of litters, number of offspring and growth of generations) in laboratory mice that were exposed to

19.3 mg/kg-day of aluminum chloride in drinking water for three generations (Ondreicka et al. 1966 in Sample et al. 1996). There were no effects of number of offspring per litter or litter numbers, but the growth of the 2nd and 3rd generations was significantly reduced. Exposure was considered to be chronic because it occurred for longer than one year and throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mice was used to estimate TRVs for mammalian wildlife (Table II-18).

Arsenic

No specific data were identified regarding the oral toxicity of arsenic to mammalian wildlife. A LOAEL of 1.26 mg/kg-day was reported for effects on reproduction (i.e., litter size) in laboratory mice that were exposed to arsenite in their drinking water for three generations (Schroeder and Mitchner 1971 in Sample et al. 1996). Exposure was considered to be chronic because it was greater than one year and throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mice was used to estimate TRVs for mammalian wildlife (Table II-19).

Barium

No specific data were identified regarding the oral toxicity of barium to mammalian wildlife. A NOAEL of 5.06 mg/kg-day was reported from reported for growth and hypertension in laboratory rats that were exposed to barium chloride by oral gavage for 16 months (Perry et al. 1983 in Sample et al. 1996). Since significance of hypertension in wild populations is unclear, the maximum dose that did not affect growth, food, or water consumption was considered a chronic NOAEL. For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Boron

No specific data were identified regarding the oral toxicity of boron to mammalian wildlife. A LOAEL of 93.6 mg/kg-day and a NOAEL of 28 mg/kg-day were reported for reproductive effects (i.e., sterility) in laboratory rats that were exposed to boric acid or borax in the diet for three generations (Weir and Fisher 1972 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for longer than one year and throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Chromium

A NOAEL of 2,737 mg/kg-day was reported for effects on reproduction and longevity of rats that were exposed to trivalent chromium in the diet for 90 days and 2 years (Ivankovic and Preussman 1975 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Cobalt

A NOAEL of 200 mg/kg cobalt in the diet and a LOAEL of 400 mg/kg cobalt in the diet was observed for effects on behaviour and neurological endpoints (e.g., anorexia, stiff legs, incoordination and muscular tremors) in pigs (Huck and Clawson 1976 in NAS 1980). The length of the study was not reported. Considering an average body weight and food ingestion rate for pigs of 225 kg and 4.5 kg/day (U.S. EPA 1988), the LOAEL and NOAEL were converted to a LOAEL of 8 mg/kg-day and a NOAEL of 4 mg/kg-day. For this assessment, the chronic LOAEL for pigs was used to estimate TRVs for mammalian wildlife (Table II-18).

Copper

No specific data were identified regarding the oral toxicity of copper to mammalian wildlife. A LOAEL of 15.14 mg/kg-day and a NOAEL of 11.7 mg/kg-day were reported for effects on reproduction (kit survivorship) in laboratory minks. The minks were exposed to 11.71, 15.14, 21.99, and 35.69 mg/kg-day of copper sulfate in their diet for 357 days (Aulerich et al. 1982 in Sample et al. 1996). Ingestion of 15.14, 21.99, and 35.69 mg/kg-day increased mink mortality, and ingestion of 11.71 mg/kg-day increased kit survivorship. Exposure was considered to be chronic because it was approximately one year in duration and occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mink was used to estimate TRVs for mammalian wildlife (Table II-19).

Lead

No specific data were identified regarding the oral toxicity of lead to mammalian wildlife. A LOAEL of 80 mg/kg-day and a NOAEL of 8 mg/kg-day were reported for effects on reproduction (i.e., number of pregnancies and number of live births) in laboratory rats. The rats were exposed to 0.8, 4, 8, 80, and 160 mg/kg-day of lead acetate in their diet for three generations (Azar et al. 1973 in Sample et al., 1996). Lead exposures of 80 and 160 mg/kg-day resulted in reduced offspring weights and produced kidney damage in young. Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction) and for greater than one year. For this assessment, the chronic LOAEL for rats was used to estimate TRVs mammalian wildlife (Table II-18).

Manganese

No specific data were identified regarding the oral toxicity of manganese to mammalian wildlife. A LOAEL of 284 mg/kg-day and a NOAEL of 88 mg/kg-day were reported for reproductive effects (i.e., pregnancy percentage and fertility) in laboratory rats that were exposed to manganese oxide in the diet for 224 days (Laskey et al. 1982 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., gestation). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Molybdenum

A LOAEL of 2.6 mg/kg-day was reported for reproductive effects (i.e., reduced reproductive success, high incidence of runts) in laboratory mice that were exposed to molybdate in their drinking water for three generations (Schroeder and Mitchener 1971 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for longer than one year and occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mice was used to estimate TRVs for mammalian wildlife (Table II-18).

Nickel

A LOAEL of 80 mg/kg-day and a NOAEL of 40 mg/kg-day were reported for effects on reproduction (i.e., reduced offspring body weights) in laboratory rats that were exposed to nickel sulfate in their diet for three generations (Ambrose et al. 1976 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction) and for greater than one year. For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Selenium

No specific data were identified regarding the oral toxicity of selenium to mammalian wildlife. A LOAEL of 0.33 mg/kg-day and a NOAEL of 0.2 mg/kg-day were reported for reproductive effects (i.e., decreased survival, reduced number of young per litter, reduced size and weight of offspring) in laboratory rats that were exposed to potassium selenate in their diet for one year, through two generations (Rosenfeld and Beath 1954 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Silver

No specific data were identified regarding the oral toxicity of silver to mammalian wildlife. Therefore, the wildlife TRV was based on the NOAEL for argyria (bluish-grey discoloration of the skin) in humans (also the human health TRV; described in Section 5.4.3). Since the significance of argyria in wildlife is unclear, and the TRV incorporates uncertainty due to sensitive sub-populations, the human TRV was applied directly to wildlife for this assessment (Table II-18).

Strontium

A NOAEL of 263 mg/kg-day was reported for effects on growth (i.e., body weight and bone changes) in laboratory rats that were exposed to strontium chloride in drinking water for 3 years (Skoryna 1981 in Sample et al., 1996). A LOAEL was not reported for this study. Exposure was considered chronic because it occurred for longer than one year. For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Thallium

No specific data were identified regarding the oral toxicity of thallium to mammalian wildlife. A LOAEL of 0.74 mg/kg-day was reported for effects on reproduction (i.e., male testicular function) in laboratory rats that were exposed to thallium sulfate in their drinking water for 60 days (Formigli et al. 1986 in Sample et al. 1996). Exposure was considered to be subchronic because its duration was only 60 days. An uncertainty factor of 10 was applied to the LOAEL for subchronic to chronic extrapolation, for a chronic LOAEL of 0.074 mg/kg-day. For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Vanadium

No specific data were identified regarding on the oral toxicity of vanadium to mammalian wildlife. A LOAEL of 2.1 mg/kg-day was reported for reproductive effects (i.e., decreased survival, reduced number of young per litter, reduced size and weight of offspring) in laboratory rats that were exposed to sodium metavanadate by oral intubaton for 60 days prior to gestation, during gestation, delivery and lactation (Domingo et al. 1986 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during gestation, delivery and lactation). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Zinc

No specific data were identified regarding the oral toxicity of zinc to mammalian wildlife. A LOAEL of 320 mg/kg-day and a NOAEL of 160 mg/kg-day were reported for reproductive effects (i.e., fetal resorption and reduced fetal growth rates) in laboratory rats that were exposed to 160 and 320 mg/kg-day of zinc oxide in the diet during days one through 16 of gestation (Schlicker and Cox 1968 in Sample et al. 1996). Increased rates of fetal resorption and reduced fetal growth rates were observed at 320 mg/kg-day. Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

Cyanide

No specific data were identified regarding the oral toxicity of cyanide to mammalian wildlife. A NOAEL of 68.7 mg/kg-day was reported for reproductive effects (offspring growth and food consumption) during gestation and lactation in rats exposed to potassium cyanide in the diet (Tewe and Maner 1981 in Sample et al. 1996). Exposure was considered to be chronic because it occurred throughout a critical lifestage (i.e., reproduction). For this assessment, the chronic NOAEL for rats was used to estimate TRVs for mammalian wildlife (Table II-18).

4.4.1.2 Toxicity Profiles for Avian Wildlife

Aluminum

No specific data were identified regarding the oral toxicity of aluminum to avian wildlife. A NOAEL of 109.7 mg/kg-day was reported for effects on reproduction for ringed doves that were exposed to aluminum sulfate in the diet for four months (Carriere et al. 1986 in Sample et al. 1996). Exposure was considered to be chronic because it was greater than ten weeks and throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic NOAEL for doves was used to estimate TRVs for avian wildlife (Table II-19).

Arsenic

No specific data were identified regarding the oral toxicity of arsenic to avian wildlife. A LOAEL of 12.8 mg/kg-/day and a NOAEL of 5.14 mg/kg-day were reported for effects on mortality for mallards that were exposed to sodium arsenite in the diet for 128 days (USFWS 1964 in Sample et al. 1996). Exposure was considered to be chronic because it was greater than ten weeks. For this assessment, the chronic NOAEL for mallard ducks was used to estimate receptor-specific TRVs for avian wildlife (Table II-19).

Barium

No specific data were identified regarding the oral toxicity of barium to avian wildlife. A LOAEL of 416.53 mg/kg-day and a NOAEL of 208.26 mg/kg-day was reported for effects on mortality for day-old chicks that were exposed to barium hydroxide in the diet for four weeks (Johnson et al. 1960 in Sample et al. 1996). An uncertainty factor of 10 was applied to the LOAEL and the NOAEL to extrapolate from subchronic to chronic exposure resulting in a chronic LOAEL of 41.7 mg/kg-day and a chronic NOAEL of 20.83 mg/kg-day. For this assessment, the chronic NOAEL for chicks was used to estimate TRVs for avian wildlife (Table II-19).

Boron

No specific data were identified regarding the oral toxicity of boron to avian wildlife. A LOAEL of 100 mg/kg-day and a NOAEL of 28.8 mg/kg-day were reported for reproductive effects (i.e., reduced egg fertility and duckling growth and increased embryo and duckling mortality) in mallard ducks exposed to boric acid in the diet for 3 weeks prior to, during and 3 weeks post reproduction (Smith and Anders 1989 in Sample et al. 1996). Exposure was considered to be chronic because it occurred throughout a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for mallard ducks was used to estimate TRVs for avian wildlife (Table II-19).

Chromium

A LOAEL of 5 mg/kg-day and a NOAEL of 1 mg/kg-day were reported for effects on reproduction for black ducks exposed to trivalent chromium in the diet for ten months (Haseltine et al. 1985 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction) and for greater than ten weeks. For this assessment, the chronic LOAEL for black ducks was used to estimate TRVs for avian wildlife (Table II-19).

Cobalt

A NOAEL of 4.7 mg/kg of cobalt in the diet was reported for chickens for emaciation and mortality (Turk and Kratzer 1960 in NAS 1980). Considering an average body weight and food ingestion rate for chickens of 1.5 kg and 0.106 kg/day (U.S. EPA 1988), the NOAEL was converted to 0.33 mg/kg-day. For this assessment, the chronic NOAEL for chickens was used to estimate TRVs for avian wildlife (Table II-19).

Copper

No specific data were identified regarding the oral toxicity of copper to avian wildlife. A LOAEL of 61.7 mg/kg-/day and a NOAEL of 47 mg/kg-day were reported for effects on growth and mortality for day-old chicks exposed to copper oxide in the diet for ten weeks (Mehring et al. 1960 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for 10 weeks. For this assessment, the chronic LOAEL for chicks was used to estimate TRVs for avian wildlife (Table II-19).

Lead

No specific data were identified regarding the oral toxicity of lead to avian wildlife. A NOAEL of 1.13 mg/kg-day and a LOAEL of 11.3 mg/kg-day were reported for effects on reproduction (hatching success) in Japanese quail exposed to lead acetate for 12 weeks in the diet (Edens et al. 1976 in Sample et al. 1996). Exposure was considered to be chronic because it occurred over 12 weeks and throughout a critical life stage. For this assessment, the chronic LOAEL for Japanese quail was used to estimate TRVs for avian wildlife (Table II-19).

Manganese

A NOAEL of 977 mg/kg-day was reported for growth and aggressive behaviour effects in male Japanese quail exposed to manganese oxide in their diet for 75 days (Laskey and Edens 1985 in Sample et al. 1996). A LOAEL was not observed during this study. Exposure was considered to be chronic because its duration was 75 days. For this assessment, the chronic NOAEL for Japanese quail was used to estimate the TRVs for avian wildlife (Table II-19).

Molybdenum

A LOAEL of 35.3 mg/kg-day and a NOAEL of 3.5 mg/kg-day were reported for effects on reproduction for chickens exposed to sodium molybdenum in their diet for 21 days during reproduction (Lepore and Miller 1965 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., during reproduction). For this assessment, the chronic LOAEL for chickens was used to estimate TRVs for avian wildlife (Table II-19).

Nickel

A LOAEL of 107 mg/kg-day and a NOAEL of 77.4 mg/kg-day were reported for effects on mortality, growth and behaviour for mallards that were exposed to nickel sulfate in their diet for

90 days during reproduction (Cain and Pafford 1981 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for longer than 10 weeks (i.e., 90 days). For this assessment, the chronic LOAEL for mallards was used to estimate TRVs for avian wildlife (Table II-19).

Selenium

No specific data were identified regarding the oral toxicity of selenium to avian wildlife. A LOAEL of 1.0 mg/kg-day and a NOAEL of 0.5 mg/kg-day were reported for effects on reproduction of mallard ducks exposed to sodium selenite in the diet for 78 days (Heinz et al. 1987 in Sample et al. 1996). Exposure was considered to be chronic because it occurred during a critical lifestage (i.e., reproduction) and for greater than ten weeks. For this assessment, the chronic LOAEL for mallard ducks was used to estimate TRVs for avian wildlife (Table II-19).

Silver

A NOAEL of 22.2 mg/kg-day (300 ppm) and a LOAEL of 66.6 mg/kg-day were reported for effects on growth and blood in commercial turkey poults exposed to silver acetate in the diet for four weeks (Jensen et al., 1974). Exposure was considered sub-chronic, so an uncertainty factor of 10 was applied to the NOAEL and LOAEL to derive a chronic NOAEL of 2.2 mg/kg-day, and a chronic LOAEL of 6.66 mg/kg-day. For this assessment, the chronic LOAEL for turkeys was used to estimate TRVs for avian wildlife (Table II-19).

Strontium

A LOAEL of 50,000 mg/kg-day and a NOAEL of 30,000 mg/kg in the diet were reported for effects on egg production, egg weight and body weight for mature hens exposed to strontium carbonate in the diet for 4 weeks (Dobrenz et al. 1969 in NAS 1980). The NOAEL and LOAEL were adjusted to account for body weight and food ingestion rate of 1.5 kg and 0.106 kg/d (U.S. EPA 1988), respectively. An uncertainty factor of 10 was applied to extrapolate from subchronic to chronic exposure. Exposure was considered to be sub-chronic because it occurred for only 4 weeks. The resulting LOAEL and NOAEL are 353 mg/kg-day and 212 mg/kg-day, respectively. For this assessment, the chronic LOAEL for hens was used to estimate TRVs for avian wildlife (Table II-19).

Thallium

No specific data were identified regarding the oral toxicity of thallium to avian wildlife. The dose causing 50% mortality amongst starlings (LD50) was 35 mg/kg-day (U.S. EPA 1999). No information regarding exposure doses was provided. An uncertainty factor of 100 was applied to account for using an acute study (i.e., to determine a chronic NOAEL). Therefore, the chronic NOAEL was 0.35 mg/kg-day. For this assessment, the chronic NOAEL for starlings was used to estimate TRVs for avian wildlife (Table II-19).

Vanadium

No specific data were identified regarding the oral toxicity of vanadium to avian wildlife. A NOAEL of 11.4 mg/kg-day was reported for effects on mortality, body weight, and blood chemistry of mallards that were exposed to vanadyl sulfate in the diet for 12 weeks (White and Dieter 1978 in Sample et al. 1996). Exposure was considered to be chronic because it occurred for more than 10 weeks. A LOAEL was not identified in the literature reviewed. For this assessment, the chronic NOAEL for mallard ducks was used to estimate TRVs for avian wildlife (Table II-19).

Zinc

No specific data were identified regarding the oral toxicity of zinc to avian wildlife. A LOAEL of 131 mg/kg-day and a NOAEL of 14.5 mg/kg-day were reported for reproductive effects in white leghorn hens that were exposed to zinc sulphate in the diet for 44 weeks (Stahl et al. 1990 in Sample et al. 1996). Exposure was considered to be chronic because it was for greater than 10 weeks and it occurred during a critical lifestage (i.e., reproduction). For this assessment, the chronic LOAEL for white leghorn hens was used to estimate TRVs for avian wildlife (Table II-19).

Cyanide

A NOAEL of 2.0 mg/kg-day for decreased adenosine triphosphate (ATP) production in heart tissue was observed in mallard ducks exposed to potassium cyanide (duration was reported as acute, but specific time period not reported) (Ma and Pritsos 1997). The LOAEL for the same study was 0.25 mg/kg-day for decreased ATP production in liver and brain tissue. No NOAEL was reported for ATP production in liver and brain tissue. An uncertainty factor of 10 was applied to the LOAEL to account for acute exposure (for derivation of a chronic LOAEL). For this assessment, the chronic LOAEL for mallard ducks was used to estimate TRVs for avian wildlife (Table II-19).

4.5 Risk Characterization

Risk estimates or Exposure Ratios (ERs) were calculated as the ratio of the estimated exposure to the TRV, as follows:

$$\text{Risk Estimate} = \frac{\text{Estimated Exposure}}{\text{TRV}}$$

For wildlife, the acceptable risk threshold is an ER of 1, since the risk assessment evaluated exposure from all sources (i.e., food, water and soil or sediment ingestion) from the Lupin mine site. ERs were calculated individually for exposure from soil or sediment, water and food.

Calculated ER values for mammals in the reference area and study area from exposure to soil, water, and food (vegetation, and caribou meat) are shown in Tables II-20, II-21, II-22, and II-23, respectively.

The ERs from each exposure route were summed to calculate the total ER for mammals exposed to metals from the study area (Table II-24).

Calculated ER values for avian wildlife in the study area from exposure to soil (or sediment), water, and food (vegetation, caribou meat, or invertebrates) are shown in Tables II-25, II-26, and II-27, respectively.

The ERs from each exposure route were summed to calculate the total ER for avian wildlife exposed to metals from the study area (Table II-28).

Table II-20
Mammalian ER Values for Exposure to Metals in Soil from the Reference Area and Study Area

Parameter[a]	Muskoxen		Caribou		Grizzly Bear		Wolverine		Fox		Wolves		Hare		Ground Squirrel	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	0.5	0.4	0.03	0.02	0.03	0.02	0.2	0.2	0.6	0.5	0.3	0.2	0.1	0.1	0.4	0.3
Arsenic	0.2	0.01	0.01	0.0006	0.01	0.0007	0.08	0.005	0.3	0.02	0.1	0.006	0.05	0.003	0.1	0.009
Barium	0.01	0.009	0.0005	0.0005	0.0006	0.0006	0.004	0.004	0.01	0.01	0.005	0.005	0.003	0.002	0.007	0.007
Boron	0.00003	0.00003	0.000001	0.000001	0.000002	0.000002	0.00001	0.00001	0.00004	0.00004	0.00001	0.00001	0.000008	0.000008	0.00002	0.00002
Chromium	0.00001	0.00001	0.0000006	0.000001	0.0000007	0.0000007	0.000005	0.000005	0.00001	0.00001	0.000006	0.000006	0.000003	0.000003	0.000008	0.000008
Cobalt	0.0006	0.0004	0.00003	0.00002	0.00004	0.00002	0.0003	0.0002	0.0008	0.0005	0.0003	0.0002	0.0002	0.0001	0.0005	0.0003
Copper	0.001	0.0007	0.00006	0.00004	0.00008	0.00004	0.0005	0.0003	0.002	0.0009	0.0006	0.0003	0.0003	0.0002	0.0009	0.0005
Lead	0.0001	0.00003	0.000005	0.000002	0.000006	0.000002	0.00004	0.00001	0.0001	0.00004	0.00005	0.00002	0.00003	0.000009	0.00007	0.00002
Manganese	0.0004	0.0003	0.00002	0.00002	0.00003	0.00002	0.0002	0.0001	0.0006	0.0004	0.0002	0.0002	0.0001	0.00009	0.0003	0.0003
Molybdenum	0.0002	0.0002	0.00001	0.000009	0.00001	0.00001	0.0001	0.00007	0.0003	0.0002	0.0001	0.00009	0.00006	0.00005	0.0002	0.0001
Nickel	0.0002	0.0002	0.00001	0.00001	0.00001	0.00001	0.00009	0.00008	0.0003	0.0002	0.0001	0.0001	0.00006	0.00005	0.0002	0.0001
Selenium	0.0004	0.0004	0.00002	0.00002	0.00002	0.00002	0.0002	0.0002	0.0005	0.0005	0.0002	0.0002	0.0001	0.0001	0.0003	0.0003
Silver	0.02	0.02	0.001	0.00098	0.001	0.001	0.009	0.009	0.03	0.03	0.01	0.0103	0.006	0.006	0.02	0.02
Strontium	0.00003	0.00003	0.000002	0.000001	0.000002	0.000002	0.00001	0.00001	0.00004	0.00003	0.00002	0.00001	0.000008	0.000007	0.00002	0.00002
Thallium	0.001	0.001	0.00006	0.00007	0.00007	0.00009	0.0005	0.0006	0.001	0.002	0.0005	0.0007	0.0003	0.0004	0.0008	0.001
Vanadium	0.01	0.01	0.0006	0.0005	0.0007	0.0006	0.005	0.004	0.01	0.01	0.006	0.005	0.003	0.003	0.008	0.008
Zinc	0.0001	0.00007	0.000005	0.000004	0.000006	0.000004	0.00004	0.00003	0.0001	0.00009	0.00005	0.00004	0.00003	0.00002	0.00007	0.00005

[a]Cyanide was not measured in soil.

Table II-21
Mammalian ER Values for Exposure to Metals in Water from the Reference Area

Parameter	Muskoxen		Caribou		Grizzly Bear		Wolverine		Fox		Wolves		Hare		Ground Squirrel	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	0.01	0.0005	0.002	0.00007	0.002	0.00007	0.01	0.0004	0.02	0.0008	0.009	0.0004	0.02	0.0008	0.02	0.0008
Arsenic	0.06	0.0001	0.009	0.00002	0.009	0.00002	0.05	0.00009	0.1	0.0002	0.05	0.00008	0.1	0.0002	0.1	0.0002
Barium	0.001	0.00007	0.0001	0.00001	0.0001	0.00001	0.0008	0.00006	0.002	0.0001	0.0008	0.00005	0.002	0.0001	0.002	0.0001
Boron	0.0002	0.000007	0.00003	0.000001	0.00003	0.000001	0.0002	0.000006	0.0004	0.00001	0.0002	0.000005	0.0004	0.00001	0.0004	0.00001
Chromium	0.0000005	0.00000002	0.00000007	0.000000003	0.00000007	0.000000003	0.0000004	0.00000002	0.0000008	0.00000004	0.0000004	0.00000002	0.0000008	0.00000004	0.0000009	0.00000004
Cobalt	0.005	0.00001	0.0008	0.000001	0.0008	0.000001	0.004	0.000008	0.009	0.00002	0.004	0.000008	0.009	0.00002	0.009	0.00002
Copper	0.004	0.00002	0.0005	0.000003	0.0005	0.000003	0.003	0.00001	0.006	0.00003	0.003	0.00001	0.006	0.00003	0.006	0.00003
Lead	0.00002	0.00000004	0.000002	0.000000005	0.000002	0.000000005	0.00001	0.00000003	0.00003	0.00000006	0.00001	0.00000003	0.00003	0.00000006	0.00003	0.00000007
Manganese	0.02	0.000003	0.004	0.0000005	0.004	0.0000005	0.02	0.000003	0.04	0.000005	0.02	0.000002	0.04	0.000005	0.04	0.000006
Molybdenum	0.002	0.00003	0.0003	0.000004	0.0003	0.000004	0.001	0.00002	0.003	0.00004	0.001	0.00002	0.003	0.00004	0.003	0.00005
Nickel	0.002	0.000005	0.0003	0.0000008	0.0003	0.0000008	0.002	0.000004	0.004	0.000009	0.002	0.000004	0.004	0.000009	0.004	0.000009
Selenium	0.003	0.0002	0.0005	0.00003	0.0005	0.00003	0.003	0.0001	0.006	0.0003	0.003	0.0001	0.006	0.0003	0.006	0.0003
Silver	0.02	0.001	0.003	0.0002	0.003	0.0002	0.02	0.001	0.04	0.003	0.01	0.001	0.04	0.003	0.04	0.003
Strontium	0.0002	0.000002	0.00003	0.0000003	0.00003	0.0000003	0.0002	0.000002	0.0004	0.000003	0.0002	0.000002	0.0004	0.000003	0.0004	0.000004
Thallium	0.01	0.00004	0.002	0.000006	0.002	0.000006	0.01	0.00003	0.02	0.00007	0.009	0.00003	0.02	0.00007	0.02	0.00007
Vanadium	0.00009	0.00003	0.00001	0.000004	0.00001	0.000004	0.00007	0.00002	0.0001	0.00005	0.00007	0.00002	0.0001	0.00005	0.0002	0.00005
Zinc	0.0002	0.000001	0.00003	0.0000002	0.00003	0.0000002	0.0001	0.0000009	0.0003	0.000002	0.0001	0.000001	0.0003	0.000002	0.0003	0.000002
Cyanide	0.004	NA	0.0006	NA	0.0006	NA	0.003	NA	0.007	NA	0.003	NA	0.007	NA	0.007	NA

NA = Data not available; cyanide concentration not measured in reference area.

Table II-22
Mammalian ER Values for Exposure to Metals in Vegetation from the Study Area and Reference Area

Parameter[a]	Muskoxen		Caribou		Grizzly Bear		Hare		Ground Squirrel	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	0.7	0.3	0.1	0.06	0.08	0.03	0.7	0.3	1	0.6
Arsenic	0.6	0.01	0.1	0.002	0.06	0.001	0.5	0.01	1	0.02
Barium	0.04	0.05	0.006	0.009	0.004	0.005	0.03	0.05	0.07	0.09
Chromium	0.00002	0.000005	0.000003	0.0000008	0.000002	0.0000005	0.00002	0.000004	0.00003	0.000009
Cobalt	0.001	0.001	0.0002	0.0002	0.0001	0.0001	0.0009	0.001	0.002	0.002
Copper	0.003	0.002	0.0004	0.0003	0.0003	0.0002	0.002	0.002	0.005	0.003
Lead	0.0006	0.00003	0.0001	0.000006	0.00006	0.000004	0.0006	0.00003	0.001	0.00006
Manganese	0.02	0.01	0.004	0.002	0.002	0.001	0.02	0.01	0.04	0.02
Molybdenum	0.005	0.0007	0.001	0.0001	0.0006	0.00007	0.005	0.0006	0.01	0.001
Nickel	0.0008	0.0007	0.0001	0.0001	0.00008	0.00007	0.0007	0.0006	0.001	0.001
Selenium	0.009	0.003	0.002	0.0005	0.0009	0.0003	0.008	0.002	0.02	0.005
Silver	0.05	0.05	0.009	0.009	0.006	0.005	0.06	0.06	0.1	0.1
Strontium	0.0005	0.0003	0.00008	0.00005	0.00005	0.00003	0.0004	0.0002	0.0009	0.0005
Thallium	0.003	0.002	0.0004	0.0004	0.0003	0.0002	0.002	0.002	0.005	0.004
Vanadium	0.004	0.003	0.0008	0.0004	0.0005	0.0003	0.004	0.002	0.008	0.005
Zinc	0.002	0.001	0.0003	0.0003	0.0002	0.0002	0.002	0.001	0.004	0.003

[a]Cyanide and boron not measured in vegetation.

Table II-23
Mammalian ER Values for Exposure to Metals in Caribou Meat from the Study Area Reference Area

Parameter	Grizzly Bear		Wolverine		Fox		Wolves	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	0.00004	0.00002	0.0005	0.0003	0.001	0.0006	0.0004	0.0002
Arsenic	0.00004	0.0000009	0.0005	0.00001	0.001	0.00003	0.0004	0.00001
Barium	0.0000002	0.0000003	0.000003	0.000004	0.000006	0.000008	0.000002	0.000003
Boron	0.000000006	0.0000000005	0.00000009	0.000000006	0.0000002	0.00000001	0.00000007	0.000000005
Chromium	0.000000005	0.000000002	0.00000007	0.00000003	0.0000001	0.00000007	0.00000006	0.00000003
Cobalt	0.00000002	0.000000003	0.0000003	0.00000004	0.0000006	0.0000001	0.0000003	0.00000004
Copper	0.000002	0.0000005	0.00002	0.000006	0.00005	0.00001	0.00002	0.000006
Lead	0.000000007	0.0000000005	0.00000009	0.000000007	0.0000002	0.00000001	0.00000008	0.000000006
Manganese	0.0000003	0.0000001	0.000005	0.000002	0.00001	0.000004	0.000004	0.000002
Molybdenum	0.0000002	0.00000002	0.000003	0.0000003	0.000006	0.0000006	0.000002	0.0000002
Nickel	0.0000005	0.0000001	0.000007	0.000001	0.00001	0.000003	0.000006	0.000001
Selenium	0.00003	0.000008	0.0005	0.0001	0.001	0.0002	0.0004	0.00009
Silver	0.000006	0.000004	0.0001	0.00007	0.0002	0.0002	0.00008	0.00006
Strontium	0.0000002	0.00000005	0.000002	0.0000007	0.000005	0.000002	0.000002	0.0000006
Thallium	0.00002	0.000003	0.0003	0.00004	0.0006	0.00009	0.0002	0.00004
Vanadium	0.0000006	0.0000005	0.000008	0.000006	0.00002	0.00001	0.000007	0.000005
Zinc	0.000006	0.000004	0.00008	0.00005	0.0002	0.0001	0.00007	0.00004

Table II-24
Total Mammalian ER Values for Exposure to Metals from all Media in the Study Area and Reference Area

Parameter	Muskoxen		Caribou		Grizzly Bear		Wolverine		Fox		Wolves		Hare		Ground Squirrel	
	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference	Study Area	Reference
Aluminum	1	0.7	0.2	0.08	0.1	0.06	0.2	0.2	0.7	0.5	0.3	0.2	0.8	0.4	2	0.9
Arsenic	0.8	0.02	0.1	0.003	0.08	0.002	0.1	0.005	0.4	0.02	0.1	0.006	0.7	0.01	1	0.03
Barium	0.05	0.06	0.007	0.009	0.005	0.006	0.005	0.004	0.01	0.01	0.006	0.005	0.04	0.05	0.08	0.1
Boron	0.0002	0.00004	0.00003	0.000002	0.00003	0.000003	0.0002	0.00002	0.0004	0.00005	0.0002	0.00002	0.0004	0.00002	0.0004	0.00003
Chromium	0.00003	0.00002	0.000003	0.000001	0.000002	0.000001	0.000005	0.000005	0.00001	0.00001	0.000006	0.000006	0.00002	0.000008	0.00004	0.00002
Cobalt	0.007	0.002	0.001	0.0002	0.0009	0.0001	0.005	0.0002	0.01	0.0005	0.004	0.0002	0.01	0.001	0.01	0.002
Copper	0.007	0.002	0.001	0.0003	0.0009	0.0002	0.003	0.0003	0.008	0.0009	0.003	0.0004	0.009	0.002	0.01	0.004
Lead	0.0007	0.00007	0.0001	0.000008	0.00007	0.000006	0.00005	0.00001	0.0001	0.00004	0.00006	0.00002	0.0006	0.00004	0.001	0.00009
Manganese	0.05	0.01	0.008	0.002	0.006	0.001	0.02	0.0002	0.04	0.0005	0.02	0.0002	0.06	0.01	0.09	0.02
Molybdenum	0.007	0.0009	0.001	0.0001	0.0008	0.00008	0.002	0.0001	0.003	0.0003	0.001	0.0001	0.008	0.0007	0.01	0.001
Nickel	0.003	0.0009	0.0005	0.0001	0.0004	0.00008	0.002	0.00009	0.004	0.0003	0.002	0.0001	0.005	0.0007	0.006	0.001
Selenium	0.01	0.003	0.002	0.0005	0.001	0.0003	0.003	0.0004	0.007	0.001	0.003	0.0004	0.01	0.003	0.02	0.006
Silver	0.09	0.07	0.01	0.01	0.009	0.006	0.03	0.01	0.06	0.03	0.02	0.01	0.1	0.06	0.2	0.1
Strontium	0.0007	0.0003	0.0001	0.00005	0.00008	0.00003	0.0002	0.00001	0.0004	0.00004	0.0002	0.00002	0.0008	0.0002	0.001	0.0005
Thallium	0.02	0.004	0.002	0.0005	0.002	0.0003	0.01	0.0007	0.02	0.002	0.01	0.0008	0.02	0.003	0.03	0.006
Vanadium	0.02	0.01	0.001	0.001	0.001	0.0009	0.005	0.004	0.01	0.01	0.006	0.005	0.007	0.005	0.02	0.01
Zinc	0.002	0.002	0.0004	0.0003	0.0002	0.0002	0.0003	0.00008	0.0006	0.0002	0.0003	0.00008	0.002	0.001	0.004	0.003
Cyanide	0.004	NA	0.0006	NA	0.0006	NA	0.003	NA	0.007	NA	0.003	NA	0.007	NA	0.007	NA

NA = cyanide concentrations not measured in the reference area.

Table II-25
Avian ER Values for Exposure to Metals from Soil or Sediment in the Study Area and Reference Area

Parameter	Ptarmigan (soil)		Hawk (soil)		Snipe (sediment)		Duck (sediment)	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Aluminum	0.06	0.05	0.02	0.02	0.1	0.04	0.1	0.03
Arsenic	0.05	0.003	0.02	0.001	3	0.004	3	0.004
Barium	0.002	0.002	0.0007	0.0006	0.003	0.001	0.003	0.001
Boron	0.00003	0.00003	0.00001	0.00001	0.00005	0.00003	0.00004	0.00003
Chromium	0.008	0.008	0.003	0.003	0.009	0.005	0.009	0.004
Cobalt	0.03	0.02	0.01	0.006	0.09	0.02	0.08	0.02
Copper	0.0003	0.0002	0.0001	0.00006	0.006	0.0001	0.006	0.0001
Lead	0.0006	0.0002	0.0002	0.00007	0.02	0.0001	0.02	0.0001
Manganese	0.00009	0.00007	0.00003	0.00002	0.0002	0.00008	0.0002	0.00007
Molybdenum	0.00002	0.00001	0.000007	0.000005	0.0003	0.00001	0.0003	0.00001
Nickel	0.0002	0.0002	0.00006	0.00006	0.0004	0.0001	0.0004	0.0001
Selenium	0.0002	0.0002	0.00005	0.00005	0.002	0.0001	0.002	0.00009
Silver	0.00002	0.00002	0.000007	0.000007	0.00001	0.00001	0.00001	0.00001
Strontium	0.00003	0.00002	0.00001	0.000008	0.0003	0.00002	0.0003	0.00002
Thallium	0.0002	0.0002	0.00006	0.00007	0.0001	0.0001	0.0001	0.0001
Vanadium	0.003	0.002	0.0009	0.0008	0.003	0.002	0.003	0.002
Zinc	0.0003	0.0002	0.0001	0.00008	0.05	0.0003	0.05	0.0002
Cyanide	NA	NA	NA	NA	330	0.01	305	0.01

NA = Cyanide not measured in soil.

Table II-26
Avian ER Values for Exposure to Metals from Water in the Study Area and Reference Area

Parameter	Ptarmigan		Hawk		Snipe		Duck	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Aluminum	0.002	0.00007	0.0006	0.00002	0.001	0.00004	0.0006	0.00002
Arsenic	0.02	0.00003	0.006	0.00001	0.01	0.00002	0.006	0.00001
Barium	0.0002	0.00002	0.00007	0.000005	0.0001	0.000009	0.00007	0.000005
Boron	0.0003	0.000009	0.00009	0.000003	0.0002	0.000005	0.00009	0.000003
Chromium	0.0004	0.00002	0.0001	0.000006	0.0002	0.00001	0.0001	0.000006
Cobalt	0.3	0.0005	0.09	0.0002	0.2	0.0003	0.09	0.0002
Copper	0.001	0.000006	0.0004	0.000002	0.0006	0.000003	0.0004	0.000002
Lead	0.0001	0.0000002	0.00003	0.00000008	0.00006	0.0000001	0.00003	0.00000008
Manganese	0.006	0.0000007	0.002	0.0000002	0.003	0.0000004	0.002	0.0000002
Molybdenum	0.0002	0.000002	0.00006	0.0000008	0.0001	0.000001	0.00006	0.0000008
Nickel	0.002	0.000005	0.0007	0.000002	0.001	0.000003	0.0007	0.000002
Selenium	0.002	0.00008	0.0005	0.00003	0.0009	0.00005	0.0005	0.00003
Silver	0.00002	0.000002	0.000007	0.0000005	0.00001	0.0000009	0.000007	0.0000005
Strontium	0.0002	0.000002	0.00008	0.0000008	0.0001	0.000001	0.00008	0.0000008
Thallium	0.002	0.000007	0.0007	0.000002	0.001	0.000004	0.0007	0.000002
Vanadium	0.00002	0.000007	0.000007	0.000002	0.00001	0.000004	0.000007	0.000002
Zinc	0.0007	0.000005	0.0002	0.000002	0.0004	0.000003	0.0002	0.000002
Cyanide	14	NA	5	NA	8	NA	5	NA

NA = Cyanide concentrations not measured in water from the reference area.

Table II-27
Avian ER Values for Exposure to Metals from Food (vegetation, prey, or invertebrates) in the Study Area and Reference Area

Parameter	Ptarmigan (vegetation)		Hawk (prey)		Snipe (invertebrates)		Duck (invertebrates)	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Aluminum	0.3	0.1	0.00005	0.00003	5	2	3	0.9
Arsenic	0.5	0.01	0.0001	0.000002	135	0.2	76	0.1
Barium	0.02	0.03	0.0000004	0.0000006	0.1	0.06	0.08	0.04
Boron	NA	NA	0.00000008	0.000000006	0.002	0.001	0.001	0.0008
Chromium	0.04	0.01	0.00004	0.00002	0.2	0.09	0.1	0.05
Cobalt	0.2	0.2	0.00001	0.000002	4	1	3	0.6
Copper	0.002	0.002	0.000005	0.000001	0.09	0.002	0.05	0.001
Lead	0.01	0.0007	0.0000004	0.00000003	0.7	0.004	0.4	0.002
Manganese	0.02	0.008	0.0000008	0.0000003	0.01	0.004	0.006	0.002
Molybdenum	0.002	0.0002	0.0000002	0.00000002	0.01	0.0006	0.008	0.0003
Nickel	0.002	0.002	0.000005	0.0000009	0.02	0.005	0.01	0.003
Selenium	0.01	0.004	0.0001	0.00003	0.1	0.004	0.06	0.002
Silver	0.0002	0.0002	0.00000008	0.00000005	0.0006	0.0006	0.0003	0.0003
Strontium	0.002	0.0008	0.000002	0.0000006	0.01	0.0009	0.008	0.0005
Thallium	0.001	0.001	0.00003	0.000005	0.007	0.007	0.004	0.004
Vanadium	0.003	0.002	0.000001	0.000001	0.1	0.09	0.08	0.05
Zinc	0.02	0.02	0.0002	0.0001	1	0.007	0.8	0.004
Cyanide	NA	NA	0.000001	NA	14,835	0.5	8,328	0.3

NA = Data not available.

Table II-28
Total Avian ER Values for Exposure to Metals from all Media in the Study Area and Reference Area

Parameter	Ptarmigan		Hawk		Snipe		Duck	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Aluminum	0.4	0.2	0.02	0.02	5	2	3	0.9
Arsenic	0.6	0.01	0.02	0.001	138	0.2	78	0.1
Barium	0.03	0.04	0.0007	0.0006	0.1	0.07	0.08	0.04
Boron	0.0003	0.00004	0.0001	0.00001	0.003	0.001	0.001	0.0008
Chromium	0.05	0.02	0.003	0.003	0.2	0.1	0.1	0.06
Cobalt	0.5	0.2	0.1	0.006	5	1	3	0.6
Copper	0.004	0.002	0.0005	0.00007	0.1	0.002	0.06	0.001
Lead	0.01	0.0009	0.0002	0.00007	0.7	0.005	0.4	0.003
Manganese	0.02	0.008	0.002	0.00002	0.01	0.004	0.008	0.002
Molybdenum	0.002	0.0002	0.00006	0.000006	0.01	0.0006	0.008	0.0003
Nickel	0.005	0.002	0.0008	0.00006	0.02	0.005	0.01	0.003
Selenium	0.01	0.004	0.0007	0.0001	0.1	0.004	0.07	0.003
Silver	0.0002	0.0002	0.00001	0.000008	0.0006	0.0006	0.0003	0.0003
Strontium	0.002	0.0009	0.00009	0.00001	0.01	0.0009	0.008	0.0005
Thallium	0.004	0.001	0.0008	0.00008	0.008	0.007	0.005	0.004
Vanadium	0.006	0.004	0.0009	0.0008	0.1	0.09	0.08	0.05
Zinc	0.02	0.02	0.0005	0.0002	2	0.008	0.9	0.004
Cyanide	14	NA	5	NA	15173	0.5	8639	0.3

NA = Data not available.

ERs based on maximum media concentrations were greater than 1 for aluminum, arsenic, cobalt, zinc, and cyanide for some VECs at the Lupin mine site. Therefore, for these selected chemicals of concern and receptors, ERs were also calculated based on average media concentrations for comparative purposes. ERs calculated from average concentrations for aluminum, arsenic, cobalt, zinc and cyanide are presented in Tables II-29, II-30, II-31, II-32, and II-33, respectively.

Table II-29
ERs for Aluminum based on Average Media Concentrations in the Study Area and Reference Area for various VECs

Receptor	Soil/Sediment[(a)]		Water		Food[(b)]		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Muskoxen	0.2	0.4	0.0009	0.0004	0.4	0.2	0.5	0.5
Ground Squirrel	0.1	0.3	0.002	0.0008	0.6	0.3	0.8	0.6
Snipe	0.08	0.04	0.00007	0.00003	3	2	3	2
Duck	0.07	0.03	0.00004	0.00002	2	0.9	2	0.9

(a) Soil ingestion is applicable to muskoxen and ground squirrel; Sediment ingestion is applicable to snipe and duck.
(b) Muskoxen and ground squirrel food is based on vegetation ingestion; Snipe and duck food is based on invertebrate ingestion.

Table II-30
ERs for Arsenic based on Average Media Concentrations in the Study Area and Reference Area for various VECs

Receptor	Soil/Sediment[(a)]		Water		Food[(b)]		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Ground Squirrel	0.07	0.006	0.00005	0.0001	0.4	0.02	0.5	0.02
Snipe	2	0.003	0.000004	0.000009	70	0.2	72	0.2
Duck	1	0.003	0.000003	0.000005	39	0.09	41	0.09

(a) Soil ingestion is applicable to ground squirrel; Sediment ingestion is applicable to snipe and duck.
(b) Ground squirrel food is based on vegetation ingestion; Snipe and duck food is based on invertebrate ingestion.

Table II-31
ERs for Cobalt based on Average Media Concentrations in the Study Area and Reference Area for various VECs

Receptor	Sediment		Water		Invertebrate Ingestion		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Snipe	0.05	0.02	0.01	0.0002	3	0.9	3	0.9

NA = Not applicable.

Table II-32
ERs for Zinc based on Average Media Concentrations in the Study Area and Reference Area for the Common Snipe

Receptor	Sediment		Water		Invertebrate Ingestion		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Snipe	0.02	0.0002	0.00009	0.000001	0.6	0.007	0.6	0.007

Table II-33
ERs for Cyanide based on Average Media Concentrations in the Study Area and Reference Area for Various VECs

Receptor	Soil/Sediment[(a)]		Water		Food[(b)]		Total	
	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area	Study Area	Reference Area
Ptarmigan	NA	NA	0.9	NA	NA	NA	0.9	NA
Hawk	NA	NA	0.3	NA	0.00000009	NA	0.3	NA
Snipe	127	0.01	0.5	0	5695	0.5	5822	0.5
Duck	117	0.01	0.3	0.0	3197	0.3	3315	0.3

(a) Soil ingestion is applicable to ptarmigan; Sediment ingestion is applicable to snipe and duck.
(b) Ptarmigan food is based on vegetation ingestion; Hawk food is based on caribou ingestion; Snipe and duck food is based on invertebrate ingestion.
NA = cyanide not analyzed in these media.

5. HUMAN HEALTH RISK ASSESSMENT

5.1 Problem Formulation

5.1.1 Human Receptor Screening

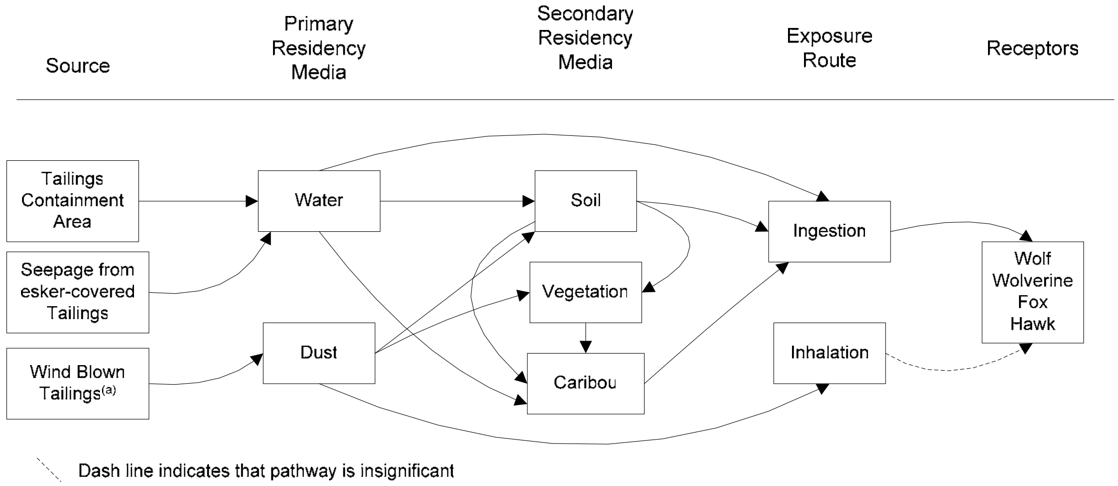
Consistent with risk assessment guidance (Health Canada 2003), the toddler life phase (i.e., seven months to four years) was chosen as the most susceptible child lifestage for evaluation of non-carcinogenic metals. The toddler phase is the most susceptible childhood phase due to their smaller body size to ingestion rate ratio. Therefore, the risk assessment estimated exposures that a hypothetical child may have after ingesting meat tissue from caribou that are exposed to metals from the Lupin mine site. A hypothetical adult receptor was also evaluated for exposure to metals in caribou meat since adults eat greater amounts of meat for a longer period of time.

5.1.2 Human Exposure Pathway Screening

Exposure pathways are the means by which a substance comes into contact with receptors. They are largely dependent on the physical-chemical properties of the substances, the environment in which the receptor lives and the likely receptor behaviour. The purpose of the exposure pathway screening process is to determine the ways in which people may come into contact with metals from the Lupin mine site.

The only exposure pathway evaluated for the human health risk assessment was ingestion of caribou meat. The Lupin mine site is not in close proximity to any communities (i.e., closest community is Bathurst Inlet, approximately 150 km northeast of Lupin). Although four families currently live in the region of Lupin mine, close to Contwoyto Lake (2 families only in the summer months), knowledge of the presence of the mine will prevent people from spending much time in the area, and these families are likely to leave after mine closure, as most of their provisions are acquired from the mine. Large-bodied fish that are consumed by people (e.g., Arctic char, lake trout), will not be present in Ponds 1 and 2 since a spillway will be constructed to prevent movement of fish into the ponds. Currently, there are no berry-producing plants growing on the esker-covered cell. Therefore, the only pathway evaluated from the human health risk assessment was ingestion of caribou, which have taken up metals from drinking water, food, and incidental soil ingestion from the Lupin mine site.

Figure II-8
Human Exposure Pathways



[a]Exposed tailings will be covered as part of closure plan.

5.2 Exposure Assessment

5.2.1 Spatial and Temporal Boundaries

It was assumed that people would eat caribou that have been exposed to metals from the Lupin mine site every day for their entire lives. This is a very conservative assumption since not all caribou would pass through the Lupin gold mine or spend significant periods of time near the study area.

5.2.2 Exposure Estimate Equations

The exposure estimate equation used for meat ingestion in the human health exposure assessment is presented in Table II-34. Meat tissue concentrations were calculated using bioconcentration factors from water, soil and food ingestion to meat tissue. The concentrations and calculations are presented in Appendix I. Although humans may consume other meat tissue such as muskoxen, the concentration in meat tissue in other organisms would be similar to caribou because the meat concentration is based on metal-specific bioconcentration factors.

Table II-34
Exposure Equations

Pathway	Equation and Equation Parameters
Meat ingestion	$EDI_{meat} = \dfrac{IR \times C_{meat}}{BW}$
	EDI_{meat} = exposure due to ingestion of meat (mg metal/kg body weight-day) IR = ingestion rate (kg/day) C_{meat} = metal concentration in caribou meat (mg/kg) BW = receptor body weight (kg)

5.2.3 Human Exposure Parameters

Details on the body weights and food ingestion rates for humans are presented in Table II-35.

Table II-35
Exposure Parameters Used in the Human Health Risk Assessment

Age class	Body weight (kg)	Wild Game (Caribou) Ingestion (kg/day)	Reference
0-6 months (infant)	8.2	0	Health Canada 2003
7 months to 4 years (toddler)	16.5	0.085	Health Canada 2003
5-11 years (child)	32.9	0.125	Health Canada 2003
12-19 years (teen)	59.7	0.175	Health Canada 2003
20+ years (adult)	70.7	0.270	Health Canada 2003

5.3 Bioavailability

As described in Section 4.3, bioavailability is typically not adjusted in a risk assessment unless one of the following occurs:

- if the medium of exposure is different than the medium on which the toxicity reference value is based (e.g., exposure is from soil, but the toxicity reference value is based on exposure from water);

- if the route of exposure is different than the route of exposures in the study used to derive the toxicity reference value (e.g., oral route of exposure, but based on an inhalation study); and
- the toxicity reference value derived by the regulatory agency has been adjusted for bioavailability.

In the human health assessment, exposure estimates were not adjusted for bioavailability because in the majority of cases, TRVs were expressed as the administered dose (i.e., amount taken into the body), rather than the absorbed dose (i.e., amount absorbed and retained in the body) and because bioavailability information was not available. However, bioavailability was incorporated into the exposure assessment for nickel because the nickel TRV is based on exposure through drinking water (Health Canada 2003), a very soluble and bioavailable form of nickel, whereas the form of nickel in food is much less bioavailable (ATSDR 1997). In humans, ingested nickel is poorly absorbed. In a study reviewed in ATSDR (1997), nickel administered in drinking water was absorbed much more readily than when administered in food (27% absorption in water versus 0.7% absorption in food). For the purpose of this assessment, bioavailability of via food ingestion was assumed to be 3% relative to bioavailability via water ingestion (ATSDR 1997).

5.4 Toxicity Assessment

Toxicity assessment involves identification of the potentially toxic effects of metals and determination of the amount of metals that can be taken into the body without experiencing adverse health effects. The toxicity assessment provides the basis for determining an acceptable exposure and what level of exposure may adversely affect people’s health. The toxicity assessment is based on chronic exposure and not acute exposure.

5.4.1 Metals That do Not Cause Cancer

For most metals, there is a threshold exposure level below which no adverse health effects occur. Above the threshold level, adverse health effects begin to occur and increase in severity with increasing exposure to the substance. The non-carcinogenic metals evaluated in this risk assessment (all but arsenic) exhibit this type of threshold-response relationship.

5.4.2 Metals That Can Cause Cancer

Carcinogenic metals, in theory, do not exhibit threshold-response behaviour. Rather, even at low doses, there is some risk of genetic damage; although nature provides ways of repairing this to some extent.

To evaluate the acceptability of environmental exposures to carcinogenic metals such as arsenic, regulatory agencies have declared that a safe dose is one that has a probability of less than 1 chance in 100,000 chances of developing cancer. This level of risk is much lower than the risk of developing cancer from other sources, such as genetics, family history, diet (risk level of 1 in 4; Health Canada 2003) and some voluntary practices such as smoking (risk level of 1 in 20). A risk level of 1 in 100,000 ensures that exposure to environmental chemicals does not significantly increase the risk of people developing cancer.

5.4.3 Toxicity Reference Values

Toxicity reference values (TRVs) are safe exposures below which there is minimal risk of adverse health effects. The TRVs used in the human health assessment were obtained from government agencies such as Health Canada (Health Canada 2003; TERA 2004), the U.S. EPA's Integrated Risk Information Service Database (IRIS 2004), the Agency for Toxic Substances and Disease Registry (2004), and the Netherlands National Institute of Public Health and the Environment (RIVM 2001). The majority of toxicity information comes from the results of experiments with laboratory animals. Some additional information on human health effects is also available for some substances where cases of workplace exposures and associated health effects have been documented.

Animal studies provide dose-response information that can be extrapolated to humans by applying safety factors. In most cases safety factors of 100 to 1,000 are applied to laboratory derived No-Observed-Adverse-Effect Level (NOAEL; the highest concentration in a toxicity test where no chronic health effects were observed or measured) to account for interspecies extrapolation and protection of the most susceptible in a population (i.e., children and elderly). Therefore, TRVs have large margins of safety to ensure that the toxicity or risk of a substance to people is not underestimated.

The TRVs used in this assessment are presented as reference doses (RfDs) for non-carcinogenic chemicals and slope factors for carcinogenic chemicals (i.e., arsenic). The RfD is defined as the amount of metal per unit body weight that can be taken into the body each day with no risk of adverse health effects. The slope factor is derived from dose-response relationships from epidemiological or animal toxicity studies that measured the relationship between exposure to substances and incidence of cancer. The RfDs and slope factor chosen for the human health risk assessment from available sources, the rationale for the selection, and a brief summary of the toxicity studies on which they were based is presented in Table II-36.

5.5 Risk Characterization

In the risk characterization step, ERs were calculated as the ratio of the estimated exposure to the toxicity benchmark value, according to the following equation:

ER = estimated exposure ÷ toxicity benchmark value

For non-carcinogenic chemicals, an ER value of less than 0.2 (considered to be the appropriate threshold for this assessment) represents exposure that does not pose a significant health risk to receptors (Health Canada 2003). As stated in Section 2.1.4, an ER value of 0.2 is considered appropriate because only one exposure pathway was evaluated for human health.

When the ER is greater than 0.2, the scenarios pose a potential concern and require further scrutiny. It is important to note that ER values greater than 0.2 do not necessarily indicate that adverse health effects will occur due to the layers of safety employed in their estimation (e.g., the toxicity reference values are protective of human health).

5.5.1 Results

ERs for the human health risk assessment are presented in Tables II-43 and II-44. ERs are based on caribou meat ingestion only, as other pathways of exposure were not evaluated for human health. ER values for non-carcinogenic metals for toddlers and adults exposed to caribou meat from the study area are presented in Table II-37. Estimated cancer incidence due to arsenic exposure via ingestion of caribou is presented in Table II-38, along with cancer incidence associated with drinking water quality guidelines for arsenic and background cancer rate.

Table II-36
Reference Doses Used for the Human Health Risk Assessment

Parameter	Reference Dose (mg/kg-day)				Rationale
	Health Canada	U.S. EPA IRIS	ATSDR	RIVM	
Aluminum	1.0	none	2.0	none	The ATSDR RfD was based on the NOAEL for neurotoxicity in a study of mice exposed to aluminum lactate in the diet. An uncertainty factor of 30 was applied to the NOAEL; 3 for extrapolation from animals to humans and 10 for human variability. The Health Canada RfD is based on operational guidance values for water treatment plants using aluminum-based coagulants. The ATSDR RfD was used in the risk assessment because it is based on a health-related outcome.
Arsenic (carcinogenic)[a]	2.8	1.5	none	none	Health Canada and IRIS derived slope factors based on the same epidemiological studies conducted for a population in Taiwan. The slope factor from Health Canada is more conservative because it was computed directly from the dose-response curve within the experimental range, whereas the IRIS slope factor was calculated from the upper 95% confidence limit on the low-dose extrapolation (TERA 2004). The Health Canada slope factor was used because the approach used to calculate the slope factor is based on the dose-response curve.
Arsenic (non-carcinogenic)	none	0.0003	0.0003	0.001	Both IRIS and ATSDR based the non-carcinogenic RfD for arsenic on the NOAEL for hyperpigmentation and keratosis in an epidemiological study for a population in Taiwan. An uncertainty factor of 3 was applied to the NOAEL for database deficiencies. The RIVM RfD is based on NOAELs from a group of human epidemiological studies. The composite NOAEL for dermal effects chosen by RIVM is higher than that noted in the Taiwanese population cited by IRIS and ATSDR. However, RIVM does not provide a substantial argument for choosing a higher NOAEL value to base the RfD. Therefore, the RfD from IRIS and ATSDR was used for the risk assessment.
Barium	0.02	0.07	none	0.02	Health Canada, IRIS, and RIVM based the RfD on the NOAEL for any effect in an epidemiological study of cardiovascular disease in humans. IRIS applied an uncertainty factor of 3 to the NOAEL for database deficiencies and human variability. Health Canada and RIVM applied an uncertainty factor of 10 to account for human variability. The Health Canada and RIVM RfD was used based on the more conservative uncertainty factor.
Boron	0.0175	0.2	none	none	The Health Canada RfD was based on the NOAEL for testicular atrophy and spermatogenesis in a two year study of dogs exposed to borax (boric acid) in the diet. An uncertainty factor of 500 was applied to the NOAEL; 10 for extrapolation from animals to humans, 10 for sensitive individuals, and 5 for limitations in the study (small number of experimental animals exposed for a small portion of their life span). The IRIS RfD was based on the benchmark dose for decreasing fetal weight calculated from two studies of rats exposed to boric acid in the diet. A data-derived uncertainty factor of 66 was applied to the benchmark dose; 3.3 for rat to human toxicokinetic variability, 2 for human toxicokinetic variability, 3.16 for rat to human toxicodynamic variability, and 3.16 for human toxicodynamic variability. The Health Canada RfD was used for the risk assessment because it was based on a clearly defined NOAEL and uncertainty factors.
Chromium (total)	0.001	1.5	0.003	5.0	The Health Canada RfD is based on the NOAEL for health effects from a variety of sources cited in the Guidelines for Canadian Drinking Water Quality, including studies of hexavalent chromium. The IRIS RfD is based on the NOAEL for any effects from a study of rats exposed to chromic oxide in the diet. An uncertainty factor of 1000 was applied to the NOAEL; 10 for extrapolation from animals to humans, 10 for human variability, and 10 for deficiencies in the database. The ATSDR RfD is based on the upper range of the NRC estimated safe and adequate daily dietary intake, and is adopted as a provisional guidance only. The RIVM RfD is based on the assumption that the toxicity of insoluble chromium is approximately 1000 times less than the toxicity of soluble forms. The IRIS RfD was used for this risk assessment because it is based on the appropriate form of the compound.
Cobalt	none	none	0.01	0.0014	The ATSDR RfD was based on a LOAEL for increased erythrocyte levels in a human epidemiological study. An uncertainty factor of 100 was applied to the LOAEL; 10 for use of a LOAEL, and 10 for human variability. The RIVM RfD is based on the LOAEL for cardiomyopathy from a different human epidemiological study. This effect was noticed in a small population, and may have been confounded by alcohol intake. An uncertainty factor of 30 was applied to the LOAEL; 10 for use of LOAEL and 3 for human variability. The ATSDR RfD was used for the risk assessment because the uncertainty in the RIVM study population (alcohol consumption) was not accounted for.
Copper	0.03	none	0.02	0.14	The RfD from Health Canada and RIVM is based on copper's function as an essential nutrient. Both agencies have used their country's recommended daily intake as the RfD. ATSDR established a minimal risk level on gastrointestinal effects in women given copper sulfate in drinking water for two weeks. The NOAEL was less than the recommended daily intake. An RfD cannot be lower than the levels required for essentiality; therefore, the RfD from Health Canada was used in the risk assessment, as it is specific to a safe level for the Canadian population.
Lead	0.0036	none	none	0.0036	The Health Canada and RIVM RfD is based on the provisional tolerable weekly intake of lead derived by the FAO/WHO. The RfD from Health Canada and RIVM was used in the risk assessment.

Parameter	Reference Dose (mg/kg-day)				Rationale
	Health Canada	U.S. EPA IRIS	ATSDR	RIVM	
Manganese	none	0.14	0.07	none	IRIS derived an RfD based on the NOAEL for CNS effects from several large epidemiological investigations of humans exposed to manganese in food. The ATSDR RfD is based on the upper range of the estimated safe and adequate daily dietary intake for manganese. The IRIS RfD was used for the risk assessment because it represents concentrations of manganese that have been measured in food and found to cause no health effects in humans.
Molybdenum	none	0.005	none	0.01	The IRIS RfD was based on the LOAEL for increased uric acid levels in a human lifetime dietary exposure study. An uncertainty factor of 30 was applied to the LOAEL; 3 for protection of sensitive individuals, and 10 for use of a LOAEL rather than an NOAEL. The RIVM RfD is based on the NOAEL for renal toxicity in rats exposed to molybdenum. An uncertainty factor of 100 was applied to the NOAEL; 10 for extrapolation from animals to humans, and 10 for human variability. The RfD from IRIS was used for the risk assessment because it was derived based on data for a human exposure study.
Nickel, soluble salts	0.0013	0.02	none	0.05	The IRIS and RIVM RfD was based on the NOAEL for decreased body and organ weights from a study of rats exposed to nickel in the diet. IRIS applied an uncertainty factor of 300; 10 for animal to human extrapolation, 10 to protect sensitive populations, and 3 for the inadequacies of the reproductive studies. RIVM applied an uncertainty factor of 100 to the NOAEL. Health Canada based the RfD on the LOAEL for pup mortality in a study of rats exposed to nickel chloride in drinking water. An uncertainty factor of 1000 was applied to the LOAEL; 10 for extrapolation from animals to humans, 10 for human variability, and 10 for use of a LOAEL rather than a NOAEL. The Health Canada RfD was used for the risk assessment because it was based on exposure that occurred during the reproductive phase. Since reproduction is a sensitive life stage, the Health Canada value was the preferred RfD for the risk assessment.
Selenium	none	0.005	0.005	none	The IRIS and ATSDR RfD was based on the NOAEL for clinical selenosis in a human epidemiological study. An uncertainty factor of 3 was applied to the NOAEL to account for sensitive individuals. The RfD from IRIS and ATSDR was used for the risk assessment.
Silver	none	0.005	none	none	The U.S. EPA RfD was based on the LOAEL for argyria (bluish-grey discoloration of the skin) in humans exposed to silver by intravenous injection of silver arsphenamine over a 2 to 9.75 year period. An uncertainty factor of 3 was applied to the LOAEL to account for use of a LOAEL rather than a NOAEL. The U.S. EPA RfD was used in the risk assessment.
Strontium	none	0.6	none	none	The U.S. EPA RfD was based on the NOAEL for bone demineralization and cartilage defects in rats exposed to strontium carbonate for 3 years. An uncertainty factor of 300 was applied to the NOAEL; 10 for animal to human extrapolation, 10 for database deficiencies, and 3 for sensitive populations. The U.S. EPA RfD was used in the risk assessment.
Thallium	none	0.00008	none	none	The U.S. EPA RfD was based on the NOAEL for increasing blood chemistry parameters in rats exposed to thallium chloride in the diet for 90 days. An uncertainty factor of 3000 was applied to the NOAEL; 10 for use of a sub-chronic study, 10 for extrapolation from animals to humans, 10 for human sensitivity, and 3 for lack of reproductive and chronic toxicity data.
Vanadium	none	0.009	0.003	none	The IRIS RfD is based on a NOAEL for decreased hair cysteine in rats exposed to vanadium pentoxide in the diet. An uncertainty factor of 100 was applied to the NOAEL; 10 for extrapolation from animals to humans and 10 to protect sensitive individuals. The ATSDR RfD is based on a dose-related trend for mild histological renal effects and increased plasma urea in rats exposed to sodium metavanadate in the diet. No dose-related responses were reported. An uncertainty factor of 100 was applied to account for human variability and extrapolation from animals to humans. The IRIS RfD was used for the risk assessment because it was based on an observed NOAEL, and the ATSDR RfD was not based on a clear dose level.
Zinc	none	0.3	0.3	0.5	IRIS, ATSDR, and RIVM based the RfD on a LOAEL for enzyme concentration from a human diet supplement study. IRIS and ATSDR applied an uncertainty factor of 3 to the LOAEL for use of a LOAEL and to account for sensitive individuals. RIVM applied an uncertainty factor of 2 to the LOAEL to account for use of the LOAEL, rather than a NOAEL. The IRIS and ATSDR RfD was used in the risk assessment because of the additional safety factor to account for sensitive sub-populations.
Cyanide	0.02	0.02	none	0.05	The Health Canada, U.S. EPA, and RIVM based the RfD on the NOAEL for weight loss and myelin degeneration in rats exposed to food fumigated with hydrogen cyanide. Health Canada and RIVM applied an uncertainty factor of 500 to the NOAEL; 10 for extrapolation from animals to humans, 10 for sensitive human individuals, and 5 for exposure in food rather than water or air (more bioavailable exposure routes for cyanide). RIVM chose a different NOAEL for increased blood thiocyanate levels. An uncertainty factor of 100 was applied to this NOAEL; 10 for extrapolation from animals to humans and 10 for sensitive human individuals. The Health Canada and U.S. EPA RfD was used for the risk assessment because a clearly defined NOAEL was used.

[(a)]Slope factor $(mg/kg\text{-}day)^{-1}$

Table II-37
Human Health ER Values for Non-carcinogenic Metals in Caribou Meat from the Study Area and Reference Area

Parameter	Study Area		Reference Area	
	Toddler	Adult	Toddler	Adult
Aluminum	0.0008	0.0006	0.0004	0.0003
Arsenic	0.3	0.3	0.008	0.006
Barium	0.0001	0.0001	0.0002	0.0001
Boron	0.00009	0.00006	0.000006	0.000005
Chromium	0.00002	0.00002	0.00001	0.000008
Cobalt	0.00006	0.00005	0.00001	0.000007
Copper	0.002	0.002	0.0006	0.0005
Lead	0.0004	0.0003	0.00003	0.00002
Manganese	0.002	0.001	0.0007	0.0005
Molybdenum	0.0002	0.0002	0.00002	0.00002
Nickel	0.0002	0.0001	0.00003	0.00002
Selenium	0.006	0.004	0.001	0.001
Silver	0.00002	0.00002	0.00002	0.00001
Strontium	0.0002	0.0001	0.0000001	0.0000001
Thallium	0.05	0.03	0.007	0.005
Vanadium	0.0004	0.0003	0.0003	0.0002
Zinc	0.01	0.01	0.01	0.007
Cyanide	0.0000004	0.0000003	NA	NA

NA = Concentrations not available for the reference area.

Table II-38
Estimated Cancer Incidence due to Exposure to Arsenic in Caribou Meat

Exposure Pathway	Reference Area	Study Area
Caribou Meat Ingestion	0.4 in 100,000	19 in 100,000
Cancer incidence based on Canadian drinking water quality guideline[(a)]	147 in 100,000	
Cancer incidence from all causes[(b)]	40,000 in 100,000	

[(a)] Health Canada 2003.

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