



**APPENDIX 6.12-A
Environmental Health Baseline Report**



KITSAULT MINE PROJECT
ENVIRONMENTAL BACKGROUND
ENVIRONMENTAL HEALTH

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ACRONYMS, ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
ADD	Average Daily Dose
AF	Soil Adherence Factor-Dermal
AIR	Application Information Requirements
API	American Petroleum Institute
Application (the)	The proponent's Application for an Environmental Assessment Certificate for the proposed Project, made under section 16 of the British Columbia <i>Environmental Assessment Act</i>
As	Arsenic
AT	Averaging Time
ATP	Adenosine Triphosphate
ATSDR	Agency of Toxic Substances and Disease Registry
AVS	Acid Volatile Sulphides
BC	British Columbia
BC MOE	BC Ministry of Environment
BC MWLAP	BC Ministry of Water, Land and Air Pollution
BW	Body Weight
BW _t	Body Weight Test Species
BW _w	Body Weight Mammalian Wildlife Species
C _F	Chemical Concentration in Food
C _{fish}	Concentration of Contaminant in Fish
C _{invertebrates}	Concentration of Contaminant in Soil Invertebrates
C _{lg mammal}	Concentration of Contaminant in Large Mammal
C _{plant}	Concentration of Contaminant in Plant Tissue
C _{sm mammal}	Concentration of Contaminant in Small Mammal
C _s	Chemical Concentration in Soil
C _{soil}	Concentration of Contaminant in Soil
C _{sw}	Concentration of Contaminants in Surface Water
C _w	Chemical Concentration in Water
CAC	Criteria Air Contaminant
CalEPA	California Environmental Protection Agency
CCME	Canadian Council of Ministers of the Environment
CDI	Chronic Daily Intake
CEC	Cation Exchange Capacity
CF	Conversion Factor
COPC	Chemicals of Potential Concern
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWF	Canadian Wildlife Federation

Abbreviation	Definition
CWS	Canadian Wildlife Service
DDT	dichloro-diphenyl-trichloroethane
EA	Environmental Assessment
EC ₂₀	Effective Concentration to Induce a 20% Effect
EC ₅₀	Effective Concentration to Induce a 50% Effect
Eco-SSL	Ecological Soil Screening Level
ED	Days per Year Exposed
EDI	Estimated Daily Intake
EFD	Exposure Frequency-Dermal
EPC	Exposure Point Concentrations
ER	Exposure Ratio
ERA	Ecological Risk Assessment
ET	Hours per Day Exposed
F	Fraction from Site
FA	Fraction Absorbed from Site
FeAsS	Arsenopyrite
H	hour
HC	Health Canada
HQ	Hazard Quotient
HHRA	Human Health Risk Assessment
ILCR	Incremental Lifetime Cancer Risk
IR	Ingestion or Inhalation Rate
IR _{fish}	Fish Ingestion Rate
IR _{invertebrates}	Soil Invertebrates Ingestion Rate
IR _{lg mammal}	Large Mammal Ingestion Rate
IR _{plant}	Plant Tissue Ingestion Rate
IR _{sm mammal}	Small Mammal Ingestion Rate
IR _{soil}	Soil Ingestion Rate
IR _{sw}	Surface Water Ingestion Rate
IRIS	Integrated Risk Information System
ISQG	Interim Sediment Quality Guidelines
LC ₅₀	Lethal Concentration Effective to Result in 50% Mortality
LCV	Lowest Chronic Value
LOAEC	Lowest Observable Adverse Effect Concentration
LOAEL	Lowest Observable Adverse Effect Level
LSA	Local Study Area
Mo	month
MDEQ	Michigan Department of Environmental Quality

Abbreviation	Definition
MoS ₂	molybdenite
NCIC	National Cancer Institute of Canada
NOAEL	No Observable Adverse Effect Level
NOAEL _w	No Observable Adverse Effect Level for Mammalian Wildlife Species
NOAEL _t	No Observable Adverse Effect Level for Test Species
NOEC	No Observable Effect Concentration
NRC	National Research Council
NRCC	National Research Council of Canada
P _{air}	Particulate Concentration in Air
PAH	Polycyclic Aromatic Hydrocarbon
PEL	Probable Effects Level
PIRI	Partnership in Risk Based Corrective Action Implementation
PM	particulate matter
proponent (the)	Avanti Kitsault Mine Ltd.
proposed Project (the)	Kitsault Mine Project
PQRA	Preliminary Quantitative Risk Assessment
PRG	Preliminary Remediation Goal
RAF	Relative Absorption Factor
RAF _D	Absorption Adjustment Factor-Dermal
RAF _o	Relative Absorption Factor-Oral
RAIS	Risk Assessment Information System
RSA	Regional Study Area
SA	Skin Surface Area
SARA	<i>Species at Risk Act</i>
SedQC	Sediment Quality Criteria
SedQC _{SS}	Sediment Quality Criteria for Sensitive Sites
SedQC _{TS}	Sediment Quality Criteria for Typical Sites
SQG	Soil Quality Guidelines
SQG _E	Soil Quality Guidelines Ecological
SQG _{HH}	Soil Quality Guidelines Human Health
TC	Tolerable Concentration
TCEQ	Texas Commission on Environmental Quality
TDI	Tolerable Daily Intake
TRV	Toxicological Reference Value
UMADW	University of Michigan (Museum of Zoology) Animal Diversity Web
US EPA	United States Environmental Protection Agency
VC	Valued Component
Yr	Year

UNITS OF MEASUREMENT

Abbreviation	Definition
cm ²	centimetres squared
g/day	grams per day
kg	kilogram
kg/day	kilograms per Day
kg/m ³	kilograms per cubic metres
kg/mg	kilograms per milligram
km	kilometre
L/day	litres per day
m	metre
m ³ /day	cubic metres per day
m ³ /hour	cubic metres per hour
µg/m ³	micrograms per cubic metre
µg/g	micrograms per gram
mg	milligram
mg/cm ²	milligrams per centimetre squared
mg/d	milligrams per day
mg/kg	milligrams per kilogram
mg/kg/d	milligrams per kilogram body weight per day
mg/kg/w	milligrams per kilogram body weight per week
mg/L	milligrams per litre
ppm	parts per million

EXECUTIVE SUMMARY

When used to evaluate environmental health, risk assessment is defined as:

“A set of procedures that combines and evaluates information on the potential toxic effects of contaminating substances on biological systems (receptors) in contact with contaminated soil, air, water and food through various exposure routes.” (Government of Alberta 1999)

Risk assessment requires consideration of both the toxic properties of chemicals and the levels of exposures from a project.

The Environmental Health Baseline Report is a Preliminary Quantitative Risk Assessment (PQRA) of current conditions at the Project site, intended as the baseline for the assessment of the Environmental Health VC (see section 6.9) of Avanti Kitsault Mine Ltd.'s (proponent) Application for an Environmental Assessment (EA) Certificate for the proposed Kitsault Mine Project, made under section 16 of the British Columbia *Environmental Assessment Act* (Application) to the British Columbia Environmental Assessment Office (BC EAO). The Kitsault property is located about 140 kilometres (km) north of Prince Rupert, British Columbia (BC), and south of the head of Alice Arm, an inlet of the Pacific Ocean. The property includes three known molybdenum deposits: Kitsault; Bell Moly; and Roundy Creek. The proposed Project only includes the Kitsault Deposit. The principal mining feature on the property is the former Kitsault open pit mine which last operated in 1982.

The PQRA addresses potential risks to human and non-human receptors present at the proposed Project site through relevant exposure pathways as a result of potential exposure to identified effects in soil, surface water, and country foods based on available historical and current site data.

Based on the findings of this risk assessment, conclusions were made with respect to the potential risk to human health and ecological receptors.

Human Health Risk Assessment

A conservative approach was taken in determining the primary exposure scenarios of concern for the proposed Project's PQRA. The exposure scenario assessed for non-carcinogenic chemicals involved that of a toddler who spent all his time in the region and could potentially be exposed via direct contact with soil, inhalation of dust, and ingestion of surface water, vegetation, wild game, and fish. Similarly for carcinogenic chemicals, an adult who spends the same amount of time in the region could also potentially be exposed via direct contact with soil, inhalation of dust, and ingestion of surface water, vegetation, wild game, and fish. The Chemicals of Potential Concern (COPC) carried forward into the PQRA were identified as:

- Arsenic;

- Chromium;
- Molybdenum;
- Nickel; and
- Selenium.

The potential non-carcinogenic hazard quotient for all COPC associated with exposure of receptors identified at the proposed Project site is below Health Canada's (HC) target risk level of 1.

The potential carcinogenic incremental lifetime cancer risk associated with exposure of receptors identified at the proposed Project site is noted to be unacceptable for arsenic based on HC's target risk level of 10^{-5} .

Ecological Risk Assessment

This report also presents a screening level Ecological Risk Assessment (ERA) of potential adverse effects from COPC on Valued Components (VCs). The ERA used both historical and current sampling data and is consistent with the methodology required by Environment Canada (EC) and the Canadian Council of Ministers of the Environment (CCME) (1996a; 1997a) for conducting screening level ERAs at federal sites in Canada. The proposed Project location is an existing mine property (brownfield site) and a natural setting. For the purposes of presentation of baseline information, residential / parkland, terrestrial ecological receptors have been selected as the reference guidelines for comparison of the proposed Project baseline soils data. Receptors that were determined to be of primary concern were large mammals (e.g., grizzly bear), small mammals (e.g., hare), birds (e.g., raptor), terrestrial plants, and soil invertebrates. These ecological receptors may be potentially exposed to COPC in direct contact with soil and ingestion of soil, surface water and food items (e.g., earthworms). Shorebirds (e.g., spotted sandpiper) may also be potentially exposed to COPC via intake of surface water and sediment during ingestion of aquatic plants and invertebrates'.

Aquatic receptors of concern were aquatic plants, aquatic invertebrates, amphibians and fish. The exposure pathway for these receptors was direct contact with surface water.

The COPC carried forward into the ERA were identified as:

- Arsenic;
- Cadmium;
- Chromium;
- Copper;
- Lead;
- Mercury

- Molybdenum;
- Nickel; and
- Selenium.

Quantitative estimates of risk were calculated using a quotient approach in which exposure estimates based on 95th percentile concentrations were compared to Toxicological Reference Values (TRVs) derived for each receptor / pathway. Exposure ratios greater than one were found for:

- Mink exposed to molybdenum in fish, small mammals, invertebrates and vegetation;
- Soil invertebrates exposed to arsenic, chromium, and molybdenum in soil;
- Terrestrial plants exposed to arsenic, chromium, molybdenum, nickel, and selenium in soil; and
- Aquatic invertebrates exposed to cadmium in surface water.

The results of a screening level ERA of the potential adverse effects from COPC identified in association with affected soil, sediment, surface water, and food / prey at the proposed Project. The ERA used both historical and current sampling data and is consistent with the methodology required by Environment Canada and CCME (1996a; 1996b; 1997a; 1997b) for conducting screening level ERAs at federal sites in Canada. The baseline data results predict no adverse effects for the representative receptors including large carnivore mammal (grizzly bear), herbivore mammal (black-tailed deer), small herbivore mammal (hare), raptor, songbird, waterfowl, shorebird, amphibians, fish, and / or aquatic plants.

1.0 ENVIRONMENTAL HEALTH

1.1 Introduction

This Environmental Health Baseline Report provides the information that facilitates evaluation of the human and ecological risks associated with the proposed Kitsault Mine Project (proposed Project). The report describes the Preliminary Quantitative Risk Assessment (PQRA) process used to evaluate human health and the Ecological Risk Assessment (ERA) methods for evaluating ecological health in anticipation of determining the potential effects that may arise from the proposed Project. Using available historic and current site data, the PQRA risk assessment addresses potential risks to human and ecological receptors present at, and in the vicinity of, the proposed Project site. Relevant exposure pathways are identified as a result of potential exposure to identified effects. This baseline was used in the assessments presented in this Application in Section 6.12 - Environmental Health and Section 10.0 Human Health.

The environmental health risk assessment involves a process of cataloguing, assessing, combining, and evaluating information collected from an environment and determining the potential toxic effects of contaminating substances on biological systems or receptors that may come in contact with contaminated soil, air, water, and food through various exposure routes or pathways. The risk assessment requires consideration of both the toxic properties of Chemicals of Potential Concern (COPC) and the levels of exposure as a result of their introduction to the environment from the activities of a project.

The purpose of this environmental health baseline is to provide the baseline human and ecological information necessary to assess the potential human and ecological risks associated with the proposed Project. This report describes the details of a human health PQRA and an ERA to support the development of the proposed Project. Quantifying the degree of potential human health risk posed by the presence of contamination at a subject site, the PQRA generally prescribes methods and assumptions. Consistent methods and assumptions ensures exposures and risks are not underestimated (Health Canada (HC) 2004a). The ERA is a formal set of scientific methods for estimating the probabilities and magnitudes of undesired effects on plants, animals, and ecosystems resulting from events in the environment, including the release of pollutants, physical modifications of the environment, and natural disasters (Fava et al. 1987). A more detailed discussion of PQRA and ERA results and findings are discussed in this document.

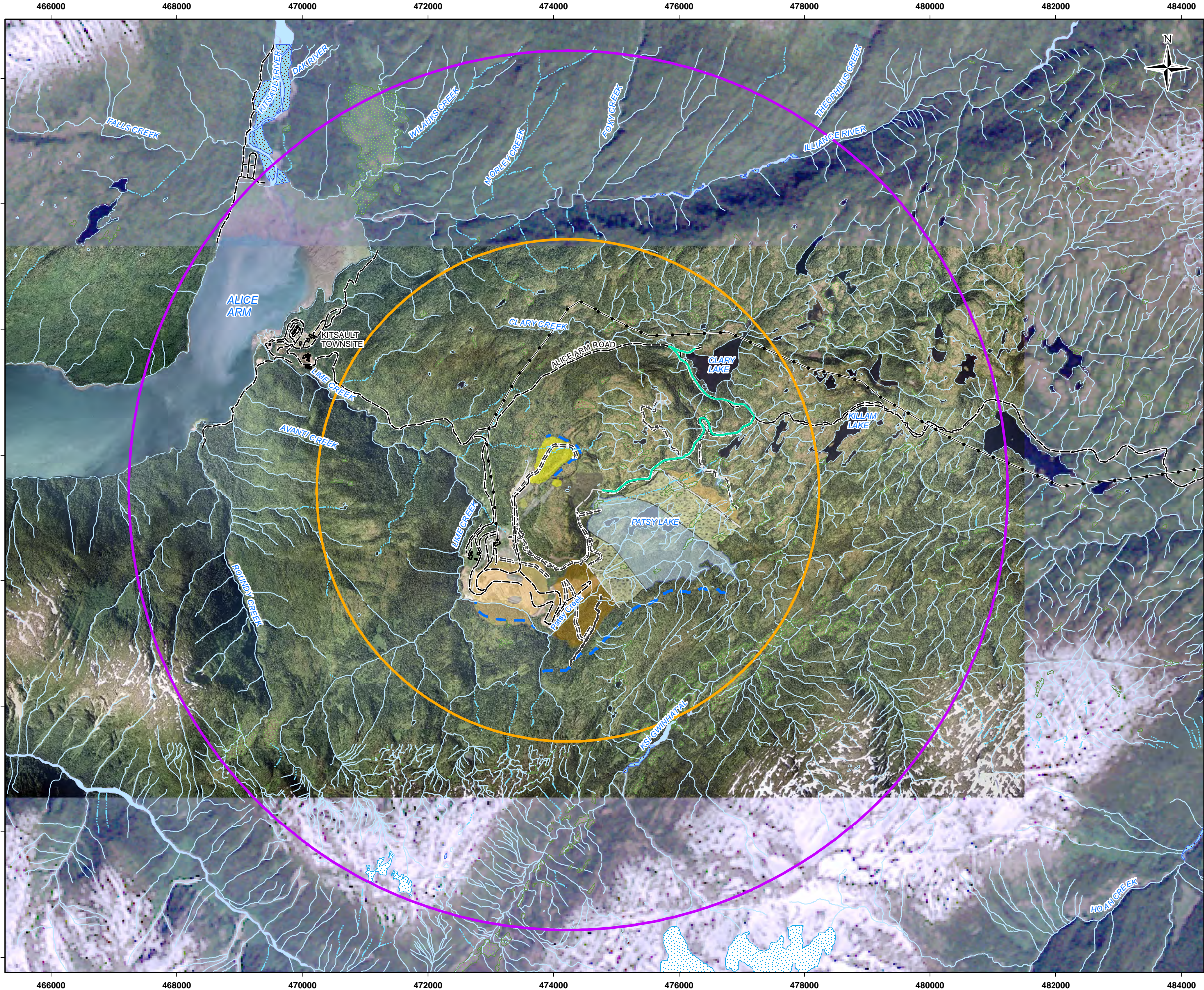
The baseline information in this report describes the environmental health of the Local Study Area (LSA) and Regional Study Area (RSA) surrounding the proposed Project. After providing a descriptive overview of the LSA and RSA surrounding the proposed Project, it then describes the information sources, scope, rationale, and methods used for evaluation of the current baseline conditions. COPC are identified and screening methods are described, with risks characterised and assessments presented for exposure and toxicity, followed by an uncertainty analysis conducted for toxicity and exposure assessments. The report goes on to examine the identified ecological risks, listing all COPC and describing the screening activities completed for soil, surface water, and sediments. Environmental

pathways are identified and the potential receptors are then presented, including the mammals, birds, amphibians, fish, soil and aquatic invertebrates, and terrestrial and aquatic plants that co-exist in the ecosystem. Exposure and toxicity assessments are also provided for mammals, birds, fish, benthic invertebrates, aquatic and terrestrial plants, and soil invertebrates. The report concludes with an evaluation of the level of certainty of this ecological risk assessment and offers a summary and conclusions reached during the process of evaluating the baseline environmental health of the proposed Project.

1.2 Spatial Boundaries

Avanti Kitsault Mine Ltd.'s (proponent) Application for an Environmental Assessment Certificate for the proposed Project, made under section 16 of the British Columbia *Environmental Assessment Act* (Application) identifies and presents the local and regional spatial boundaries to be used for the Environmental Assessment (EA) relative to each Valued Component (VC) and the rationale for selecting each boundary.

Spatial boundaries used to prepare this baseline report are consistent with those used to conduct the EA for the proposed Project, and consider, among other criteria, the extent of terrestrial, freshwater aquatic, and marine ecosystems and applicable resources that may potentially be affected by the proposed Project. Maps outlining the spatial extent of the proposed Project footprint, LSA, and RSA are provided below in Figure 1.1-1. The proposed Project footprint includes the on-site facilities described in Section 3.7 and the mine site roads. The LSA includes the proposed Project footprint plus buffer, encompassing the zone of potential direct effects specific to the proposed Project, while the RSA includes the proposed Project and surrounding region encompassing the zone of influence for potential effects specific to the proposed Project. The environmental health LSA has been determined to be the same as the air quality LSA (Section 6.2); air quality study areas define the LSA as 2 kilometres (km) wide surrounding the proposed Project footprint. The environmental health RSA has been determined to be the same as the air quality RSA (Section 6.2), which is defined as 2.5 km beyond the LSA and 4.5 km off the proposed Project footprint.





- Legend**
- Road
 - Transmission line
 - Diversion Ditch
 - Clary Lake Freshwater Pipeline
 - Process Plant
 - Open Pit
 - Ore Stockpile
 - Topsoil Stockpiles
 - Clary Lake Freshwater Intake
 - East Waste Rock Management Facility
 - Tailing Beach
 - TMF Supernatant Pond
 - Local Study Area
 - Regional Study Area



Reference

1. Base Data
 - Geobase 1:20,000 (TRIM)
 - Land and Resource Data Warehouse 1:20,000 (TRIM)
 - Image: Orthophoto 40cm
2. Project Infrastructure
 - Supplied by AMEC and Knight Piesold December 2010

CLIENT:  Avanti Kitsault Mine Ltd.		
PROJECT: Kitsault Mine Project		
Local and Regional Study Areas for Environmental Health		
DATE: September 2011	ANALYST: MY	Figure 1.2-1
JOB No: VE51988	QA/QC: RP	PDF FILE: 18-50-004_study_area.pdf
GIS FILE: 18-50-004.mxd		
PROJECTION: UTM Zone 9	DATUM: NAD83	

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1.3 Information Sources, Definitions, and Methods

According to the British Columbia Ministry of Environment's (BC MOE) document "Quantitative Human Health Risk Assessment – Phase 1 Review of Methods and Framework Recommendation" (BC MOE 1993), human health risk assessment is:

The process whereby all available scientific information is brought together to produce a description of the nature and magnitude of the risk associated with exposure of human receptors to an environmental chemical. This information includes:

- Identification of chemicals present in the environment;
- Toxicity assessment: an evaluation of the types of toxicity that the chemical can produce and an evaluation of the conditions of exposure – dose and duration – under which the chemical's toxicity can be produced;
- Exposure assessment: an identification of the conditions – dose, timing and duration – under which the population whose risk is being evaluated is or could be exposed to the chemical; and
- Risk characterisation: an estimation of the risk and uncertainty in that risk. (BC MOE 1993)

Defining human health risk as "the likelihood that a given exposure or series of exposures may have damaged or will damage the health of individuals," the US Environmental Protection Agency (US EPA) (1985) defines ecological risk assessment as:

The application of a formal framework, analytical process, or model to estimate the effects of human action(s) on a natural resource and to interpret the significance of those effects in light of the uncertainties identified in each component of the assessment process. Such analysis includes initial hazard identification, exposure and dose-response assessments, and risk characterisation.

Environmental risk, according to the US EPA, "is the chance that human health or the environment will suffer harm as the result of the presence of environmental hazards" (US EPA 1985).

ERAs are typically conducted using an iterative approach involving increasingly stringent tiers of evaluation. The ERA for the proposed Project was conducted according to ERA procedures as described in the "Recommended Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia" (BC Ministry of Environment, Lands and Parks 1998) and in the Canadian Council of Ministers of the Environment's (CCME) "A Framework for Ecological Risk Assessment" guidance and associated appendices and documents (CCME 1997a).

The approach adopted in evaluating the potential effects on human health of the proposed Project was consistent with the approach recommended by Health Canada (HC) (2007a), which has established a four-step paradigm for conducting health-based risk assessments.

This paradigm has also been adopted by Canadian federal and provincial health and environmental agencies (e.g., BC MOE, Atlantic Partnership in Risk Based Corrective Action Implementation (PIRI), and the Ontario Ministry of the Environment).

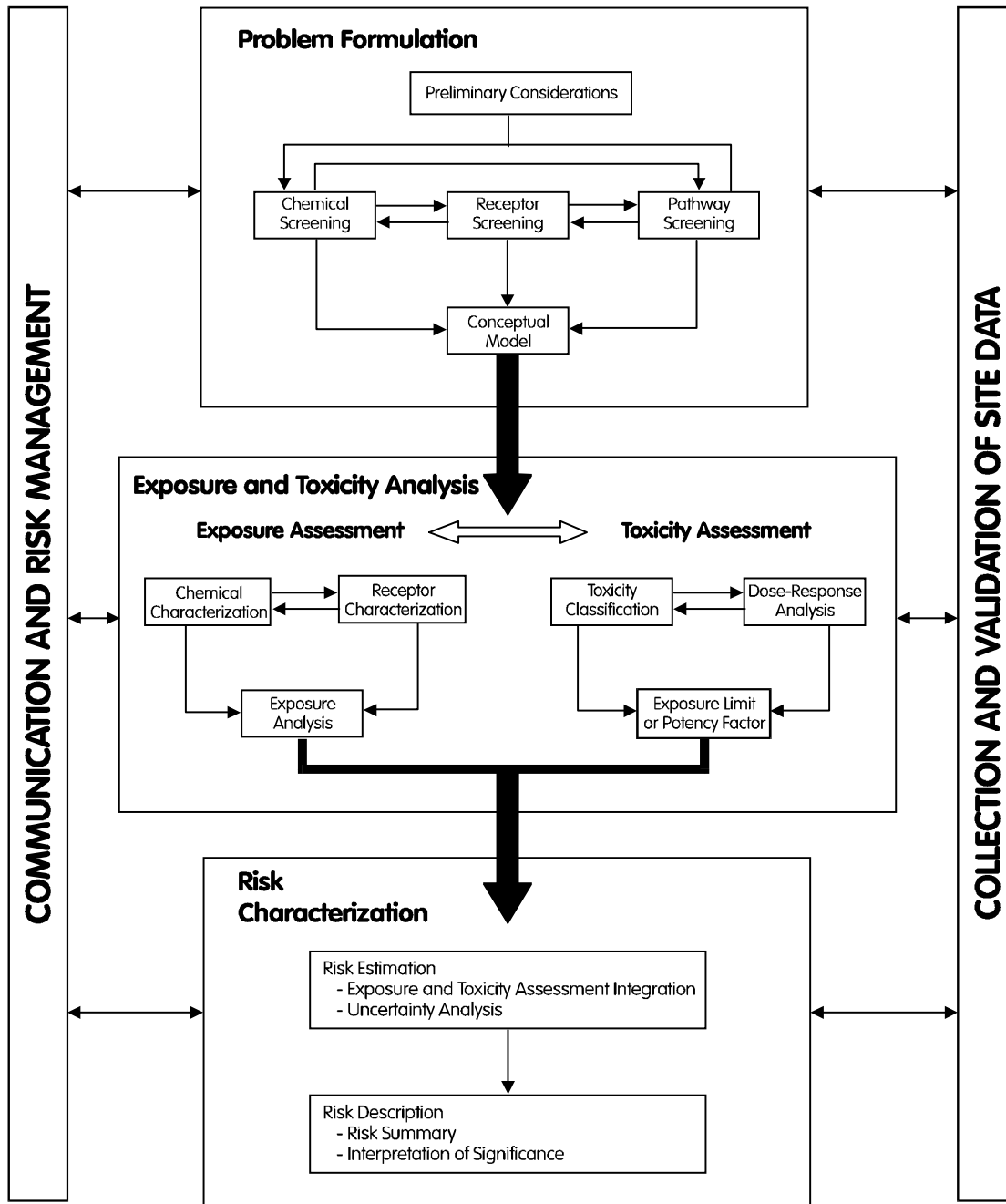
Conceptually, PQRA and ERA procedures both consist of the same four main steps:

1. **Problem formulation:** The three key elements of risk (receptors, COPC, and exposure pathways) are identified to determine qualitatively whether or not a potential risk exists at the site.
2. **Toxicity assessment:** Dose-response information for each COPC is reviewed and the acceptable doses each receptor may receive are estimated.
3. **Exposure assessment:** The potential exposure dose of each COPC that each receptor could receive from each complete exposure pathway is estimated. An exposure dose is a function of the COPC concentration in various environmental media, biological and life characteristics of the receptor, and chemical-specific parameters that influence COPC absorption.
4. **Risk characterisation:** The results of the toxicity assessment are integrated with the results of the exposure assessment to provide a quantitative assessment of health risk.

This shared risk assessment approach is further illustrated in Figure 1.3-1. According to this framework, the risk assessment progresses from a more qualitative first phase (problem formulation), through exposure and toxicity analysis, and culminates in a final quantitative risk characterisation. Based on the risk characterisation, baseline human and / or ecological health can then be assessed based on the magnitude of the predicted risk, the degree of uncertainty, and the potential consequences to environmental health.

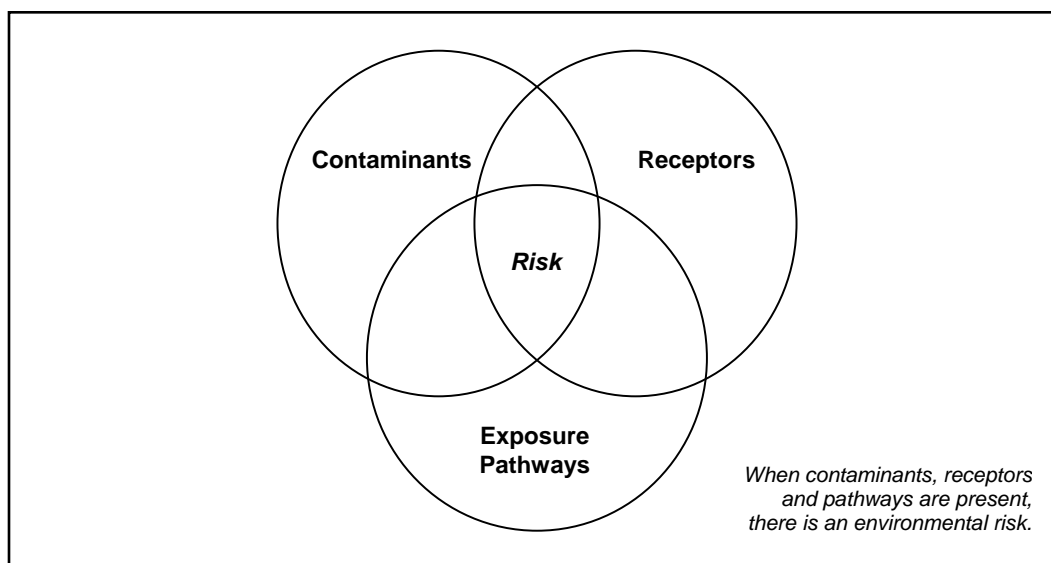
The problem formulation step of a risk assessment determines qualitatively whether or not a potential risk may exist, and involves identifying the three key elements of risk: COPC; receptors; and exposure pathways via which a receptor could be exposed to COPC. If any one of these three key elements of risk is missing, there can be no risk. The following Figure 1.3-2 illustrates the basis for environmental risks.

The PQRA and ERA evaluated each of these factors in order to determine the degree of overlap (i.e., risk) associated with the exposures to COPC.



Source: HC. 2007. Federal Contaminated Site Risk Assessment In Canada. Part V: Guidance On Complex Site Specific Human Health Risk Assessment Of Chemicals (SSRACHEM). Contaminated Sites Division, Safe Environments Programme.

Figure 1.3-1: Risk Assessment Framework



Source: HC 2007a

Figure 1.3-2: Basis for Environmental Risks

COPC and receptors were selected based entirely on information from baseline data collected from other disciplines, including:

- Hydrology, Surface Water, and Sediment Quality;
- Freshwater Aquatics;
- Marine Aquatic Resources;
- Terrestrial Environment;
- Wildlife Environment; and
- Human Health.

Air emission data from the proposed Project area were not collected during baseline sampling and therefore, were not available during the selection of COPC and receptors.

Environmental health involves integrating information from each of the disciplines outlined above, and as such, a single, worst-case scenario risk assessment was conducted. Risks were assessed using the most conservative information available from each of the disciplines. If risks are acceptable for the worst-case scenario, then risks for all other scenarios will also be acceptable.

1.4 Scoping, Issues Identification and Confirmation

The environmental health LSA and RSA include the communities and occupied areas near the proposed Project where sensitive receptors reside and could be affected by the air emissions from past or future mining activities. The LSA and RSA is similar to that of air quality study areas (described in Section 6.2, Atmospheric Environment). Air quality study areas have defined the LSA as a 2-km-wide area surrounding the proposed Project footprint and the RSA as a 2.5 km zone beyond the LSA (i.e., 4.5 km off the proposed Project footprint).

COPC associated with the proposed Project are relevant to environmental health as they could adversely affect the long-term health of humans and / or non-human organisms. Emphasis is placed on identifying metal COPC, as metals usually pose the most potential for chronic health risks at mines due to their effects on human and non-human health. Mining projects often have high metals concentrations; metals in mining wastes and dust generated from mining activities can often persist in the environment. The environmental health component provides information, including chemical analyses and modelling results, and data through exposure modelling calculations to assess effects on human health.

Risk-based guidelines are purposely set by regulatory agencies to be conservative, so that they can quickly and easily be used in screening procedures. They provide confidence that if the guidelines are not exceeded, there will be no unacceptable risks to human or ecological receptors, regardless of the exposure scenario. The level of detail of the risk assessment adopted for a particular situation should be equal to the degree and extent of potential effects to ecological receptors, and may progress to a more detailed assessment where evidence indicates that adverse effects may occur. If the 95th percentile of the baseline concentration of a metal was less than its respective screening criterion, then the metal was excluded as a COPC.

If the 95th percentile of the baseline concentration of a metal is greater than its respective screening criterion, then the metal was included as a COPC. The conservatism of each screening guideline is such that an exceedance does not necessarily mean there is an unacceptable risk; rather, an exceedance simply serves to identify the chemical as being of potential concern so that risks are quantitatively assessed using site-specific exposure assumptions.

1.5 Human Health Preliminary Quantitative Risk Assessment

1.5.1 Problem Formulation

1.5.1.1 Screening and Identification of Chemicals of Potential Concern

In total, 17 metals were included in the COPC screening procedure, and five metals were retained as COPCs for the PQRA. The results of the COPC screening procedure are summarised in Table 1.5-1, and each metal included in the COPC screening procedure is discussed sequentially in the subsections that follow. A summary of all available soil and surface water data is provided in Appendix 1. It is important to note that each of the COPC

retained in the risk assessment are naturally occurring elements. Elements can be neither created nor destroyed, and human activities only serve to redistribute these naturally present metals, some of which have naturally high baseline concentrations.

1.5.1.2 Screening for Soil

Baseline soils data were assessed using the following federal and provincial regulatory guidelines for the purposes of identifying COPC:

- *BC Contaminated Sites Regulation (BC CSR)* (Government of BC 2011) of the *BC Environmental Management Act (BC EMA)* (Government of BC 2003), Schedule 4 Generic Numerical Soil Standards, for park and residential use; and
- Canadian Environmental Quality Guidelines: “Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health” (CCME 2007), assuming a residential/parkland land use. According to the HC’s Responsible Authority (RA) guidance documents (2007), of the four land use categories (Agricultural Land, Commercial Land, Industrial Land and Residential / Parkland) the category of Residential / Parkland is the only land use category that relates to a natural, undisturbed land.

Identification of COPC in soil for the human health PQRA for the proposed Project is provided in Table 1.5-1.

For the Soil Quality Guidelines (SQGs), the CCME developed both human health (SQG_{HH}) and ecological (SQG_E) values based on various exposure pathways, and selected the lower of the two values to represent the final SQG. As the PQRA is restricted to the evaluation of human receptors, reported concentrations were compared to the SQG_{HH} component values, where possible, for the purposes of selecting final contaminants of potential concern in soil for the proposed Project.

Table 1.5-1: Screening of Chemicals of Potential Concern in Soil and Surface Water

Metal COPC	Soil (mg/kg) n=?			Surface Water (mg/L) n=?			
	95 th Percentile of Baseline Concentration ^a	Screening Guideline		95 th Percentile of Baseline Concentration ^d	Screening Guideline		
		CCME ^b	Government of BC ^c		Health Canada ^e	Government of BC ^{f,g}	Adjusted US EPA (PRGs) ^h
Antimony	5.0	20	20	0.00044	0.006	0.006 (g)	0.03
Arsenic	29.0	12	n/a	0.00047	0.01	0.025 (g)	0.009
Barium	175.5	500	n/a	0.0658	1	1 (g)	0.52
Beryllium	0.84	4	4	0.00025	n/a	n/a	0.015
Cadmium	0.97	10	n/a	0.0010	0.005	0.005	0.0036
Chromium	97.0	64	n/a	0.00025	0.05	0.05 (g)	0.022
Cobalt	26.2	50	50	0.00018	n/a	n/a	0.15
Copper	49.2	63	n/a	0.0014	1	0.5 (f)	0.3
Lead	48.0	140	n/a	0.00065	0.01	0.01 (g)	NA
Mercury	0.25	6.6	n/a	0.000005	0.001	0.001 (g)	0.0022
Molybdenum	94.9	10	10	0.322	n/a	0.25 (f)	0.036
Nickel	99.4	50	100	0.0021	n/a	n/a	0.015
Selenium	1.4	1	3	0.0003	0.01	0.01 (f)	0.036
Silver	7.2	20	20	0.0002	n/a	n/a	0.036
Thallium	0.5	1	n/a	0.0002	n/a	n/a	0.00048
Vanadium	98.1	130	200	0.0005	n/a	n/a	0.0072
Zinc	163.5	200	n/a	0.016	5	5 (f)	2.2

Note: (a) 95th percentile of baseline soil concentrations. Concentrations provided by Rescan and AMEC Soil Quality Group. (b) Canadian Environmental Quality Guidelines: "Canadian Soil Quality Guideline for the protection of human health" (CCME 2007). Value represents guideline protective of residential / parkland uses. (c) BC *Environmental Management Act, Contaminated Sites Regulation*, Schedule 4 Numeric Soil Standards (Government of BC 1997). (d) 95th percentile of baseline water concentrations. Concentrations provided by Rescan and AMEC Water/Sediment Quality Group. (e) HC drinking water quality guidelines (HC 2008). (f) BC Water Quality Guideline (maximum) for Drinking Water for the Protection of Human Health (BC MOE 2010). 30-day average guideline not available. (g) BC Water Quality Guideline (interim maximum) for Drinking Water for the Protection of Human Health (BC MOE 2010). 30-day average guideline not available. (h) US EPA Region IX Preliminary Remediation Goals for tap water (US EPA 2004) were adjusted according to CCME when using guidelines from other jurisdictions.

Highlighted cell indicates metal is a COPC in specified medium for PQRA. Metal was selected as a COPC: in soil if the 95th percentile of the baseline concentration exceeded screening guideline in soil ; and in water if the 95th percentile of the baseline concentration exceeded screening guidelines in water.

BC - British Columbia; CCME - Canadian Council of Ministers of the Environment; COPC - Chemical of Potential Concern; mg/kg - milligrams per kilogram; mg/L - milligrams per litre; PRG - Preliminary Remediation Goal

1.5.1.3 Screening for Surface Water

The reported concentration data for surface water were assessed and evaluated for the purposes of identifying COPC using:

- BC “Water Quality Guidelines” (BC MOE 2010); and
- “Guidelines for Drinking Water Quality” (HC 2008).

In the absence of applicable Canadian guidelines, the screening for the COPC used the US EPA “Region IX PRGs” for tap water guidelines (US EPA 2004b). US EPA guidelines have been adopted to evaluate water because for some chemicals other jurisdictions’ guidelines were not available.

The identification of COPC in surface water for the PQRA is provided in Table 1.5-1.

1.5.1.4 Summary of Identified Chemicals of Potential Concern

Based on the screening conducted, the following metals have been carried forward in the PQRA as COPC in soil for the proposed Project:

- Arsenic;
- Chromium;
- Molybdenum;
- Nickel; and
- Selenium.

Based on the screening conducted, the following metal has been carried forward in the PQRA as a COPC in surface water.

- Molybdenum.

1.5.1.5 Identification of Potential Receptors

Since there is human habitation in the area, it was conservatively assumed that there are residential land uses in the vicinity of the proposed Project area. It was assumed that there are cabins located in the area which are used as temporary bases for subsistence and recreational activities (i.e., hunting, trapping, and fishing). Whether these cabins represent potential year round residential locations is unknown, but it was assumed that this was the case.

In order to characterise the risks associated with contamination in the region, one must first identify the receptors at the site that would be exposed to COPC. Because of the unrestricted access in the region, it would be expected that potential receptors could include all age groups (as defined by HC 2007a), including infants (0 - 6 months), toddlers (7 months - 4 years), children (5 years - 11 years), teens (12 years - 19 years), and adults

(20+ years). Depending on age, lifestyle, and genetic and environmental factors, different individuals will have vastly different potentials to assimilate metals into their bodies. To account for this uncertainty, health risks were evaluated using biological characteristics for the most conservative age class for a given category of metal (HC 2007a).

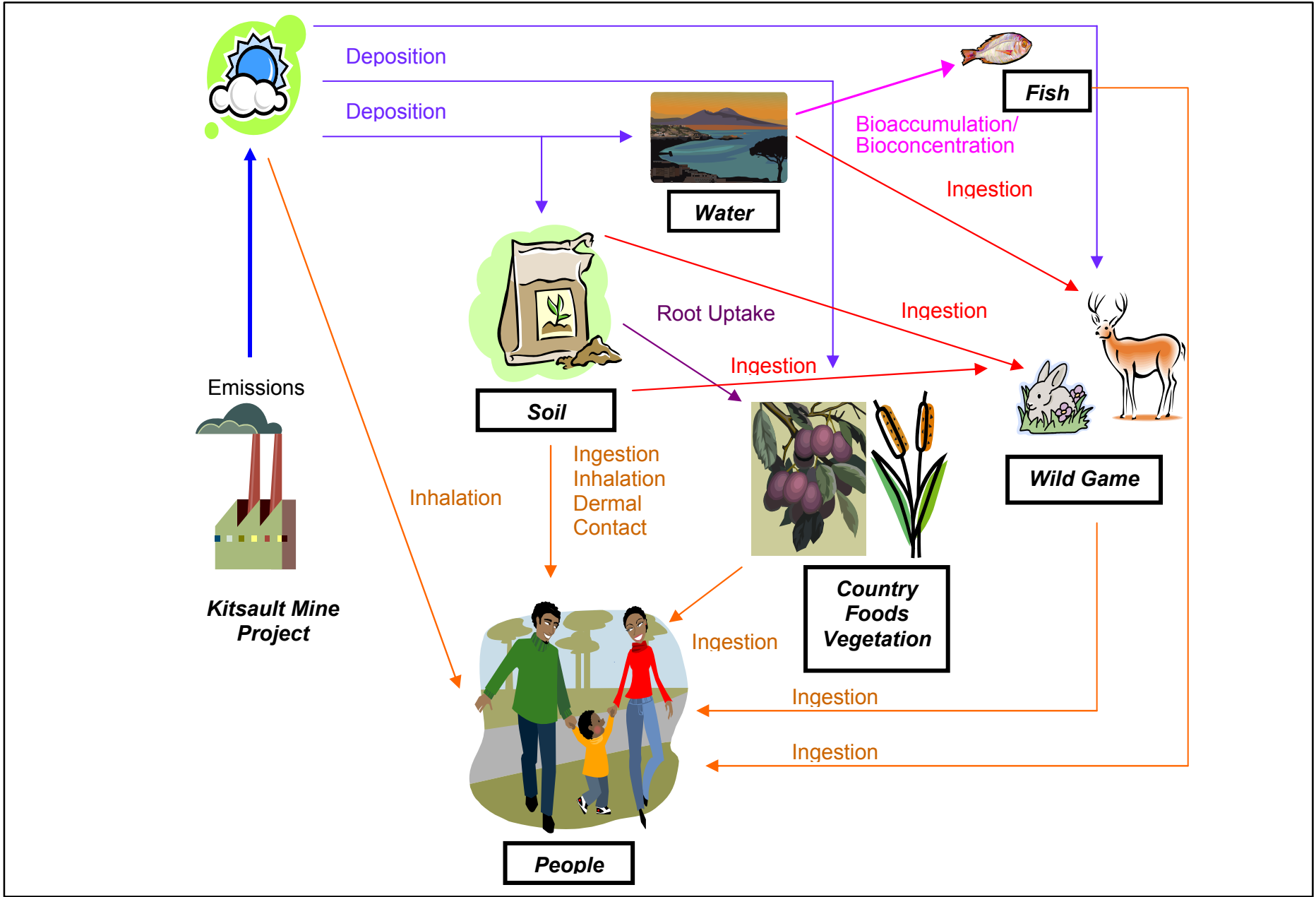
For the purpose of this PQRA for the proposed Project, it was assumed that a local Aboriginal resident from one of the four nearby Nisga'a Villages was identified as the potential receptor of concern. The critical receptor was assumed to be an Aboriginal child accompanying an adult during traditional harvesting of country foods (i.e., hunting, fishing) or recreational activities (i.e., hiking) in the vicinity of the proposed Project.

Health risks from non-carcinogenic metals were evaluated using toddler characteristics, because toddlers ingest more soil and water per unit body mass, and have higher rates of hand-to-mouth activities (e.g., increasing their exposure to metals in soil) than any other age class. This is an extremely conservative scenario because toddlers are not expected to be in the vicinity of the proposed Project during operations and could not easily access the proposed Project site at closure; thus, they would not be participating in activities that could lead to ingestion of soil.

Health risks from carcinogenic metals are typically evaluated using adult characteristics because most cancers develop over a longer period of time (i.e., long latencies), usually over the entire lifespan. Arsenic was identified as the lone carcinogenic metal associated with the proposed Project.

1.5.1.6 Identification of Operable Pathways

After identifying the receptors at the site that could be exposed to COPC, the method by which the receptor could be exposed to the contamination (i.e., the source to receptor exposure pathway) must be identified. Pathways are considered to be complete when there is a potential for the receptor to be exposed to a COPC. Incomplete pathways represent situations where exposure or contact with the COPC is unlikely to occur and therefore poses no risk to the receptor. An analysis of the potential exposure pathways for receptors at the site is summarised in the form of a HC Conceptual Site Exposure Model (Figure 1.5-1). The potential exposure media in the area of the proposed Project include soil, surface water, vegetation, fish, and wild game.



Y:\GIS\Projects\VE\VE51988 - Kitsault Mapping\18_Environmental-health\18-50-003.mxd

Note: All species depicted are for illustrative purposes only and may not match those selected VCs for the proposed project

CLIENT  Avanti Kitsault Mine Ltd.		ANALYST: MY QA: JK DATUM: N/A PROJECTION: N/A SCALE: N/A
AMEC Earth & Environmental 2227 Douglas Road, Burnaby, B.C., V5C 5A9 Tel. 604-294-3811 Fax 604-294-4664		

PROJECT	Kitsault Mine Project
TITLE	Human Health Conceptual Site Exposure Model

REV. NO.:	A
DATE:	December 2010
PROJECT NO.:	VE51988
FIGURE No.	1.5-1

Human receptors can be potentially exposed to COPC in the various environmental media by the following pathways (HC 2007a):

- Inhalation of emissions:

This exposure pathway was considered complete (i.e., exposure pathway could result in exposure to receptors at a point of exposure under a potential exposure scenario), since particulate matter (PM) and emissions will be generated from heavy equipment and mining activities. However, baseline air data were not collected and are not available at this time. As discussed in the Air Quality Baseline Report (Appendix 6.2-A), long-term ambient monitoring at near-by sites has not been implemented because of lack of anthropogenic activities, the remote location with difficult access, and likely ultra-low concentrations of criteria air contaminants (CAC) which would be below the detection limit of a typical portable monitoring station. Developing background concentrations by means of air dispersion modelling is also not feasible for this proposed Project because of a lack of specific emission sources.

- Ingestion of groundwater:

Based on the “Hydrogeology and Watershed Model” completed in January of 2011 by Knight Piésold Consulting Ltd. (Knight Piésold) (Appendix 6.5-E), two wells were identified on the BC Water Resources Atlas that were within the proposed Project area. One well located near the northwest of the Kitsault Pit is classified as commercial and industrial and it is unlikely that the well is operational. The other well was identified as a drinking water extraction point and is an active water supply for the Kitsault Townsite. Given the distance of the well from the proposed Project, it is likely that any potential effects would be minimal. Therefore, based on this consideration, the human ingestion of drinking groundwater was identified as an incomplete pathway and was not considered in the assessment;

- Ingestion of surface water:

There are currently no potable uses of surface water in the vicinity of the proposed Project. However, because of activities being conducted by recreational users and the reliance on country foods by Aboriginal groups, people may be present in the area for extended periods of time and ingesting surface water. Individuals that may be engaging in such activities may be consuming water from the local surface water bodies. Under such circumstances, they may be exposed to COPC in the water for short periods of time and the surface water pathway was considered complete. Therefore, this exposure pathway will be further considered in the assessment;

- Inadvertent ingestion of soil:

There are currently no restrictions for site access; therefore, anybody can enter the site and be exposed to the soil through their normal activities on the site. Incidental exposure via soil ingestion may occur when residual soil particles remain on the hands and are accidentally ingested. Other possible routes of soil ingestion include

exposures through respiratory actions. Therefore, this route of exposure was considered a complete pathway and requires further assessment;

- Inhalation of re-suspended soil particles:

Contaminants present in surface soils may potentially be re-suspended into the air as a result of weather conditions, vehicle traffic, etc. People who are in the area (i.e., recreational users or residents) may be exposed to chemicals in the soil as they inhale the airborne particles. Since areas of the RSA are exposed (i.e., not under asphalt or concrete), the re-suspension of soil particles would likely occur.

Therefore, a complete exposure pathway exists and requires further assessment;

- Dermal contact with soil:

People within the RSA may potentially come in direct contact with the surface soil if they touch the soil directly or indirectly. Chemicals adsorbed onto the soil particles may be redistributed through the re-suspension of the soil particles. Deposition of these soil particles onto the surface soil can occur distant to the site and therefore, off-site receptors may come in direct contact. As the soil particles adhere to the skin of the receptors, chemicals in the particles may be absorbed through the epidermal layer of the skin. People may then be exposed to the chemicals present in the soil via this complete exposure pathway. This route of exposure requires further assessment;

- Ingestion of vegetation:

Aboriginal groups engage in the harvesting of native vegetation (e.g., blueberries, Labrador tea) for subsistence. Chemicals deposited in the soil from the air emissions of the proposed Project may potentially be accumulated in the plant tissues. Therefore, people may be exposed to these chemicals when they consume the harvested vegetation. The ingestion of vegetation was considered a complete exposure pathway and requires further assessment;

- Ingestion of wild game:

Hunting for wild game is a common occurrence in the region. Wild game is consumed for subsistence purposes. Wild game could be exposed to chemicals emitted from the proposed Project through direct inhalation of the chemicals in the air, ingestion of the soil and water, and consumption of vegetation. Chemicals that accumulate in wild game tissues represent a potential source of exposure for human receptors that consume the wild game. This was considered a complete exposure pathway and requires further assessment; and

- Ingestion of fish from the RSA:

The major surface water bodies in the region have the potential to support a fishery. Aboriginal people are anticipated to fish these surface water bodies and may rely on the fish for subsistence. Aside from the provincial and federal regulations for fishery management, there are no limits on the collection and consumption of fish in the

area. Therefore, this exposure pathway was considered complete and risks associated with the consumption of fish will be further assessed.

1.5.2 Exposure Assessment

The receptors are assumed to be an adult Aboriginal resident accompanied by a young Aboriginal child who may participate in traditional (i.e., hunting) and recreational (i.e., hiking) activities within the region of the proposed Project. The exposure pathways that are considered complete for the receptors and included in the exposure assessment are:

- Soil direct contact (ingestion and dermal contact);
- Inhalation of dust;
- Ingestion of surface water;
- Ingestion of traditional plant food (berries, roots and leaves);
- Ingestion of wild game; and
- Ingestion of fish.

Soil, surface water, vegetation, and fish sampling was completed to characterise the concentrations of chemicals in the exposure media in the vicinity of the proposed Project. The programs involved collecting soil, surface water, vegetation, berries, and fish samples from across the region. Soil samples were collected from the upper 1 metre (m) of organic or mineral matter. Surface water samples and fish were collected from both streams and lakes near the proposed Project. Vegetation samples that were available for collection and considered suitable for country foods assessment were berry producing species in the genus *Vaccinium*.

Soil, surface water, vegetation, and fish samples were collected from the locations reported in their respective baseline reports. The analysis of baseline soil, surface water, vegetation, and fish data can be found in Appendix 1.

1.5.2.1 Characterisation of Potential Receptors

As previously mentioned in Section 1.5.1.5, given the use of the property, a local Aboriginal resident from one of the Nisga'a Villages was identified as the potential receptor of concern in the PQRA. The critical receptor was considered to be a young child accompanying an adult during traditional hunting or recreational activities in the vicinity of the proposed Project, and who may spend all their time in or around the area.

The proposed Project site is accessible to anyone, even children accompanying their parents. As mentioned earlier, the age groups "toddler" and "adult" have been selected as a reasonable guide to assess the characteristics of the receptors.

For the purpose of the PQRA, the exposure scenario assumes that local Aboriginal residents are living on-site and are being exposed to the surrounding environment 24 hours per day, 365 days a year.

These assumptions provide the basis of the exposure assessment. Table 1.5-2 has been adapted from HC (2007a) and provides a summary of the characteristics of potential receptors at the proposed Project. With respect to dermal exposures, it was assumed that receptors would be exposed through direct dermal contact with an individual's hands, arms, and legs.

Table 1.5-2: Summary of Human Health Receptor Characteristics for the Proposed Project

Receptor Characteristic	Receptor Parameters		Source
	Toddler	Adult	
Age	7 months - 4 years	>20 years	HC 2007a
Exposure duration (years)	4.5	60	Based on 80 year lifespan
Body weight (kg)	16.5	70.7	Richardson 1997
Soil ingestion rate (g/d)	0.08	0.02	CCME 1996a
Surface water ingestion rate (L/d)	0.6	1.5	Richardson 1997
Inhalation rate (m ³ /d)	9.3	15.8	Richardson 1997; and Allan and Richardson 1998
Food ingestion (g/d)			
Roots and traditional below-ground plants	1	3	Wein 1989
Traditional above-ground plants	1	3	Wein 1989
Berries	5	23	Wein 1989
Fish ¹	95	220	Richardson 1997
Skin surface area (cm²)			
Hands	430	890	Richardson 1997
Arms (upper and lower)	890	2,500	Richardson 1997
Legs (upper and lower)	1690	5,720	Richardson 1997
Total area	3010	9,110	Richardson 1997
Soil loading to exposed skin (mg/cm²)			
Soil adhesion to skin (based on hands)	0.1	0.1	Kissel et al. 1996; 1998

Note: ¹ Fish ingestion rate for Canadian First Nations Populations; CCME - Canadian Council of Ministers of the Environment; cm² - centimetres squared; g/d - grams per day; HC - Health Canada; kg - kilogram; L/d - litres per day; m³/d - cubic metres per day; mg/cm³ - milligrams per cubic centimetre

1.5.2.2 Exposure Point Concentrations

Exposure Point Concentrations (EPCs) are chemical concentrations in soil, surface water and foods to which receptors were assumed to be exposed. For the purpose of the PQRA,

EPCs in soil surface water and country foods were assumed to be equivalent to the 95th percentile concentration detected within the vicinity of the proposed Project. The use of the 95th percentile concentration is consistent with HC's policy for conducting human health PQRA (HC 2007a). A summary of baseline soil, surface water, and country foods data can be found in Appendix 1.

1.5.2.3 Estimation of Potential Exposure Via Incidental Ingestion and Dermal Contact with Soil

In this assessment, dermal exposures were summed with oral exposures. In general, for the incidental ingestion pathway, the exposure to soil depends on the amount of soil ingested on a daily basis (milligrams per day (mg/d)), and the number of days per year that exposures are likely to occur (i.e., the frequency and duration of exposure).

The general equation used to calculate the dose due to soil ingestion and dermal contact is as follows:

Soil Ingestion:

$$ADD = \frac{C_s \cdot IR \cdot F \cdot RAF_o \cdot ED \cdot CF}{AT \cdot BW}$$

- Where:
- ADD = Average Daily Dose
 - C_s = Chemical Concentration in Soil (milligrams per kilogram (mg/kg) or micrograms per gram (µg/g))
 - IR = Ingestion Rate (mg/d)
 - F = Fraction from Site (unitless)
 - RAF_o = Relative Absorption Factor – Oral (unitless)
 - SA = Skin Surface Area (centimetres squared (cm²)/event)
 - AF = Soil Adherence Factor – Dermal (milligrams per centimetres squared (mg/cm²))
 - FAS = Fraction Absorbed from Site (unitless)
 - RAF_D = Absorption Adjustment Factor – Dermal (unitless)
 - EFD = Exposure Frequency – Dermal (event/day)
 - ED = Days per Year Exposed / 365 days/year
 - CF = Conversion Factor (kilograms per milligram (kg/mg))
 - AT = Averaging Time (365 days/year X 4.5 years for toddler or 60 years for adult)
 - BW = Body Weight (kilograms (kg))

Soil Dermal Contact:

$$ADD = \frac{C_s \cdot SA \cdot AF \cdot FA \cdot RAF_D \cdot ED \cdot CF}{AT \cdot BW}$$

- Where:
- ADD = Average Daily Dose
 - C_s = Chemical Concentration in Soil (mg/kg or µg/g)

- SA = Skin Surface Area (cm²/event)
- AF = Soil Adherence Factor – Dermal (mg/cm²)
- FAS = Fraction Absorbed from Site (unitless)
- RAF_D = Absorption Adjustment Factor – Dermal (unitless))
- ED = Days per year exposed / 365 days/year
- CF = Conversion Factor (kg/mg)
- AT = Averaging time (365 days/year X 4.5 years for toddler or 60 years for adult)
- BW = Body Weight (kg)

Values for the parameters above are outlined in Table 1.5-2.

1.5.2.4 Estimation of Potential Exposure Via Inhalation of Dust

The local Aboriginal receptor may inhale dust as a result of disturbance of the soil. The general equation used to estimate the dose to receptors via inhalation of dust is the following:

$$ADD = \frac{C_s \cdot P_{air} \cdot IR \cdot RAF_I \cdot ET \cdot ED}{AT \cdot BW}$$

- Where:
- ADD = Average Daily Dose (mg/kg/day)
 - C_s = Chemical Concentration in Soil (mg/kg)
 - P_{air} = Particulate Concentration in Air (kilograms per cubic metres (kg/m³))
 - IR = Inhalation Rate (cubic metres per hour (m³/hr))
 - RAF_I = Relative Absorption Factor – Inhalation (unitless)
 - ET = Hours per Day exposed (hour/day)
 - ED = Days per Year Exposed / 365 days/year
 - AT = Averaging time (365 days/year X 4.5 years for toddler or 60 years for adult)
 - BW = Body Weight (kg)

Values related to the receptor exposure parameters are outlined in Table 1.5-2.

To determine the concentration of a COPC present in dust in air, HC notes that COPC concentration in the dust particle should be assumed to be equal to the concentration present in soil. HC (2007a) notes that an average airborne concentration of respirable particulate matter should be assumed to be 0.76 micrograms per cubic metres (µg/m³).

1.5.2.5 Estimation of Potential Exposure Via Ingestion of Surface Water

The equation used to estimate potential exposures to the local Aboriginal resident via ingestion of surface water is the following:

$$ADD = \frac{C_w \cdot IR \cdot RAF_o \cdot ED}{AT \cdot BW}$$

Where:

- ADD = Average Daily Dose (mg/kg/day)
- C_w = Chemical Concentration in surface water (mg/L)
- IR = Ingestion Rate of water (mg/L)
- RAF_o = Relative Absorption Factor – Oral (unitless)
- ED = Days per Year Exposed / 365 days/yr
- AT = Averaging Time (365 days/year X 4.5 years for toddler or 60 years for adult)
- BW = Body Weight (kg)

Values for each of the parameters used in this equation are presented in Table 1.5-2.

1.5.2.6 Estimation of Potential Exposure Via Ingestion of Contaminated Food (Produce, Wild Game and Fish)

The equation used to estimate potential exposures to the local Aboriginal resident via ingestion of contaminated foods is the following:

$$ADD = \frac{C_F \cdot IR \cdot RAF_o \cdot ED}{AT \cdot BW}$$

Where:

- ADD = Average Daily Dose (mg/kg/day)
- C_F = Chemical Concentration in Food (mg/kg)
- IR = Ingestion Rate for food (kg/day)
- RAF_o = Relative Absorption Factor – Oral (unitless)
- ED = Days per Year Exposed / 365 days/year
- AT = Averaging Time (365 days/year X 4.5 years for toddler or 60 years for adult)
- BW = Body Weight (kg)

1.5.3 Toxicity Assessment

The purpose of the toxicity assessment is to identify both the types of adverse health effects a chemical may potentially cause as well as the relationship between the magnitude of the COPC to which receptors may be exposed (dose) and the likelihood of an adverse effect (response). This is called the dose-response relationship. In addition, toxicity assessment involves the classification of the potential toxicological effects of chemicals as carcinogenic or non-carcinogenic, and the subsequent estimation of the amounts of chemicals that can be received by human receptors without experiencing adverse effects on their health. A toxicity assessment is conducted for all COPC that are screened into the assessment and considers possible modes of toxicity associated with following different routes and durations of exposure. The toxicity assessment provides an estimate of how much chemical exposure may occur without unacceptable health effects occurring from lifetime exposure (or significant portion of a lifetime), and provides a basis to interpret exposure rates.

1.5.3.1 Carcinogens

Compounds with known or potential carcinogenic effects do not have a dose below which no adverse effect occurs. For carcinogens, the exposure limit is called a slope factor, which is an upper-bound estimate of the probability of a carcinogenic response per unit intake of a constituent over a lifetime. According to the US EPA (2010), either central or upper-bound estimates may be appropriate for evaluation of the carcinogenic risk; or the selection of the estimate to be used is dependent on the type of assessment that may be required. Central estimates are applicable for characterising a typical individual's risk, while upper-bound estimates conservatively exaggerate the risk to ensure that the risk is not underestimated if the underlying model is correct. Central estimates are useful for assessing aggregate risk across a population and for comparing or ranking environmental hazards. Upper-bound estimates provide information about the precision of the comparison or ranking. Cancer slope factors from HC (2007b) and US EPA (2010) are used in the current assessment. The Toxicological Reference Value (TRV) utilised in this risk assessment for the carcinogenic COPC is summarised in Table 1.5-3.

Table 1.5-3: Toxicological Reference Values

Metal COPC	Oral TRV (mg/kg/d)	Dermal TRV (mg/kg/d)	Chronic Inhalation TRV (mg/m ³)	Inhalation TRV (mg/kg/d)	Cancer Slope Factor		
					Oral	Dermal	Inhalation
					(1/mg/kg/d)		(1/mg/m ³)
Arsenic	0.0003(a)	0.0003 (d)	0.000015 (f)	0.95 (e)	1.8 (a)	1.8 (d)	28 (a)
Chromium	0.001 (a)	0.001 (d)	0.0001 (b)	0.000056 (e)	n/a	n/a	n/a
Molybdenum	0.023 (a)	0.023 (d)	0.005 (c)	0.0028 (e)	n/a	n/a	n/a
Nickel	0.02 (b)	0.02 (d)	0.000018 (a)	0.00001 (e)	n/a	n/a	n/a
Selenium	0.0062 (a)	0.0062 (d)	0.0002 (c)	0.00011 (e)	n/a	n/a	n/a

Note: (a) HC (2007a); (b) US EPA (2010) – IRIS; (c) TCEQ (2010); (d) Extrapolation from oral TRV; (e) Extrapolation from inhalation TRV; (f) California Environmental Protection Agency (CalEPA) (2010); COPC - Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; mg/m³ - milligrams per cubic metre; n/a - not applicable

1.5.3.2 Non-Carcinogens

Compounds with known or potential non-carcinogenic effects are assumed to have a dose below which no adverse effect occurs, or conversely, above which an effect may (but not always) be seen. This toxicological reference value or dose is called the threshold dose. In laboratory experiments, this dose is known as the No Observable Adverse Effect Level (NOAEL). The lowest dose at which an adverse effect is seen is called the Lowest Observable Adverse Effect Level (LOAEL). HC has used these types of values to develop TRVs for chronic exposures to compounds with potential non-carcinogenic effects. For compounds with potential non-carcinogenic effects, the TRV provides reasonable certainty that if the specified exposure dose is below the threshold, then no non-carcinogenic health effects are expected to occur even if daily exposure were to occur for a lifetime.

The TRVs for non-carcinogens utilised in this risk assessment are summarised in Table 1.5-3. For compounds where TRVs are not available from HC, current toxicological information is available from a number of different jurisdictions including the Texas Commission on Environmental Quality (TCEQ) (2010) and the US EPA (2010).

It should be noted that the metals may exhibit different toxicological mechanisms of action depending on the route (i.e., ingestion, dermal, inhalation) of exposure. Different TRVs are often provided for oral and inhalation exposure routes, depending on whether toxicity studies have been conducted and assessed for that route. In general, very few studies are available for dermal TRVs.

The oral TRV value was adopted for all compounds that didn't have a published dermal TRV.

These exposure limits have been used in conjunction with the exposure estimates as calculated in Appendix 2 to characterise potential risks associated with exposures to each of the COPC for the identified human receptors (e.g., hunter or hiker).

1.5.3.3 Relative Absorption Factors

To estimate the potential risk to human health that may be posed by the presence of a COPC in various environmental media (such as soil, sediment, water or air), it is first necessary to estimate the human exposure dose of each COPC. The exposure dose is similar to the administered dose or applied dose of a laboratory experiment. The exposure dose is then combined with an estimate of the toxicity of the compound to produce an estimate of risk posed to human health.

The estimate of toxicity of a compound, termed the dose-response value, can be derived from human epidemiological data, but it is most often derived from experiments with laboratory animals. In animals, as in humans, the administered dose of a compound is not necessarily completely absorbed. Moreover, differences in absorption exist between laboratory animals and humans, as well as between different media and routes of exposure. In many cases, a correction factor in the calculation of risk is needed to account for differences between absorption in the dose-response study and absorption likely to occur upon human exposure to a compound. Without such a correction, the estimate of human health risk could be over- or under-estimated.

This correction factor is termed the Relative Absorption Factor (RAF). The RAF is used to adjust the human potential dose so that it is expressed in the same terms as the doses used to generate the dose-response curve in the dose-response study. The RAF is the ratio between the estimated human absorption factor for the specific medium and route of exposure, and the known or estimated absorption factor for the laboratory study from which the dose-response value was derived.

$$\text{RAF} = \frac{\text{(fraction absorbed in humans for the environmental exposure)}}{\text{(fraction absorbed in the dose-response study)}}$$

The use of an RAF allows the risk assessor to make appropriate adjustments if the efficiency of absorption between environmental exposure and experimental exposure is known or expected to differ because of physiological effects and / or matrix or vehicle effects. Relative absorption factors can be less than one or greater than one, depending on the particular circumstances at hand. If it is thought that absorption from the site-specific exposure is the same as absorption in the laboratory study, then the RAF is 1.0.

A summary of RAFs used in the assessment is provided in Table 1.5-4. It should be noted that dermal absorption values (RAFs) were obtained directly from HC (2007b), Risk Assessment Information System (RAIS) (2010), TCEQ (2010) and the California Environmental Protection Agency (CalEPA) (2010).

Table 1.5-4: Summary of Relative Absorption Factors

Metal COPC	Oral Soil		Dermal Soil		Inhalation		Oral Surface Water	
	Cancer	Non-Cancer Chronic	Cancer	Non-Cancer Chronic	Cancer	Non-Cancer Chronic	Cancer	Non-Cancer Chronic
Arsenic	0.95 (e)	0.95 (e)	0.03 (a)	0.03 (a)	1 (d)	1 (d)	0.95 (e)	0.95 (e)
Chromium	n/a	0.013 (b)	n/a	0.1 (a)	n/a	1 (d)	n/a	0.013 (b)
Molybdenum	n/a	1 (e)	n/a	0.01 (a)	n/a	1 (d)	n/a	1 (e)
Nickel	n/a	0.2 (e)	n/a	0.2 (a)	n/a	1 (d)	n/a	0.2 (e)
Selenium	n/a	1 (e)	n/a	0.01 (a)	n/a	1 (d)	n/a	1 (e)

Note: (a) HC (2007b); (b) TCEQ (2010); (d) CalEPA (2010); (e) RAIS (2010); COPC - Chemicals of Potential Concern; n/a - not applicable

1.5.4 Risk Characterisation

Risk characterisation is the step in the risk assessment process that combines the results of the exposure assessment and the toxicity assessment for each COPC in order to estimate the potential for carcinogenic and non-carcinogenic human health effects from exposure to that COPC. This section summarises the results of the risk characterisation for each receptor evaluated in the risk assessment.

The risk characterisation compares estimated site-specific risk levels to target risk levels. HC's allowable Incremental Lifetime Cancer Risk (ILCR) target is set at 10^{-5} (1 in 100,000) (HC 2007a). For non-carcinogens, HC's target non-cancer hazard index is set at 1 (HC 2007a).

1.5.4.1 Approach for Non-Carcinogenic Risk Characterisation

For the assessment of non-carcinogenic health effects, the calculated Chronic Daily Intake (CDI) is compared to the Tolerable Daily Intake (TDI). The TDI is defined as an estimate of compound intake that is unlikely to cause adverse health effects even if exposure occurs for an entire lifetime.

The potential for exposures to result in adverse non-carcinogenic health effects is estimated by comparing the daily intake with the TDI. The resulting ratio, which is unitless, is known as the Hazard Quotient (HQ) for that compound. The HQ is calculated using the following formula:

$$HQ = \frac{Intake}{TDI}$$

where: HQ = Hazard Quotient (unitless)
 Intake = Average daily or weekly exposure (mg/kg/d / mg/kg/w)
 TDI = Tolerable daily or weekly intake (mg/kg/d / mg/kg/w)

For exposures to receptors at the proposed Project location (excluding background estimated daily intake for off-site sources including consumer products, food, air and water) HC accepts that when the HQ for a given COPC and pathway does not exceed 1 there are no unacceptable risks.

1.5.4.2 Approach for Carcinogenic Risk Characterisation

For carcinogenic chemicals, the risk estimate (i.e., ILCR) was determined by the following equation:

$$ILCR = Estimated \ Daily \ Intake \times Toxicological \ Reference \ Value$$

Suter et al. (2000) have proposed a model for organising the results of a risk assessment for evaluation of health risks, as well as evaluation of the effects posed by different remedy options. Suter et al. (2000) proposed three categories of human risk. The first category is *de manifestis* risks, which are those risks that require remedial action, unless it conflicts with the protection of human health. *De manifestis* human-health risks are defined by an incremental cancer risk greater than or equal to 10^{-4} or a HQ greater than or equal to a value of 1 for any individual contaminant or for combined exposures across contaminants of similar toxicological effects.

The second category is *de minimis* risks. *De minimis* risks do not normally require remediation because the risks are considered trivial. Suter et al. (2000) defines *de minimis* human health risk as incremental cancer risk less than or equal to 10^{-6} or a HQ less than a value of 0.2 for any individual contaminant or for combined exposures across contaminants of similar toxicological effects.

The third category of risk is intermediate health and ecological risks, which fall between *de manifestis* and *de minimis* risks and generally require further evaluation and cost-benefit analyses to determine the need for remediation.

Based on HC (2007a), an ILCR greater than 10^{-5} (i.e., one-in-one hundred thousand) is considered to represent an unacceptable level of risk.

1.5.4.3 Quantitative Interpretation of Risk Hazard

A quantitative comparison of the estimated exposures and the selected exposure limits for receptors for soil, surface water, plants and berries, wild game, and fish are discussed Section 1.5.6. The detailed exposure, and risk calculations for each receptor and environmental media are described in Appendix 2.

Risks to all receptors in association with arsenic are noted to be above the HC risk target level of 1 for non-carcinogenic effects and 1×10^{-5} for carcinogenic effect. In examining the risks from all other chemicals, no unacceptable risks are noted.

1.5.5 Uncertainty Analysis

Within any of the four steps of the risk assessment process, assumptions must be made due to a lack of absolute scientific knowledge. Some of the assumptions are supported by considerable scientific evidence, while others have less support. Every assumption introduces some degree of uncertainty into the risk assessment process. Conservative assumptions are made throughout the risk assessment to ensure that human health is protected. Therefore, when all of the assumptions are combined, it is much more likely that actual risks, if any, are overestimated rather than underestimated.

The assumptions that introduce the greatest amount of uncertainty in this risk assessment are discussed in this section. They are discussed in general terms, because, for most of the assumptions, there is not enough information to assign a numerical value that can be factored into the calculation of risk.

1.5.5.1 Toxicity Assessment

A dose-response relationship describes how the likelihood and severity of adverse health effects (the responses) are related to the amount and condition of exposure to an agent (the dose provided). A dose-response assessment is the process of quantitatively evaluating toxicity information, characterising the relationship between the dose of the contaminant received (or the inhalation exposure concentration, for inhalation assessments) and the incidence of adverse health effects in the receptors (US EPA 2010). In general, the dose-response values are usually based on limited toxicological data. For this reason, a margin of safety is built into TRV estimates, and actual risks are lower than those estimated. The two major areas of uncertainty introduced in the dose-response assessment are: (1) animal to human extrapolation; and (2) high to low dose extrapolation. These are discussed below.

Human dose-response values are often extrapolated, or estimated, using the results of animal studies. Extrapolation from animals to humans introduces a great deal of uncertainty in the risk assessment because in most instances it is not known how different a human may react to the constituent compared to the animal species used to test the constituent. The procedures used to extrapolate from animals to humans involve conservative assumptions and incorporate several uncertainty factors that overestimate the adverse effects associated with a specific dose. As a result, overestimation of the potential for adverse effects to humans is more likely than underestimation.

Predicting potential health effects from the exposure to media at the site requires the use of models to extrapolate the observed health effects from the high doses used in laboratory studies to the anticipated human health effects from low doses experienced in the environment. The models contain conservative assumptions to account for the large degree of uncertainty associated with this extrapolation and therefore, tend to be more likely to overestimate than underestimate the risks.

1.5.5.2 Exposure Assessment

In general, it should be noted that the sampling was biased towards areas where higher concentrations of COPCs were anticipated. In addition, except in the case of fish, the exposure estimates are based on the 95th percentile of baseline concentrations. Fish are mobile and can integrate exposures from multiple locations, which may result in higher COPC concentrations. The exposure point concentration (i.e., the 95th percentile) used in risk estimates is likely biased high, resulting in conservative estimates of potential risk. Therefore, fish exposure estimates were based on the 90th percentile concentrations.

1.5.5.3 Risk Characterisation

In the risk characterisation step, toxicity and exposure information are combined to estimate the potential for non-carcinogenic health effects. The toxicity factors developed by regulatory agencies are developed using very conservative models and approaches employing several “safety factors.” The conservatism of this approach is compounded by the assumption that only a fraction of TDI for non-carcinogenic compounds is “allowed” to come from the site, while the remainder is allocated to non-site related food (and other background) exposures. The use of this approach is far more likely to overestimate potential risk than to underestimate hazard.

1.5.6 Human Health Risk Assessment Summary and Conclusions

This report has presented a PQRA associated with potential exposures to the COPC identified in association with affected soil, surface water, and traditional country foods at the proposed Project site. The PQRA used both historical and current sampling data and is consistent with the methodology required by HC (2007a) for conducting preliminary human health risk assessments at federal sites in Canada. Arsenic was identified as the lone carcinogenic metal associated with the proposed Project.

This is now the point of the PQRA where the results of the toxicity assessment are integrated with the results of the exposure assessment to provide a quantitative assessment of the health risk associated with non-carcinogenic and carcinogenic COPC associated with the proposed Project.

For the purpose of this PQRA for the proposed Project, it was assumed that a local Aboriginal resident from one of the four nearby Nisga’a Villages was identified as the potential receptor of concern. The critical receptor was assumed to be an Aboriginal child accompanying an adult during traditional harvesting of country foods (i.e., hunting, fishing) or recreational activities (i.e., hiking) in the vicinity of the proposed Project.

Health risks from non-carcinogenic metals were evaluated using toddler characteristics, because toddlers ingest more soil and water per unit body mass, and have higher rates of hand-to-mouth activities (e.g., increasing their exposure to metals in soil) than any other age class. This is an extremely conservative scenario because toddlers are not expected to be in the vicinity of the proposed Project during operations and could not easily access the proposed Project site at closure, thus would not be participating in activities that could lead to ingestion of soil.

Health risks from carcinogenic metals are typically evaluated using adult characteristics, because most cancers develop over a longer period of time (i.e., long latencies), usually over the entire lifespan. Although the adult would have the opportunity to access the site, it is also recognised that the potential for them to be at the site for extended time to allow the level of exposure assumed in the risk assessment is highly unlikely.

For the purposes of this preliminary assessment, it was determined that an appropriate exposure scenario would involve that of a toddler spending all of his or her time in the region and potentially being exposed to a non-carcinogenic COPC via direct contact with soil, inhalation of dust and ingestion of soil, surface water, vegetation, wild game, and fish. Similarly for carcinogenic chemicals, an adult, who spends the same amount of time in the region, could also potentially be exposed via direct contact with soil, inhalation of dust and ingestion of soil, surface water, vegetation, wild game, and fish. The findings of the assessment are as follows:

- The potential non-carcinogenic hazard quotient for all COPCs associated with exposure of receptors identified for the proposed Project is below Health Canada's target risk level of 1; and
- The potential carcinogenic incremental lifetime cancer risk associated with exposure of adult receptors identified for the proposed Project is noted to be unacceptable for arsenic based on HC's target risk level of 10^{-5} .

When assessing risks posed by exposure to carcinogenic substances, HC assumes that any level of exposure (other than zero) is associated with some hypothetical cancer risk. As a result, it is necessary to specify a level of carcinogenic risk that is considered acceptable, tolerable, or essentially negligible (HC 2007a). In this vein, HC (2007a) has determined that the acceptable incremental lifetime cancer risk is 1 in 100,000 (i.e., in a population of 100,000 people exposed to the defined exposure regime, there will be one additional case of cancer above the background incidence of cancer). It is important to note that the background incidence of cancer in Canada is approximately 40% or 40,000 cases in 100,000 (National Cancer Institute of Canada (NCIC) 2001). Therefore, within a general exposed population, the acceptable incremental lifetime cancer risk of one in 100,000 (i.e., 1×10^{-5}) would only increase the incidence of cancer from 40,000 cases in 100,000 to 40,001 cases in 100,000 (HC 2007a). Although the ILCR for arsenic of 1.3×10^{-4} exceeds HC's cancer risk of 1×10^{-5} , the incremental increase in the cancer rate would only be approximately 13 cases in 100,000 people exposed to arsenic via the exposure routes evaluated in the assessment. Under such situations, the risks can be considered low.

Although not applicable in this evaluation, the US EPA (1985) indicates that the maximum acceptable incremental lifetime cancer risks would actually range from one in 10,000 to one in 1,000,000. If the US EPA (1985) guideline was selected as the basis of the assessment, the arsenic exposures would only result in incremental lifetime cancer risks that are marginally higher than one in 10,000. Therefore, this would suggest that the carcinogenic risks due to arsenic exposures, particularly through surface water ingestion and fish consumption may be low.

Arsenic usually occurs in surface water as inorganic oxides in the pentavalent form. Levels of arsenic in surface water show seasonal variation (Cullen et al. 1989). The trivalent inorganic arsenic compounds are more toxic to humans and aquatic organisms. Phytoplankton readily take up arsenate from water and rapidly detoxify arsenate by reduction and methylation, resulting in the formation of organic arsenic and other methylated arsenic compounds (Phillips 1990). Aquatic organisms including fish accumulate organic arsenic, predominantly as a non-toxic but readily available form such as arsenobetaine and arsenocholine. Arsenobetaine and arsenocholine contribute to the ratio of total arsenic accumulated in fish and should be considered when evaluating the ILCR for arsenic. A summary of carcinogenic and non-carcinogenic risks is provided in Tables 1.5-5 and 1.5-6.

Table 1.5-5: Summary of Risks – Non-Carcinogenic

Metal COPC	HQ								Total HQ
	Soil			Surface Water	Plant	Berries	Wild Game	Fish	
	Ingestion	Dermal	Inhalation	Ingestion	Ingestion	Ingestion	Ingestion	Ingestion	
Arsenic	4.5×10^{-1}	1.2×10^{-2}	1.5×10^{-3}	5.4×10^{-2}	8.8×10^{-4}	8.8×10^{-3}	3.5×10^{-3}	4.4×10^{-1}	9.6×10^{-1}
Chromium	6.1×10^{-3}	4.0×10^{-2}	7.4×10^{-4}	1.2×10^{-4}	2.0×10^{-4}	2.0×10^{-3}	3.8×10^{-4}	2.5×10^{-2}	7.5×10^{-2}
Molybdenum	2.0×10^{-2}	1.7×10^{-4}	1.4×10^{-5}	5.1×10^{-1}	1.5×10^{-3}	1.5×10^{-2}	2.6×10^{-4}	5.3×10^{-3}	5.5×10^{-1}
Nickel	4.8×10^{-3}	4.1×10^{-3}	4.2×10^{-3}	7.6×10^{-4}	3.0×10^{-4}	3.0×10^{-3}	3.5×10^{-4}	1.2×10^{-2}	3.0×10^{-2}
Selenium	1.1×10^{-3}	9.4×10^{-6}	5.3×10^{-6}	1.8×10^{-3}	2.4×10^{-3}	2.4×10^{-2}	1.7×10^{-4}	8.0×10^{-1}	8.3×10^{-1}

Note: COPCs - Chemicals of Potential Concern; HQ - Hazard Quotient

Table 1.5-6: Summary of Risks – Carcinogenic

Metal COPC	ILCR								Total ILCR
	Soil			Surface Water	Plant	Berries	Wild Game	Fish	
	Ingestion	Dermal	Inhalation	Ingestion	Ingestion	Ingestion	Ingestion	Ingestion	
Arsenic	1.0×10^{-5}	2.8×10^{-6}	1.0×10^{-7}	1.7×10^{-5}	2.5×10^{-7}	3.9×10^{-6}	1.0×10^{-6}	9.6×10^{-5}	1.3×10^{-4}

Note: COPCs - Chemicals of Potential Concern; ILCR - Incremental Lifetime Cancer Risk

1.6 Screening Level Ecological Risk Assessment

1.6.1 Problem Formulation

The problem formulation step of the screening-level ERA defines the issues at the proposed Project site as they relate to ecological receptors. In this step, COPC for the ERA are identified, and an Ecological Conceptual Site Model is developed that describes basic assumptions regarding fate and transport of COPC, ecological receptors, and exposure pathways.

1.6.2 Screening and Identification of Chemicals of Potential Concern

Ecological COPC were identified by screening the 95th percentile of baseline concentrations against CCME guidelines (or other toxicity-based guidelines as appropriate) and local background concentrations. Any chemical for which the 95th percentile concentration exceeded the relevant guideline, or the detection limit exceeded the guideline, was carried forward and assessed in the ERA unless screened out on the basis of other criteria (where screened out, justification is provided).

For the purpose of the ERA, the proposed Project was considered to be “residential / parkland.” The site was considered to represent residential / parkland land use because: (1) it is an environment dominated primarily of open woodland areas and barren areas; and (2) it is expected to provide habitat for ecological receptors.

1.6.3 Screening for Soil

Analytical data for soils data as presented in Section 6.9 Soils and associated appendices were assessed to establish a baseline condition for the proposed Project footprint. The sample locations are shown in Figure 1.1-1 and analytical data as shown in Appendix 6.9-A were collected from the brownfield area of the historic mine site and the greenfield area that will be utilised for the new infrastructure intended for the proposed Project. This data was evaluated using the following federal and provincial regulatory guidelines for the purposes of identifying COPC:

- CCME’s Canadian Environmental Quality Guidelines: “Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health” (CCME 2007), for residential / parkland land use; and
- *BC CSR* (Government of BC 2011) of the *BC EMA* (Government of BC 2003, Schedule 4 Generic Numerical Soil Standards, for park and residential use.

In many cases, both SQG_{HH} and SQG_E were derived by the CCME, with the lower of the two values being selected as the basis of the SQG. Given that the ERA is restricted to the evaluation of ecological receptors, the SQG_E was used in the identification of COPC in soil.

In the absence of a CCME guideline for a specific chemical, concentrations were screened against the *BC CSR*, Schedule 4 Generic Numerical Standards, assuming a residential /

parkland land use. These criteria were developed to be protective of both environmental and human health. The identification of COPC in soil is shown in Table 1.6-1.

Table 1.6-1: Screening of Chemicals of Potential Concern in Soil and Surface Water for Ecological Receptors

Metal COPC	Soil (mg/kg)			Surface Water (mg/L)		
	95 th Percentile of Baseline Concentration (a)	Screening Guideline		95 th Percentile of Baseline Concentration (d)	Screening Guideline	
		CCME (b)	Government of BC (c)		Freshwater Aquatic Life Health	Wildlife Health
Antimony	5.0	20	20	0.00044	0.02 (f)	n/a
Arsenic	29.0	12	n/a	0.00047	0.005 (e)	0.025 (i)
Barium	175.5	500	n/a	0.0658	5 (f)	n/a
Beryllium	0.84	4	4	0.00025	0.0053 (h)	n/a
Cadmium	0.97	10	n/a	0.0010	0.00017 (e)	0.08 (k)
Chromium	97	64	n/a	0.00025	0.001 (f)	0.05 (k)
Cobalt	26.2	50	50	0.00018	0.11 (f)	1 (k)
Copper	49.2	63	n/a	0.0014	0.002 (e)	0.3 (i)
Lead	48.0	140	n/a	0.00065	0.001 (e)	0.1 (k)
Mercury	0.25	6.6	n/a	0.000005	0.000026 (e)	0.003 (k)
Molybdenum	94.9	10	10	0.322	0.073 (e)	0.05 (g)
Nickel	99.4	50	100	0.0021	0.025 (e)	1 (k)
Selenium	1.4	1	3	0.0003	0.002 (e)	0.004 (g)
Silver	7.2	20	20	0.0002	0.0015 (e)	n/a
Thallium	0.5	1	n/a	0.0002	0.0003 (h)	n/a
Vanadium	98.1	130	200	0.0005	0.006 (h)	0.1 (k)
Zinc	163.5	200	n/a	0.016	0.033 (e)	2 (j)

Note: (a) 95th percentile of baseline soil concentrations. Concentrations provided by Rescan and AMEC Soil Quality Group. (b) CCME Soil Quality Guideline for the Protection of Environmental Health (CCME 2007). Value represents guideline protective of residential / parkland uses. (c) *BC Environmental Management Act, Contaminated Sites Regulation*, Schedule 4 Numeric Soil Standards (Government of BC 1997). (d) 95th percentile of baseline surface water concentrations. Concentrations provided by Rescan and AMEC Water / Sediment Quality Group. (e) CCME Canadian Environmental Quality Guidelines: "Canadian Water Quality Guideline for the Protection of Aquatic Life" (CCME 2007). (f) BC Water Quality Guideline (maximum) for the Protection of Freshwater Aquatic Life (Government of BC 2010). (g) BC Water Quality Guideline (30-day average) for the Protection of Wildlife (Government of BC 2010). (h) BC Water Quality Guideline (30-day average) for the Protection of Freshwater Aquatic Life (Government of BC 2010). (i) BC Water Quality Guideline (maximum) for the Protection of Wildlife (Government of BC 2010). (j) BC Water Quality Guideline (interim maximum) for the Protection of Wildlife (Government of BC 2010). (k) BC Water Quality Guideline (maximum) for the Protection of Livestock (surrogate for wildlife) (Government of BC 2010).

Highlighted cell indicates metal is a COPC in specified medium for ecological risk assessment. Metal was selected as a COPC in soil if the 95th percentile of the baseline concentration exceeded screening guideline in soil; and in water if 95th percentile of the baseline concentration exceeded screening guidelines in water; COPC - Chemicals of Potential Concern; mg/kg - milligrams per kilogram; mg/L - milligrams per litre; n/a - not applicable

1.6.4 Screening for Surface Water

The reported concentration data for surface water were assessed and evaluated for the purposes of identifying COPC using:

- BC “Surface Water Quality Guidelines” (BC MOE 2010); and
- CCME’s Canadian Environmental Quality Guidelines: “Canadian Water Quality Guidelines for the Protection of Aquatic Life” (CCME 2007).

The identification of COPC in surface water for the proposed Project is provided in Table 1.6-1.

1.6.5 Screening for Sediments

Analytical chemistry data for sediment were assessed and evaluated using the following federal and provincial regulatory guidelines for the purposes of identifying COPC:

- CCME’s “Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life” (CCME 2002); and
- “Criteria for Managing Contaminated Sediment Sites in British Columbia, Technical Appendix” (BC Ministry of Water, Land and Air Protection (BC MWLAP) 2002a).

Several inorganic contaminants exceeded the CCME Interim Freshwater Sediment Quality Guidelines (ISQG) and the Probable Effects Levels (PEL), BC Sediment Quality Criteria (SedQC) (Table 1.6-2). The following parameters exceeded the guidelines:

- Arsenic exceeded the ISQG of 5.9 mg/kg in all of the sediment samples;
- Cadmium exceeded the ISQG of 0.6 mg/kg in 19 of 22 sediment samples;
- Chromium exceeded the ISQG of 37.3 mg/kg in 20 of 22 sediment samples;
- Copper exceeded the ISQG of 35.7 mg/kg in 19 of 22 sediment samples;
- Lead exceeded the ISQG of 35.0 mg/kg in 16 of 22 sediment samples; and
- Mercury exceeded the ISQG of 0.17 mg/kg in 6 of 22 sediment samples.

Arsenic, cadmium, copper, and lead concentrations in the sediments exceeded BC MOE SedQC for typical (SedQC_{TS}) and sensitive sites (SedQC_{SS}). Chromium concentrations in sediments also exceeded the SedQC_{SS}. Both types of SedQC are intended to identify the concentrations of COPC, and determine which risks to sediment-dwelling organisms are considered to be tolerable.

Sediment criteria or guidelines for antimony, barium, beryllium, cobalt, molybdenum, nickel, selenium, silver, and vanadium were not available and were not carried forward in the assessment. Sediment data can be found in Appendix 1.

Table 1.6-2: Identification of Chemicals of Potential Concern in Sediment

Parameter	95 th Percentile of Baseline Concentration (mg/kg)	Number of Samples Analysed	CCME		BC MOE		COPC?
			ISQG	PEL	SedQC _{TS}	SedQC _{SS}	
Antimony	7.8	22	n/a	n/a	n/a	n/a	no
Arsenic	340	22	5.9	17	20	11	yes
Barium	299	22	n/a	n/a	n/a	n/a	no
Beryllium	2.1	22	n/a	n/a	n/a	n/a	no
Cadmium	14.5	22	0.6	3.5	4.2	2.2	yes
Chromium	88.7	22	37.3	90	110	56	yes
Cobalt	123	22	n/a	n/a	n/a	n/a	no
Copper	256	22	35.7	197	240	120	yes
Lead	420	22	35	91.3	110	57	yes
Mercury	0.3	22	0.17	0.486	0.58	0.3	yes
Molybdenum	377	22	n/a	n/a	n/a	n/a	no
Nickel	155	22	n/a	n/a	n/a	n/a	no
Selenium	4.1	22	n/a	n/a	n/a	n/a	no
Silver	8.8	22	n/a	n/a	n/a	n/a	no
Vanadium	70.3	22	n/a	n/a	n/a	n/a	no
Zinc	n/d	0	123	315	380	200	no

Note: BC MOE - British Columbia Ministry of Environment; CCME - Canadian Council of Ministers of the Environment; COPCs - Chemicals of Potential Concern; ISQG - Interim Sediment Quality Guidelines; mg/kg - milligrams per kilogram; n/a - not available; n/d - no data; PEL - Probable Effects Level; SED_{SS} - Sediment Quality Criteria for Sensitive Sites; SED_{TS} - Sediment Quality Criteria for Typical Sites

1.6.6 Summary of Identified Chemicals of Potential Concern

Based on the screening conducted for soil concentrations (Table 1.6-1), arsenic, chromium, molybdenum, nickel, and selenium compounds were identified COPC in soil and are being carried forward in the ERA for the proposed Project. The remaining COPC found in soil were below their respective guidelines and were not carried forward in the assessment. In terms of the screening conducted for surface water concentrations (Table 1.6-1), cadmium and molybdenum compounds were identified as a COPC in surface water and are being carried forward in the ERA for the proposed Project. The remaining COPC found in surface water were below their respective guidelines for aquatic and wildlife health and were not carried forward in the assessment. In addition, the screening conducted for sediment concentrations (Table 1.6-2) identified arsenic, cadmium, chromium, copper, lead, and mercury compounds as COPC in sediment, and are being carried forward in the ERA for the proposed Project. The remaining COPC found in sediments were below their respective guidelines and were not carried forward in the assessment.

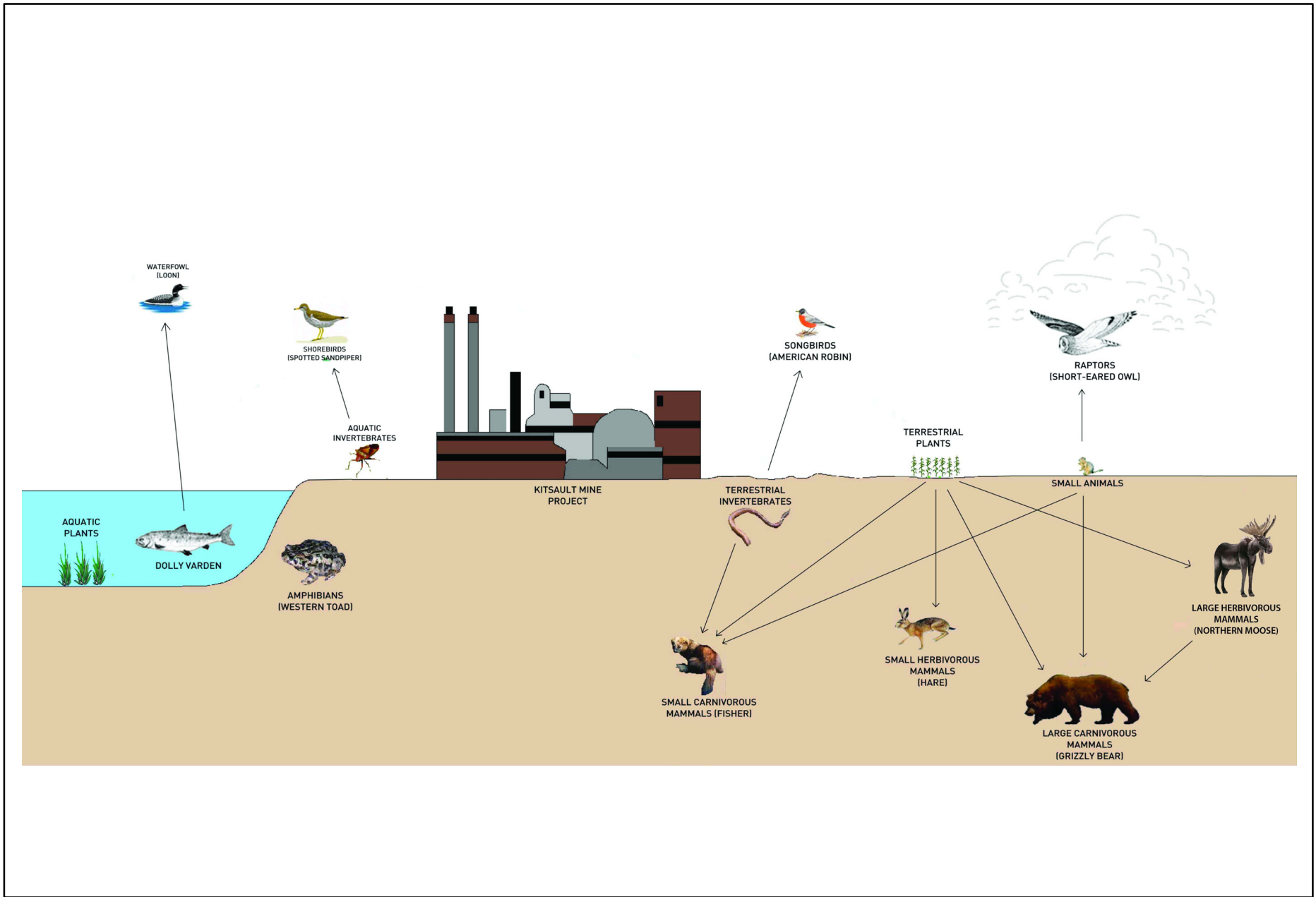
1.6.7 Ecological Conceptual Site Exposure Model

All COPC identified for the proposed Project are inorganic parameters. No significant transport, transformation, or degradation is anticipated. The chemical form of inorganic parameters may be altered under different conditions (e.g., pH, redox state, etc.), but only if subsurface conditions change appreciably. Considering the site characteristics of the proposed Project area, major variations in subsurface conditions are not anticipated. The inorganic parameters identified as COPCs are present as insoluble complexes at circumneutral pH and tend to be associated with soil particles rather than the dissolved phase, undergoing minimal subsurface migration.

The proposed Project is located in a natural area (assumed to be residential / parkland land use) with nearby freshwater lakes. Ecological receptors that might reasonably be expected to reside at or frequent the proposed Project site for the purposes of foraging include terrestrial plants, soil invertebrates, mammals, and birds. Also, ecological receptors such as invertebrates and fish are expected to be present in nearby lakes and creeks. Given the COPC present in soil, sediments, and surface water, ecological receptors are potentially exposed to COPC via several exposure pathways:

- Large carnivore / omnivore mammals can potentially be exposed to COPC in foods, soil, and water ingestion;
- Large herbivore mammals can potentially be exposed to COPC in foods, soil, and water ingestion;
- Small carnivore / omnivore mammals can potentially be exposed to COPC in foods, soil, and water ingestion;
- Small herbivore mammals can potentially be exposed to COPC in foods, soil, and water ingestion;
- Birds can potentially be exposed to COPC in foods, soil, sediments, and water ingestion;
- Amphibians can potentially be exposed to COPC through direct contact with surface water;
- Fish can potentially be exposed to COPC through direct contact with surface water;
- Terrestrial plants can potentially be exposed to COPC in soil;
- Soil invertebrates can potentially be exposed to COPC in soil;
- Aquatic plants can potentially be exposed to COPC in surface water; and
- Aquatic invertebrates can potentially be exposed to COPC in surface water.

Contaminants, media, ecological receptors, and exposure pathways examined in the ERA are illustrated in the Ecological Conceptual Site Exposure Model (Figure 1.6-1). The section rationale for the ecological receptors is further explained in Section 1.7.2.



Note:
All species depicted are for illustrative purposes only and may not match those selected VCs for the proposed project

CLIENT



Avanti Kitsault Mine Ltd.

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ANALYST:

MY

QA:

JK

DATUM:

N/A

PROJECTION:

N/A

SCALE:

N/A

PROJECT

Kitsault Mine Project

TITLE

Ecological Conceptual Site Exposure Model

REV. NO.:

A

DATE:

January 2010

PROJECT NO.:

VE51988

FIGURE No.

1.6-1

1.7 Receptor Characterisation

The receptor characterisation step in an ERA includes the characterisation of the proposed Project site with respect to the ecological habitats or resources present or likely to be present. Receptor characterisation is designed to: (1) identify VCs (i.e., biological communities, populations, individuals or habitats potentially at risk, including rare, threatened, or endangered species); (2) identify potential exposure pathways and routes by which ecological receptors may be exposed to chemicals in the environment; and (3) determine the appropriate assessment endpoints for the ERA.

1.7.1 Valued Components

A receptor is defined as an organism or group of organisms that have the potential to be affected by a chemical or other stressors. Receptors selected for assessment represent VCs, which are defined as resources or environmental features that are important to human populations, have economic and / or social value, or have intrinsic ecological significance. The VCs have local, regional, provincial, national, and / or international profiles, and serve as a baseline from which the effects of development can be evaluated, including changes in management or regulatory policies. Because it is not possible to evaluate all ecological species that may potentially be present at a site, representative VCs are selected based on several criteria (CCME 1996a), including:

- Threatened or endangered species;
- Sensitivity to chemicals;
- Biological and ecological relevance;
- Ability to measure or predict effects; and
- Social relevance (i.e., species of recreational, commercial, or social importance).

VCs are not always identified at the species level; rather, VCs can represent major groups of receptors deemed to be important and are sometimes defined by trophic level. For example, benthic invertebrates may be identified as an important ecological component, due to their role as filter feeders and prey for fish; individual species of invertebrates are not typically identified as VCs.

The exception is when at-risk (endangered or otherwise threatened) species are present. When such species are present, additional consideration should be given to providing protection at the level of the species or individual.

According to the *Species at Risk Act (SARA)* (Government of Canada 1992), species at risk are categorised as:

- **Extinct:** A wildlife species that no longer exists anywhere in the world;
- **Extirpated:** A wildlife species that no longer exists in the wild in Canada, but exists elsewhere;

- **Endangered:** A wildlife species that is facing imminent extirpation or extinction;
- **Threatened:** A wildlife species likely to become an endangered species if nothing is done to reverse the factors leading to its extirpation or extinction; and
- **Special Concern:** A wildlife species that may become a threatened or endangered species because of a combination of biological characteristics and identified threats.

1.7.2 Identification of Potential Receptors

VCs are limited to three groups of ecological receptors that may be exposed to contaminated medias: (1) aquatic receptors directly exposed to contaminants in surface water and / or sediment; (2) wildlife exposed to contaminants via ingestion of surface water / sediment, direct soil contact, and food items; and (3) terrestrial plants and soil invertebrates exposed by direct contact with the soil. Several VCs representing major ecosystem components were identified for inclusion in the ERA including: mammals; birds; amphibians; fish; invertebrates (soil, aquatic); and plants (terrestrial, aquatic).

Justification for the selection of each VC, as well as details on receptor characteristics and potential uptake pathways for each receptor are provided in the following subsections.

1.7.2.1 Mammals

Large carnivorous / omnivorous mammals were assessed as a receptor because they were identified as a VC. The grizzly bear (*Ursus arctos horribilis*) was assessed as a representative species. It was assumed that if risks were acceptable for a typical grizzly bear, then risks would be acceptable for all large carnivorous / omnivorous mammals. The dominant pathways by which grizzly bear may be exposed to COPC at the proposed Project include ingestion of food, water, and soil. The grizzly bear is omnivorous, preying directly on a variety of small mammals (e.g., mice, lemmings, voles, and ground squirrels) and large mammals (e.g., caribou, deer, moose), as well as feeding on large amounts of berries and vegetation.

Large, herbivorous ungulate mammals were assessed as a receptor because they were identified as a VC in the Application Information Requirements (AIR). While moose were specifically identified for this EA, the selection rationale describes moose as a representative species of large, herbivorous ungulates. Black-tailed deer are also representative of large, herbivorous ungulates that share the same habitat and consume a similar variety of plants and vegetation as do moose. Its role in this Environmental Health Baseline Report is as a representative species; if risks are acceptable for a typical black-tailed deer, then risks would be acceptable for all large herbivorous ungulate mammals, including moose. The dominant pathways by which black-tailed deer (and by extension moose) may be exposed to COPC at the proposed Project include ingestion of food, water, and soil.

Small carnivorous / omnivorous furbearing mammals have been assessed as a receptor because they (namely fisher) were identified as a VC in the AIR. For the purposes of this

assessment, the mink (*Mustela vison*) has been selected as the representative species of small, carnivorous / omnivorous furbearing mammals. The mink has been identified in the region and shares the same habitat and food sources as the fisher. It was assumed that if risks were acceptable for a typical mink, then risks would be acceptable for all small, carnivorous / omnivorous furbearing mammals, including fishers. The dominant pathways by which minks may be exposed to COPC at the proposed Project include ingestion of food, water, and soil. The mink, similar to the fisher, is carnivorous, and its diet consists of waterfowl, fish and small mammals such as mice, lemmings, voles, and ground squirrels.

Small, herbivorous furbearing mammals were assessed as a receptor because they were identified as a VC. The hare (*Caprolagus hispidus*) is commonly found in the region and was also assessed as a representative species of small herbivorous furbearing mammals. It was assumed that if risks were acceptable for a typical hare, then risks would be acceptable for all small, herbivorous furbearing mammals. The dominant pathways by which a hare may be exposed to COPCs at the proposed Project include ingestion of food, water, and soil.

1.7.2.2 Birds

The surrounding region provides suitable habitat for a number of avian species, both as long-term inhabitants and migratory species. Raptors or birds of prey, namely the Northern goshawk and Western screech-owl, and, by association, the short-eared owl (*Asio flammeus*) were identified as a VC in the region. For the purposes of this report, short-eared owls have been categorised as a representative receptor for raptors, since it was assumed that if risks were acceptable for a short-eared owl with characteristics that are typical of raptors, then risks would be acceptable for all raptors, including the goshawk and the Western screech-owl. The dominant pathways by which raptors may be exposed to COPCs at the proposed Project include ingestion of food, water, and soil. Raptors are carnivorous, preying on a variety of small birds and mammals.

Songbirds – namely, the barn swallow, olive-sided flycatcher, and rusty blackbird – were assessed as a receptor because they were identified as a VC. The North American robin (*Turdus migratorius*) is commonly found in the region and was assessed as a representative species, since it shares the same habitat and food sources as the swallow, olive-sided flycatcher, and rusty blackbird. It was assumed that if risks were acceptable for a typical robin, then risks would be acceptable for all songbirds. The dominant pathways by which songbirds may be exposed to COPC at the proposed Project include ingestion of food, water, and soil. Songbirds feed on a variety of insects, invertebrates, and vegetation.

Waterfowl were assessed as a receptor because they were identified as a VC. The loon (*Gavia pacifica*) is identified in the region, was selected as a VC in the AIR and was assessed as a representative species in this Environmental Health Baseline Report. As is the case with the other representative species identified in this report, it was assumed that if risks were acceptable for a typical loon, then risks would be acceptable for all waterfowl. The dominant pathways by which waterfowl may be exposed to COPC at the proposed Project include ingestion of food and water. Waterfowl feed on a variety of fish.

Shorebirds were assessed as a receptor because they were identified as a VC, along with a variety of marine birds. The spotted sandpiper (*Actitis macularius*) is identified in the region and was assessed as a representative species. It was assumed that if risks were acceptable for a spotted sandpiper with typical characteristics, then risks would be acceptable for all marine birds and shorebirds. The dominant pathways by which shorebirds may be exposed to COPC at the proposed Project include ingestion of food, water, and soil. Shorebirds feed on a variety of insects and invertebrates.

1.7.2.3 Amphibians

Many amphibian species, including frogs and toads, live in the surrounding region of the proposed Project. Amphibians were identified as a VC in the AIR – specifically, the Western toad, which is a Blue- listed species. The spotted frog (*Rana luteiventris*) is also found in the region and shares the same habitat as the Western toad, which is why this species has been assessed as a receptor. The spotted frog is also an ideal species for the purposes of this Environmental Health Baseline Report because of their distinct diet and importance in the ecosystem. For the purpose of the ERA, the route of potential exposure to COPC for the spotted frog (and by extension, the Western toad) was assumed to be dermal contact to surface water.

1.7.2.4 Fish

Freshwater fish, such as Dolly Varden (*Salvelinus malma miyabei*), were selected as a VC in the AIR. For the purposes of this assessment, Dolly Varden have been selected as a receptor because of their importance in the ecosystem as a predator and also as a food source for piscivorous birds and mammals. It was assumed that if risks were acceptable for typical Dolly Varden, then risks would be acceptable for all freshwater fish.

Because Dolly Varden are primarily carnivorous, they are an important predator / consumer in any larger aquatic system, and are considered to be important from a social aspect as well. Depending on their life history traits, different species of fish can be exposed to contaminants in surface water and sediment; however, the route of potential exposure for Dolly Varden is assumed to be via uptake of COPC in surface water across their gills.

1.7.2.5 Invertebrates – Soil

Open areas not covered by buildings or areas with barren earth likely support indigenous soil invertebrates such as earthworms, grubs, arthropods, etc. In terms of sensitivity to toxicants, earthworms are considered to be one of the most sensitive receptors for soil contaminants. Earthworms are in near-constant direct dermal contact with soil. Earthworms are probably the most important soil invertebrate in promoting soil fertility (Edwards 1992). Their feeding and burrowing activities break down organic matter and release nutrients and improve aeration, drainage, and aggregation of soil. Earthworms are also important components of the diets of many higher animals. Due to their importance in a healthy ecosystem, as well as their ubiquity in the environment, earthworms were selected as a representative surrogate for all soil invertebrate species.

1.7.2.6 Invertebrates – Aquatic and Benthic

Aquatic and benthic invertebrates are an important group of organisms in most freshwater systems. Macroinvertebrates, as prey for many fish species, are critical for the proper functioning of aquatic ecosystems. Aquatic invertebrates are in direct contact with surface water. Benthic invertebrates are in direct contact with sediments and pore water, and as such, receive more exposure to sediment-borne contaminants than any other group. Additionally, invertebrates as a group tend to be one of the most sensitive to environmental contaminants, so protection of invertebrates also tends to result in protection of other species. Invertebrates are often used as “indicators” of environmental degradation, because of their rapid and predictable response to various environmental contaminants and other stressors. Aquatic and benthic invertebrates are a critical source of food for predatory fish such as the trout. Aquatic invertebrates may potentially be exposed to COPC in surface water while benthic invertebrates may be exposed to COPC in sediment and pore water. Since baseline pore water data were not available at the time of the assessment, metal toxicity to benthic invertebrates were not evaluated.

1.7.2.7 Plants – Terrestrial

Terrestrial plants were assessed as a receptor to ensure that their health in the vicinity of the proposed Project would not be adversely affected by accumulating COPC from soil. Certain plants in the vicinity of the proposed Project represent important country foods for local Aboriginal community populations. As autotrophs, plants are the foundation of any terrestrial ecosystem, including those heavily influenced by humans. The type and quality of vegetative growth is the most visible indicator of forest health.

1.7.2.8 Plants – Aquatic

Aquatic plants play an important role in most freshwater systems. Aquatic plants take a variety of forms, including submerged, emergent, and free-floating forms. Aquatic plants, including algae, oxygenate water and form the basis of the aquatic food chain. Submerged macrophytes also provide habitat / cover for a variety of fish. Emergent forms, such as cattails, bullrushes, and reeds, are used by birds for cover and food. Plants are not especially sensitive to bioaccumulative substances, but are sensitive to toxicity from some metals. Aquatic plants were evaluated as a group rather than as individual species.

1.7.2.9 Species Not Assessed

Other species or groups of organisms not selected as VCs may also inhabit the proposed Project site, and are potentially exposed to COPC. However, given the number of species potentially present in the area, it is neither practical nor appropriate to consider all species. Only those species likely to be exposed to contaminants, those which are important components of the ecosystem, or those which possess social and cultural value were considered.

1.7.3 Assessment Endpoints

Assessment endpoints are descriptions of ecosystem properties that are to be assessed. For ERAs, these often include properties at higher levels of organisation, such as population abundance or diversity (Suter et al. 2000).

Assessment endpoints identified for the ERA were:

- Survival and reproduction of large mammals (represented by the grizzly bear and black-tailed deer);
- Survival and reproduction of small mammals (represented by the mink and hare);
- Survival and reproduction of bird species such as raptors, songbirds, shorebirds and waterfowl (represented by the short-eared owl, North American robin, spotted sandpiper and loon);
- Survival and reproduction of amphibian populations (represented by the spotted frog);
- Survival and reproduction of fish populations (represented by the Dolly Varden);
- Survival and growth of soil invertebrates (represented by the earthworm);
- Survival and growth of aquatic invertebrate communities;
- Survival and growth of terrestrial plants (including grasses, shrubs, bushes, and trees); and
- Survival and growth of aquatic plant communities.

Measurement endpoints are conceptually related to assessment endpoints but are quantifiable using standard toxicological methods such as laboratory exposures. For wildlife, measurement endpoints are usually defined as some low-effect threshold concentration in a sensitive species. For this ERA, the LOAEL or Lowest Observable Adverse Effect Concentration (LOAEC) derived from laboratory studies using oral exposures in representative small mammals, fish, and birds were selected as the measurement endpoints. The LOAEL was the lowest concentration at which a relevant adverse effect (e.g., diminished growth or fewer offspring) was demonstrated in a study using appropriate exposure conditions. Where toxicological data for the surrogate species (VC) was not available, LOAELs were estimated using allometry (i.e., relationship of body size to anatomy, physiology, and behaviour). For plants and invertebrates, it is not possible to estimate concentrations that would constitute thresholds for toxic effects at a particular site from published toxicity data, due to the diversity of soils, sediments, chemical forms, species, and test procedures used in the generation of these data. Therefore, for these VCs, measurement endpoints sometimes consisted of benchmark concentrations derived from multiple endpoints (e.g., 10th percentile of (effective concentration to induce a 50% effect (EC₅₀)) data from several different endpoints).

1.8 Exposure Assessment

The exposure assessment includes an analysis of the pathways through which VCs may be exposed to COPC and an estimate of the concentrations to which they may be exposed. For COPC to have deleterious effects on ecological receptors, they must gain access to the organism or receptor. The route by which this occurs is referred to as an exposure pathway and is dependent on the nature of the chemical and the nature of the receptor. A complete exposure pathway is one that meets the following criteria:

- A source of constituents of interest must be present;
- Release and transport mechanisms and media must be available to move the constituents from the source to the ecological receptors;
- An opportunity must exist for the ecological receptors to contact the affected media; and
- A means must exist by which the constituent is taken up by ecological receptors, such as ingestion, inhalation, or direct contact with skin or membranes.

Exposure assessment consists of several steps, including the identification of COPC, description of the fate and transport of COPC in the environment, an examination of potential exposure pathways, and estimation of exposure levels for each VC.

1.8.1 Pathway Analysis

1.8.1.1 Root Uptake

Plants are potentially exposed to COPC via root uptake and, in some cases, foliar uptake. Root uptake is the primary route of exposure for terrestrial plants.

For metals and metalloids, root uptake is partly determined by chemical characteristics determining the mobility of the element in the soil environment, partly by soil characteristics (e.g., pH, clay and organic matter content and type, and moisture content), and partly by the selective absorption from soil solution by the root. Many metals and metalloids tend to be taken up easily through plant roots if dissolved in water. Metals may be taken up passively with the mass flow of water into roots, or by membrane transport systems responsible for uptake of nutrient elements. Depending on the metal's chemical properties, it can be translocated via the vascular system to most areas of the plant.

For root uptake to occur, roots must make contact with contaminants in soil pore water. Therefore, rooting depth is a major factor limiting uptake. Although rooting depth varies among different plant species and according to soil properties (e.g., mechanical resistance, aeration, fertility, moisture), relatively few plant species have rooting depths greater than 1 m, and in most natural ecosystems the majority of root mass is contained in the upper 0.5 m depth (Suter et al. 2000). Even large, mature trees in temperate climates do not typically have tap root systems extending to great depths. A large data set of root dimensions on windthrown trees (Gasson and Cutler 1990) revealed only 5% of mature

trees extended roots below 2 m depth, and 90% to 99% of root mass was contained within the upper 1 m. Considering that elevated metal concentrations were noted in the shallow soil, uptake of metals from soil and groundwater is assumed to be a complete pathway for plants.

1.8.1.2 Direct Soil Contact

The primary route of exposure for soil invertebrates is direct contact with, or ingestion of, COPC in soil. Earthworms are known to take up various inorganic and organic soil contaminants through consumption of humus (well-decomposed organic material) in surface soil and less decomposed leaf litter at the ground surface. The uptake of metals into the tissue of earthworms depends primarily on the metal's physicochemical properties. Site-specific factors such as organic content of the soil can also affect availability.

The feeding and burrowing habits of earthworms determine their exposure to chemicals in soil and litter. Earthworms may be categorised into three groups based on feeding habits and the structure of burrows:

- Litter-feeding species forage on surface litter, but build deep, vertical burrows up to 3 m below the surface;
- Geophagus species consume large amounts of soil during feeding on humus in near-surface strata, and construct primarily shallow (< 1 m), horizontal burrows; and
- Worms resting during cold or dry conditions construct ephemeral vertical burrows in upper (< 1 m) soil strata.

Depending on the depth of contamination, geophagus organisms and those living on or near the soil surface may have very different exposure to chemicals than worms feeding on litter pulled down into burrows in the subsoil (Curl et al. 1987). For a situation such as exists at the proposed Project site, burrowing depth is the dominant factor affecting exposure. Lee (1985) reviewed studies of earthworm burrow morphology for several species in various countries. Although a few species not present in Canada (e.g., *Microchaetus microchaetus*, *Octochaetus multiporus*) are known to burrow to depths as great as 3 m below the surface, more common species of *Lumbricus* and *Eisenia* generally burrow only in the upper 0.8 m, or even the upper 0.1 m (Lee 1985). Zicsi (1983) identified several European species that burrow up to 1.5 m (Suter et al. 2000). Other studies have demonstrated that even among species known to be capable of creating deep casts, the largest fraction of biomass is frequently found in the upper soil strata where concentrations of organic materials are greatest (Suter et al. 2000). For example, densities of *Aporrectodea caliginosa*, which burrows to depths up to 0.3 m or more, were greatest from 0 to 8 cm depth, intermediate in layers 8 to 15 cm and 15 to 20 cm, and lowest from 20 to 30 cm (Pitkanen and Nuutinen 1997).

Given the distribution of metals in soil at the site, exposure of earthworms to COPC via direct contact with contaminated soil was assumed to be a complete exposure pathway in the ERA.

Although soil contact (dermal) is a potential operating pathway for terrestrial wildlife such as the hare and mink, the contribution from this pathway in most cases is negligible compared to other pathways such as ingestion.

1.8.1.3 Incidental Soil Ingestion

Wildlife is exposed to contaminants in soil via several pathways, including ingestion and dermal contact. While both pathways can potentially result in uptake depending on the properties of the chemical, the dominant pathway for both birds and mammals is usually ingestion. Feathers and fur limit the amount of contact that chemicals have with skin, and soil adhered to feathers or fur is ultimately ingested during grooming (Sample and Suter 1994).

Soil comprises a small fraction of the diet for many organisms; the actual quantity of soil ingested depends on the life history traits of the species. For burrowing mammals such as the hare which are frequently in direct contact with soil, quantities of soil ingested are not insignificant. A major source of soil ingested by both mammals and birds is soil adhered to the surface and the gut of prey items, such as earthworms. Quantities of soil ingested from these different sources are not typically distinguished; rather, exposure is quantified through the estimation of average overall soil consumption (as a fraction of diet) for each species.

Of the COPC consumed by an organism, only a fraction is absorbed through the gut and is available to cause toxicity. However, uptake depends on a number of site-specific and organism-specific factors. Therefore, for the purposes of this risk assessment, it is assumed that the entire quantity of COPC in soil consumed by large and small mammals and the robin is available and can potentially result in adverse effects.

1.8.1.4 Ingestion of Food / Prey

Omnivorous wildlife such as the mink can be exposed to COPC in soil via consumption of vegetable matter (e.g., leaves, berries) of plants that have accumulated COPC from soils. Plants growing in soils containing elevated concentrations of chemicals may accumulate and can potentially distribute those chemicals to portions of the plant consumed by herbivores and omnivores. Similarly, soil invertebrates in contact with contaminated soil can accumulate metals, which can be assimilated by minks or birds upon consumption of prey.

Although uptake from soil to vegetation and soil invertebrates varies according to soil chemistry, a reasonable estimate of metal accumulation can be achieved using uptake factors / equations. Uptake factors / equations are based on studies in which measured concentrations in both soil and vegetation / invertebrates were reported.

1.8.1.5 Direct Exposure of Benthic Invertebrates to Chemicals of Potential Concern in Sediment

Sediment-dwelling organisms are potentially exposed to COPC in sediment and interstitial (pore) water via several pathways, including ingestion, dermal contact, and uptake across respiratory membranes. All pathways are potentially present for benthic invertebrates, and

may contribute in part to the overall uptake of chemicals from sediment. However, exposure assessment for sediments primarily involves determining the bulk concentrations of COPC in sediment, as effects (toxicity) data are generally available only for this compartment; body burdens, or tissue concentrations, are useful for estimating uptake to other organisms (e.g., wildlife), but are not used to evaluate effects to benthic organisms.

Actual uptake varies for each contaminant, and depends on a number of factors. Sediment is a combination of solid and liquid phases. For most contaminants, uptake is assumed to occur from the aqueous phase. In general, metals associated with the solid phase are largely unavailable for uptake by organisms. Uptake for most exposure routes occurs primarily from pore water. Bioavailability of metals in sediments is the determining factor in metal toxicity. As previously mentioned in Section 1.6.2.6, pore water data was not available at the time of the assessment and therefore, metal toxicity to benthic invertebrates was not evaluated.

1.8.1.6 Direct Exposure to Chemicals of Potential Concern in Surface Water

Metals in surface water can exist in several forms, most commonly in dissolved forms or absorbed to suspended particulates. Metals dissolved in surface water readily bind to respiratory surfaces and induce adverse effects in fish or amphibians. It is generally accepted that toxicological effects are most closely associated with the dissolved fraction of metals, and most toxicological models assume metals must be in solution to induce toxicity. Nevertheless, in practical terms this has little bearing on the evaluation of exposure in a screening level ERA, as aqueous toxicological data is, in almost all cases, simply related to total metal concentration.

Uptake from surface water is a major exposure pathway for aquatic invertebrates and plants. Aquatic invertebrates accumulate and transfer COPC up the food chain. Aquatic invertebrate organisms are exposed to COPC through the water column. Aquatic plants take two forms: rooted to the sediment (submerged or emergent); and free-floating. Uptake in floating plants is limited to contaminants in surface water only, while rooted species potentially take up contaminants from sediment as well as surface water. However, as most chemicals must be in the dissolved phase prior to root uptake, uptake from sediment actually occurs via the sediment pore water. Moreover, despite physiological differences between rooted aquatic plants and terrestrial plants, uptake from surface water is the major exposure pathway and more important than uptake from roots. In many species, roots primarily serve a physical role as anchors, rather than an organ by which nutrients (and contaminants) are taken up. Therefore, the dominant uptake pathway for metals into aquatic plants is the aqueous pathway.

1.8.1.7 Ingestion of Benthic Invertebrates

Shorebirds may be exposed to COPC via ingestion of invertebrates which have accumulated contaminants from sediment. The level to which contaminants accumulate in benthic invertebrates is a function of the physicochemical properties of the COPC, the rate of uptake into invertebrate tissue, and the ability of the COPC to be sequestered, metabolised, or otherwise eliminated. In general, metals are not accumulated to a

significant degree compared to other COPC, because uptake is strongly regulated, and organisms sequester or eliminate metals through various pathways. Therefore, ecological receptors can be exposed to metals through ingestion of benthic invertebrates, but exposure levels are generally similar to or lower than those in sediment, and the risk from this pathway is considered minor for these COPC.

1.8.1.8 Bioaccumulation and Biomagnifications in Terrestrial and Aquatic Organisms

Ecological receptors at the top of the food web (e.g., piscivorous birds and mammals) are susceptible to adverse effects as a result of consuming prey that have accumulated these compounds. Biomagnification occurs when the following conditions occur at all trophic levels:

- Contaminant is ingested as food;
- Transformation not significant;
- Elimination rate is low; and
- Transfer occurs at several trophic levels.

Contaminants that bioaccumulate in fish are potentially available for uptake by consumers of fish. Exposure to these chemicals via consumption of fish is a relevant exposure pathway for piscivorous avian species and piscivorous mammals. As uptake can vary from site to site due to differences in sediment chemistry, the best estimate of metal content in invertebrates and wildlife species is achieved by sampling and measuring metal content in tissues. Since the COPC are metals, the likelihood of bioaccumulation and biomagnification in the trophic levels is low and exposures through the ingestion of fish are reduced.

1.8.2 Exposure Estimates and Parameters

Exposure estimates are provided for ecological receptors with complete exposure pathways. For terrestrial plants and soil invertebrates which are only exposed to COPC in soil via root uptake or direct contact, exposure estimates are represented by soil concentrations. For the mammals and the birds, exposure estimates are presented as weight-normalised daily doses.

1.8.2.1 Exposure Estimates for Mammals

Grizzly bears are potentially exposed to COPC via ingestion of soil, ingestion of plant tissue, ingestion of small mammals, ingestion of large mammals and ingestion of surface water that have accumulated COPC. For grizzly bears, uptake via ingestion of soil, plant tissue, small and large mammals and surface water pathways are typically summed by calculating an ADD (in units of mg/kg/d). Doses calculated in such a manner can be compared to reference doses reported in the literature, which are also based on weight-normalised doses. This approach assumes mechanisms of toxicity for chemicals are the same regardless of the method of intake.

Estimated doses of COPC in the grizzly bear were calculated using standard exposure equations incorporating uptake from ingestion of soil and food (Sample and Suter 1994). Country food concentrations are based on the 95th percentile concentrations of baseline data (Table 1.8-1).

The ADD of COPC was calculated as:

$$ADD_{\text{ingestion}} = \frac{C_{\text{soil}} \cdot IR_{\text{soil}}}{BW} + \frac{C_{\text{plant}} \cdot IR_{\text{plant}}}{BW} + \frac{C_{\text{sm mammal}} \cdot IR_{\text{sm mammal}}}{BW} + \frac{C_{\text{lg mammal}} \cdot IR_{\text{lg mammal}}}{BW} + \frac{C_{\text{fish}} \cdot IR_{\text{fish}}}{BW} + \frac{C_{\text{sw}} \cdot IR_{\text{sw}}}{BW}$$

where:

- ADD = average daily dose (mg/kg/d);
- C_{soil} = concentration of contaminant in soil (mg/kg);
- IR_{soil} = soil ingestion rate (kg/d);
- C_{plant} = concentration of contaminant in plant tissue (mg/kg);
- IR_{plant} = plant tissue ingestion rate (kg/d);
- C_{sm mammal} = concentration of contaminant in small mammal (mg/kg);
- IR_{sm mammal} = small mammal ingestion rate (kg/d);
- C_{lg mammal} = concentration of contaminant in large mammal (mg/kg);
- IR_{lg mammal} = large mammal ingestion rate (kg/d);
- C_{fish} = concentration of contaminant in fish (mg/kg);
- IR_{fish} = fish ingestion rate (kg/d);
- C_{sw} = concentration of contaminant in surface water (milligrams per litre (mg/L));
- IR_{sw} = surface water ingestion rate (litres per day (L/d)); and
- BW = body weight (kg).

Table 1.8-1: Exposure Parameters for Mammals in the Vicinity of the Proposed Project

Mammal Receptor	Body Weight (kg)	Total Food Intake (kg/d)	Ingestion Rate (kg/day)							
			Soil (e)	Surface Water (L/day)	Plant Tissue (h)	Soil Invertebrates (h)	Meat from Small Mammals (h)	Meat from Large Mammals (h)	Meat from Birds (h)	Meat from Fish (h)
Grizzly Bear (a)	200	10	0.3	11.7 (f)	9.1	n/a	0.4	0.4	n/a	0.1
Black-tailed deer (b)	56.5	1.74(g)	0.052	3.7 (g)	1.74	n/a	n/a	n/a	n/a	n/a
Mink (c)	1	0.137(g)	0.00041	0.099 (g)	0.012	0.018	0.0115	n/a	0.0115	0.0836
Hare (d)	1.23	0.237(g)	0.0071	0.12 (g)	0.237	n/a	n/a	n/a	n/a	n/a

Note: (a) Grizzly bear is assumed to be representative of any large carnivorous / omnivorous mammal in the vicinity of the proposed Project. Exposure parameters for a typical grizzly bear estimated based on information obtained from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (2002b), Canadian Wildlife Service (CWS) and Canadian Wildlife Federation (CFA) (2008b), Gau and Case (1998), Government of BC (2002b), and UMADW (2010). (b) Black-tailed deer is assumed to be representative of any large herbivorous ungulate mammal in the vicinity of the proposed Project. Exposure parameters for a typical deer estimated based on information obtained from Government of BC (2000), and UMADW (2010). (c) Mink is assumed to be representative of any small carnivorous/omnivorous furbearing mammals in the vicinity of the proposed Project. (d) Hare is assumed to be representative of any small herbivorous furbearing mammals in the vicinity of the proposed Project. Exposure parameters for a typical hare estimated based on information obtained from CWS and CWF (2008b) and UMADW (2010). (e) Conservatively estimated at 3% of total dietary intake for grizzly bear and black-tailed deer (US EPA 1993). (f) Estimated using allometric equation for total water intake for mammals (total water intake $L = 0.099 \times \text{body weight}^{0.90}$), US EPA (1993). (g) Based on Sample et al. 1996. Reference values for mammalian species. (h) Based on estimated percentage of total food in the diet; kg/d - kilograms per day; L/d - litres per day; n/a - not applicable

For grizzly bears, seasonal availability and distribution of food is an important determinant of home range size. Grizzly bears are omnivorous and opportunistic in their feeding habits. Although diets vary among individual populations of grizzly bears, vegetation and plants contributed 91% of diets of grizzly bears in British Columbia (Hobson et al. 2000). The high contribution of vegetation in their diet also accounted for the importance of the ungulates in their early spring and late fall diets (McLellan and Hovey 1995). Due to a large home range and a diverse concentration of suitable food resources it is difficult to identify a definitive breakdown of a grizzly bear's diet in the vicinity of the proposed Project. Therefore, for the purposes of this Environmental Health baseline report, assessors relied on published research results to assume that the grizzly bear consumes 91% of its diet as vegetation and the remaining 9% of its diet as meat sources (i.e. small and large mammals and fish). Total ingestion rate of food for the grizzly bear was estimated at 10 kg/day. Total ingestion rate of water for the grizzly bear was estimated using body-weight scaling equations recommended by US EPA (1993). The ingestion rate of soil for the grizzly bear was estimated at a conservative 3% of total food intake. All biological and life characteristics for a typical grizzly bear were estimated based on information obtained from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (2002b), the Canadian Wildlife Service (CWS) and Canadian Wildlife Federation (CWF) (2008a), Gau and Case (1998), the Government of BC (2002b), and University of Michigan (Museum of Zoology) Animal Diversity Web (UMADW) (2010).

Minks are potentially exposed to COPC via ingestion of soil, plant tissue, invertebrates, birds, fish, small mammals, and surface water that have accumulated COPC. For minks, uptake via ingestion of soil, plant tissue, soil invertebrates, birds, small mammals, fish and surface water pathways are typically summed by calculating an ADD (in units of mg/kg/d). Doses calculated in such a manner can be compared to reference doses reported in the literature also based on weight-normalised doses. This approach assumes mechanisms of toxicity for chemicals are the same regardless of the method of intake.

Similar to the grizzly bear, a number of factors, including location, habitat selection, and the availability of food influence the mink's diet. For example, mink feeding in lake habitats prey more heavily on fish, birds, and insects, whereas mink in streams feed more often on mammals (Gilbert and Nancekivell, 1982). Minks are almost strictly carnivorous with only a limited amount of plant material reported in their diet (Proulx et al. 1987). Based on observations and studies in minks collected along streams, the mink diet was found to be 61% fish, 17% bird / mammal prey, 13% invertebrates and 4 % unidentified (Alexander, 1977, as cited in EPA 1993). Due to a diverse prey and habitat selection it is difficult to identify a definitive breakdown of a mink's diet in the vicinity of the proposed Project. Therefore, for the purposes of this Environmental Health baseline report, assessors relied on published research results to determine the following assumptions: the mink consumes 61% of its diet as fish, 17% of its diet as birds and small mammals, 13% of its diet as invertebrates and the remaining 9% of its diet as other food sources (i.e. vegetation). Total food and water ingestion rates for the mink were provided by Sample et al. (1996). The ingestion rate of soil for the mink was estimated at a conservative 3% of total food intake.

Estimated doses of COPC in the mink were calculated using standard exposure equations incorporating uptake from ingestion of soil and food (Sample and Suter 1994). Country food concentrations are based on the 95th percentile concentrations of baseline data (Table 1.8-1).

The ADD was calculated as:

$$ADD_{\text{ingestion}} = \frac{C_{\text{soil}} \cdot IR_{\text{soil}}}{BW} + \frac{C_{\text{plant}} \cdot IR_{\text{plant}}}{BW} + \frac{C_{\text{invertebrates}} \cdot IR_{\text{invertebrates}}}{BW} + \frac{C_{\text{sm mammal}} \cdot IR_{\text{sm mammal}}}{BW} + \frac{C_{\text{birds}} \cdot IR_{\text{birds}}}{BW} + \frac{C_{\text{fish}} \cdot IR_{\text{fish}}}{BW} + \frac{C_{\text{sw}} \cdot IR_{\text{sw}}}{BW}$$

where:

- ADD = average daily dose (mg/kg/d);
- C_{soil} = concentration of contaminant in soil (mg/kg);
- IR_{soil} = soil ingestion rate (kg/d);
- C_{plant} = concentration of contaminant in plant tissue (mg/kg);
- IR_{plant} = plant tissue ingestion rate (kg/d);
- C_{invertebrates} = concentration of contaminant in soil invertebrates (mg/kg);
- IR_{invertebrates} = soil invertebrates ingestion rate (kg/d);
- C_{sm mammal} = concentration of contaminant in small mammal (mg/kg);
- IR_{sm mammal} = small mammal ingestion rate (kg/d);
- C_{birds} = concentration of contaminant in birds (mg/kg);
- IR_{birds} = bird ingestion rate (kg/d);
- C_{fish} = concentration of contaminant in fish (mg/L);
- IR_{fish} = fish ingestion rate (kg/d);
- C_{sw} = concentration of contaminant in surface water (mg/L);
- IR_{sw} = surface water ingestion rate (litres per day (L/d)); and
- BW = body weight (kg).

Black-tailed deer and hares are potentially exposed to COPC via ingestion of soil, plant tissue and surface water that have accumulated COPC. For black-tailed deer and hares, uptake via ingestion of soil, plant tissue, and surface water pathways are typically summed by calculating an ADD (in units of mg/kg/d). Doses calculated in such a manner can be compared to reference doses reported in the literature providing that these are also based on weight-normalised doses. This approach assumes mechanisms of toxicity for chemicals are the same regardless of the method of intake.

The black-tailed deer and the hare are herbivores and forage on most available plants and herbs that are located within the proposed Project footprint. For the purposes of this ERA, it was assumed that 100% of the black-tailed deer's and the hare's diet consists of vegetation. Total ingestion rates of food and water for the black-tailed deer and the hare were provided by Sample et al. (1996). The ingestion rate of soil was estimated at a conservative 3% of total food intake for the black-tailed deer and hare (US EPA 1993).

Estimated doses of COPC in the black-tailed deer and the hare were calculated using standard exposure equations incorporating uptake from ingestion of soil and food (Sample and Suter 1994). Country food concentrations are based on the 95th percentile concentrations of baseline data (Table 1.8-1).

The ADD was calculated as:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{plant} \cdot IR_{plant}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

- ADD = average daily dose (mg/kg/d);
- C_{soil} = concentration of contaminant in soil (mg/kg);
- IR_{soil} = soil ingestion rate (kg/d);
- C_{plant} = concentration of contaminant in plant tissue (mg/kg);
- IR_{plant} = plant tissue ingestion rate (kg/d);
- C_{sw} = concentration of contaminant in surface water (mg/L);
- IR_{sw} = surface water ingestion rate (L/d); and
- BW = body weight (kg).

Unlike sedentary organisms such as plants and earthworms, large and small mammals can integrate exposure from different areas of the proposed Project site, not only the areas with the highest concentrations of COPC. To account for variability in the data, exposure estimates were based on the 95th percentile of soil, food items and surface water concentrations (Table 1.8-1).

Food and soil consumption rates and dietary composition of the large and small mammals is presented in Table 1.8-1. Consumption rates and dietary composition were taken from Sample and Suter (1994) based on values reported in “Wildlife Exposure Factors Handbook” (US EPA 1993).

1.8.2.2 Exposure Estimates for Birds

Raptors or birds of prey (i.e., short-eared owl) are potentially exposed to COPC via ingestion of small mammals and surface water that have accumulated COPC. For raptors, uptake via ingestion of small mammals and surface water pathways is typically summed by calculating an ADD (in units of mg/kg/d). Doses calculated in such a manner can be compared to reference doses reported in the literature providing that these are also based on weight-normalised doses. This approach assumes mechanisms of toxicity for chemicals are the same regardless of the method of intake.

Estimated doses of COPC in the raptor were calculated using standard exposure equations incorporating uptake from ingestion of surface water and food (Sample and Suter 1994).

The ADD was calculated as:

$$ADD_{ingestion} = \frac{C_{sm\ mammal} \cdot IR_{sm\ mammal}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

- ADD = average daily dose (mg/kg/d);
- $C_{\text{sm mammal}}$ = concentration of contaminant in small mammal (mg/kg);
- $IR_{\text{sm mammal}}$ = small mammal ingestion rate (kg/d);
- C_{sw} = concentration of contaminant in surface water (mg/L);
- IR_{sw} = surface water ingestion rate (L/d); and
- BW = body weight (kg).

For the purposes of this risk assessment, it was assumed that a typical raptor consumes 100% of its diet as small animals. Total ingestion rates of food and water for a typical raptor were provided by Sample et al. (1996) avian reference values table. All biological and life characteristics for a typical raptor were estimated based on information obtained from COSEWIC (2000; 2007), CWS and CWF (2008a), the Government of BC (2000a, 2004) and UMADW (2010).

Songbirds (i.e., North American robin) are potentially exposed to COPC via ingestion of soil, soil invertebrates and surface water that have accumulated COPC. For songbirds, uptake via ingestion of soil, soil invertebrates and surface water pathways are typically summed by calculating an ADD (in units of mg/kg/d). Doses calculated in such a manner can be compared to reference doses reported in the literature providing that these are also based on weight-normalised doses. This approach assumes mechanisms of toxicity for chemicals are the same regardless of the method of intake.

For the purposes of this risk assessment it was assumed that the songbird consumes 100% of its diet as soil invertebrates. Ingestion rates of food for the songbird were estimated using body-weight scaling equations recommended by US EPA (1993). Ingestion rates of water were provided by Sample et al. (1996). The ingestion rate of soil for the songbirds was estimated at a conservative 3% of total food intake (US EPA 1993). All biological and life characteristics for the songbird were estimated based on information obtained from UMADW (2010).

Estimated doses of COPC in the songbird were calculated using standard exposure equations incorporating uptake from ingestion of soil and food (Sample and Suter 1994). Soil, soil invertebrates, and surface water concentrations are based on the 95th percentile of the baseline data (Table 1.8-2).

Table 1.8-2: Exposure Parameters for Birds in the Vicinity of the Proposed Project

Mammal Receptor	Body Weight (kg)	Total Food Intake (kg/d)	Ingestion Rate (kg/day)					
			Soil (e)	Surface Water (L/d)	Soil Invertebrates (i)	Invertebrates (i)	Meat from Small Mammals (i)	Meat from Fish (i)
Raptor (Short-eared Owl) (a)	0.47	0.06(g)	0.002	0.035 (g)	n/a	n/a	0.06	n/a
Songbird (North American Robin) (b)	0.077	0.009(h)	0.0003	0.011 (g)	0.009	n/a	n/a	n/a
Waterfowl (Loon) (c)	1	0.1(h)	0.003	0.1(f)	n/a	n/a	n/a	0.1
Shorebird (Spotted Sandpiper) (d)	0.2	0.02(h)	0.0006	0.02 (f)	n/a	0.02	n/a	n/a

Note: (a) Exposure parameters for a typical raptor estimated based on information obtained from COSEWIC (2000, 2007), CWS and CWF (2008a), Government of BC (2000a, 2004), and University of Michigan (Museum of Zoology) Animal Diversity Web (UMADW) (2010) unless otherwise indicated. (b) Exposure parameters for a typical songbird estimated based on information obtained from COSEWIC (2006) and UMADW (2010). (c) Exposure parameters for a typical waterfowl estimated based on information obtained from US EPA (1993). (d) Exposure parameters for a typical shorebird estimated based on information obtained from US EPA (1993). (e) Conservatively estimated at 3% of total dietary intake (US EPA 1993). (f) Estimated using allometric equation for total water intake for birds (total water intake L = 0.059 x body weight^{0.67}), US EPA (1993). (g) Based on Sample et al. 1996. Reference values for avian species. (h) Estimated using allometric equation for total food intake for birds (total food intake (kg) = 0.0582 x body weight^{0.651}); U.S. EPA 1993. (i) Based on estimated percentage of total food in the diet; kg - kilograms; kg/d - kilograms per day; L/d - litres per day; n/a - not applicable

The ADD was calculated as:

$$ADD_{ingestion} = \frac{C_{soil} \cdot IR_{soil}}{BW} + \frac{C_{invertebrates} \cdot IR_{invertebrates}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

- ADD = average daily dose (mg/kg/d);
- C_{soil} = concentration of contaminant in soil (mg/kg);
- IR_{soil} = soil ingestion rate (kg/d);
- C_{invertebrates} = concentration of contaminant in soil invertebrates (mg/kg);
- IR_{invertebrates} = soil invertebrates ingestion rate (kg/d);
- C_{sw} = concentration of contaminant in surface water (mg/L);
- IR_{sw} = surface water ingestion rate (L/d); and
- BW = body weight (kg).

Waterfowl (i.e., loon) are potentially exposed to COPC via ingestion of fish and surface water that have accumulated COPC. For waterfowl, uptake via ingestion of fish and surface water pathways is typically summed by calculating an ADD (in units of mg/kg/d). Doses calculated in such a manner can be compared to reference doses reported in the literature providing that these are also based on weight-normalised doses. This approach assumes mechanisms of toxicity for chemicals are the same regardless of the method of intake.

For the purposes of this risk assessment it was assumed that waterfowl consumes 100% of its diet as fish. Ingestion rate for food and water for waterfowl were estimated using body-weight scaling equations recommended by US EPA (1993). All biological and life characteristics for waterfowl were estimated based on information obtained from UMADW (2010).

Estimated doses of COPC in waterfowl were calculated using standard exposure equations incorporating uptake from ingestion of soil and food (Sample and Suter 1994). Fish and surface water concentrations are based on the 95th percentile of the baseline data (Table 1.8-2).

The ADD was calculated as:

$$ADD_{ingestion} = \frac{C_{fish} \cdot IR_{fish}}{BW} + \frac{C_{sw} \cdot IR_{sw}}{BW}$$

where:

- ADD = average daily dose (mg/kg/d);
- C_{fish} = concentration of contaminant in fish (mg/kg);
- IR_{fish} = fish ingestion rate (kg/d);
- C_{sw} = concentration of contaminant in surface water (mg/L);
- IR_{sw} = surface water ingestion rate (L/d); and
- BW = body weight (kg).

Shorebirds (i.e., spotted sandpiper) are potentially exposed to COPC via intake of surface water and sediment during the ingestion of invertebrates. For shorebirds, uptake via ingestion of sediment, aquatic invertebrates, and surface water pathways is typically

summed by calculating an ADD (in units of mg/kg/d). Doses calculated in such a manner can be compared to reference doses reported in the literature providing that these are also based on weight-normalised doses. This approach assumes mechanisms of toxicity for chemicals are the same regardless of the method of intake.

For the purposes of this risk assessment it was assumed that a typical shorebird consumes 100% of its diet as invertebrates. Ingestion rate for food and water for shorebirds were estimated using body-weight scaling equations recommended by US EPA (1993). The ingestion rate of sediment for the shorebird was estimated at a conservative 3% of total food intake (US EPA 1993). All biological and life characteristics for shorebirds were estimated based on information obtained from UMADW (2010).

Estimated doses of COPC in shorebirds were calculated using standard exposure equations incorporating uptake from ingestion of sediment and food (Sample and Suter 1994). Sediment, invertebrates, and surface water concentrations are based on the 95th percentile of the baseline data (Table 1.8-2).

The ADD was calculated as:

$$ADD_{\text{ingestion}} = \frac{C_{\text{sed}} \cdot IR_{\text{sed}}}{BW} + \frac{C_{\text{invertebrates}} \cdot IR_{\text{invertebrates}}}{BW} + \frac{C_{\text{sw}} \cdot IR_{\text{sw}}}{BW}$$

where:

- ADD = average daily dose (mg/kg/d);
- C_{sed} = concentration of contaminant in sediment (mg/L);
- IR_{sed} = sediment ingestion rate (L/d); and
- C_{invertebrates} = concentration of contaminant in invertebrates (mg/kg);
- IR_{invertebrates} = invertebrates ingestion rate (kg/d);
- C_{sw} = concentration of contaminant in surface water (mg/L);
- IR_{sw} = surface water ingestion rate (L/d); and
- BW = body weight (kg).

Unlike sedentary organisms such as plants and earthworms, birds can integrate exposure from different areas of the proposed Project site, not only the areas with the highest concentrations of COPC. To account for variability in the data, exposure estimates were based on the 95th percentile of sediment, food items, and surface water concentrations (Table 1.8-2).

Food and soil consumption rates and dietary composition of birds are presented in Table 1.8-2. The majority of the consumption rates and dietary composition are from Sample and Suter (1994) based on values reported in the US EPA “Wildlife Exposure Factors Handbook” (1993).

1.8.2.3 Exposure Estimates for Amphibians

Amphibians are potentially exposed to metals in surface water. Amphibians are mobile and can integrate exposures from multiple locations. Amphibians found in the vicinity of the proposed Project are potentially exposed to elevated concentrations of metals in surface

water. Therefore, exposure estimates for amphibians are based on the 95th percentile concentrations in surface water collected (Table 1.8-3).

Table 1.8-3: Ecological Risk Assessment Exposure Estimates

Metal COPC	95th Percentile Surface Water Concentration (mg/L)	95th Percentile Soil Concentration (mg/kg)	95th Percentile Plant Tissue Concentration (mg/kg)	95th Percentile Fish Concentration (mg/kg)	95th Percentile Sediment Concentration (mg/kg)
Arsenic	0.00047	29.0	0.025	0.13	340.3
Cadmium	0.001	0.97	0.010	0.15	14.5
Chromium	0.00025	97.0	0.50	0.45	88.7
Copper	n/a	n/a	n/a	n/a	255.7
Lead	n/a	n/a	n/a	n/a	419.8
Mercury	0.000005	n/a	n/a	n/a	0.3
Molybdenum	0.32	95.0	1.1	0.03	n/a
Nickel	0.0021	99.5	1.0	0.26	n/a
Selenium	0.0003	1.4	0.50	0.89	n/a

Note: COPC - Chemicals of Potential Concern; mg/kg - milligrams per kilogram; mg/L - milligrams per litre; n/a - not available / not applicable

1.8.2.4 Exposure Estimates for Fish

Fish are potentially exposed to metals in surface water. Dolly Varden are mobile and can integrate exposures from multiple locations. Dolly Varden found in freshwater near the proposed Project are potentially exposed to elevated concentrations of metals in surface water. Therefore, exposure estimates for fish are based on the 95th percentile concentrations in surface water collected (Table 1.8-3).

1.8.2.5 Exposure Estimates for Aquatic Invertebrates

Aquatic invertebrates are primarily exposed to COPC in surface water. This Environmental Health baseline report relies on modelling for aquatic invertebrate exposure to surface water because of an absence of porewater data. Although invertebrates are somewhat mobile, the range of movement of these organisms is generally small compared to the spatial extent of contamination at most sites. Therefore, they are often considered to be immobile for the purposes of estimating exposure. This is a conservative assumption, as migration results in an average exposure which is lower than the upper limit. Exposure estimates for invertebrates were based on the 95th percentiles of COPC concentrations in surface water (Table 1.8-3).

The 95th percentile for data sets with non-detect values were calculated using half of the method detection limit as surrogate values for the non-detects.

1.8.2.6 Exposure Estimates for Aquatic Plants

Aquatic plants in creeks and lakes near the proposed Project are potentially exposed to elevated concentrations of dissolved metals in surface water. Most aquatic plants are sessile and remain fixed in one spatial location (with the exception of some macrophytes which reproduce vegetatively). Therefore, exposure estimates for aquatic plants were based on the 95th percentile concentrations in surface water collected from surrounding creeks and lakes (Table 1.8-3).

1.8.2.7 Exposure Estimates for Terrestrial Plants

Because plants are immobile, exposure to contaminants cannot be averaged or integrated among areas of a site with higher and lower concentrations. Some fraction of individuals in a population at a site is potentially exposed to the highest concentrations of COPC. Therefore, exposure estimates are based on upper estimates of concentrations at the proposed Project site. Although the maximum measured concentration can be used as a very conservative estimate of exposure, use of the maximum would ensure protection of 100% of individuals, which is not consistent with the objectives of the assessment or standard practice in ERA. Instead, the 95th percentile of the distribution of COPC concentrations is a reasonable estimate of exposure (Table 1.8-3). Use of the 95th percentile describes the concentration to which 95% of individuals are exposed; only 5% of individuals are potentially exposed to greater concentrations. Loss of 5% of individuals is considered acceptable in ERA if the viability of populations is maintained.

Sources of uncertainty associated with the exposure estimates for plants concern the location of the plants in relation to the areas of greatest contamination, and the efficiency of plant uptake. Most plants on the site will not be exposed to soil with the highest metal concentrations. Uptake by plant roots is dependent on the depth at which COPC reside in soil. For parameters which are relatively immobile in soil, uptake only occurs in the upper soil layers where COPC can be accessed by plant root systems.

1.8.2.8 Exposure Estimates for Soil Invertebrates

Similar to terrestrial plants, soil invertebrates are considered to be essentially immobile. Exposure estimates for this receptor were based on the 95th percentile of COPC concentrations in soil at the proposed Project site (Table 1.8-3).

1.9 Toxicity Assessment

The following section details the potential adverse effects on the VCs associated with exposure to COPC. For each receptor, TRVs representing concentrations of COPC protective of most ecological receptors were identified.

1.9.1 Arsenic

Arsenic is naturally present in rock and soils with concentrations in soils reflecting the geology of the region as well as anthropogenic inputs. Higher concentrations are associated with igneous and sedimentary rocks, particularly with sulfidic ores (American

Petroleum Institute (API) 1998). Extensive discussions of the sources, concentrations, and chemical species are presented in API (1998) and Cullen and Reimer (1989). Arsenic is used in multiple manufacturing and industrial processes including the production of wood treating chemicals, herbicides, pesticides, desiccants, metal alloys, glass, pharmaceuticals, and semi-conductors. Elevated arsenic soil concentrations are often associated with mining activities, smelters, pesticide / herbicide manufacturing facilities and agricultural lands (API 1998).

Arsenic can exist in four oxidation states: +5, +3, 0 and -3. In soil, arsenic is a constituent of numerous minerals and is found frequently associated with sulphur, most commonly as arsenopyrite (FeAsS). Inorganic arsenate can also be bound to iron and aluminum cations or any other cation that may be present (e.g., calcium, zinc, magnesium, lead), as well as organic matter in soils (API 1998). Arsenic occurs in contaminated soils primarily as the inorganic arsenic (V) and arsenic (III), but soil microorganisms can produce organic forms (Cullen and Reimer 1989; Huang 1994; CCME 1997b). Transformations among inorganic and organic forms are controlled by the oxidation-reduction, precipitation / adsorption, and biomethylation processes, in addition to the biological production and volatilisation of the arsines (API 1998). The availability or solubility of arsenic in soils depends on the source (natural vs. anthropogenic) and the soil's clay content, redox potential, and pH. Generally, factors that tend to increase arsenic availability are anthropogenic sources (e.g., pesticides), low clay content, low redox potential (reducing conditions), and high pH (alkaline conditions) (Cullen and Reimer 1989; API 1998).

During the screening of metals (see Sections 1.6.2 - 1.6.6), the 95th percentile of baseline concentrations for arsenic in soil and sediment was found to be greater than CCME "Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health" (CCME 2007) and CCME "Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life" (CCME 2002). Since exceedances of arsenic were only identified in soil and sediment, the health of ecological receptors exposed to COPC in soil and sediment was evaluated. Sections 1.9.1.1 - 1.9.1.4 describe the derivation of toxicological reference values (TRVs) used in the assessment for ecological receptors potentially exposed to arsenic in soil and sediment.

1.9.1.1 Mammals

Arsenic-containing compounds vary in toxicity to mammals according to valence state, form (i.e., inorganic or organic), physical state (i.e., gas, solution, or powder), and factors such as solubility, particle size, rates of absorption and elimination, and presence of impurities. Inorganic arsenic is generally considered more toxic than organic arsenic. The toxicity of arsenic as the trivalent form (i.e., arsenic (III)) is several times greater than that of the pentavalent form (i.e., arsenic (V)) primarily due to arsenic (III)'s higher potential for cellular uptake. Metalloid arsenic is generally regarded as non-poisonous due to its insolubility in water and body fluids (Agency for Toxic Substances and Disease Registry (ATSDR) 2007).

Chronic toxicity due to inorganic exposures may result in dermal or neurological symptoms. Dermal effects may include hyperpigmentation or hyperkeratosis on the palms, soles, and

torso. Peripheral neuropathy may appear with symmetrical paresthesia. Neurotoxicity begins with sensory changes, paresthesia, and muscle tenderness, followed by weakness, which progresses from proximal to distal muscle groups. Chronic hepatic and renal damage is common with jaundice occurring due to liver injury.

An Ecological Soil Screening Level (Eco-SSL) for mammals has been calculated by the US EPA (2005). This was based on a comparison of the geometric mean of the NOAEL values for growth and reproduction from a number of studies with the LOAEL for reproduction, growth or survival. The geometric mean of NOAEL values was 2.47 mg arsenic/kg bw/day. However, this value is higher than the lowest bounded LOAEL. Therefore, the TRV was established at 1.04 mg/kg/day, representing the highest NOAEL which was still lower than the lowest LOAEL for reproduction, growth, or survival.

NOAEL (or LOAEL) based on reproduction, growth, or mortality endpoints in rats and mice were adjusted using standard allometric relationships (Sample et al. 1996). If a NOAEL is available for a mammalian test species ($NOAEL_t$), then the equivalent NOAEL for a mammalian wildlife species ($NOAEL_w$) can be calculated by using the adjustment factor for differences in body size (Sample et al. 1996):

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{1/4}$$

where $NOAEL_t$ = the NOAEL reported in the study for the test species;
 bw_t = body weight of the test species; and
 bw_w = body weight of the mammals used in the assessment.

Body weights for test species were obtained from either Sample et al. (1996) or US EPA Eco-SSL (2005). Body weight of the mammals used in this assessment and the adjusted TRVs are presented in Table 1.9-1.

Table 1.9-1: Toxicological Reference Value Derivations for Mammals

Receptor	Test Species (a)	Test Species Body Weight (kg) (a)	Receptor Body Weight (kg)	TRV (mg/kg/day) (b)	Adjusted TRV (mg/kg/d) (c)
Arsenic					
Grizzly Bear	Dog	10	200	1.04	0.49
Black-tailed deer	Dog	10	56.5	1.04	0.67
Mink	Dog	10	1	1.04	1.85
Hare	Dog	10	1.23	1.04	1.76
Cadmium					
Grizzly Bear	Rat	0.35	200	0.77	0.16
Black-tailed deer	Rat	0.35	56.5	0.77	0.22
Mink	Rat	0.35	1	0.77	0.59
Hare	Rat	0.35	1.23	0.77	0.56
Chromium					
Grizzly Bear	Rat	0.35	200	3.28	0.67
Black-tailed deer	Rat	0.35	56.5	3.28	0.92
Mink	Rat	0.35	1	3.28	2.52
Hare	Rat	0.35	1.23	3.28	2.40
Molybdenum					
Grizzly Bear	Mouse	0.03	200	2.6	0.29
Black-tailed deer	Mouse	0.03	56.5	2.6	0.39
Mink	Mouse	0.03	1	2.6	1.08
Hare	Mouse	0.03	1.23	2.6	1.0
Nickel					
Grizzly Bear	Rat	0.35	200	40	8.2
Black-tailed deer	Rat	0.35	56.5	40	11.2
Mink	Rat	0.35	1	40	30.8
Hare	Rat	0.35	1.23	40	29.2

Receptor	Test Species (a)	Test Species Body Weight (kg) (a)	Receptor Body Weight (kg)	TRV (mg/kg/day) (b)	Adjusted TRV (mg/kg/d) (c)
Selenium					
Grizzly Bear	Rat	0.35	200	0.2	0.041
Black-tailed deer	Rat	0.35	56.5	0.2	0.06
Mink	Rat	0.35	1	0.2	0.15
Hare	Rat	0.35	1.23	0.2	0.15

Note: TRV - Toxicological Reference Value. (a) Studies on test species and body weight provided by US EPA Eco-SSL (2005) and Sample et al. (1996). (b) Eco-SSL) for mammals calculated by the US EPA (2005) or a geometric mean of the NOAEL values for reproduction and growth calculated by Sample et al. 1996). (c) NOAEL for a mammalian wildlife species (NOAEL_w) calculated by using the adjustment factor for differences in body size (Sample et al. 1996); kg - kilogram; mg/kg/d - milligrams per kilogram per day

1.9.1.2 Birds

The clinical effects of arsenic toxicity in avian species is similar to that in mammals, but birds in general are more sensitive to the adverse effects of arsenic. Recent research suggests that physiological scaling factors developed for mammals may not be appropriate for interspecies extrapolation among birds (Sample et al. 1996). The TRV for birds was based on studies collated by US EPA (2005). The adopted TRV for the songbird, shorebird, waterfowl, and raptor is 2.24 mg/kg/day. For shorebirds (i.e., spotted sandpiper), exposure to arsenic may occur via uptake of surface water and sediment during ingestion of aquatic invertebrates.

1.9.1.3 Soil Invertebrates

Vaughan and Greenslade (1998) investigated the effects of arsenic on earthworms (*Eisenia andrei*) growing in an artificial soil for 14 days. The Lethal Concentration effective to induce 50% mortality (LC_{50}) of 472 parts per million (ppm) was derived from the study. In the same study, a 28 day reproduction investigation was completed with adult springtails (*Folsomia candida*). A No Observable Effect Concentration (NOEC) of 10 ppm and an EC_{50} of 119 ppm was estimated from the study.

Savannah River Site has listed a TRV of 60 mg/kg for earthworms (US Department of Energy 1999), but there is no explanation provided for the basis of the TRV.

The CCME's SQG_E of 17 mg/kg for residential / parkland property use was adopted as the TRV for soil invertebrates. This guideline is intended to protect plants and other terrestrial biota from direct soil contact at a level consistent with the purposes of a residential / parkland land use.

1.9.1.4 Terrestrial Plants

Arsenic is not essential for plant growth. Roots take it up actively, with arsenate being more easily absorbed than arsenite. The phytotoxicity of arsenic is strongly affected by the form in which it occurs in soils. Arsenite is more toxic than arsenate, and both are considerably more toxic than organic forms (Peterson et al. 1981). Symptoms of arsenic toxicity include wilting of new-cycle leaves, followed by retardation of root and top growth, and leaf necrosis (Aller et al. 1990). Arsenic (III) probably reacts with sulphhydryl enzymes leading to membrane degradation and cell death. Arsenic (V) is known to uncouple phosphorylation and affect enzyme systems (Peterson et al. 1981). The mechanism of toxicity of organo-arsenicals is unclear. An average toxicity threshold of 40 mg/kg was established for crop plants (Sheppard et al. 1992).

Rosehart and Lee (1973) tested the tolerance of spruce seedlings to arsenic in field plots. Three-year-old seedlings were grown for 335 days in soil to which 1000 parts per million (ppm) arsenic was added as arsenic (III) (lowest concentration tested). A 50% reduction in the height of the seedlings was observed.

Jiang and Singh (1994) assessed the toxicity of arsenic (III) and arsenic (V) on barley and ryegrass yields. The plants were grown from seed for one year in two different soils in a greenhouse. The soils tested were a loam (pH 4.9, 3% organic carbon, and 19% clay) and a sand (pH 5.6, 0.4% organic carbon, and 3% clay). Sodium arsenite was more toxic to barley plants than sodium arsenate in both soils. Barley seedlings exhibited the greatest toxicity when grown in the sand (24% decrease at 2 ppm, the lowest concentration tested). Arsenic (V) at 250 ppm was associated with a greater reduction in ryegrass yield (63%) than the same concentration of arsenic (III) in the loam soil (22%). In the sand, sodium arsenite reduced ryegrass yield 34% at 50 ppm. A concentration of 250 ppm arsenic (V) caused a 91% decrease in yield while 50 ppm had no effect.

The CCME's SQG_E of 17 mg/kg for residential / parkland property use was adopted as the TRV for plants. This guideline is intended to protect plants and other terrestrial biota from direct soil contact at a level consistent with the purposes of a residential / parkland property.

1.9.2 Cadmium

In the environment, cadmium occurs as a divalent metal that is insoluble in water, but its chloride and sulfate salts are freely soluble (Eisler 1985). If released or deposited on soil, cadmium is largely retained in the surface layers of soil. Cadmium is adsorbed to soil but to a much lesser extent than most other heavy metals. The most important soil properties influencing adsorption are pH and organic content. Adsorption increases with pH and organic content; therefore, leaching is more likely to occur under acid conditions in sandy soil. The availability of cadmium to organisms in the environment is dependent on a number of factors including pH and chemical speciation (Eisler 1985). Cadmium is taken up by plants from soils and translocated through the terrestrial food chain (Shore and Douben 1994).

During the screening of metals (see Sections 1.6.2 - 1.6.6), the 95th percentile of baseline concentrations for cadmium in surface water and sediment was found to be greater than CCME "Canadian Water Quality Guidelines for the Protection of Aquatic Life" (CCME 2007) and CCME "Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life" (CCME 2002). Since exceedances of cadmium were only identified in surface water and sediment, the health of ecological receptors exposed to COPC in surface water and sediment was evaluated. Sections 1.9.2.1 - 1.9.2.6 describe the derivation of TRVs used in the assessment for ecological receptors potentially exposed to cadmium in surface water and sediment.

1.9.2.1 Mammals

In mammals, cadmium exposure adversely affects health, and mechanisms of toxicity are varied. Cadmium is highly toxic to wildlife; it is cancer-causing and teratogenic, and potentially mutation-causing, with severe sublethal and lethal effects at low environmental concentrations (Eisler 1985a). It is associated with increased mortality, and it affects respiratory functions, enzyme levels, muscle contractions, growth reduction, and reproduction.

Ecological Soil Screening Level (Eco-SSL) for mammals has been calculated by the US EPA (2005). This was based on a comparison of the geometric mean of the NOAEL values for growth and reproduction from a number of studies with the LOAEL for reproduction, growth or survival. The geometric mean of NOAEL values was 1.86 mg cadmium/kg bw/day. However, this value is higher than the lowest bounded LOAEL. Therefore, the TRV was established at 0.77 mg/kg/day, representing the highest NOAEL, which was still lower than the lowest LOAEL for reproduction, growth and survival.

1.9.2.2 Birds

The main routes of cadmium absorption are via ingestion. Factors that are reported to affect dietary cadmium absorption from the gastrointestinal tract include age, sex, chemical form, levels of protein, levels of calcium, and the presence of other elements (Nriagu 1981). Cadmium-induced effects associated with oral intake include nephrotoxicity and also possible effects on the liver, reproductive organs, and the hematopoietic, immune, skeletal, and cardiovascular systems (Shore and Douben 1994). The TRV for birds was based on studies collated by US EPA (2005). The adopted TRV for the songbird, shorebird, waterfowl and raptor is 1.47 mg/kg/day. For shorebirds (i.e., spotted sandpiper), exposure to cadmium may potentially occur via uptake of surface water and sediment during ingestion of aquatic invertebrates.

1.9.2.3 Amphibians

Nebeker et al. (1993) provide a LOAEL value of 0.044 mg/L based on studies involving the effects of cadmium on leg regeneration in larvae of the Northwest salamander *Ambystoma gracile*. The results of the study concluded that cadmium significantly affected limb regeneration. The LOAEL value of 0.044 mg/L was adopted as the TRV for cadmium exposure to amphibians.

1.9.2.4 Fish

A reduction in toxicity associated with increased hardness is evident for several fish species. Cadmium has a lowest chronic value for fish that was based on studies collated by Sauter et al. (1976). The lowest chronic value for cadmium is 0.0017 mg/L. This was adopted as the TRV for cadmium exposure to Dolly Varden.

1.9.2.5 Aquatic Invertebrates

Carlson et al. (1982) provides an EC₂₀ value chronic value of 0.0008 mg/L for cadmium based on a life-cycle test on *Daphnia magna*. The study revealed a population decrease when cadmium was present. This benchmark value was adopted as the TRV for the assessment.

1.9.2.6 Aquatic Plants

Aquatic plants are affected by cadmium concentrations ranging from 0.002 to 7.4 mg/L. These values are in the same range as the values seen in fish and invertebrates. Conway (1977) provides a lowest chronic value of 0.002 mg/L based on a study involving the

application of low cadmium concentrations to aquatic plants. The study resulted in reduced population growth rate in aquatic plants. The lowest chronic value of 0.002 mg/L was adopted as the TRV for the assessment.

1.9.3 Chromium

Chromium speciation in soils is complex. Factors that affect the speciation of chromium in soil and water and its uptake into animals and plants include: organic matter content; ferrous ion content; redox state; and pH (Outridge and Scheuhammer 1993; CCME 1996a). In general, chromium (VI) is favored by higher pH, aerobic conditions, low amounts of organic matter, and the presence of manganese and iron oxides which oxidise chromium (III). Transformation of chromium (VI) to the trivalent form tends to occur in acidic, anoxic soils with high organic content. Chromium (III) is cationic and adsorbs onto clay particles, organic matter, metal oxyhydroxides, and other negatively charged particles. This is in contrast to chromium (VI), which does not interact significantly with clay or organic matter. As a result, chromium (VI) is more water-soluble and mobile than chromium (III) (Outridge and Scheuhammer 1993).

During the screening of metals (see Sections 1.6.2 - 1.6.6), the 95th percentile of baseline concentrations for chromium in soil and sediment was found to be greater than CCME “Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health” (CCME 2007) and CCME “Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life” (CCME 2002). Since exceedances of chromium were only identified in soil and sediment, the health of ecological receptors exposed to COPC in soil and sediment was evaluated. Sections 1.9.3.1 - 1.9.3.4 describe the derivation of TRVs used in the assessment for ecological receptors potentially exposed to chromium in soil and sediment.

1.9.3.1 Mammals

Chromium has been shown to be an essential nutrient for animals (NRC 1997). Chromium (III) has been shown to have antioxidative properties in vivo and it is integral in activating enzymes and maintaining the stability of proteins and nucleic acids. Its primarily metabolic role is to potentiate the action of insulin through its presence in an organometallic molecule called the glucose tolerance factor.

A geometric mean of the NOAEL values for reproduction and growth was calculated at 3.28 mg chromium/kg bw/day (Sample et al. 1996).

NOAEL (or LOAEL) based on reproduction, growth, or mortality endpoints in rats and mice were adjusted using standard allometric relationships (Sample et al. 1996). If a NOAEL is available for a mammalian test species ($NOAEL_t$), then the equivalent NOAEL for a mammalian wildlife species ($NOAEL_w$) can be calculated by using the adjustment factor for differences in body size (Sample et al. 1996):

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{1/4}$$

where $NOAEL_t$ = NOAEL reported in the study for the test species;
 bw_t = body weight of the test species; and
 bw_w = body weight of the mammals used in the assessment.

Body weights for test species were obtained from either Sample et al. (1996) or US EPA Eco-SSL (2005). Body weight of the mammals used in this assessment and the adjusted TRVs is presented in Table 1.9-1.

1.9.3.2 Birds

The clinical effects of chromium in avian species are similar to those in mammals. Recent research suggests that physiological scaling factors developed for mammals may not be appropriate for interspecies extrapolation among birds (Sample et al. 1996). The adopted TRV for the songbird, shorebird, waterfowl, and raptor is 1 mg/kg/day (Sample et al. 1996). For shorebirds (i.e., spotted sandpiper), exposure to chromium may potentially occur via uptake of surface water and sediment during ingestion of aquatic invertebrates.

1.9.3.3 Soil Invertebrates

The CCME's SQG_E of 64 mg/kg for residential / parkland property use was adopted as the TRV for soil invertebrates. This guideline is intended to protect plants and other terrestrial biota from direct soil contact at a level consistent with the purposes of a residential / parkland land use.

1.9.3.4 Terrestrial Plants

Sample et al. (1996) uses a screening benchmark value for chromium in terrestrial plants of 1 mg/kg. This value was adopted as the TRV. The screening benchmark is intended to protect plants and other terrestrial biota from direct soil contact.

1.9.4 Copper

Copper may be present as soluble compounds including nitrates, sulfates, and chlorides, and insoluble compounds such as oxides, hydroxides, carbonates, and sulfides (Bodek et al. 1988). Soluble copper compounds strongly sorb to particles of organic matter, clay, soil, or sand, and demonstrate low mobility in soils (Bodek et al. 1988). Most copper compounds have a high melting point and low vapour pressure, and are not expected to volatilise from moist or dry soil surfaces (Bodek et al. 1988).

During the screening of metals (see Sections 1.6.2 - 1.6.6), the 95th percentile of baseline concentrations for copper in sediment was found to be greater than CCME "Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life" (CCME 2002). Since exceedances of copper were only identified in sediment, the health of ecological receptors exposed to COPC in sediments was evaluated. Section 1.9.4.1 describes the derivation of TRVs used in the assessment for ecological receptors potentially exposed to copper in sediment.

1.9.4.1 Birds

Copper is essential for hemoglobin formation, carbohydrate metabolism, catecholamine biosynthesis, and cross-linking of collagen, elastin, and hair keratin (US EPA 1987). The primary route of exposure to copper is through ingestion. Generally, the normal intake of copper by inhalation is a negligible fraction of the total (Friberg et al. 1986) and absorption through the skin is minimal (Venugopal and Luckey 1978). For shorebirds (i.e., spotted sandpiper) exposure to copper may potentially occur via uptake of sediment during ingestion of aquatic invertebrates. The TRV for shorebirds was based on studies collated by US EPA (2005). The adopted TRV for shorebirds exposed to copper is 47 mg/kg/day.

1.9.5 Lead

The efficient fixation of lead in soils limits the transfer of lead to aquatic systems. However, leaching of lead can be relatively rapid from some soils, especially at highly contaminated sites or landfills (Kayser et al. 1982). Lead is most available from acidic sandy soils which contain little material capable of binding lead (National Research Council of Canada 1978). Concentrations of lead in soil solution reach a minimum between pH 5 and 6 because metal-organic complexes form in this pH range. The uptake of lead by plants also depends on other factors including cation exchange capacity, soil composition (e.g., organic matter content and calcium content), metal concentrations, precipitation, light, and temperature. Lead uptake by plants is favored at lower pH values and in soils with low organic carbon content (DeMayo et al. 1982).

During the screening of metals (see Sections 1.6.2 - 1.6.6), the 95th percentile of baseline concentrations for lead in sediment was found to be greater than CCME "Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life" (CCME 2002). Since exceedances of lead were only identified in sediment, the health of ecological receptors exposed to COPC in sediments was evaluated. Section 1.9.5.1 describes the derivation of TRVs used in the assessment for ecological receptors potentially exposed to lead in sediment.

1.9.5.1 Birds

Clinical signs of lead toxicity in birds are manifested differently for different species, but the overall signs are of encephalopathy preceded and accompanied by gastrointestinal malfunction (Booth and MacDonald 1982). Behavioural signs of toxicity include anxiety, apprehension, hyperexcitability, vocalisation, rolling of eyes, apparent fear or terror, possible belligerence, pressing of the head against a wall or post, attempts to climb a wall, sudden jumping into the air, and frenzied or maniacal behavior (Booth and MacDonald 1982). Locomotor disturbances of lead poisoning range from a stiff, stilted gait with ataxia and in coordination to rigidity of all postural muscles, swaying, and posterior weakness to compulsive hypermotility (i.e., circling, pacing, and running) (Booth and MacDonald 1982). For shorebirds (i.e., spotted sandpiper), exposure to lead may potentially occur via uptake of sediment during ingestion of aquatic invertebrates. The TRV for shorebirds was based on studies collated by US EPA (2005). The adopted TRV for the shorebirds exposed to lead is 3.85 mg/kg/day.

1.9.6 Mercury

Mercury is a mutagen (mutation-causing), teratogen, and carcinogen, with toxicity and environmental effects varying with the form of mercury, dose, and route of ingestion, and with the exposed organism's species, sex, age, and general condition (Eisler, 1987a). Methylmercury is the most toxic form. Inorganic mercury is methylated primarily by bacteria in both anaerobic and aerobic environments. The organic mercury compounds are more readily absorbed and poorly excreted in comparison with inorganic forms. The primary targets of acute exposures are the central nervous system and kidneys in fish, birds, and mammals.

During the screening of metals (see Sections 1.6.2 - 1.6.6), the 95th percentile of baseline concentrations for mercury in sediment was found to be greater than CCME "Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life" (CCME 2002). Since exceedances of mercury were only identified in sediment, the health of ecological receptors exposed to COPC in sediments was evaluated. Section 1.9.6.1 describes the derivation of TRVs used in the assessment for ecological receptors potentially exposed to mercury in sediment.

1.9.6.1 Birds

Birds may be exposed to chronic low levels of mercury present in the environment. There are numerous effects in birds, including delayed testicular development, altered mating behaviour, reduced fertility and reduced survivability and growth in young (ATSDR 1994). For shorebirds (i.e., spotted sandpiper), exposure to mercury may potentially occur via uptake of sediment during ingestion of aquatic invertebrates. The TRV for shorebirds was based on studies collated by US EPA (2005). The adopted TRV for shorebirds exposed to mercury is 0.0064 mg/kg/day.

1.9.7 Molybdenum

Molybdenum is usually found in nature as molybdenite (MoS_2). It is an essential nutrient for plants and animals. In plants, it is necessary in the bacterial nitrogen fixing process while it is a cofactor for several enzymes in animals.

During the screening of metals (see Sections 1.6.2 - 1.6.6), the 95th percentile of baseline concentrations for molybdenum in soil and sediment was found to be greater than CCME's "Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health" (CCME 2007) and CCME "Sediment Quality Guidelines for the Protection of Freshwater Aquatic Life" (CCME 2002). Since exceedances of molybdenum were only identified in soil and sediment, the health of ecological receptors exposed to COPC in soil and sediment was evaluated. Sections 1.9.7.1 - 1.9.7.8 describe the derivation of TRVs used in the assessment for ecological receptors potentially exposed to molybdenum in soil and sediment.

1.9.7.1 Mammals

A geometric mean of the LOAEL values for reproduction and growth was calculated at 2.6 mg molybdenum/kg bw/day (Sample et al. 1996).

NOAEL (or LOAEL) based on reproduction, growth, or mortality endpoints in rats and mice were adjusted using standard allometric relationships (Sample et al. 1996). If a NOAEL is available for a mammalian test species ($NOAEL_t$), then the equivalent NOAEL for a mammalian wildlife species ($NOAEL_w$) can be calculated by using the adjustment factor for differences in body size (Sample et al. 1996):

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{1/4}$$

where $NOAEL_t$ = NOAEL reported in the study for the test species;
 bw_t = body weight of the test species; and
 bw_w = body weight of the mammals used in the assessment.

Body weights for test species were obtained from either Sample et al. (1996) or US EPA Eco-SSL (2005). Body weight of the mammals used in this assessment and the adjusted TRVs are presented in Table 1.9-1.

1.9.7.2 Birds

Recent research suggests that physiological scaling factors developed for mammals may not be appropriate for interspecies extrapolation among birds (Sample et al. 1996). The adopted TRV for the songbird, shorebird, waterfowl, and raptor is 3.5 mg/kg/day (Sample et al. 1996).

1.9.7.3 Soil Invertebrates

The CCME's interim SQG_E of 10 mg/kg for residential / parkland property use was adopted as the TRV for soil invertebrates. This guideline is intended to protect plants and other terrestrial biota from direct soil contact at a level consistent with the purposes of a residential / parkland land use.

1.9.7.4 Terrestrial Plants

Sample et al. (1996) uses a screening benchmark value for molybdenum in terrestrial plants of 2 mg/kg. This value was adopted as the TRV. The screening benchmark is intended to protect plants and other terrestrial biota from direct soil contact.

1.9.7.5 Amphibians

Birge (1978) provides an LC50 of 0.96 mg/L from a study involving effects of molybdenum on larval toads. The LC50 value of 0.96 mg/L was adopted as the TRV for molybdenum exposure to amphibians.

1.9.7.6 Fish

Molybdenum has a secondary chronic value for fish that was based on studies collated by Sample et al. (1996). The secondary chronic value for molybdenum is 0.37 mg/L. The secondary chronic value was adopted as the TRV for molybdenum in Dolly Varden (*Salvelinus malma miyabei*).

1.9.7.7 Aquatic Plants

No information is available for an appropriate TRV for molybdenum exposures to aquatic plants. However, studies collated by Sample et al. (1996) provide a LCV value for molybdenum for all organisms in freshwater. The lowest chronic value for molybdenum for all organisms is 0.88 mg/L. The lowest chronic value was adopted as the TRV for molybdenum in aquatic plants.

1.9.7.8 Aquatic Invertebrates

Molybdenum has a LCV value for aquatic invertebrates that was based on studies collated by Sample et al. (1996). The lowest chronic value for molybdenum is 0.88 mg/L. The lowest chronic value was adopted as the TRV for molybdenum in aquatic invertebrates.

1.9.8 Nickel

In soils, nickel may be present as soluble compounds including chlorides and nitrates, and insoluble compounds such as oxides and sulfides. Soluble nickel compounds tend to exhibit greater mobility than insoluble nickel compounds (Dean 1985). The degree of mobility is influenced by the formation of complexes in the presence of organic substances and sulfates (Anderson and Christensen 1988). The distribution of nickel between solid and solution phases is primarily controlled by pH with secondary factors being clay content and the amount of hydrous iron and manganese oxides. Soluble nickel increases with decreases in pH. Increases in metal loading and cation exchange capacity (CEC) increase the amount of metal adsorbed by soil (Alloway 1990). Due to low vapour pressures, most nickel compounds are not expected to volatilise from moist or dry soil surfaces, with one notable exception being nickel carbonyl (Ohe 1976). The concentration of nickel in plants generally reflects the concentration in soil, although the relationship is more related to soluble and exchanged forms of nickel. Factors that increase solubility and exchangeability of nickel in soils also result in an increase of the element in plant tissue (Alloway 1990).

During the screening of metals (see Sections 1.6.2 - 1.6.6), nickel was identified as a metal associated with the proposed Project that could affect the health of ecological receptors exposed to COPCs in soil. The 95th percentile of baseline concentrations for nickel in soil is greater than CCME "Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health" (CCME 2007). Sections 1.9.8.1 - 1.9.8.4 describe the derivation of TRVs used in the assessment for ecological receptors potentially exposed to nickel in soil.

1.9.8.1 Mammals

A geometric mean of the LOAEL values for reproduction and growth was calculated at 40 mg nickel/kg bw/day (Sample et al. 1996).

NOAEL (or LOAEL) based on reproduction, growth, or mortality endpoints in rats and mice were adjusted using standard allometric relationships (Sample et al. 1996). If a NOAEL is available for a mammalian test species ($NOAEL_t$), then the equivalent NOAEL for a mammalian wildlife species ($NOAEL_w$) can be calculated by using the adjustment factor for differences in body size (Sample et al. 1996):

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{1/4}$$

where $NOAEL_t$ = NOAEL reported in the study for the test species;
 bw_t = body weight of the test species; and
 bw_w = body weight of the mammals used in the assessment.

Body weights for test species were obtained from either Sample et al. (1996) or US EPA Eco-SSL (2005). Body weight of the mammals used in this assessment and the adjusted TRVs are presented in Table 1.9-1.

1.9.8.2 Birds

Recent research suggests that physiological scaling factors developed for mammals may not be appropriate for interspecies extrapolation among birds (Sample et al. 1996). The adopted TRV for the songbird, shorebird, waterfowl, and raptor is 77.4 mg/kg/day (Sample et al. 1996).

1.9.8.3 Soil Invertebrates

Scott-Fordsmand et al. (1999) investigated the effects of nickel on springtail (*Folsomia fimetaria* L.) growing in an artificial soil. A geometric mean of NOAEL and LOAEC values of 387 mg/kg was derived from the study. The Eco-SSL value for nickel for soil invertebrates is 280 mg/kg. The value was adopted as the TRV for soil invertebrates. This guideline is intended to protect soil invertebrates.

1.9.8.4 Terrestrial Plants

In plants nickel is necessary for healthy growth and is essential for metabolic processes (Alloway 1990). Nickel is generally not accepted as an essential trace element for mammals and birds as there is no clearly defined biochemical function. Under laboratory experimental conditions nickel deprivation can result in adverse effects including growth depression, impaired reproduction, and other biochemical changes (NRC 2005).

Sample et al. (1996) provides a screening benchmark value for nickel in terrestrial plants of 30 mg/kg. This value was adopted as the TRV. The screening benchmark is intended to protect plants and other terrestrial biota from direct soil contact.

1.9.9 Selenium

In soils, the chemical forms of selenium are largely dependent on pH and oxidation-reduction potentials (McNeal and Balistrieri 1989). Selenium can exist in the 2-, 0, 4+, and 6+ oxidation states (McNeal and Balistrieri 1989). Speciation of selenium in soils is also influenced by the chemical and mineralogical composition of the soil, microbial intervention, and the nature of the adsorbing surfaces (Neal 1990). Selenium has a sorptive affinity for hydrous metal oxides, clays, and organic materials. In well-aerated alkaline soils, inorganic selenium exists primarily as the oxyanions selenite (Se(4+)) and selenate (Se(6+)). Selenite is soluble, but can strongly adsorb to soil minerals and organic material (Tokunaga et al. 1997), while selenate is the most mobile of selenium compounds because of its high water solubility and inability to adsorb to soil particles (ATSDR 1996). Alkaline soils formed from parent materials high in selenium are also high in biologically available selenium (Mayland et al. 1989). In poorly aerated soils, inorganic selenium predominates as the relatively soluble selenide and elemental forms (Mayland et al. 1989).

During the screening of metals (see Sections 1.6.2 - 1.6.6), selenium was identified as a metal associated with the proposed Project that could affect the health of ecological receptors exposed to COPC in soil. The 95th percentile of baseline concentrations for selenium in soil is greater than CCME's "Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health" (CCME 2007). Sections 1.9.9.1 - 1.9.9.4 describe the derivation of TRVs used in the assessment for ecological receptors potentially exposed to selenium in soil.

1.9.9.1 Mammals

Selenium is an essential trace element in animals and has been shown to be a natural component in the enzyme glutathione peroxidase and other proteins. Selenium toxicity is most likely to occur in animals grazing on seleniferous forage, or as a result of including seleniferous grain in their diet. Acute effects in animals following the ingestion of plants containing high levels of selenium include abnormal posture and movement, watery diarrhea, labored respiration, abdominal pain, prostration, and death. Chronic effects in animals include alkali disease and bind staggers. In wildlife, elevated selenium concentrations in the diet are associated with adverse reproductive and developmental effects including reduced growth or survival of young (Ohlendorf 1989).

A geometric mean of the LOAEL values for reproduction and growth was calculated at 0.2 mg selenium/kg bw/day (Sample et al. 1996).

NOAEL (or LOAEL) based on reproduction, growth, or mortality endpoints in rats and mice were adjusted using standard allometric relationships (Sample et al. 1996). If a NOAEL is available for a mammalian test species (NOAEL_t), then the equivalent NOAEL for a

mammalian wildlife species ($NOAEL_w$) can be calculated by using the adjustment factor for differences in body size (Sample et al. 1996):

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{1/4}$$

where $NOAEL_t$ = NOAEL reported in the study for the test species;
 bw_t = body weight of the test species; and
 bw_w = the body weight of the mammals used in the assessment.

Body weights for test species were obtained from either Sample et al. (1996) or US EPA Eco-SSL (2005). Body weight of the mammals used in this assessment and the adjusted TRVs are presented in Table 1.9-1.

1.9.9.2 Birds

The clinical effects of selenium in avian species are similar to those in mammals, but birds in general are more sensitive to the effects of selenium. Recent research suggests that physiological scaling factors developed for mammals may not be appropriate for interspecies extrapolation among birds (Sample et al. 1996). The adopted TRV for the songbird, shorebird, waterfowl, and raptor is 0.5 mg/kg/day (Sample et al. 1996).

1.9.9.3 Soil Invertebrates

Checkai et al. (2004) investigated the effects of selenium on the earthworm growing in an artificial soil. An EC_{20} (effective concentration to induce a 20% effect) value of 3.4 mg/kg was derived from the study. The Eco-SSL value for selenium for soil invertebrates is 4.1 mg/kg. The value was adopted as the TRV for soil invertebrates. This guideline is intended to protect soil invertebrates.

1.9.9.4 Terrestrial Plants

In plants, selenium is an essential element for growth. In the environment, uptake and accumulation by plants is influenced by the concentration and form of selenium present in soils (Neal 1990). The most bio-available forms of selenium are considered to be those fractions which are soluble (McNeal and Balistrieri 1989). Other factors that influence selenium content in plants include pH, soil mineralogical composition, and plant species (Neal 1990).

Sample et al. (1996) provides a screening benchmark value for selenium in terrestrial plants of 1 mg/kg. This value was adopted as the TRV. The screening benchmark is intended to protect plants and other terrestrial biota from direct soil contact.

1.9.10 Risk Characterisation

Characterisation of risk to ecological receptors in a screening level ERA can employ qualitative or quantitative methods. Exposure ratios (ER) comprise a simple approach that

provides a quantitative estimate of overall risk. The ER is a unitless value defined as the ratio of the magnitude of exposure to magnitude of a standard effect:

$$\text{Exposure Ratio} = \frac{\text{Exposure Estimate}}{\text{TRV}}$$

ERs are interpreted as follows:

If the ER is less than one, no unacceptable risks to ecological receptors would be expected, because concentrations are below levels known to cause adverse effects. Conversely, if the ER exceeds one, it may be inferred that adverse effects to individuals are possible.

Given a certain magnitude and type of effect associated with a particular TRV or assessment endpoint, inferences about potential effects can be made. For example, if the level of exposure exceeds a TRV based on a 25% reduction in a growth-based endpoint (ER > 1), it can be inferred that one possible outcome may be diminished growth of individuals, potentially (but not necessarily) leading to a reduction in population abundance of that receptor. It is important to note that exceeding an ER of one does not necessarily mean adverse effects will occur; rather, it suggests that we have less confidence that adverse effects will not occur. For a variety of reasons, adverse effects demonstrated in laboratory studies often fail to manifest in the field as a measurable or meaningful effect. It is also important to recognise that the magnitudes of ERs are not directly associated with the magnitude of potential effects. That is, a large ER (>10) should not be interpreted as a 10-fold greater risk than an ER of one.

For those COPC with ERs greater than one, potential risks at a population level cannot be ruled out and should be evaluated further. Evidence from sources other than chemical analysis may be employed, including evidence of toxicity at the proposed Project site (e.g., senescent vegetation), toxicity of media in laboratory exposures (i.e., bioassays), the absence of species formerly present or commonly found at similar sites, or diminished populations compared to a reference location.

1.9.10.1 Mammals

As previously discussed in Section 1.6.6, COPC that exceeded guidelines for soil and surface water were carried forward in the assessment. Risks to mammals exposed to COPC in all potential pathways were characterised by comparing the weight-normalised exposure estimates for each COPC to TRVs for the grizzly bear, black-tailed deer, mink, and the hare. ERs for all COPC were below one for the grizzly bear, black-tailed deer and the hare (Table 1.9-2). The ER for molybdenum exceeded one for the mink while the ERs for the remaining COPC were below one.

Table 1.9-2: Risk Estimates for Mammals

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	Exposure Ratio
Grizzly bear			
Arsenic	0.044	0.49	0.09
Cadmium	0.002	0.16	0.015
Chromium	0.17	0.67	0.25
Molybdenum	0.29	0.29	0.997
Nickel	0.23	8.2	0.03
Selenium	0.025	0.04	0.61
Black-tailed deer			
Arsenic	0.028	0.67	0.04
Cadmium	0.001	0.22	0.006
Chromium	0.10	0.92	0.11
Molybdenum	0.15	0.39	0.38
Nickel	0.145	11.22	0.013
Selenium	0.017	0.06	0.30
Mink			
Arsenic	0.014	1.85	0.073
Cadmium	0.011	0.59	0.18
Chromium	0.552	2.52	0.22
Molybdenum	11.4	1.08	10.5
Nickel	0.803	30.77	0.026
Selenium	0.081	0.15	0.53
Hare			
Arsenic	0.18	1.8	0.10
Cadmium	0.008	0.56	0.015
Chromium	0.70	2.4	0.29
Molybdenum	0.94	1.0	0.92
Nickel	1.06	29.2	0.036
Selenium	0.15	0.15	1.0

Note: COPC - Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; TRV - Toxicological Reference Value

1.9.10.2 Birds

As previously discussed in Section 1.6.6, COPC that exceeded guidelines for soil, surface water, and sediments were carried forward in the assessment. Risks to birds exposed to COPC in all potential pathways were characterised by comparing the weight-normalised exposure estimates for each COPC to TRVs for the raptor, songbird, waterfowl, and shorebird. ERs for all COPC were below one for all birds (Table 1.9-3).

Table 1.9-3: Risk Estimates for Birds

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	Exposure Ratio
Raptor			
Arsenic	0.000079	2.2	0.000035
Cadmium	0.000077	1.47	0.00005
Chromium	0.0005	1.0	0.0005
Molybdenum	0.024	3.5	0.007
Nickel	0.00097	77.4	0.000013
Selenium	0.000066	0.50	0.00013
Songbird			
Arsenic	0.15	2.2	0.07
Cadmium	0.15	1.47	0.10
Chromium	0.89	1.0	0.89
Molybdenum	0.52	3.5	0.15
Nickel	1.3	77.4	0.02
Selenium	0.027	0.50	0.05
Waterfowl			
Arsenic	0.013	2.2	0.0057
Cadmium	0.015	1.47	0.01
Chromium	0.045	1.0	0.045
Molybdenum	0.035	3.5	0.01
Nickel	0.026	77.4	0.00033
Selenium	0.089	0.50	0.18
Shorebird			
Arsenic	1.23	2.2	0.56
Cadmium	1.15	1.47	0.79
Chromium	0.70	1.0	0.70
Copper	2.28	47.0	0.06
Lead	2.94	3.85	0.76
Mercury	0.0011	0.0064	0.17
Molybdenum	1.57	3.5	0.45
Nickel	1.74	77.4	0.023
Selenium	0.055	0.50	0.11

Note: Shorebirds are the only birds in this assessment that are exposed to sediments; therefore, the list of parameters for shore birds is greater than for other receptors.

COPC - Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; TRV - Toxicological Reference Value

1.9.10.3 Soil Invertebrates

As previously discussed in Section 1.6.6, COPC that exceeded guidelines for soil were carried forward in the assessment. Risks to soil invertebrates exposed to COPC in soil were characterised by comparing 95th percentile concentrations of COPC in soil to TRVs for the

soil invertebrates. The ER for arsenic, chromium, and molybdenum exceeded one, but the ER for the remaining COPC were below one (Table 1.9-4).

Table 1.9-4: Risk Estimates for Soil Invertebrates

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	Exposure Ratio
Arsenic	29.0	17	1.7
Chromium	97.0	64	1.5
Molybdenum	94.9	10	9.5
Nickel	99.4	280	0.36
Selenium	1.4	4.1	0.34

Note: Bold results = Exceedances; COPC - Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; TRV - Toxicological Reference Value

It may be inferred from these results that levels of arsenic, chromium, and molybdenum in soil may pose a risk to terrestrial invertebrates at the proposed Project site. However, major, widespread adverse effects to invertebrate populations are considered unlikely. Given the level of arsenic, chromium, and molybdenum across much of the site compared to the low effect level TRV, adverse effects would likely be limited to a minor decrease in growth or diminished abundance of invertebrates within areas having the highest arsenic, chromium, and molybdenum concentrations. As such, these adverse effects would not appreciably diminish soil invertebrate populations.

1.9.10.4 Terrestrial Plants

As previously discussed in Section 1.6.6, COPC that exceeded guidelines for soil were carried forward in the assessment. Risks to terrestrial plants exposed to COPC in soil were characterised by comparing 95th percentile concentrations of COPC in soil to TRVs. ERs were greater than one for all COPC in soil (Table 1.9-5).

Table 1.9-5: Risk Estimates for Terrestrial Plants

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	Exposure Ratio
Arsenic	29.0	17	1.7
Chromium	97.0	1	97
Molybdenum	94.9	2	47
Nickel	99.4	30	3.3
Selenium	1.4	1	1.4

Note: Bold results = Exceedances; COPC - Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; TRV - Toxicological Reference Value

It may be inferred from these results that levels of certain inorganic parameters in soil may pose a risk to terrestrial plants. However, as discussed previously, an ER greater than one does not indicate adverse effects are certain. ERs for immobile plants were based on the 95th percentile of COPC concentrations, an approach designed to ensure conservatism in the screening assessment. Concentrations at the majority of sampling locations were likely below levels capable of causing adverse effects for most COPC. In all likelihood, adverse effects from elevated concentrations of COPC would not be observed across most of the proposed Project site and, if present, would likely be limited to small areas in the vicinity of “hot spots.” Therefore, although some effects may be possible, significant impacts to the plant community from COPC in soil are unlikely.

1.9.11 Amphibians

Spotted frogs located in creeks and ponds in the vicinity of the proposed Project are potentially exposed to elevated metals in surface water. As previously discussed in Section 1.6.6, COPC that exceeded guidelines for surface water were carried forward in the assessment. Risks to amphibians exposed to COPC in surface water were estimated by comparing the 95th percentile concentration of cadmium and molybdenum in surface water to the Lowest Chronic Value (LCV) benchmark for frogs. The ER for cadmium and molybdenum were below one (Table 1.9-6).

Table 1.9-6: Risk Estimates for Amphibians

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	Exposure Ratio
Cadmium	0.0010	0.044	0.023
Molybdenum	0.32	0.96	0.33

Note: Bold results = Exceedances; COPC - Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; TRV - Toxicological Reference Value

1.9.12 Fish

Dolly Varden in creeks and lakes in the vicinity of the proposed Project are potentially exposed to elevated metals in surface water. As previously discussed in Section 1.6.6., COPC that exceeded guidelines for surface water were carried forward in the assessment. Risks to fish exposed to COPC in surface water were estimated by comparing the 95th percentile concentration of cadmium and molybdenum in surface water to the Lowest Chronic Value (LCV) benchmark for fish. The ER for cadmium and molybdenum was below one (Table 1.9-7).

Table 1.9-7: Risk Estimates for Fish

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	Exposure Ratio
Cadmium	0.94	0.0017	0.61
Molybdenum	128.8	0.37	0.87

Note: Because selenium was not carried forward for surface water, there was no exposure to fish or aquatic life. Bold results = Exceedances; COPC - Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; TRV - Toxicological Reference Value

1.9.13 Aquatic Plants

As previously discussed in Section 1.6.6, COPC that exceeded guidelines for surface water were carried forward in the assessment. Risks to aquatic plants exposed to COPC in surface water were calculated by comparing the 95th percentile of cadmium and molybdenum concentrations in surface water samples to the LCV benchmark (Table 1.9-8). The ER for molybdenum was below one (1).

Table 1.9-8: Risk Estimates for Aquatic Plants

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	Exposure Ratio
Cadmium	0.0010	0.0020	0.52
Molybdenum	0.322	0.88	0.37

Note: Bold results = Exceedances; COPC - Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; TRV - Toxicological Reference Value

1.9.14 Aquatic Invertebrates

As previously discussed in Section 1.6.6, COPC that exceeded guidelines for surface water and sediments were carried forward in the assessment. Risks to aquatic invertebrates exposed to COPC in surface water and sediments were calculated by comparing the 95th percentile of the COPC concentrations in surface water and sediment samples to the LCV benchmark (Table 1.9-9). The ER for cadmium slightly exceeded one and the ER for molybdenum was below one.

Table 1.9-9: Risk Estimates for Aquatic Invertebrates

COPC	Exposure Estimate (mg/kg/d)	TRV (mg/kg/d)	Exposure Ratio
Cadmium	0.0010	0.008	1.4
Molybdenum	0.322	0.88	0.37

Note: Bold results = Exceedances; COPC-Chemicals of Potential Concern; mg/kg/d - milligrams per kilogram per day; TRV-Toxicological Reference Value

1.10 Ecological Risk Assessment Uncertainty

Uncertainty in risk assessment is introduced by the necessary use of assumptions concerning various aspects or characteristics of the system which cannot be measured accurately. Incomplete understanding of environmental processes is inherent in any ERA. Uncertainty is acknowledged, documented, and addressed primarily by the use of conservative assumptions, which ensure risk is overestimated rather than underestimated. Uncertainty associated with certain aspects of the ERA (e.g., exposure assessment) was addressed within the appropriate sections of the ERA. In this section, various sources of uncertainty associated with the current ERA are discussed.

Exposure: Uncertainty in the exposure assessment was related primarily to assumptions regarding the presence of VCs. As the area that could be affected by the proposed Project has been characterised for this baseline assessment primarily as residential / parkland, use of the proposed Project site by ecological receptors may be infrequent. Conservative assumptions were made to ensure any ecological receptors that might use the proposed Project site are provided sufficient protection.

Toxicity assessment: Because of the inherent uncertainty in predicting toxicological responses from literature studies rather than directly measuring toxicity at the site, there is some uncertainty associated with toxicity reference values. In most cases, TRVs are assumed to be conservative (i.e., no toxicity is anticipated if site concentrations are below TRVs). This is because most reference values are based on the most sensitive species tested or a similar low effect level (e.g., 10th or 25th percentile of species sensitivity distribution), and toxicity tests upon which they are based are typically conducted under conditions that maximise toxicity (i.e. the use of soluble metal salts).

Risk characterisation: For the most part, the ERs generated in the risk characterisation phase of the ERA should be considered to be quite conservative. ERs greater than one do not necessarily mean toxicity is occurring. There is greater inherent uncertainty associated with results of screening level assessments than higher-tier assessments, because results are based primarily on modelled or estimated concentrations and TRVs derived from literature studies, rather than direct measurements of exposure and effects. At the proposed Project site, no direct measurements of exposure were made and no toxicity studies were performed. In many cases, toxicity at a site is considerably diminished compared to effects predicted from laboratory studies, for a variety of reasons. Higher-tier assessments (i.e., Preliminary Quantitative ERA) incorporate site-specific toxicity data in a lines-of-evidence approach, which can reduce the level of uncertainty in this phase of the assessment.

1.11 Ecological Risk Assessment Summary and Conclusions

This report has presented a screening level ERA of the potential adverse effects from COPC identified in association with affected soil, sediment, surface water, and food / prey at the proposed Project. The ERA used both historical and current sampling data and is

consistent with the methodology required by Environment Canada and CCME (1996a; 1996b; 1997a; 1997b) for conducting screening level ERAs at federal sites in Canada.

Quantitative estimates of risk were calculated using a quotient approach in which exposure estimates based on 95th percentile concentrations were compared to TRVs derived for each receptor / pathway. ERs greater than one were found for:

- Mink exposed to molybdenum in fish, small mammals, invertebrates, and vegetation;
- Soil invertebrates for arsenic, chromium, and molybdenum in soil;
- Terrestrial plants for arsenic, chromium, molybdenum, nickel, and selenium in soil; and
- Aquatic invertebrates exposed to cadmium in surface water.

No adverse effects were predicted for the large carnivore mammal (grizzly bear), herbivore mammal (Black-tailed deer), small herbivore mammal (hare), raptor, songbird, waterfowl, shorebird, fish, and aquatic plants.

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