

Appendix 8.0-A Human Health Risk Assessment



Tenas Project

Human Health Risk Assessment Report

February 2022

Project No.: 0403488-702

Document details	The details entered below are automatically shown on the cover and the headers / footers. PLEASE NOTE: This table must NOT be removed from this document.
Document title	Tenas Project
Document subtitle	Human Health Risk Assessment Report
Project No.	0403488-702
Date	February 2022
Version	B.1
Author	Entia Environmental Ltd. under subcontract to ERM
Client name	Telkwa Coal Limited

Document history

Version	Date	Name	Comments
0.5	18 August 2021	Annette Muttray	First Draft
0.6	20 August 2021	S Mendelaoui	Convert to ERM Template
0.7	30 August 2021	Lesley Shelley	Further edits
0.8	30 August 2021	Lesley Shelley	Further edits
A.1	31 August 2021	Robert Tarbuck	Publish draft for client review
	4. October 2021	Daryl Johannesen	Client comments
A.2	5. October 2021	Annette Muttray	Addressing client comments
A.2	26. November 2021	Ashleigh Bellanova, Dan Farmer	Client comments
A.3	3. December 2021	Annette Muttray	Addressing client comments
B.1	2 February 2022	Robert Tarbuck	Publish final version
B.2	18 February 2022	Annette Muttray	Respond to Curtis' comments; Update report to include new TRVs and Water quality model results from December 16, 2021; version for April 2022 EA resubmission

Version control:

We follow a two-part numbering system to keep track of revisions. Letters of the alphabet denote drafts that have been sent to the client, and numbers denote internal revisions. For example:

0.1	1 st version of report by author	A.5	5 th round of internal ERM edits since sent
0.10	10 th round of internal ERM edits	B.1	2 nd draft submitted to the client
A.1	1 st draft sent to the client	B.6	6 th round of internal ERM edits since sent
A.2	1 st round of addressing client comments	C.1	Final version submitted to the client

February 2022

Tenas Project

Human Health Risk Assessment Report

ERM Consultants Canada Ltd.

#1000 - 1100 Melville Street
Vancouver, BC
Canada V6E 4A6

T: +1 604 689 9460

F: +1 604 687 4277

© Copyright 2022 by The ERM International Group Limited and/or its affiliates ("ERM").
All rights reserved. No part of this work may be reproduced or transmitted in any form,
or by any means, without the prior written permission of ERM.

EXECUTIVE SUMMARY

Telkwa Coal is proposing to develop the Tenas Project (the Project), a surface coal mine designed to produce metallurgical coal located approximately 25 kilometres (km) south of Smithers and 7 km southwest of the Village of Telkwa, that lies within the Wet'suwet'en territory.

This report presents the results of a Human Health Risk Assessment (HHRA) prepared by Entia Environmental Consultants Ltd. (Entia) under sub-contract to ERM Consultants Canada Ltd. (ERM). The purpose of this HHRA is to support the assessment of potential effects on the Human Health Valued Component (VC) as part of the Application for the Environmental Assessment Certificate (EAC Application) for the Project under the British Columbia *Environmental Assessment Act* in accordance with the Project Application Information Requirements (BC EAO 2021).

The objective of the HHRA was to identify incremental changes that may occur to human health between the Baseline (or Base Case) and future Project Case conditions should the Project go ahead. To identify these changes, evaluations of health risk to people who may be exposed to contaminants of potential concern (COPCs) in the local study area (LSA) under both scenarios were completed following standard risk assessment methodology (Health Canada 2019a; BC MOH 2021).

Human Receptors, Transport Pathways, and Exposure Pathways (Section 3)

Two categories of people and two age groups who have the highest potential for risk were selected for evaluation: Indigenous and non-Indigenous Resident Land Users (toddlers and adults) living year-round in the study area and Recreational Land Users (toddlers and adults) who visit the LSA for eight weeks every year.

There are three main potential transport pathways through which COPCs may be transferred from the Project to the environment where people could come into contact with them:

- atmospheric transport of particulates and gases that can be inhaled;
- atmospheric transport and deposition of fugitive dust that can then be taken up by plants and thus ingested by people; and
- effluent discharge (to surface water) and seepage (to groundwater) that can then be ingested by people and terrestrial biota used as subsistence food.

Once COPCs enter the environment they can be taken up into the aquatic or terrestrial food chain; this was included in the HHRA as an indirect transport pathway for exposure to people through ingestion of subsistence foods.

The following complete pathways of exposures to COPCs were evaluated in this report: inhalation of air, ingestion of drinking water sourced from surface water and groundwater, incidental ingestion and dermal contact with soil, and ingestion of subsistence foods and market foods (i.e., foods purchased from the grocery store). Both threshold (non-carcinogens) and carcinogenic COPCs were considered.

Data Sources and Selection of Contaminants of Potential Concern (Section 3)

Baseline data were obtained from Baseline studies conducted between 2006 and 2019 for air quality, surface- and groundwater (residential wells) quality, soil, vegetation, and fish. Base Case and Project Case (Operation and Closure, which includes Decommissioning and Reclamation, and Post-closure phases of the Project) water quality data for risk calculations were sourced from modelling studies conducted for surface- and groundwater (Water and Load Balance Technical Report and Groundwater Technical Report, respectively). Predicted Project Case COPC concentrations in air and dust were

obtained from the Air Dispersion Model. Predicted Project COPC concentrations in soil, vegetation, and subsistence and market foods were derived in this HHRA.

COPCs carried forward for evaluation in the HHRA were selected through a screening process based on comparison of the maximum contaminant concentration to the most relevant human health-based screening level (i.e., a guideline, standard, criteria/objective, or minimum risk level) protective of relevant exposure pathways. Inhalable particulate matter (PM₁₀ and PM_{2.5}) and 18 metal COPCs were selected for evaluation in the HHRA; COPCs including hydrocarbons and other criteria air contaminants were also considered but not carried forward for further evaluation as they did not screen into the HHRA.

Exposure point concentrations (EPCs) for the selected COPCs were the upper-bound estimates of measured or modelled concentrations to ensure that risks were not underestimated.

Exposure Assessment (Section 4)

In the exposure assessment, physical characteristics of people relevant to contaminant exposures were described and the total dose of each COPC was estimated. A dose is the amount of COPC that a person takes into the body daily, normalized to body weight. Doses were estimated based on human receptor characteristics and the EPC of the COPC that a person may be exposed to in environmental media or from the food chain. Human receptor characteristics were based on Health Canada guidance and information obtained during Baseline studies.

Toxicity Assessment (Section 5)

The toxicity assessment step is to identify applicable toxicity benchmarks to incorporate in the risk characterization step. The toxicity benchmark is the level of exposure that is associated with no adverse effects or an acceptable risk threshold. Toxicity information was typically derived from laboratory or epidemiological studies and benchmarks generally have large margins of safety to ensure that the toxicity or risk of a substance to people is not underestimated.

Risk Characterization (Section 6)

Using the results of the exposure assessment and toxicity assessment, human health risks were quantified using either concentration ratios (CRs, for criteria air contaminants) or hazard quotients (HQs, for metals). The CR is the ratio between the concentration (in air) and a guideline. The HQ is the ratio between the dose and the toxicity benchmark. In addition, the incremental lifetime cancer risk (ILCR) was determined for COPCs with carcinogenic potential via inhalation (i.e., arsenic, cadmium, chromium, and nickel) or ingestion (i.e., arsenic).

No human health risks from the inhalation of fine particulate matter (PM_{2.5} and PM₁₀) were predicted at receptor locations closest to the Project (i.e., Horsemen Camp, PM Kerr and other rural residences). The Project was also not predicted to contribute to human health risks from the inhalation of fine particulate matter in Telkwa, where elevated concentrations exist under Baseline conditions.

Risk characterization for metals suggested that no adverse effects on human health were predicted for Resident Land Users or Recreational Land Users due to Project-related changes in exposure media (i.e., air, water, soil, subsistence foods). While HQs for 15 COPCs were higher than acceptable risk benchmarks, the elevated risk was frequently associated with consumption of market foods. Incremental changes in HQs for Resident Land Users or Recreational Land Users due to the Project (i.e., change between the Base Case and Project Case) were small (less than 20%), except for cobalt, lithium, and thallium. Predicted increases in HQs for these three COPCs were due to cobalt, lithium, and thallium intake from subsistence foods, especially rainbow trout. Concentrations in fish may increase because concentrations of these COPCs were predicted to increase in surface water downstream of the Project,

particularly in the smaller waterways immediately downstream of the Project (i.e., Tenas Creek and Goathorn Creek). However, there is uncertainty in the assessment due to conservative assumptions made throughout the HHRA, and background risks from ingestion of market foods are generally in the same order of magnitude compared to risks from subsistence foods for these COPCs. Therefore, it is unlikely that the predicted increases in HQs for cobalt, lithium, and thallium will adversely affect human health.

Risks from carcinogenic metal COPCs due to the Project were generally below acceptable risk thresholds and no adverse effects would be expected. The acceptable risk threshold for Project-Only effects was exceeded for arsenic in surface water, but risks already exist under Baseline conditions and are lower than risks from arsenic in market foods.

Uncertainties and Conservatism in the Risk Assessment (Section 7)

Some uncertainties in the HHRA were identified related to types and availability of Baseline data, subsistence foods information, and uncertainties that are typical of predicting future concentrations of COPCs using modelling. The risk estimates incorporate multiple conservative assumptions, which suggest that risks under both the Base Case and predicted Project Case scenarios were likely overestimated, in particular those associated with consumption of water and subsistence foods. Risks from consumption of water and subsistence foods were comparable or lower than background risks calculated for consumption of market foods.

Conclusions and Recommendations (Section 8)

The potential for adverse health effects resulting from the Project is considered negligible. It is recommended that future monitoring of concentrations of arsenic, cobalt, lithium, and thallium in air, soil, surface water, groundwater, fish tissue, and plant tissue should be completed during all phases of the Project (i.e., Construction, Operation, Decommissioning and Reclamation, and Post-closure phases) to confirm key exposure assumptions made in the risk assessment.

CONTENTS

EXECUTIVE SUMMARY	I
ACRONYMS AND ABBREVIATIONS	X
1. INTRODUCTION.....	1-1
1.1 Project Proponent	1-1
1.2 Project Description	1-1
1.3 Objectives	1-1
1.4 Definitions of Health and Scope of the Report	1-2
2. BACKGROUND INFORMATION	2-1
2.1 General Risk Assessment Methodology	2-1
2.2 Regulatory and Policy Framework	2-2
2.3 Spatial Boundaries: Local Study Area.....	2-3
2.4 Temporal Boundaries.....	2-3
2.5 Risk Assessment Scenarios.....	2-4
3. PROBLEM FORMULATION.....	3-1
3.1 Human Receptors of Concern and Assessment Locations	3-1
3.1.1 Indigenous Land Use	3-1
3.1.2 Indigenous Subsistence Foods	3-2
3.1.3 Non-traditional Land Use and Human User Groups.....	3-3
3.1.3.1 Recreation	3-3
3.1.3.2 Hunting	3-3
3.1.3.3 Fishing	3-4
3.1.3.4 Gardening/Subsistence Farming	3-4
3.1.4 Residential Land and Water Use.....	3-4
3.1.5 Identification of Groups of Receptors of Concern.....	3-7
3.2 Types, Sources, and Transport Pathways of Contaminants of Potential Concern	3-7
3.2.1 Base Case Sources and Types of Contaminants of Potential Concern.....	3-7
3.2.2 Project Case Sources and Types of Contaminants of Potential Concern.....	3-8
3.2.3 Transport Pathways of Contaminants of Potential Concern	3-9
3.3 Complete Exposure Pathways	3-9
3.4 Data Sources	3-11
3.4.1 Air.....	3-11
3.4.1.1 Baseline Data	3-11
3.4.1.2 Project Case Data.....	3-13
3.4.2 Soil	3-14
3.4.2.1 Baseline Data	3-14
3.4.2.2 Project Case Data.....	3-18
3.4.3 Vegetation	3-21
3.4.3.1 Baseline Data	3-21
3.4.3.2 Project Case Data.....	3-22
3.4.4 Surface Water	3-24

3.4.4.1	Baseline Data	3-24
3.4.4.2	Project Case Data.....	3-24
3.4.5	Groundwater	3-24
3.4.5.1	Baseline Data	3-24
3.4.5.2	Project Case Data.....	3-24
3.4.6	Fish Tissue.....	3-25
3.4.6.1	Baseline Data	3-25
3.4.6.2	Fish Tissue Bioconcentration Factors	3-25
3.4.6.3	Project Case Data.....	3-25
3.5	Screening for Contaminants of Potential Concern	3-25
3.5.1	Methodology.....	3-25
3.5.2	Results	3-27
3.5.2.1	Air	3-27
3.5.2.2	Soil.....	3-28
3.5.2.3	Surface Water.....	3-28
3.5.2.4	Groundwater	3-28
3.5.2.5	Fish Tissues.....	3-29
3.5.2.6	Subsistence Foods	3-29
3.5.2.7	Special Case Contaminants of Potential Concern	3-29
3.6	Problem Formulation Summary: Conceptual Site Model.....	3-30
4.	EXPOSURE ASSESSMENT	4-1
4.1	Human Receptor Characteristics	4-1
4.1.1	General Human Receptor Characteristics (applicable to all ROCs):	4-1
4.1.2	Receptor-specific Characteristics: Indigenous and Non-Indigenous Resident	4-2
4.1.2.1	Traditional Subsistence Food Harvester	4-2
4.1.2.2	Non-traditional Subsistence Food Harvester	4-5
4.1.3	Receptor-specific Characteristics: Recreational Land User	4-6
4.2	Inhalation of Criteria Air Contaminants.....	4-6
4.3	Exposure Point Concentrations and Doses of Non-carcinogenic Contaminants of Potential Concern	4-6
4.3.1	Inhalation of Contaminants of Potential Concern in Air	4-7
4.3.2	Water Ingestion	4-10
4.3.2.1	Exposure Point Concentrations in Groundwater	4-10
4.3.2.2	Exposure Point Concentrations in Surface Water	4-10
4.3.2.3	Dose from Drinking Water.....	4-11
4.3.3	Inadvertent Soil Ingestion.....	4-14
4.3.4	Dermal Absorption from Soil	4-17
4.3.5	Subsistence Foods Ingestion	4-21
4.3.5.1	Exposure Point Concentrations in Fish.....	4-21
4.3.5.2	Exposure Point Concentrations in Vegetation.....	4-21
4.3.5.3	Exposure Point Concentrations in Terrestrial Wildlife Tissue.....	4-22
4.3.5.4	Dose from Subsistence Foods Ingestion	4-22
4.3.6	Market Foods Ingestion.....	4-23

4.3.7	Total Dose of Non-carcinogenic Contaminants from all Pathways	4-37
4.4	Dose for Non-threshold Contaminants of Potential Concern.....	4-37
4.4.1	Inhalation Exposure Route	4-37
4.4.2	Ingestion Exposure Route	4-39
4.4.2.1	Dose from Drinking Water.....	4-39
4.4.2.2	Inadvertent Soil Ingestion	4-40
4.4.2.3	Dermal Absorption from Soil	4-41
4.4.2.4	Dose from Subsistence and Market Foods Ingestion	4-42
5.	TOXICITY ASSESSMENT	5-1
5.1	Introduction	5-1
5.2	Selection of Regulatory Thresholds for Risk Characterization	5-1
6.	RISK CHARACTERIZATION	6-1
6.1	Introduction	6-1
6.2	Estimation of Non-carcinogenic Risks Using Concentration Ratios: Inhalation of Criteria Air Contaminants.....	6-1
6.3	Estimation of Non-carcinogenic Risks Using Hazard Quotients	6-2
6.3.1	Contaminants of Potential Concern with Incremental Increase Greater than 20%	6-5
6.3.1.1	Boron and Strontium	6-5
6.3.1.2	Thallium	6-5
6.3.1.3	Lithium and Cobalt.....	6-7
6.3.1.4	Other Considerations	6-7
6.3.2	Organ System Toxicity	6-8
6.4	Estimation of Incremental Lifetime Cancer Risks	6-11
6.4.1	Incremental Lifetime Cancer Risk via the Inhalation Exposure Route	6-11
6.4.2	Incremental Lifetime Cancer Risk due to Arsenic via the Ingestion Exposure Route.....	6-14
6.4.3	Incremental Lifetime Cancer Risk due to Arsenic via Dermal Contact with Soil	6-15
6.4.4	Summary: Incremental Change in the Incremental Lifetime Cancer Risk due to Arsenic between Project Case and Base Case	6-15
7.	UNCERTAINTIES AND CONSERVATISM IN THE RISK ASSESSMENT	7-1
7.1	Contaminants of Potential Concern.....	7-1
7.2	Estimated Environmental Concentrations	7-1
7.2.1	Predictive Modelling	7-1
7.2.2	Terrestrial Subsistence Food Species.....	7-2
7.2.3	Fish	7-3
7.3	Human Exposure Pathways	7-3
7.3.1	Locations of Subsistence Foods Harvested	7-3
7.3.2	Subsistence Foods Consumption Quantity and Frequency.....	7-4
7.3.3	Bioavailability	7-4
7.4	Toxicity Reference Values	7-4
7.5	Uncertainties in Risk Estimates.....	7-5
7.6	Definitions of Health	7-5

8. CONCLUSIONS.....	8-1
9. REFERENCES.....	9-1

APPENDIX A	BASLINE AND PREDICTED DATA
APPENDIX B	COPC SCREENING TABLES
APPENDIX C	DERIVATION OF SCREENING BENCHMARKS FOR SUBSISTENCE FOODS
APPENDIX D	FOOD CHAIN MODEL AND PREDICTED CONCENTRATIONS OF CONTAMINANTS OF POTENTIAL CONCERN IN THE TISSUES OF SUBSISTENCE FOOD SPECIES
APPENDIX E	DERIVATION OF DOSE FROM MARKET FOODS
APPENDIX F	TOXICITY BENCHMARKS
APPENDIX G	RISK CHARACTERIZATION RESULTS

List of Tables

Table 2.4-1: Project Phases	2-3
Table 3.1-1: Important Food Plants Used by the Wet'suwet'en People.....	3-2
Table 3.3-1: Potential Exposure Pathways.....	3-10
Table 3.4-1: PM ₁₀ and PM _{2.5} Results at PM Kerr Station, November 1, 2018 to January 16, 2020 (µg/m ³).....	3-11
Table 3.4-2: PM _{2.5} Data Summary – BC ENV Telkwa Station.....	3-12
Table 3.4-3: Total Dustfall Results Measured Concurrently with Metals Analysis in Dust, September 2017 to February 2018 (mg/dm ² /day).....	3-12
Table 3.4-4: Maximum Predicted Concentrations of Criteria Air Contaminants and Dust Deposition Rates	3-17
Table 3.5-1: Screening Criteria and Guidelines for Identifying Contaminants of Potential Concern to be included in the Human Health Risk Assessment.....	3-26
Table 3.6-1: Final Selection of Contaminants of Potential Concern	3-32
Table 4.1-1: Top Ten Traditional Subsistence Food Items Consumed by Moricetown and Nat'oot'en Peoples Living On-Reserve	4-2
Table 4.1-2: Important Mammals and Birds Consumed by Wet'suwet'en People for Nutritional Purposes.....	4-3
Table 4.1-3: Final Selection of Subsistence Foods Evaluated in this HHRA and the Frequency and Rate of their Ingestion.....	4-4
Table 4.3-1: Dose of Contaminants of Potential Concern from Inhalation of Particulate Matter in Base Case	4-8
Table 4.3-2: Dose of Contaminants of Potential Concern from Inhalation of Particulate Matter in Project Case (Operation)	4-9
Table 4.3-3: Dose of Contaminants of Potential Concern via the Drinking Water Ingestion Route in the Base Case	4-11
Table 4.3-4: Dose of Contaminants of Potential Concern via the Drinking Water Ingestion Route in the Project Case (Operation)	4-13
Table 4.3-5: Dose of Contaminants of Potential Concern via the Drinking Water Ingestion Route in the Project Case (Closure).....	4-14

Table 4.3-6: Estimated Daily Dose of COPCs via Inadvertent Soil Ingestion in the Base Case	4-16
Table 4.3-7: Estimated Daily Dose of COPCs via Inadvertent Soil Ingestion in Project Case (Operation and Closure)	4-17
Table 4.3-8: Dose of Contaminants of Potential Concern via Dermal Soil Contact in Base Case	4-18
Table 4.3-9: Dose of Contaminants of Potential Concern via Dermal Soil Contact in Project Case (Operation and Closure)	4-20
Table 4.3-10: Dose of Contaminants of Potential Concern from the Ingestion of Subsistence Food by Human Receptors in the Base Case	4-25
Table 4.3-11: Dose of Contaminants of Potential Concern from the Ingestion of Subsistence Food by Human Receptors in the Project Case (Operation)	4-29
Table 4.3-12: Dose of Contaminants of Potential Concern from the Ingestion of Subsistence Food by Human Receptors in the Project Case (Closure)	4-33
Table 4.4-1: Lifetime Average Daily Dose of Contaminants of Potential Concern from Inhalation of Non-threshold Metals ($\mu\text{g}/\text{m}^3$)	4-38
Table 4.4-2: Lifetime Average Daily Dose of Arsenic from Ingestion with Drinking Water	4-40
Table 4.4-3: Lifetime Average Daily Dose of Arsenic from Incidental Ingestion with Soil	4-40
Table 4.4-4: Lifetime Average Daily Dose of Arsenic from Dermal Contact with Soil	4-42
Table 4.4-5: Lifetime Average Daily Dose of Arsenic from the Ingestion of Subsistence and Market Food by Human Receptors in the Base Case	4-44
Table 4.4-6: Lifetime Average Daily Dose of Arsenic from the Ingestion of Subsistence and Market Food by Human Receptors in the Project Case (Operation)	4-46
Table 4.4-7: Lifetime Average Daily Dose of Arsenic from the Ingestion of Subsistence and Market Food by Human Receptors in the Project Case (Closure)	4-48
Table 5.5-1: Ambient Air Quality Criteria for Criteria Air Contaminants	5-1
Table 5.5-2: Slope Factors and Unit Risks Used in the Human Health Risk Assessment	5-2
Table 5.5-3: Toxicity Reference Values Used in the Human Health Risk Assessment.	5-3
Table 6.2-1: Concentration Ratios for Criteria Air Contaminants at Receptor Locations in the Base Case and Project Case (Operations)	6-1
Table 6.3-1: Total Hazard Quotients (from all Exposure Pathways) in the Base Case, Project Case (Operation), and Project Case (Closure), and Incremental Change between the Base Case and Project Case for Contaminants of Potential Concern	6-3
Table 6.3-2: Target Organ System Toxicity of Contaminants of Potential Concern	6-8
Table 6.3-3: Hazard Indices for Each Target Organ System for the Baseline and Project Phases	6-9
Table 6.3-4: Incremental Change in Hazard Indices for Each Target Organ System for the Baseline and Project Phases	6-10
Table 6.4-1: Incremental Lifetime Cancer Risk for Inhalation of Carcinogenic Metals in Air for Each Life Stage in the Base Case	6-12
Table 6.4-2: Incremental Lifetime Cancer Risk for Inhalation of Carcinogenic Metals in Air for Each Life Stage for the Project Case (Operation)	6-12
Table 6.4-3: Incremental Lifetime Cancer Risk for Inhalation of Carcinogenic Metals in Air for Each Life Stage for the Project-Only Case (Operation)	6-13
Table 6.4-4: Summary of Incremental Lifetime Cancer Risk from Arsenic in the Base Case and Project Case (Operation and Closure) from All Exposure Pathways	6-16
Table 6.4-5: Incremental Changes between Incremental Lifetime Cancer Risk for the Base Case and Project Cases (Project-Only ILCR)	6-17

List of Figures

Figure 1.2-1: Tenas Project Components.....	1-4
Figure 2.3-1: Human Health Local Study Area and Wet'suwet'en House Boundaries	2-5
Figure 3.1-1: Recreational Land Use near the Tenas Project	3-5
Figure 3.4-1: Location of Human Receptors, Soil and Vegetation Sites.....	3-15
Figure 3.4-2: Soil and Vegetation Baseline Sample Locations, Minesite.....	3-19
Figure 3.4-3: Soil and Vegetation Baseline Sample Locations, Rail Infrastructure and Tenas Access Corridor	3-20
Figure 3.6-1: Conceptual Site Model.....	3-31

ACRONYMS AND ABBREVIATIONS

AAQO	Ambient air quality objective
ACL	Allegiance Coal Limited
ADAF	Age-dependant adjustment factor
ADD	Average daily dose
ADI	Acceptable daily intake
AG	Agricultural land use
AMS	Airshed Management Society
AO	Aesthetic objective
ASIL	Acceptable Source Impact Levels
AT	Averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
BC	British Columbia
BC CSR	British Columbia Contaminated Sites Regulation
BC ENV	British Columbia Ministry of Environment and Climate Change Strategy
BCF	Bioconcentration factor
BTEX	Benzene, toluene, ethylene, and xylene
BTF	Biotransfer factor
BVLD	Bulkley Valley Lakes District
BW	Body weight
C	Concentration
CAC	Criteria Air Contaminant
CCME	Canadian Council of Ministers of the Environment
CEPA	<i>Canadian Environmental Protection Act</i>
CO	Carbon monoxide
COPC	Contaminant of potential concern
DAD	Dermally absorbed dose
EA	Environmental assessment

ED	Exposure duration
EPC	Exposure point concentration
EPH	Extractable petroleum hydrocarbons
EV	Event frequency
FAO	Food and Agriculture Organisation
HHRA	Human Health Risk Assessment
HI	Hazard index
HQ	Hazard quotient
ILCR	Incremental lifetime cancer risk
IR	Inhalation rate or Ingestion rate
IRIS	Integrated Risk Information System
JECFA	FAO/WHO Expert Committee on Food Additives
LAAD	Lifetime average daily dose
LE	Life expectancy
LEPH	Light extractable petroleum hydrocarbons
LOAEL	Lowest observed adverse effect levels
LSA	Local Study Area
MAC	Maximum allowable concentration
MPOI	Maximum point of impingement
MRL	Minimum risk level
NH ₃	Ammonia
NOAEL	No observed adverse effect levels
NO _x	Nitrogen oxides
O ₃	Ozone
OW	Office of the Wet'suwet'en
PAH	Polycyclic aromatic hydrocarbons
PAMP	Public Access Management Plan
PM	Particulate matter

PTDI	Provisional tolerable daily intake
PTWI	Provisional tolerable weekly intake
RAF	Relative absorption factor
RAIS	Risk Assessment Information System
RfC	Reference concentration
RfD	Reference dose
ROC	Receptor of concern
RP	Residential and parkland land use
SA	Skin surface area
SF	Slope factor
SL	Soil loading rate
SO _x	Sulphur oxides
t	Time
TCL	Telkwa Coal Limited
TDI	Tolerable daily intake
THQ	Threshold Hazard Quotient
TPM	Total particulate matter
TR	Threshold Risk
TRV	Toxicity reference value
UCF	Unit conversion factor
UCLM	Upper confidence limit of the mean
UF	Uncertainty factor
UR	Unit risk
US EPA	United States Environmental Protection Agency
VC	Valued Component
VOC	Volatile organic compounds
WHO	World Health Organisation
wwt	Wet weight

1. INTRODUCTION

This Human Health Risk Assessment (HHRA) was completed by Entia Environmental Consultants Ltd. (Entia) under sub-contract to ERM Consultants Canada Ltd. (ERM) to support the assessment of potential effects on the Human Health Valued Component (VC) as part of the Application for the Environmental Assessment Certificate (EAC Application) for the Tenas Project (the Project), initiated by Telkwa Coal Limited (TCL).

1.1 Project Proponent

Telkwa Coal Limited is a wholly-owned subsidiary of Allegiance Coal Limited (ACL), a publicly-listed company on the Australia stock exchange (ASX: AHQ) with headquarters in Sydney, Australia. In addition to the Project, ACL owns two other coal mining projects located in central Queensland, Australia: the Kilmain and Back Creek projects, and recently acquired the New Elk metallurgical underground coal mine in Colorado, USA, and the Black Warrior Minerals metallurgical surface coal mine located in Alabama, USA.

The Project is the company's flagship project. TCL has offices in Telkwa and Vancouver, BC. The company was registered in BC on September 10, 2014 (BC1013154). The ACL website is: <http://www.allegiancecoal.com.au> while the TCL website is <http://www.telkwacoal.com>.

1.2 Project Description

TCL is proposing to develop the Project, a proposed surface metallurgical coal mine in northwestern BC, approximately 7 km southwest of Telkwa (**Figure 1.2-1**). The Project is within Wet'suwet'en traditional territory, specifically the Gitdumden and Laksilyu clans. Telkwa Coal Limited formally submitted the final Project Description (Telkwa Coal Ltd. 2018) in November 2018 to the BC Environmental Assessment Office.

The proposed Project will produce metallurgical coal at a production rate of between 775,000 and 825,000 metric tonnes of processed coal with a maximum daily production rate of 2,500 metric tonnes of processed coal per day. The mine life of the Project is expected to be approximately 26.5 years, including Construction, Operation, and Decommissioning and Reclamation phases. This is followed by the Post-closure Phase, which is expected to last 25 years but is dependent on regulatory approvals. The metallurgical coal produced from the mine will be exported to the Asian marketplace.

The Project's initial estimated capital cost is 123.5 million Canadian Dollars (CDN\$) (2018 dollars) to get to commercial production rates. The Project is anticipated to generate 125 person-years of direct employment during the Construction Phase. The Project is anticipated to require between 55 and 145 full-time equivalent employees during the Operation Phase and generate approximately 3,125 person-years of employment over the life of the Project excluding the Construction activities

1.3 Objectives

Human Health is a VC in the EA for the proposed Project. A quantitative HHRA, presented in this report, supports the effects assessment for the Human Health VC.

The main objective of the HHRA is to identify incremental changes that may occur to human health between the Baseline and future Project conditions to evaluate potential effects should the Project go ahead. To identify these changes, evaluations of risk to public human receptors that may be exposed to contaminants of potential concern (COPCs) under both scenarios are completed following standard risk assessment methodology as provided in Section 2.2.

This report describes the Baseline (or Base Case) and Project (or Project Case) HHRA for the purposes of the EAC Application under the British Columbia *Environmental Assessment Act*, SBC 2002, c 43

(Government of British Columbia [GovBC] 2002) (EAA) in accordance with the Project Application Information Requirements (AIR) (BC EAO 2022).

1.4 Definitions of Health and Scope of the Report

Canadian federal and provincial governments and health officials have accepted the World Health Organization's (WHO 1948) definition of holistic health:

A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

This was expanded to include (WHO 1984):

The extent to which an individual or group is able, on the one hand, to realize aspirations and to satisfy needs, and on the other, to change or cope with the environment. Health is therefore seen as a resource for everyday life, not the objective of living; it is seen as a positive concept emphasizing social and personal resources, as well as physical capacities.

This definition indicates that all aspects of well-being should be considered when assessing human health, including physical, social, emotional, spiritual, and environmental effects on health. There are many determinants of human health, such as: the physical environment (including environmental contaminants), heredity, lifestyle (e.g., smoking, drinking, diet, exercise, and coping skills), occupation, education, and the social and economic environment a person lives in (Health Canada 2000). However, not all of the health aspects are relevant for an HHRA since they would not be considered susceptible to effects from contaminants or would not be pathways for contaminant exposure in human receptors, which are assessed in this risk assessment.

Humans, and consequently human health, have the potential to interact with Project components and health is of high importance to society and individuals. The physical component of human health was considered in the HHRA because the physical health of humans living in or adjacent to or travelling through the area surrounding the Project has the potential to be affected directly through biochemical pathways (e.g., contaminants in water, air, or subsistence foods). **Section (S) 5 Chapter (C) 2 (S5-C2) Economic Development VC, S6-C4 Land and Resource Use VC, and S6-C5 Community Well-Being VC** of the EAC Application contain assessments of other non-physical determinants of health that are not included in this HHRA, such as education, employment and income, health and community well-being, and land use.

Indigenous perspectives on food and health are integrated throughout the HHRA. The social, cultural, spiritual, nutritional, and economic benefits of subsistence foods together play a role in how Indigenous people perceive subsistence foods. The hunting, fishing, and gathering of subsistence foods, and subsequent sharing of these foods with others throughout the community are social activities that bring individuals and families together (Chan et al. 2011).

The scope of the HHRA report encompasses potential changes in environmental media and their potential effect on human health within the Human Health Local Study Area (LSA; **Figure 2.3-1**; see Section 2.3) through phases of the mine. Future activities associated with development of the proposed Project could change the concentrations of COPCs in environmental media, plant or animal tissues, which could have the potential to affect the health of human receptors. Thus, a Baseline assessment of health risk associated with COPCs in the vicinity of the Project (pre-development; Base Case HHRA) and a Project assessment of health risk associated with the potential release of COPCs into the environment due to the Project (Project Case HHRA, with Operation and Closure [Decommissioning and Reclamation plus Post-closure] Scenario HHRAs) are necessary to support the effects assessment process. Following Health Canada's guidance on health impact assessments in environmental assessments (Health Canada 2010c, 2019a) and BC's Ministry

of Health guidance for prospective HHRA (BC MOH 2021), this report presents the methods and results of the Base Case and Project Case HHRAs conducted for the Project.



Tabloid

2. BACKGROUND INFORMATION

2.1 General Risk Assessment Methodology

Quantitative risk assessment is a tool used to estimate whether a contaminant in air, water, soil, sediment, or in subsistence (country) foods might pose a risk to human health and, if so, under what circumstances. The need to conduct a HHRA is determined by whether one or more COPCs are predicted to be elevated due to a proposed project (Health Canada 2019a).

For there to be risk to human and ecological health, the following three conditions must be met:

1. Contaminant of potential concern must be present

Exposure to COPCs as sources of potential risk are the focus of the HHRA. A COPC is any constituent that, when present in high enough concentrations and taken up by people, could cause adverse effects on human health. A COPC must be present in the environment where people or other biota that are used as subsistence food can be exposed to it.

2. Receptors of concern (ROCs) must be present

Receptors of concern refer to the potential user groups/individuals that are potentially present around the Project (e.g., Indigenous and non-Indigenous local residents, hunters, subsistence food gatherers, hikers, campers). Their behaviours and activities may lead to exposure to COPCs.

3. Exposure pathways must be operable

An operable exposure pathway is the means by which ROCs are exposed to the sources of COPCs. Examples include people being exposed to substances through direct contact with soil or through consumption of collected berries and traditional plants.

As shown in HHRA guidance (Health Canada 2019a) there can only be risk when all three factors overlap; if any of the three factors are absent (e.g., the exposure pathway is not complete or the receptors are not present), there is no risk. When the three factors overlap, additional assessment is completed to characterize the risk, providing a more in-depth understanding of the behaviour and activities of the receptors, the spatial and temporal characteristics of the COPCs, and the exposure pathways describing how ROCs are exposed to COPCs.

There are five main components to be completed in a quantitative HHRA:

1. Problem formulation: defines the scope of the risk assessment, including identification of COPCs, ROCs, and exposure pathways;
2. Exposure assessment: determines the level of exposure for each ROC taking into consideration environmental concentrations of COPCs, exposure durations, and receptor characteristics;
3. Toxicity assessment: determines the level of exposure that would not be expected to cause adverse effects for each ROC;
4. Risk characterization: integrates the exposure assessment and toxicity assessment to characterize the overall risk to each ROC from the COPCs; and
5. Uncertainties: identify uncertainties and assumptions made in the risk assessment and how these affect confidence in the results.

The Base Case and Project Case HHRAs in this report follow these five steps.

In a screening level risk assessment, such as this HHRA, it is common to make a number of conservative assumptions (discussed in Section 7) during the assessment which will overestimate the actual risk to

human health. If no unacceptable risks are identified using this conservative approach, then it is unlikely that human health will be affected by the exposure pathways considered and the rates used in the assessment. However, identification of potential risks in the Base Case due to background conditions does not necessarily mean that human health will be adversely affected, since the risk has been overestimated intentionally in a screening level HHRA.

2.2 Regulatory and Policy Framework

Guidance documents that outline recommended methodologies and approaches for human health risk assessment are available from both federal and provincial jurisdictions. Guidance sourced from other jurisdictions may also be adopted in the absence of federal and provincial guidance. The following is a list of the guidance documents that were considered in the Base Case and Project Case HHRAs:

- *British Columbia Guidance for Prospective Human Health Risk Assessment. Version 1.0* (BC MOH 2021).
- *Guidance for Evaluating Human Health Impacts in Environmental Assessment: Human Health Risk Assessment* (Health Canada 2019a).
- *British Columbia Contaminated Sites Regulation (CSR) Protocol 13 Screening Level Risk Assessment* (BC ENV 2019b).
- *Guidance for Evaluating Human Health Impacts in Environmental Assessments: Country Foods*. (Health Canada 2018).
- *Supplemental Guidance on Human Health Risk Assessment of Air Quality, Version 2.0*. (Health Canada 2017).
- *Guidance for Evaluating Human Health Impacts in Environmental Assessments: Air Quality* (Health Canada 2016a).
- *Guidance for Evaluating Human Health Impacts in Environmental Assessments: Drinking and Recreational Water Quality* (Health Canada 2016b).
- *Guidance on Human Health Risk Assessment. Version 1.0*. (Northern Health 2015a).
- *Standard Working Group Comments and Recommendations for Provincial Environmental Assessments in Northern British Columbia. Version 2.1*. (Northern Health 2015b).
- *Federal Contaminated Site Risk Assessment in Canada: Interim Guidance on Human Health Risk Assessment for Short-Term Exposure to Carcinogens at Contaminated Sites* (Health Canada 2013).
- *CSAP Technical Guidance for Risk Assessment COPC Screening* (CSAP 2012).
- *Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment* (Health Canada 2021a).
- *Federal Contaminated Site Risk Assessment in Canada: Toxicological Reference Values (TRVs), Version 3.0*. (Health Canada 2021b).
- *Federal Contaminated Sites Risk Assessment in Canada Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRA)* (Health Canada 2010a).
- *Federal Contaminated Site Risk Assessment in Canada, Supplemental Guidance on Human Health Risk Assessment for Country Foods (HHRA_{Foods})* (Health Canada 2010b).
- *United States Environmental Protection Agency's (USEPA) Risk Assessment Guidance for Superfund (RAGS) Part A, Part B, and Part E* (US EPA 1989, 1991, 2004).

2.3 Spatial Boundaries: Local Study Area

The LSA for the HHRA is the area surrounding the Project, where there is a reasonable potential for the Project or Project-related activities to interact with and potentially have an adverse effect on the Human Health VC through changes in exposure media COPC concentrations. The LSA (**Figure 2.3-1**) was developed based on the following principles:

- The LSA encompasses the area around the Project where direct effects from Project activities may occur (e.g., environmental quality changes as a result of Project activities or components such as changes in water quality or dust deposition). This will contribute conservatism to the risk assessments by maximizing the incremental change in risk in the Project Case HHRA compared to the Base Case HHRA.
- The LSA aligns with or encompasses the LSAs or modelling domains developed for other VCs and their subcomponents on which the risk assessments depend (e.g., Air Quality subcomponent, Surface Water Quality subcomponent, Fish and Fish Habitat VC, and Terrain and Soils VC). This supports consistency in the EA and allows the results of the risk assessments to be used in the assessment of effects for other VCs.
- The boundaries for the HHRA were selected so that the same assessment areas will be applicable to the EAC Application effects assessment for the Human Health VC.

Following the above principles, the Human Health LSA follows the LSA boundary of the Atmospheric Environment VC Air Quality Subcomponent (air quality modelling domain). It was determined to be the largest LSA boundary within which direct effects from Project activities may occur in air, soil and vegetation. The Surface Water Quality LSA falls within the selected LSA boundaries and thus no direct effects from the Project on the Surface Water VC are expected to occur beyond this area.

The Regional Study Area (RSA) boundaries are the same as the LSA boundaries because the Base Case and Project Case HHRAs rely on models that do not go beyond an area within which biophysical effects or changes are expected to occur.

2.4 Temporal Boundaries

Temporal boundaries are selected that consider the different phases of the Project and their durations. The Project's temporal boundaries reflect those periods during which planned activities will occur and have potential to affect the health of people. The mine life of the Project is estimated at 26.5 years which includes the Construction, Operation, and Decommissioning and Reclamation phases. This is followed by the Post-closure Phase, which is expected to last 25 years. Project phases are listed in **Table 2.4-1**. Details of the Project are provided in the Project Description (Telkwa Coal Ltd. 2018).

Table 2.4-1: Project Phases

Phase	Year	Duration (years)	Description of Activities
Construction	-0.5 to 0	1.5	Site clearing, soil salvage, open pit development, building construction, service and haul road development, Rail Infrastructure construction, bridge construction and development of onsite utilities and services. Development of mine rock, and overburden storage piles, stockpiling of reclamation material such as soil, overburden and other materials suitable for reclamation. Development of water management systems and management ponds for storage of potentially acid generating (PAG) materials.

Phase	Year	Duration (years)	Description of Activities
Operation	1 to 21	21	Development of the open pit through drilling, blasting, loading, and hauling functions. Development of mine rock, and overburden storage piles, stockpiling of reclamation material such as soil, overburden and other materials suitable for reclamation. Development of water management systems and management ponds for PAG storage. Conducting coal processing, stockpiling of raw coal prior to processing, and stockpiling of processed coal prior to shipping. Progressive reclamation will be accomplished during operation including, where available, reclamation activities such as sloping, topsoil placement and revegetation.
Decommissioning and Reclamation	22 to 25	4	Tear-down of infrastructure onsite plus reclamation activities, including sloping of storage piles, backfill materials, and placement of reclamation materials including growth media, overburden and non-PAG rock for management pond covers and revegetating surfaces that are planned to be reclaimed.
Post-closure	26 to 50	10	Active: This involves the filling of the open pit with water, monitoring of vegetation growth and water quality for both groundwater and surface water and wildlife. Control and sedimentation ponds may still be needed for settling of total suspended solid levels. The management ponds are left as dry land reclamation except for portions that will be left as open water.
		15	Passive: This stage is when the control and sedimentation ponds are no longer required for settling of total suspended solid (TSS) levels and the management ponds are left as dry land reclamation except for portions that will be left as open water. Telkwa Coal Limited (TCL) is now simply monitoring the site.

2.5 Risk Assessment Scenarios

The risk assessment scenarios to be evaluated in the HHRA will be aligned with those used in other predictive modelling, such as the surface water quality and air quality predictive modelling. The scenarios include:

- Base Case HHRA: considers potential risks to ROCs under existing (or Baseline) conditions; and
- Project Case HHRA: considers potential risks to ROCs during the Construction, Operation, Decommissioning and Reclamation, and Post-closure phases of the Project.

For the purposes of the Project Case HHRA, only the phases with the greatest potential for effects on human health were assessed. This was done to represent the “worst-case” scenarios expected from Project-related changes and therefore represents the phases associated with the greatest levels of risk; risk during other phases would be expected to be lower. Thus, Construction and Operation phases were combined into risk estimates for the Project Case (Operation) scenario, while the Decommissioning and Reclamation phase and the Post-closure phase were combined into risk estimates for the Project Case (Closure) scenario.

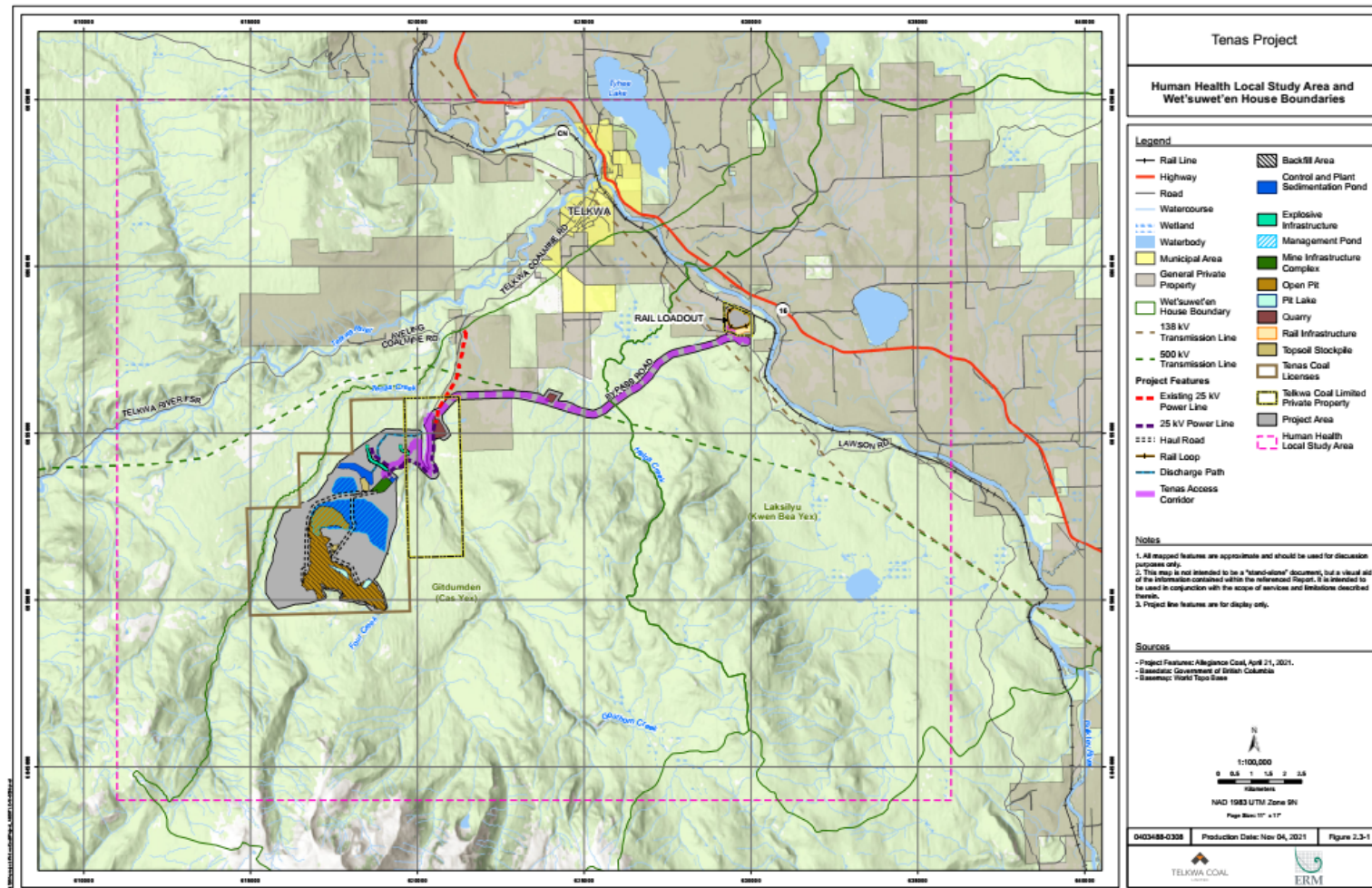


Figure 2.3-1: Human Health Local Study Area and Wet'suwet'en House Boundaries

GIS No.: TLC-16-030b_T

Tabloid recto

Tabloid verso

Specific objectives of the HHRAs were to:

- assess the potential for adverse effects on human health associated with exposure to COPCs under existing or Baseline conditions (Base Case HHRA);
- assess the potential for adverse effects on human health associated with exposure to Project-related COPCs under predicted future conditions (Project Case HHRA for Operation and Closure); and
- determine the incremental change in potential effects on human health between the Base Case and Project Case.

3. PROBLEM FORMULATION

The objectives of the problem formulation stage are to:

- identify potential human ROCs that may be in the area, their characteristics, and the most sensitive and relevant life stages;
- identify the relevant human exposure pathways;
- identify and select the relevant COPCs within the Human Health LSA; and
- create a conceptual model for the Base Case and Project Case HHRAs.

3.1 Human Receptors of Concern and Assessment Locations

Human ROCs are selected with consideration of activities that are known or reasonably expected to occur in the Human Health LSA. Additionally, they are selected based on likelihood to experience the greatest exposure.

Workers and contractors, while on shift for the Project, and visitors to the Project, will not be assessed in the HHRA as they are protected under the *Health, Safety and Reclamation Code for Mines in British Columbia* (British Columbia Ministry of Energy 2021) and off-duty workers and contractor live outside of the Project's footprint while not at work. Although many workers and contractors live outside of the LSA, it was conservatively assumed that exposure of off-duty workers and contractors is similar to that of a resident who lives within the LSA.

3.1.1 Indigenous Land Use

The Project is within the traditional territory of the Wet'suwet'en Nation (**Figure 2.3-1**). There are 31 Wet'suwet'en reserves throughout their traditional territory. Reserves are primarily occupied by people for residential and agricultural land uses, with some commercial and industrial use. Reserves classified as forest can also be considered occupied through Indigenous land use (Telkwa Coal Ltd. 2018).

The Mine Infrastructure is within the traditional territory of the Cas'Yex House Territory of the Gitdumden clan of the Wet'suwet'en, while a portion of the Tenas Access Corridor (TAC) and Project Rail Infrastructure is located within the Kwen Bea Yex House Territory of the Laksilyu clan of the Wet'suwet'en. These territories were and are still frequently harvested for resources (Telkwa Coal Ltd. 2018). Wet'suwet'en oral histories indicate that these territories have been utilized for generations (Crossroads 2021).

The Project is situated in proximity to places of cultural importance to the Wet'suwet'en. *Yintah* (or *Yinta*) is a Wet'suwet'en concept in which everything is connected to the land. This world view embodies within it the responsibility of stewardship over the territories that sustain Wet'suwet'en lifeways. As such, individual locations of specific land use are not considered as relevant in the context of the HHRA, but rather the entirety of the land. It has to be acknowledged that this approach is not without complication, as the western approach to risk assessment relies on assessment of effects at specified locations (within modelling boundaries). The Wet'suwet'en continue to practice deliberate resource management strategies that are designed to ensure generational succession of territorial resources. The Office of the Wet'suwet'en (OW), as governed by the hereditary Chiefs, continues to collectively manage lands and resources, fisheries and wildlife, human and social services, and treaty negotiations on behalf of the Wet'suwet'en (Crossroads 2021).

Traditional land use is described in detail in the **Part C Wet'suwet'en Rights and Interests** and in **Appendix 7.1-B Cultural Use Study** of the **EAC Application**.

3.1.2 Indigenous Subsistence Foods

Subsistence foods include a wide range of animal, plant, and fungi species that are harvested for medicinal or nutritional use.

As indicated in the Project Description (Telkwa Coal Ltd. 2018) and in **Appendix 7.1-B**, Wet'suwet'en people currently hunt and trap primarily from April to December, although hunting and trapping can take place at any time of the year. Main targeted species include moose, deer, bear and beaver. Other species harvested include coyote, wolf, lynx, marmot, snowshoe hare, rabbit, muskrat, squirrel, marten, weasel, groundhog, and blue grouse. For conservation reasons, mountain goat and caribou are generally not hunted.

However, the LSA for the Project is not known to contain hunting areas that are favoured by the Wet'suwet'en. For example, Telkwa Pass, an area where Wet'suwet'en are known to prefer to hunt grouse, is outside the Human Health LSA (TERA 2015, in (Crossroads Cultural Resource Management 2020). However, there are several Indigenous use trails that cross the LSA or are adjacent (west) of the Project (**Part C S11.0-C9 Consultation of the EAC Application**). Some of these trails are used today for recreation and access to Hunter's Basin.

Chinook salmon are traditionally the first salmon species to be harvested during the year, followed by sockeye in late June and early July. Other important fish species include Kokanee, whitefish, trout, char, suckers, and burbot. Chub, dace, Dolly Varden, Northern Pike Minnow, sculpin, and White Sturgeon are harvested as well (**Appendix 7.1-B**).

Plants are harvested for food, materials, and medicines from forest and woodland settings within the traditional territory in a seasonal-round system. Plant foods include green vegetables (e.g., wild celery), fruits and berries, inner bark-cambium, roots and rhizomes, and beverages. Huckleberries, soapberries, cranberries, raspberries, saskatoon berries, high-bush blueberries, gooseberries, salmonberries, juniper berries, and thimbleberries are harvested during late summer and autumn. Medicines are derived from leaves or foliage, roots, and inner barks and are harvested according to season. The Wet'suwet'en also harvest plant material, including fibrous plants, bark, wood, sap, and dyes and pigments. The names and uses of 59 species of vascular plants and three nonvascular taxa were documented in studies by Gottesfeld (1994a, 1994b, 1999). Some of the important plants and their uses identified by Gottesfeld are listed in **Table 3.1-1**.

Table 3.1-1: Important Food Plants Used by the Wet'suwet'en People

Common Plant Name	Scientific Name	Use
Cow parsnip, "wild rhubarb"	<i>Heracleum lanatum</i>	Medicinal, Green vegetable
Stonecrop; "stone berries"	<i>Sedum divergens</i>	Green vegetable
Lodgepole pine	<i>Pinus contorta</i>	Medicinal, Cambium (for food)
Western hemlock	<i>Tsuga heterophylla</i>	Cambium (for food)
Huckleberry, black	<i>Vaccinium membranaceum</i>	Berries
Blueberry, low-bush	<i>Vaccinium caespitosum</i>	Berries
Kinnikinnik	<i>Arctostaphylos uva-ursi</i>	Medicinal, Berries
Bunchberry	<i>Comus canadensis</i>	Berries
Cranberry, high-bush	<i>Viburnum edule</i>	Medicinal, Berries
Cranberry, low-bush; bog	<i>Vaccinium oxycoccus</i>	Berries

Source: Gottesfeld (1994b)

Today, however, substantially fewer Wet'suwet'en persons gather plants for food, medicine, and cultural goods due to concerns over contamination from industrial herbicides used by forestry companies. According to cultural protocol, "it is not advisable to gather plants near a road, as such plants are frequently impacted and absorb the bad spirits of the humans who caused the impact. To gather plants, one should travel deep into the woods, where plants have not been affected by any anthropogenic activity and, thus, have the purest spirit." (**Appendix 7.1-B**).

The feast system is of paramount importance to Wet'suwet'en life-ways. Central to this system is the sharing of traditional foods at feasts. As was done in the past, today Wet'suwet'en continue to use almost all parts of their hunted animals or fish. For example, in addition to eating moose muscle, they also eat moose organs, such as heart, liver, stomach lining, tongue, nose, intestine, and kidney (TERA 2015, *in* Crossroads 2021). Potential threats to the continuity of the Wet'suwet'en way-of-life from climate change, industrial development, and resource development are of great concern to many Wet'suwet'en today.

3.1.3 *Non-traditional Land Use and Human User Groups*

Non-traditional land use is described in the **Baseline Land and Resource Use Report (Appendix 6.4-A of the EAC Application)** and summarized in **S6.0-C4 Land and Resource Use VC of the EAC Application**. Non-traditional land users engage in recreation (e.g., hiking, camping, horseback riding, swimming, mountain biking, ATV-ing/quad riding, motorized and non-motorized winter sports) in provincial parks, on TCL-owned lands, or on public lands throughout the Human Health LSA. In addition, trapping of mammalian species for their pelts and hunting and fishing occur within the Human Health LSA.

3.1.3.1 *Recreation*

Horseback riding and camping occurs throughout the summer at and near the "Coalmine Camp" on TCL property 2 km north of the proposed Minesite which is a joint Project developed by TCL and the Northwest chapter of the Back Country Horseman of BC.

The closest provincial park to the Project, and within the Human Health LSA, is Tyhee Lake Provincial Park, approximately 11 km to the northeast, where people may engage in swimming, fishing, or canoeing. Other private parks and recreation areas, such as the Fort Telkwa Riverfront RV campground just south of Telkwa and east of the Bulkley River, are also located within the LSA. The LSA overlaps with access trails to Hunters Basin, a well-known hiking spot in the Telkwa Mountain range approximately 10 km to the south of the Project. Some of these trails have been used traditionally by Wet'suwet'en (refer to Sections 3.1.1 and 3.1.2 above). There are no formal campsites or facilities at Hunter Basin, however, the area remains accessible to Indigenous and non-Indigenous land users.

According to numerous individuals interviewed for the Baseline Land and Resources Use Report (**Appendix 6.4-A**), recreation sites north of the Telkwa River receive much more use than those on the south side of the Telkwa River, where the Project is located.

It is assumed that people will collect berries and other subsistence foods while recreating in all areas of the LSA. Identified recreational land use areas and trails located within the LSA are shown on **Figure 3.1-1**.

3.1.3.2 *Hunting*

The LSA is found within the boundaries of guiding certificate 601109, which is owned by Skeena Mountain Guide Outfitters (Skeena Mountain). Skeena Mountain has been in operation since 2006 and offers hunts for black bear, mountain goat, wolf and moose, year-round depending on species. The LSA also overlaps with guiding certificate 610002 (Telkwa River Outfitters Inc.), and has a very small overlap with guiding certificate 601107 (Telkwa River Outfitters Inc.)

In Wildlife Management Unit 6-9, which overlaps with the Human Health LSA, resident hunters have harvested moose most successfully, followed by black bear and mule deer. Most hunting takes place south of the Minesite and occurs year-round, predominantly on weekends. Residents hunt in most green spaces throughout the Bulkley Valley (**Appendix 6.4-A**).

Hunting and guide outfitting, and trapping areas are shown on **Figure 4.2-12** and **Figure 4.2-14**, respectively, in **S6.0-C4 Land and Resource Use VC**.

3.1.3.3 *Fishing*

Fishing is an important food source and recreational opportunity in the Bulkley Valley. Licences are available in a range of options from single day to annual licences. The Bulkley River is a well-known fishing location and the fishing lodges in the region primarily fish on the Bulkley River for Steelhead Trout. The Telkwa River can only be fished by residents during September and October and does not allow guiding days. The Telkwa River is a favoured spot for resident anglers, as well as families looking for an easy spot to fish. It is recognized for its wild Coho salmon and Steelhead Trout runs, as well as its Bull Trout fishery. The 24 km stretch of the Telkwa River is an enhanced spawning habitat for Coho salmon (**Appendix 6.4-A**).

The main species of fish caught in the area are salmon and Steelhead Trout, particularly on the Bulkley River. Chinook, Coho and Steelhead have historically had strong runs in the Bulkley River but have declined in recent years. Coho salmon are a common species to catch in the Telkwa River.

The LSA includes Goathorn Creek and Tenas Creek, which feed into the Telkwa River, and the Bulkley River. The Bulkley River and the Telkwa River are the most popular fishing rivers in the area. During the interviews for the Baseline Land Use Report, there were no comments made about the use of Tenas Creek and Goathorn Creek for fishing. Although Tenas Creek and Goathorn Creek are not known as popular fishing locations, there could potentially be anglers using these creeks and, thus, they are included in the HHRA (**Appendix 6.4-A**).

3.1.3.4 *Gardening/Subsistence Farming*

Rural land owners may engage in part time farming, as income is supplemented by other activities such as mining, forestry and the service industry (Regional District of Bulkley-Nechako 2012). The products generated on the farm are normally sold to local consumers based on a desire to eat and support local agriculture, as well as the distance to large grocery stores (Regional District of Bulkley-Nechako 2012). Although subsistence (country) foods are defined as those that may be produced in an agricultural or backyard setting, they do not include foods grown for commercial sale (Health Canada 2018). Therefore, only foods grown by residents on private farms or gardens for personal use are included in this HHRA.

3.1.4 *Residential Land and Water Use*

The Human Health LSA includes the Village of Telkwa, as well as private, rural properties near the Project, including along Telkwa Coalmine Road, Lawson Road, the proposed TAC, and the Rail Infrastructure. The Village of Telkwa is located approximately 7 km northeast of the Minesite, at the closest point. The community is dependent on the resource-based economy, including mining, agriculture and forestry. The Village also functions as a satellite community, housing workers who commute to Smithers, Houston, or other surrounding areas. In 2016, Telkwa's population was 1,327, a small decrease of 1.7% from the 2011 census (Telkwa Coal Ltd. 2018).

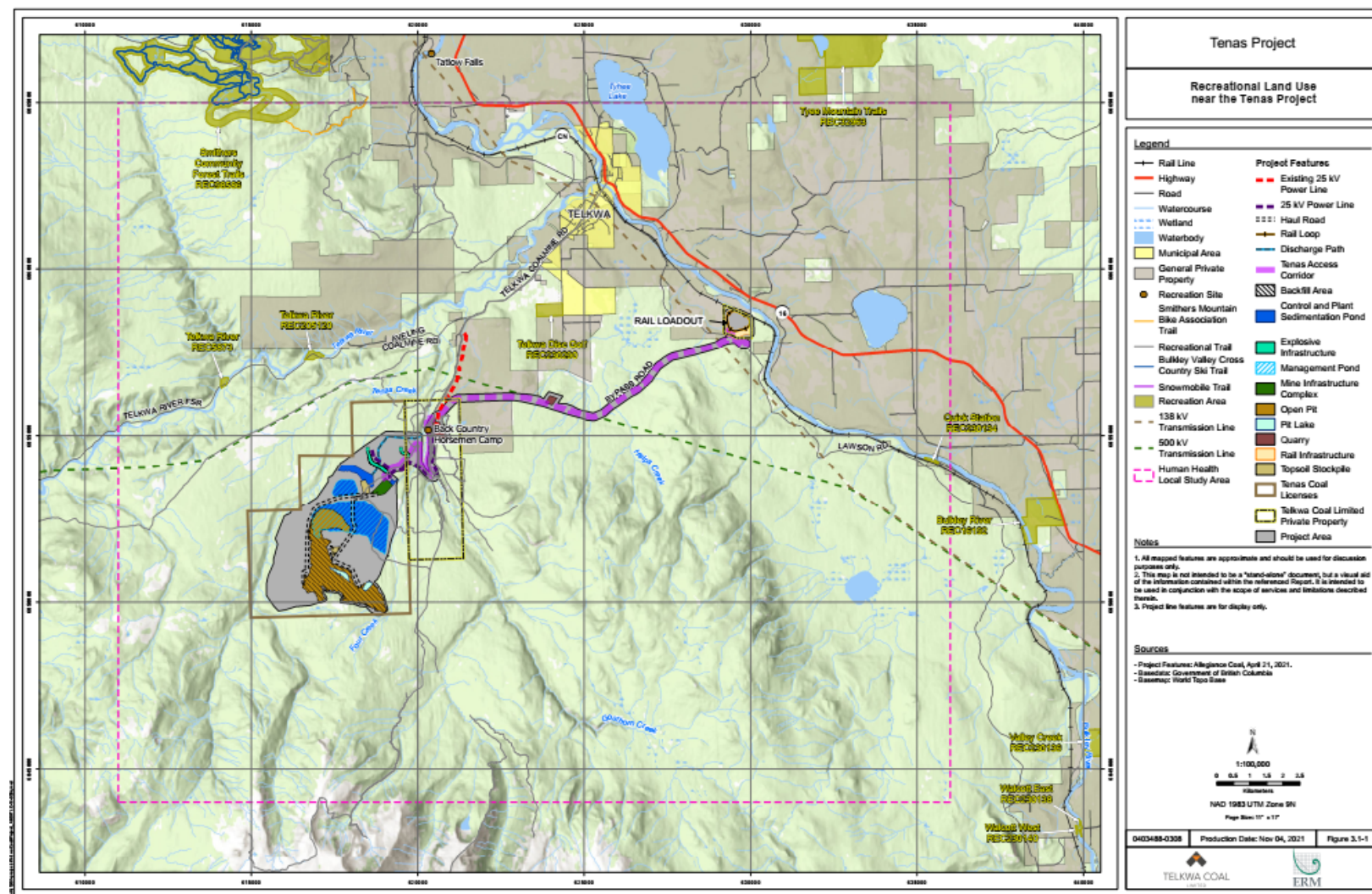


Figure 3.1-1: Recreational Land Use near the Tenas Project

GIS No.: TLC-16-030c_T

Tabloid verso

The Village of Telkwa has a central water distribution system for domestic water operated by the Village. Rural properties commonly have domestic groundwater wells as a source of drinking and irrigation water. **Figure 36 in Appendix 1.0-U Groundwater Technical Report for the Tenas Coal Project of the EAC Application** shows known locations of private wells within the LSA. The closest private domestic wells are located:

- About 3.8 km north of the Project, to the west of Goathorn Creek, along the expected groundwater flow paths towards the Telkwa River; and
- About 3.1 km and 4.5 to 5.4 km north-west of the Project, to the east of Goathorn Creek; they are located downgradient of the Project but not along the expected groundwater flow paths towards the Goathorn Creek or the Telkwa River.

3.1.5 Identification of Groups of Receptors of Concern

Based on the information in the preceding subsections (Sections 3.1.1 to 3.1.4), two main land user groups, or ROCs, with distinct characteristics were identified to conservatively focus the HHRA on ROCs with the highest potential for exposure:

- **Indigenous and non-Indigenous Resident Land Users** (infants to adults): These ROCs live in the Human Health LSA in residential areas, especially closer to the Project (i.e., the Cottonwood neighborhood and rural residences along Lawson Road), and spend time fishing/hunting/collecting or farming subsistence foods for their own consumption (in addition to eating store-bought foods). They may drink water from groundwater at their residences or surface water while spending time on the land within the LSA.
- **Recreational Land Users**: These ROCs do not live in the LSA but may spend some time in the LSA to recreate and hunt. While doing so, they are assumed to drink surface water from within the LSA and eat store-bought and subsistence foods. This group includes campers, hikers, horseback riders, and other recreationists who do not live in the LSA.

Quantitative characteristics for ROCs used in the HHRA models are described in Section 4.1.

3.2 Types, Sources, and Transport Pathways of Contaminants of Potential Concern

3.2.1 Base Case Sources and Types of Contaminants of Potential Concern

The sources of COPCs in the Base Case are from the water, soil, and air in the Human Health LSA. Given the nature of the Project, Base Case COPCs are metals in air, water, soil and tissues, ions in water, and criteria air contaminants (CACs). Hydrocarbons (such as polycyclic aromatic hydrocarbons; PAHs) or volatile organic compounds (VOCs, such as benzene, toluene, ethylene, and xylene [BTEX]) may also occur in some environmental media such as air, water, soil, or sediments. Some of the COPCs in the Base Case are naturally occurring (e.g., metals or ions in surface water or metals in dust from re-suspended soil particles in air), while some may be due to existing anthropogenic sources or activities within the Human Health LSA (e.g., air emissions from vehicles on roads, smoke from wood burning).

Contaminants of potential concern can have different characteristics and can be described as CACs, non-threshold COPCs and threshold COPCs, and carcinogens and non-carcinogens. The following paragraphs define each term:

CACs are a set of air pollutants that can cause smog, acid rain, and other health hazards. They include total particulate matter (TPM), particulate matter with diameter equal to or less than 2.5 µm and 10 µm (PM_{2.5} and PM₁₀, respectively), nitrogen oxides (NO_x; a group of gases

consisting primarily of nitric oxide [NO] and nitrogen dioxide [NO₂], sulphur oxides (SO_x; a group of gases consisting mainly of sulphur dioxide [SO₂]), ozone (O₃), carbon monoxide (CO), volatile organic compounds (VOCs), and ammonia (NH₃). Particulate matter consists of solid or liquid particles of varied chemical constituents.

Non-threshold contaminants are considered to pose a non-zero health risk at any level of exposure, with risks expected to increase with increasing exposure. Non-threshold contaminants are typically carcinogens, however, there are some air contaminants for which thresholds for non-carcinogenic effects (e.g., respiratory and cardiovascular morbidity and mortality) have not been quantified, including PM_{2.5}, O₃, and nitrogen dioxide (NO₂), as well as lead (Health Canada 2013, 2016c, 2019a).

Threshold contaminants are considered to have a threshold level below which no adverse effects are anticipated to occur. The health effect can be either non-carcinogenic or carcinogenic (e.g. arsenic; Health Canada 2019a). Above the threshold, a linear dose-response relationship is generally assumed.

Carcinogens are contaminants that are genotoxic or mutagenic by binding to or reacting with DNA, thereby inducing “*permanent, transmissible changes in the amount, chemical properties or structures of the genetic material. In most cases, mutation involves changes in DNA structure that either have no effect or cause harm*” [(US EPA 2005a) in (Health Canada 2013)]. Typical harm is the development of cancer.

In contrast, **non-carcinogens** are contaminants that cause health risks other than cancer.

3.2.2 Project Case Sources and Types of Contaminants of Potential Concern

The Telkwa Coal Project Description (Telkwa Coal Ltd. 2018) was used to identify potential Project-related sources of COPCs. The same classes of COPCs considered in the Base Case are considered in the Project Case (i.e., metals, ions, hydrocarbons, VOCs, CACs). The following Project activities or components were identified as having the potential to release COPCs to the environment that could affect human health:

- Air emissions of CACs from mine activities (diesel equipment, blasting), and transportation (on-road vehicles and train operation, including idling) (**Atmospheric Environment VC S4.0-C1**);
- Fugitive dust emissions (containing metals) from mining activities and quarry activities (scrapping, drilling, blasting, and bulldozing), road grading, vehicle movement (particularly on unpaved roads), handling and processing of materials, vegetation clearing or removal, wind erosion from stockpiles and disturbed surface soils, road dust re-entrainment (**S4.0-C1**);
- Changes in groundwater recharge and changes to groundwater levels and flow resulting in changes to groundwater quality or surface water quality (metals and ions) (**Surface Water VC S4.0-C3** and **Groundwater VC S4.0-C4**);
- Effluent discharge that may result in changes to surface water quality (metals and ions) (**S4.0-C3**); and
- Seepage from mine infrastructure that may result in changes to groundwater and surface water quality (metals and ions) (**S4.0-C3** and **S4.0-C4**).

An air emissions inventory is provided in **Appendix 4.1-B Air Quality Modelling Report** of the **EAC Application**. Source terms to the water quality model are described in **Appendix 4.3-A Tenas Water and Load Balance Technical Report** of the **EAC Application**.

Project components and activities that involve the combustion of a fuel source will result in air emissions. This applies to a wide range of activities or mobile and stationary equipment, such as: blasting, material

handling and processing, diesel equipment, train operation and idling, employee and service vehicles, and the waste oil boiler (for space heating). The primary air pollution emissions from these components and activities include SO₂ and NO_x, and fine particulate matter (PM_{2.5} and PM₁₀) that will cause changes in the ambient air quality.

Any Project components and activities that involve the disturbance of ground material (e.g., rock, dirt, soil, silt) or the exposure of ground material (e.g., stockpiles, tailings and water management infrastructure) have the potential to release fugitive dust emissions. This applies to a wide range of components and activities, such as: blasting, earthworks, general infrastructure construction, ground material handling and transfers, mobile equipment and vehicles travelling on unpaved roads and surfaces, rock crushing, unpaved road and pad maintenance, and operation of quarries, stockpiles, and the tailings storage facility. The primary pollution emissions from these components and activities include Total Suspended Particles (TSP), and PM₁₀ and PM_{2.5} that will cause changes in the ambient air quality. Fugitive dust (including TSP and PM) may be associated with metal COPCs.

Potential sources of Project-related COPCs could also be from fuel, explosives, inert chemical fire suppression systems, dust suppression, and other chemicals that may be used for the Project. However, these chemicals and materials are only likely to reach the air, terrestrial, or freshwater environments in the event of unusual circumstances such as accidents or malfunctions. Mitigation and management plans will be implemented to guide the safe handling and storage of these materials to prevent their release to the environment where exposures to people could occur (refer to Chemicals and Materials Storage, Transfer, and Handling Plan [S13-C3] [CMSTHP]; Explosives Management Plan [S16-C6] [EMP]; and Fuel Management and Spill Control Plan [S13-C7] [FMSCP]). Therefore, the constituents that may come from these potential sources are not considered in the HHRA.

Other contaminants such as persistent organic pollutants (POPs) and radionuclides are not considered, as these are not typically associated with coal mining and are unlikely to be affected by Project-related activities.

3.2.3 *Transport Pathways of Contaminants of Potential Concern*

There are three main potential transport pathways through which COPCs may be transferred from the Project to the environment where people could come into contact with them:

1. Atmospheric transport of gases and particulates, where Project sources of CACs and metals are conveyed into the environment via dispersion in the air, which is then inhaled by humans;
2. Atmospheric transport of fugitive dust, where dust generated by Project activities can be deposited from the air onto the ground or plant surfaces, which can then be taken up by plant roots into plant tissue, which can then be ingested by people and terrestrial biota; and
3. Effluent discharge (to surface water) and seepage (to groundwater) that may contain Project-related COPCs from Project activities or infrastructure, which can then be ingested by people and terrestrial biota.

Once COPCs enter the environment they can be taken up into the aquatic or terrestrial food chain; this is also included in the risk assessments as an indirect transport pathway for exposure (subsistence foods) of people.

3.3 **Complete Exposure Pathways**

Exposure pathways are routes by which people can be exposed to COPCs in various exposure media. These pathways can either be direct (e.g., ingestion of surface water) or indirect (e.g., ingestion of an animal that has been drinking surface water).

Exposure pathways are classified as complete or incomplete. Pathways are considered complete when a link is established between the COPC source and people. All pathways considered complete are carried forward for further assessment in the HHRA. Exposure pathways are considered incomplete when there is no documented or anticipated link; these pathways are not carried forward for further assessment.

Table 3.3-1 summarizes the complete exposure routes (green), the incomplete exposure routes (red), and the exposure routes that may be complete but are not considered further (yellow).

Table 3.3-1: Potential Exposure Pathways

Receptor of Concern	Potential Exposure Pathway									
	Ingestion					Dermal Contact				Inhalation
	Surface Water	Groundwater	Soil	Sediment	Subsistence Food	Surface Water	Groundwater	Soil	Sediment	Air
Resident Land User*	Green	Green	Green	Yellow	Green	Yellow	Yellow	Green	Yellow	Green
Recreational Land User	Green	Red	Green	Yellow	Green	Yellow	Red	Green	Yellow	Green

Notes:

* This includes Indigenous and non-Indigenous Resident Land Users.

Green – pathway is complete.

Yellow – pathway may be complete but is not considered further (additional rationale for exclusion is provided in text).

Red – pathway is incomplete.

Complete (green) exposure pathways were identified for the Indigenous and non-Indigenous Resident Land User for the ingestion of surface water, groundwater, soil, and subsistence food, and for the inhalation of air. Complete exposure pathways were identified for the Recreational Land User for the ingestion of surface water and soil, and for the inhalation of air. Significant

The Recreational Land User has incomplete (red) exposure pathways for the ingestion of and dermal contact with groundwater as they don't reside within the LSA and are not expected to obtain drinking water from groundwater wells while visiting the LSA, but rather will use surface water for drinking and recreational purposes.

The rationale for excluding the potentially complete exposure pathways shown in yellow is:

- For exposure to sediments, significant exposure is not expected for either ROC group:
 - Indigenous and non-Indigenous Resident Land Users: individuals may contact sediment while fishing. It is anticipated that individuals would be wearing boots or waders; thus, clothing is expected to block this pathway.
 - Recreational Land Users – individuals may contact sediment while on shorelines or while swimming. Exposure while swimming is not complete as sediment is washed off while an individual is in the water. Exposure while on a shoreline is expected to be low as limited beach areas are available for use. Additionally, assessment of soil exposure is considered a conservative surrogate.
- For dermal exposure to water, as per BC Ministry of Environment and Climate Change Strategy's (BC ENV) Technical Guidance 7 (BC ENV 2017) "The dermal exposure pathway from water for

metals does not require evaluation.” This pathway is typically excluded for metals because the amount of metal uptake that occurs through the skin is negligible compared to other, more significant exposure pathways such as eating subsistence foods or drinking water. As the COPCs for this Project are metals, the dermal exposure pathway from metals in water was not evaluated further.

Metal COPCs may also be present in foods in the market (retail or commercial) food system. As per guidance from the BC Ministry of Health and Health Canada (Health Canada 2019b; BC MOH 2021), in addition to subsistence foods, the assessment also includes background exposure from ingestion of market foods to estimate the overall exposure to COPCs from food ingestion. The doses from market foods are independent of Project phase as it is assumed that people will consume the same amount of market foods or the same quality every year (in addition to subsistence foods). Thus, the same dose of POCs from market foods is applied to both the Base Case and Project Case.

3.4 Data Sources

3.4.1 Air

3.4.1.1 Baseline Data

Baseline air quality was assessed in the **EAC Application in S4.0-C1** (subcomponent air quality) as part of the atmospheric effects assessment. Details of the Baseline sampling program can be found in **Appendix 4.1-C Tenas 2017-2019 Baseline Report** (Chapter 3 Air Quality) of the **EAC Application**.

The Project is located in west-central BC, in the Bulkley Valley Lakes District (BVLD), where currently the primary ambient air pollutants of concern are particulate matter (e.g., PM₁₀ and PM_{2.5}). The BVLD Airshed Management Society (AMS) has identified six primary categories of PM emissions that affect ambient air quality in the region (BVLD 2012): open burning, industrial sources, wood burning appliances (e.g., wood burning stoves are commonly used in the area for home heating), backyard burning, road dust, and vehicle emissions.

Criteria Air Contaminants

An air quality baseline program was initiated for the Project in 2017. Base Case air quality and dustfall data were compiled for the HHRA from results presented in **Appendix 4.1-C**.

Selection of Baseline data for the HHRA dataset followed the criteria and steps outlined in **Appendix 4.1-C**. Baseline air quality data for Project-PM Kerr and BC ENV Telkwa monitoring stations are applicable to the Human Health LSA and statistical summaries for PM_{2.5} and PM₁₀ from these locations are provided in **Table 3.4-1**, **Table 3.4-2**, and **Table 3.4-3**.

Table 3.4-1: PM₁₀ and PM_{2.5} Results at PM Kerr Station, November 1, 2018 to January 16, 2020 (µg/m³)

Year	PM ₁₀ Results (µg/m ³)			PM _{2.5} Results (µg/m ³)		
	Period Average of 24-hour Values ^a	Maximum 24-hour Average	No. of Events > 24-hour BC AAQO	Period Average of 24-hour Values ^a	Maximum 24-hour Average	No. of Events > 24-hour BC AAQO ^f
2018 ^b	4.0	12.8	0	3.4	11.1	0
2019 ^c	5.1	21.0	0	2.8	14.7	0
2020 ^d	2.7	5.7	0	2.1	4.2	0

Year	PM ₁₀ Results (µg/m ³)			PM _{2.5} Results (µg/m ³)		
	Period Average of 24-hour Values ^a	Maximum 24-hour Average	No. of Events > 24-hour BC AAQO	Period Average of 24-hour Values ^a	Maximum 24-hour Average	No. of Events > 24-hour BC AAQO ^f
Current BC AAQO ^e	-	50	n/a	8.0	25	n/a

Notes:

No data available from BC ENV-Telkwa station.

Dash (-) = data not available; n/a = not applicable

BC AAQO (2020). British Columbia Ambient Air Quality Objectives. Updated February 28, 2020. Available at https://www2.gov.bc.ca/assets/gov/environment/air-land-water/air/reports-pub/prov_aqo_fact_sheet.pdf.

^a Period average value is the average of 24-hour values observed in each period.

^b Year 2018 includes data recorded from November 1, 2018 to December 31, 2018.

^c Year 2019 includes data recorded from January 1, 2019 to December 31, 2019.

^d Year 2020 includes data recorded from January 1 to 16, 2020.

^e The 24-hour calculation metric is the annual 98th percentile of daily average, over one year. The annual calculation metric is the annual average, over one year.

^f The number of events represent the number days in the year when the daily average concentration was greater than 25 µg/m³, regardless of percentile.

Table 3.4-2: PM_{2.5} Data Summary – BC ENV Telkwa Station

Year	Annual 98 th Percentile of 24-hour Average (µg/m ³)	Annual Average (µg/m ³)
2014	34	10.7
2015	34	12.6
2016	-	-
2017	-	-
2018	-	-
2019	-	-
Current BC AAQO ^a	25	8.0

Notes:

2019 data (all stations), and 2015 - 2018 data from the Telkwa station are raw preliminary data and are subject to future review and revisions by the reporting agency.

dash (-) = data not available for this station and year.

^a The 24-hour calculation metric is the annual 98th percentile of daily average, over one year. The annual calculation metric is the annual average, over one year.

BC AAQO (2020). British Columbia Ambient Air Quality Objectives. Updated February 28, 2020. Available at https://www2.gov.bc.ca/assets/gov/environment/air-land-water/air/reports-pub/prov_aqo_fact_sheet.pdf.

Table 3.4-3: Total Dustfall Results Measured Concurrently with Metals Analysis in Dust, September 2017 to February 2018 (mg/dm²/day).

Monitoring Period	DF-Telkwa	DF-Kerr	DF-TenasDep	DF-Rail
Sept/Oct 2017	0.80	1.71	0.47	0.11
Oct/Nov 2017	0.52	0.74	0.66	0.29
Nov/Dec 2017	0.27	0.19	0.07	0.07

Monitoring Period	DF-Telkwa	DF-Kerr	DF-TenasDep	DF-Rail
Dec 2017 / Jan 2018	0.05	0.11	0.07	0.05
Jan/Feb 2018	0.67	1.96	0.50	0.52

NO₂ and O₃ were measured at the BC ENV Smithers Station. However, there are no Base Case data available for these CACs in the Human Health LSA.

Metals

Baseline dustfall levels and metal concentrations in dustfall (in mg/dm²/day) were monitored in 2017-2018 at four locations throughout the LSA. Dustfall metal data are presented in the **Atmospheric Environment VC S4.0-C1** and the **Appendix 4.1-C** of the **EAC Application**.

To determine the dose of metal COPCs for inhalation it is necessary to calculate the Base Case COPC concentrations bound to PM₁₀ in the air, as that is the size fraction of particles that can be inhaled into the lungs. The metal concentrations bound to PM₁₀ were estimated based on the metal concentrations measured in dustfall.

The Base Case concentration of metals attached to PM₁₀ was derived by first determining the ratio of each metal in dustfall. The 95% upper confidence limit of the mean (UCLM) Baseline metal concentration in dustfall for each metal was divided by the total 95% UCLM concentration of all metals in dustfall. The 95% UCLM concentration of dustfall from all monitoring stations (DF-Deep, DF-Kerr, DF-Rail, DF-Telkwa; **Table 3.4-3**) was used as a background dustfall level for this calculation (0.72 mg/dm²/day). The ratio for each metal was then multiplied by the 95% UCLM concentration of 24-hour PM₁₀ concentrations measured at station PM-Kerr between November 2018 and January 2020 (n=127; 5.45 µg/m³) to derive the concentration of each metal attached to PM₁₀. The metal concentrations in PM₁₀ are presented together with chronic screening levels in Section 3.5.2.1 as part of COPC screening.

Station PM-Kerr is the most representative of Baseline PM₁₀ concentrations at and near the future Project site (rural, largely undeveloped) compared to stations PM-Smithers and PM-Houston (urban, more developed). The stations in Smithers and Houston are outside of the Human Health LSA and are strongly affected by the primary contributors to PM emissions in the region such as other industrial emissions and wood-burning appliances and heating. By using a lower PM₁₀ concentration for Base Case (from PM-Kerr), the potential for incremental change by the Project to PM₁₀ concentrations will be maximized, resulting in a more conservative assessment of Project-related risks.

3.4.1.2 Project Case Data

Resident and Recreational Land Users could be exposed to air contaminants released into the atmosphere by the Project via inhalation. A detailed inventory of Project-related emission sources, points of release and quantities of air contaminants released is provided in the assessment of the Air Quality subcomponent of the **Atmospheric Environment VC (S4.0-C1)** and in **Appendix 4.1-B** of the **EAC Application**. Sources were summarized in Section 3.2.2.

Air Quality Receptor Locations

Air quality receptor locations included soil and vegetation sampling sites within the LSA, rural residences closest to the Project and within Telkwa (n = 76) and sensitive receptor locations in Telkwa, such as the Telkwa Elementary School, the Ark Playday Centre, and the Tot Spot Family Day Care. Receptor locations are identified on **Figure 3.4-1**. Receptors assessed in the HHRA include land users who were conservatively assumed to experience the highest predicted concentration (the worst air quality) in the LSA at the Maximum Point of Impingement (MPOI), sensitive receptors in Telkwa, the Back Country Horsemen Camp adjacent to the Telkwa Coalmine Road just north of the Minesite, and the nearest rural

residence. These receptors (except Telkwa) were chosen because they would likely experience the highest CAC exposures in the LSA.

Criteria Air Contaminants

The air quality model considered all the Project-related sources of air pollutants. The maximum predicted concentrations of CACs and dustfall for Project Case and Project plus Background during Operation are shown in **Table 3.4-4**. Predicted Project Case concentrations of CACs at modelled human health receptor locations in the LSA are presented in **Appendix A to this HHRA, Table A-1**. Emissions of CACs and dustfall during Construction was assumed to be similar to emissions during Operation.

The MPOI location is a hypothetical receptor location adjacent to the Project footprint. Although this location is considered as a potential receptor location that Recreational and Indigenous and non-Indigenous Resident Land Users could temporarily occupy when recreating or hunting/gathering subsistence foods, it is highly unlikely that land users will actually spend any substantial amount of time there. The **Public Access Management Plan (S13.0-C14 of the EAC Application) (PAMP)** indicates that certain areas of the Tenas Property will be designated as “no hunting” as stated in the *Wildlife Act* and “no unauthorized entry” (NUE) under the *Mines Act*, RSBC 1996, c 293, and *Land Act*, RSBC 1996, c 245. This will affect some current trails (motorized and non-motorized recreational use) and access points that fall within the Project’s planned development area. From the Backcountry Horsemen Camp, TCL will establish a trail along the east side of Goathorn Creek that will be a multiuse trail for hikers, bikers, motorized use and horseback riders and ultimately provide access to Hunter’s Basin. This restricts access to the Project development area by the general public and, therefore, the nearest location to the Project where people could recreate and spend time is considered to be the Horsemen Camp. This location was chosen as the closest land use receptor.

Metals

Annual concentrations of inhalable metals in PM₁₀ were estimated from the results of the Air Dispersion Model and are presented in **Appendix A to this HHRA, Table A-2** for all air quality receptor sites. The Project-related metal proportions in PM₁₀ during Construction and Operation is based on the maximum concentration of each metal as the weighted sum of the maximum concentration for all individual source groups (e.g., coal, waste rock, and soil).

Dust deposition rates for COPCs were estimated from the Air Dispersion Model and are presented in **Appendix A to this HHRA, Table A-3**. The model methodology is presented in **Appendix 4.1-B** of the **EAC Application**.

3.4.2 Soil

3.4.2.1 Baseline Data

Soil quality is assessed in the **Terrain and Soils VC (S4.0-C2)** of the EAC Application. Full details on Baseline sampling methodology, Baseline data, and summary statistics of soil quality parameters are presented in **Appendix 4.2-A Terrain and Soil Baseline Report** of the **EAC Application**.

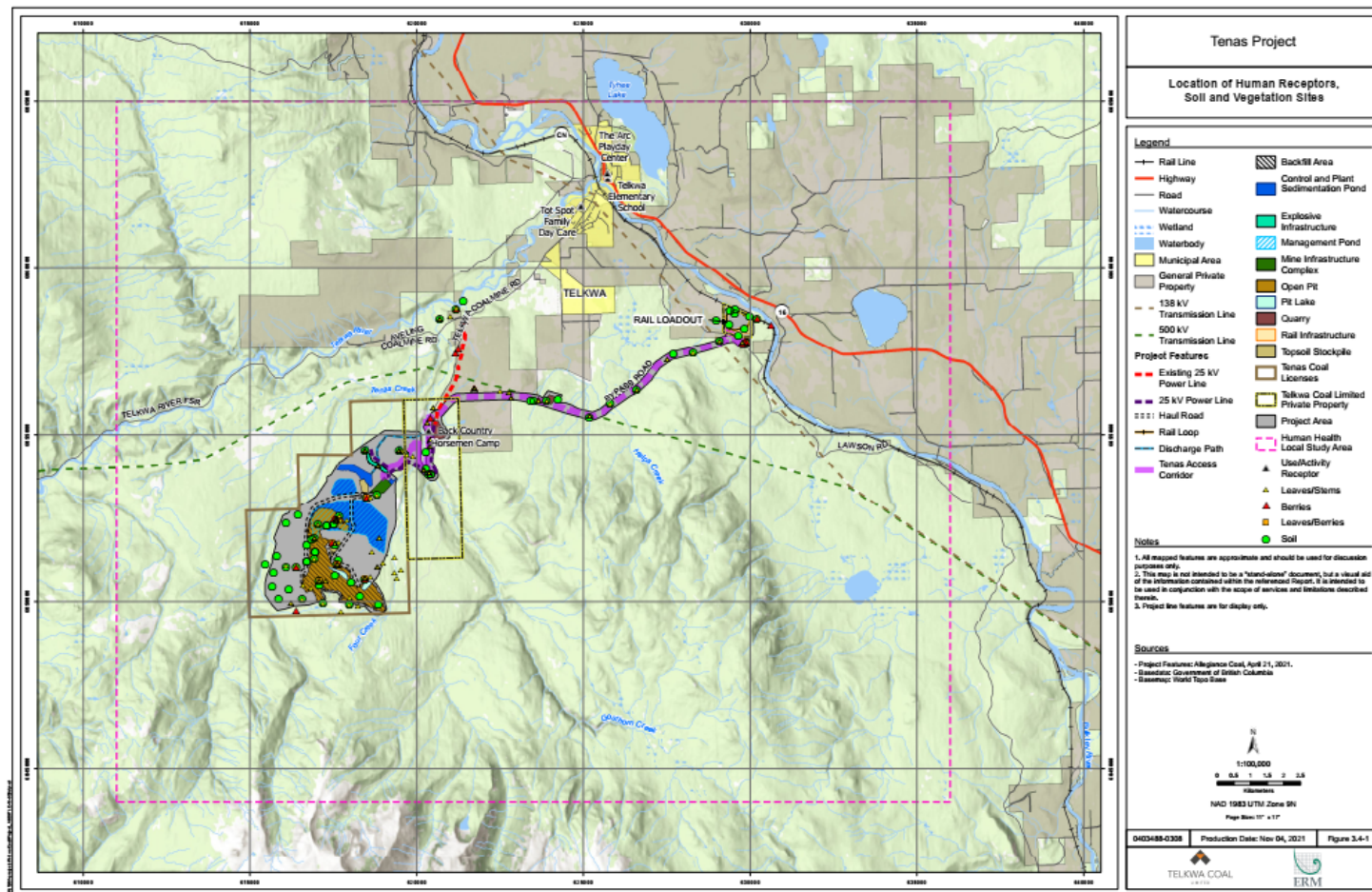


Figure 3.4-1: Location of Human Receptors, Soil and Vegetation Sites

GIS No.: TLC-16-030d_T

Tabloid recto

Tabloid verso

Table 3.4-4: Maximum Predicted Concentrations of Criteria Air Contaminants and Dust Deposition Rates

Contaminant	Averaging Period	Maximum in LSA at MPOI ($\mu\text{g}/\text{m}^3$)	Maximum in Telkwa ($\mu\text{g}/\text{m}^3$)	Maximum at Horsemen Camp ($\mu\text{g}/\text{m}^3$)	Maximum at Residence ($\mu\text{g}/\text{m}^3$)	AAQO ($\mu\text{g}/\text{m}^3$)
Project-Only Contribution						
TSP	24-hour	863	2.2	39.0	21.0	120
	Annual	154	0.4	5.2	4.4	60 ^(a)
PM ₁₀	24-hour	424	1.5	25.0	10.9	50
PM _{2.5}	24-hour	53.5	0.4	4.3	2.2	25 ^(b)
	Annual	8.4	0.06	0.5	0.4	8 ^(c)
NO ₂	1-hour	1,481	64.1	97.3	85.2	113 ^(d)
	Annual	149	0.4	5.2	7.9	32
SO ₂	1-hour	4.4	0.05	0.5	1.0	183 ^(e)
	Annual	0.4	0.002	0.02	0.03	13
Dustfall*	30-day	8.9	0.007	0.1	0.06	1.7 mg/dm ² -d (residential) 2.9 mg/dm ² -d (other)
Project Plus Background						
TSP	24-hour	896	115	72.9	54.9	120
	Annual	163	37.8	14.7	13.9	60 ^(a)
PM ₁₀	24-hour	439	57.8	40.2	26.1	50
PM _{2.5}	24-hour	63.7	34.4	14.5	12.4	25 ^(b)
	Annual	11.2	11.3	3.3	3.2	8 ^(c)
NO ₂	1-hour	1,499	76.9	103	91.8	113 ^(d)
	Annual	161	12.3	17.1	19.8	32
SO ₂	1-hour	18.0	13.7	14.1	14.6	183 ^(e)
	Annual	1.4	1.0	1.0	1.0	13
Dustfall*	30-day	9.7	0.8	0.9	0.9	1.7 mg/dm ² -d (residential) 2.9 mg/dm ² -d (other)

Notes:

Values in bold font exceed the BC AAQO (BC ENV 2020).

^(a) Based on geometric mean.

^(b) Based on 98th percentile of daily average.

^(c) There is also a longer term aspirational target of 6 $\mu\text{g}/\text{m}^3$ to support continuous improvement.

^(d) Based on annual 98th percentile of daily 1-hour maximum, averaged over three consecutive years.

^(e) Based on annual 99th percentile of daily 1-hour maximum, averaged over three consecutive years.

MPOI = Maximum Point of Impingement.

* The unit for dustfall is mg/dm²-day.

Baseline soil quality samples were collected in 2017 and 2018. Sampling locations are shown in **Figure 3.4-2** for the Minesite area and **Figure 3.4-3** for the Rail Infrastructure, Pipeline and Bypass Road. All soil quality samples collected in the LSA, except locations under the footprints of future development at the Minesite and Rail Infrastructure where soils would likely be disturbed, removed, or inaccessible, were used for the purpose of screening for COPCs in soil and for the calculation of exposure point concentrations. This resulted in the inclusion of 30 soil Baseline samples. Locations adjacent to development areas at the Minesite, Bypass Road, and Rail Infrastructure that are unlikely to be disturbed were included in the dataset, although they will not be accessible to land users during Construction, Operation, and Decommissioning and Reclamation (refer to **PAMP**). This provides for a conservative assessment for potential exposures in Post-closure when public access is re-opened. This also ensures that Base Case and Project Case datasets are directly comparable by using the same sites for both cases. Soil data included in the HHRA and statistical data summaries are located in **Appendix A to this HHRA, Table A-4**.

3.4.2.2 Project Case Data

Project Case soil COPC concentrations were modelled based on COPCs in dust emitted from the Project settling or depositing onto surfaces adjacent to the Minesite, TAC, and Rail Infrastructure.

Fugitive dust will arise from several Project activities as described in Section 3.2.2. Generally, dust emissions will occur sporadically and be suspended for a relatively short time prior to deposition. Dust particles can be a carrier of metals that naturally occur in rocks and coal and can deposit onto soils. Resident and Recreational Land Users could be exposed to the COPCs in soil via incidental soil ingestion and dermal contact.

Project metal concentrations in soil were based on dust deposition rates for COPCs estimated from the Air Dispersion Model. The incremental increase in soil COPC concentration was calculated as recommended by the US EPA (2005b):

$$C_s = 100 \times \frac{D_y}{BD \times Z_s} \times tD \quad \text{[Equation 1]}$$

Where:

C_s	= predicted incremental increase in COPC concentration in soil (mg/kg)
D_y	= yearly deposition rate of COPC in dustfall (g/m ² -year, from Air Dispersion Model)
Z_s	= soil mixing zone depth, conservatively assumed to be 2 cm, as recommended for 'untilled' soil in Section 5.2.4.1 of US EPA 2005
BD	= soil bulk density, assumed to be 1.5 g/cm ³ (US EPA 2005)
tD	= time period of dust deposition (years), assumed to be 22.5 years
100	= unit conversion factor (mg m ² /kg cm ²)

In addition to assumptions made in the air dispersion model, assumptions made in the prediction of concentrations of COPCs in soil were as follows:

- The Project-related metal proportions in dust during Construction and Operation are based on the maximum concentration / deposition of each metal as the weighted sum of the maximum concentration / deposition for all individual source groups (e.g., coal, waste rock, soil).
- The worst-case annual amount of dustfall modelled for the Operational phase is assumed to occur during the one year of Construction and each of the 22 years of Operation. This overestimates the actual amount of dust depositing onto soil.
- The 90th percentile of the annual deposition rate predicted to occur across the LSA was used as a conservative statistic, resulting in an overestimate of the actual amount of dust depositing onto soil.
- All dust deposited onto soil is conservatively assumed to remain in place and not run-off during rain events.

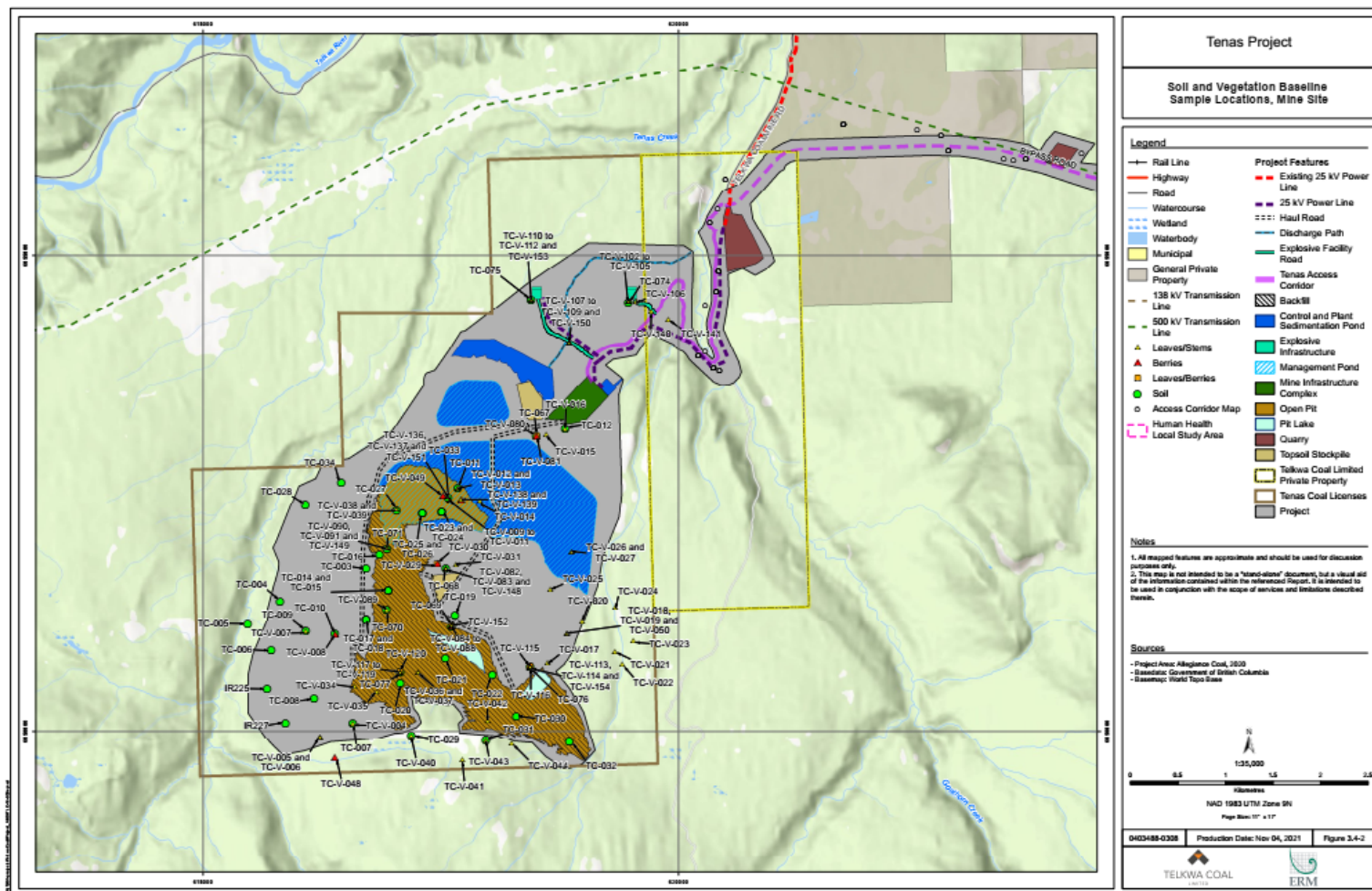


Figure 3.4-2: Soil and Vegetation Baseline Sample Locations, Minesite

TLC-16-030e_T

Tabloid recto

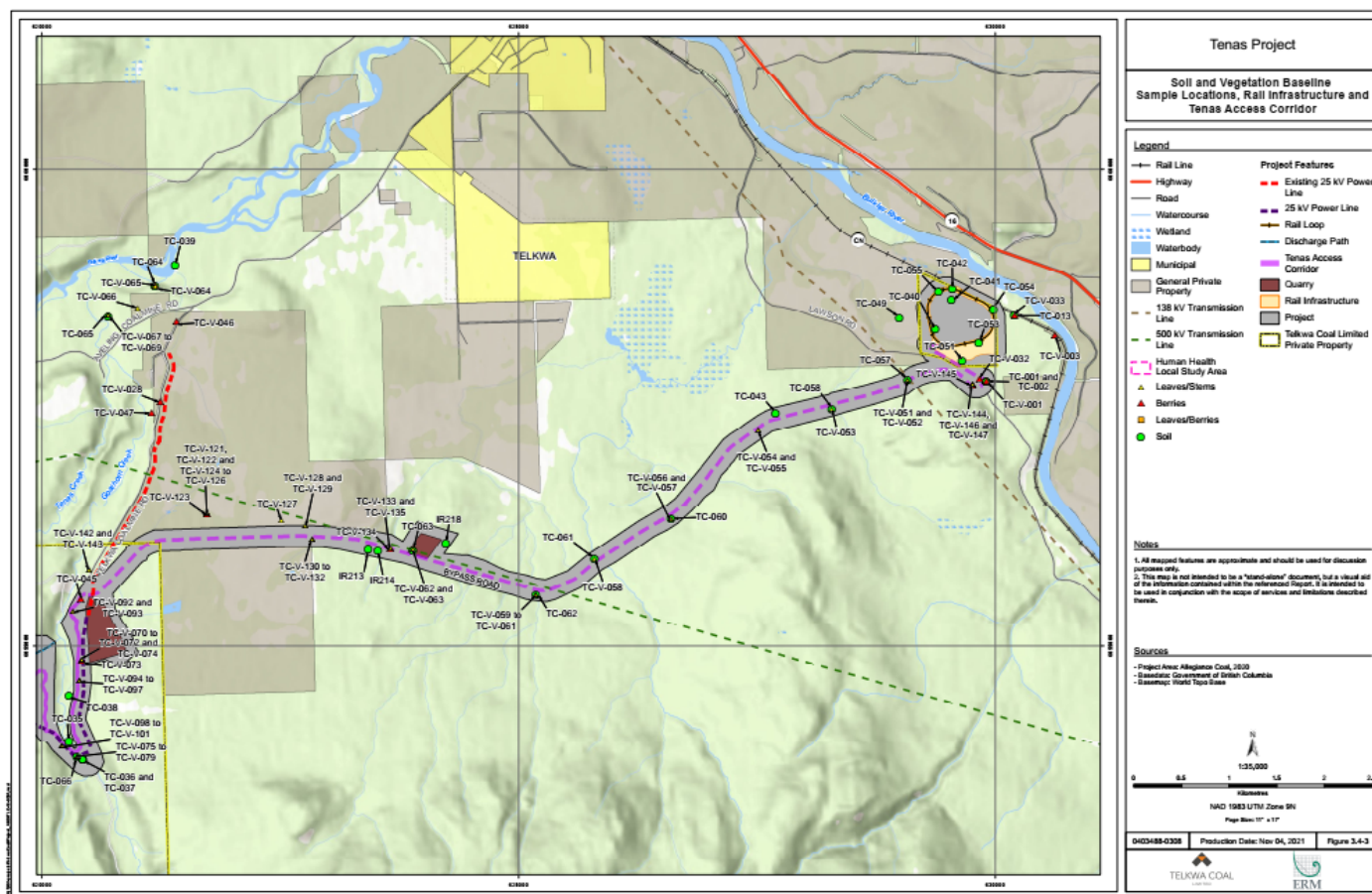


Figure 3.4-3: Soil and Vegetation Baseline Sample Locations, Rail Infrastructure and Tenas Access Corridor

TLC-16-030f_T

Tabloid verso

- Soil mixing zone depth was assumed to be 2 cm (US EPA 2005b) although agricultural soils may be tilled to 20 cm depth. This overestimates the concentration of Project-related COPCs in soil, especially in areas of backyard garden use.
- There is no soil loss at receptor sites due to wind, water erosion, or biological activity.

The incremental increase in soil COPC concentrations was added to the Baseline soil COPC concentration. The resulting Project Case soil metal concentrations are presented in **Appendix A to this HHRA, Table A-4**.

An example calculation for aluminum based on Equation 1 is presented below:

$$C_s = 100 \times \frac{0.0832 \frac{g}{year - m^2}}{\left(1.5 \frac{g}{cm^3} \times 2cm\right)} \times 22.5 years$$

$$C_s = 62.4 \frac{mg}{kg}$$

$$C_{S-Operation} = C_{S-Baseline} + C_s$$

$$C_{S-Operation} = (19404 + 62.4) \frac{mg}{kg} = 19466 \frac{mg}{kg}$$

3.4.3 Vegetation

3.4.3.1 Baseline Data

Vegetation tissue metals are included in the **Vegetation VC (S4.0-C7)** of the **EAC Application**. Details of the Baseline sampling program and results can be found in **Appendix 4.7-A Ecosystems and Vegetation Baseline Report** of the **EAC Application**.

Baseline vegetation tissue quality samples were collected in 2017, 2018, and 2019. Sampling locations are shown in **Figure 3.4-2** and **Figure 3.4-3**.

Typically in subsistence foods studies, a vegetation species is selected as a subsistence food for direct human consumption. In addition, where measured animal tissue COPC concentrations are not available, models require COPC concentrations in vegetation for estimation of COPC concentrations in the animal subsistence foods. Therefore, vegetation COPC concentration data are part of the subsistence foods assessment both as direct contributions (i.e., direct ingestion of vegetation or berries) or as indirect contributors through the consumption of subsistence foods (i.e., intake of vegetation by wildlife and subsequent intake of wildlife by humans).

Vegetation samples included 23 plant species in 20 genera and were selected based on potential consumption by humans and/or wildlife, as well as frequency of occurrence in sufficient quantity to produce at least a single sample. During the 2017, 2018 and 2019 field programs, 150 samples of plant tissue (25 berry samples and 125 leaf/stem samples) were collected and analyzed for trace metals from 74 sites located in the areas of the Pit, Pipeline, Bypass Road and Rail Infrastructure. Soil samples were gathered from 29 of the sites in conjunction with vegetation sampling (i.e., not all sites had co-collection of plant and soil samples), of which three (3) sites were within the Project planned development area.

For the purpose of the HHRA, it was necessary to create an “artificial” berry and leaf/stem COPC dataset that aligned with the soil dataset (for soil sites not under future development, as outlined in Section 3.4.2) so that uptake of COPCs from soil into plant tissues under Project conditions can be calculated. The first step was the derivation of a soil-to-plant bioconcentration factor (BCF) for each metal parameter.

The BCF was calculated from co-collected soil and vegetation samples (**Figure 3.4-2** and **Figure 3.4-3**) at 26 vegetation sites located outside the Project planned development area, as follows:

$$BCF_{plant} = \frac{C_p}{C_s} \quad [\text{Equation 2}]$$

Where:

BCF_{plant} = bioconcentration factor from soil to plant (unitless)
 C_p = COPC concentration in plant tissue (mg/kg wet weight; ww)
 C_s = COPC concentration in soil (mg/kg dry weight)

The dataset of soil and plant or berry metal concentrations used to calculate the BCF_{plant} is presented in **Appendix A to this HHRA, Table A-5**. The BCFs calculated for each site and the average BCF_{plant} are presented in **Appendix A to this HHRA, Table A-6**. The average BCF_{plant} used in the assessment were not derived on a plant species-specific basis because soil to plant BCFs can vary by orders of magnitude based on the natural variability in parameter concentrations in tissues and soils, and because sample numbers for individual plant species were too low to reliably calculate statistical summaries. However, two BCF_{plant} were derived for each metal, one for berries (based on $n = 13$) and one for leaf/stem tissue (based on $n = 42$).

To calculate plant Baseline COPC concentrations at all soil Baseline sites to facilitate the calculation of the incremental change in vegetation COPC concentration due to the incremental change in soil COPC concentration (i.e., the “artificial” Baseline vegetation data set), the average BCF_{plant} for each parameter was multiplied with the soil parameter concentration at each soil site. The summary statistics of these Baseline metal concentrations in berry and leaf/stem tissues are presented in **Appendix A to this HHRA, Tables A-7 and A-8**, respectively.

3.4.3.2 Project Case Data

To facilitate derivation and assessment of incremental change in subsistence food concentrations under future Project conditions, the BCF_{plant} (Section 3.4.3.1) was applied to future soil COPC concentrations. Due to the inherent variabilities in soil characteristics, COPC concentrations in soil and vegetation, and collected plant species, BCF_{plant} can vary significantly between and even within sites, and therefore the site-averaged BCF_{plant} (**Appendix A to this HHRA, Table A-6**) was applied to each COPC in soil to predict plant COPC concentration. The predicted soil COPC concentration was based on the 95% UCLM Baseline soil COPC concentration and the 90th percentile (P90) of predicted dust deposition across the Human Health LSA.

The P90 statistic for dust deposition was chosen as a conservative (high) approximation of actual dust deposition on vegetation in the LSA due to Project activities because the majority of predictions in the grid of the air quality model is located in areas of little Project dust deposition (i.e., away from the Minesite, Bypass Road, and Rail Infrastructure areas). It has been shown that 30% to 50% of dust, depending on the type of vegetation, is removed from the atmosphere over a distance of 30 m from an unpaved roadway source (Cowherd 2008). In addition, people are unlikely to collect berries along unpaved roads or consume such berries unwashed, and public access is restricted to the Bypass Road, Rail Infrastructure, and the Minesite throughout the duration of Construction, Operation, and Decommissioning and Reclamation (refer to the **PAMP**).

The berry and stem/leaves COPC concentration due to root uptake was calculated as:

$$C_{root} = C_s \times BCF_{plant} \quad [\text{Equation 3}]$$

Where:

C_{root} = concentration of COPC in vegetation due to root uptake (mg/kg)
 C_s = concentration of COPC in soil (mg/kg)
 BCF_{plant} = average soil to plant biotransfer factor (unitless)

Assumptions:

- A LSA-wide COPC-specific BCF_{plant} is a reasonable representation of soil to plant BCFs that are inherently highly variable.
- The application of the 90th percentile dust deposition rate across the LSA is a conservative estimate of future soil COPC concentrations.

In addition to root uptake, COPC deposition in dust on vegetation surfaces was included to calculate the total COPC concentration in vegetation under Operation conditions where dust is of concern. Dust on vegetation surfaces was not included for Closure conditions (Decommissioning and Reclamation and Post-closure phases) because dust-generating activities are considered negligible during these phases and therefore were not modeled by the air quality model. Including dust during Operation overestimates the concentration of COPCs that people could ingest because people will likely wash fruits or vegetables prior to consumption.

The aboveground produce COPC concentration due to dust deposition (Pd , mg/kg wwt) was calculated as per US EPA (2005b) as:

$$Pd = \frac{1000 \times C_s \times R_p \times (1 - \exp(-k_p \times T_p))}{Y_p \times k_p} \quad [\text{Equation 4}]$$

Where:

- Pd = concentration from dust deposition (mg/kg wwt)
- 1000 = conversion factor (1000 mg/g)
- C_s = concentration of COPC in soil (mg/kg)
- R_p = interception fraction (weighted average of class-specific R_p values for fruits and vegetables, unitless; US EPA 2005b)
- k_p = plant surface loss coefficient (year⁻¹)
- T_p = length of plant exposure per harvest (yr)

Assumptions:

- R_p was assumed to be 0.39 as per recommendation from the US EPA (2005b);
- For berries, T_p was assumed to be one (1) month per year as a conservative estimate of the amount of time berries ripen on the plant prior to harvesting;
- For leaves (farm produce), T_p was assumed to be three (3) months per year as a conservative estimate of the amount of time produce requires to grow prior to harvesting; and
- The 95% UCLM concentrations were used as EPCs to calculate COPC dose to humans from consumption of berries and farm produce and as an input to the food chain model.

The total COPC concentration for vegetation (C_{veg}) was the sum of the COPC concentration due to root uptake from soil and due to dust deposition, as shown in the following equation:

$$C_{veg} = C_{root} + Pd \quad [\text{Equation 5}]$$

EPCs in vegetation tissues for Project Case (Operation and Closure) are shown in **Appendix A to this HHRA, Table A-9**.

3.4.4 Surface Water

3.4.4.1 Baseline Data

Surface water quality is assessed in the Surface Water VC **S4.0-C3** of the EAC Application. Full details on Baseline sampling methodology, Baseline data, and summary statistics of water quality parameters are presented in **Appendix 4.1-C** of the **EAC Application**.

Selection of Baseline data for screening of COPC followed the criteria and steps outlined in **Appendix 4.1-C**. Thus, the HHRA dataset for COPC screening included data collected between 2006 and 2019 from locations within the LSA (WQS01 to WQS17, and historical data from the British Columbia Environmental Monitoring System (EMS). Surface water sampling locations are shown on **Figure 8.1-1** in **Appendix 4.1-C**.

3.4.4.2 Project Case Data

Project Case water quality datasets were based on predicted water quality for Operation and Closure for Base Case at 12 modelling nodes throughout the LSA as described in **Appendix 4.3-A** of the **EAC Application**.

3.4.5 Groundwater

3.4.5.1 Baseline Data

As part of the Baseline program, one residential well was sampled quarterly during the groundwater sampling events from June 2018 to April 2019. Four residential wells were each sampled once during winter 2019, for a total of 8 samples. The locations of sampled groundwater wells are indicated on **Figure 36** in **Appendix 1.0-U Groundwater Technical Report for the Tenas Coal Project** of the **EAC Application**.

The Baseline groundwater quality data are provided in **Appendix A, Table A-10 of this HHRA**. The maximum concentrations measured in these wells were used to screen COPCs in Baseline groundwater (Section 3.5.2.4).

Base Case exposure point concentrations (EPCs) for groundwater were selected based on background groundwater quality (P50) presented in the **Appendix 1.0-U**. Groundwater background concentrations were available for bedrock and for overburden. Overburden background groundwater was selected for the Base Case as the residential wells are in a fluvial aquifer at a relatively shallow depth.

3.4.5.2 Project Case Data

Wells sampled during Baseline are not located within the groundwater flow path from the proposed Project and drinking water quality in these wells is therefore not expected to change due to Project activities.

Three residential wells located in the Telkwa River valley are potentially within the paths of mine affected groundwater (**Figure 36** in **Appendix 1.0-U**). Numerical groundwater modelling was completed to predict open pit inflows, potential changes to baseflows, and contributions/travel times of mine-affected groundwater to creeks and these residential wells. Two models, a base and high case (high hydraulic conductivity), were developed to evaluate the potential groundwater effects from the Project (**Appendix 1.0-U**). The base case model results (winter averages) for the residential wells for Post-closure were used for the Project case (Closure). Parameter concentrations are generally higher in winter compared to summer, and thus using winter concentrations year-round is a more conservative approach.

3.4.6 Fish Tissue

3.4.6.1 Baseline Data

Fish tissue metals are assessed in **S4.0-C6 Fish and Fish Habitat VC** of the EAC Application. Details of the Baseline sampling program and results can be found in **Appendix 4.1-C** of the **EAC Application**.

Fish metal concentrations were obtained in rainbow trout muscle tissues from the Bulkley River, Telkwa River, Goathorn Creek, and Tenas Creek. Sampling was conducted in October 2017 and June 2018, with the objective being to target sexually mature fish for analyses of fecundity. Rainbow trout of similar fork length (generally between 90 and 180 mm) were targeted for tissue metals analysis at each site.

Analysis results and statistical summaries for tissue metals at each water quality prediction node are presented in **Appendix A to this HHRA, Table A-11**.

3.4.6.2 Fish Tissue Bioconcentration Factors

To be able to compare Baseline and Project effects on fish tissue from potential changes in water quality, the 95% UCLM of Baseline fish tissue concentration at water quality prediction nodes was divided by the Baseline P50 total metal concentration in water to derive a water-to-fish tissue BCF (BCF_{fish}) for each parameter. The BCF_{fish} was used to predict fish tissue so that the Base Case and Project Case effects can be compared. The BCF_{fish} data are presented in **Appendix A to this HHRA, Table A-12**.

3.4.6.3 Project Case Data

Project Case fish tissue concentrations were derived by multiplying the predicted maximum of yearly 95% UCLM water concentration (Section 3.4.4.2) for Operation and Closure phases with the BCF_{fish} for water quality prediction nodes WQS02 (Tenas Creek), WQS05 (Goathorn Creek), WQS09 (Telkwa River), WQS11 and WQS12 (Bulkley River). The Project Case fish tissue concentrations are presented in **Appendix A to this HHRA, Table A-13**.

3.5 Screening for Contaminants of Potential Concern

3.5.1 Methodology

Parameters measured during Baseline included metals (measured in all media), and phenols, PAHs, BTEX, and petroleum hydrocarbons (measured in surface water only). The Baseline and Project HHRAs focused on metals as the COPCs since they naturally occur in environmental media (e.g., air, soil, and water) due to local physical and geological processes and their concentrations could potentially change due to Project activities. Parameters that were considered to be innocuous (e.g., calcium, magnesium, potassium) were excluded from the risk assessment as exposure concentrations are not high enough to have the potential to cause adverse effects on people.

The potential risk from exposure to PAHs in coal dust deposits was considered negligible and was not carried forward in the risk assessment. There is a strong body of scientific literature that indicates that PAHs from coal are not readily bioavailable (Chapman et al. 1996; Ghosh, Talley, and Luthy 2001; Thorsen, Cope, and Shea 2004; Neff, Stout, and Gunster 2005; Deepthike et al. 2009; Achten et al. 2011). This is in contrast to PAHs from other sources such as oil, which are bioavailable and could result in adverse effects on exposed biota (Chapman et al. 1996). In a microbial degradation study, no significant decrease in coal-based PAH concentrations were observed after 29 weeks incubation (Achten et al. 2011), suggesting that PAHs are not bioavailable to microbes. Additional work suggests absorption of PAHs from coal dust through direct contact with the skin is limited (Yang, Roy, and Mackerer 1986a, 1986b; Yang et al. 1989; Sartorelli et al. 1999; Sartorelli et al. 2001). However, the concentrations of PAH

in coal, overburden, and surface soil were compared to the CCME and BC CSR agricultural guidelines for illustration purposes to show that they are orders of magnitude below guidelines, even in the coal sample (**Appendix B to this HHRA, Table B-1**).

The key to COPC screening is selecting environmental and biota tissue chemistry datasets that are representative of the conditions being assessed, as presented in Section 3.4. COPCs carried forward for evaluation in the HHRA were selected through a screening process based on comparison of the maximum contaminant concentration to the most relevant human health-based screening level (i.e., a guideline, standard, criteria/objective, or minimum risk level) and protective of relevant exposure pathways. Parameters with concentrations that exceeded the screening level were carried forward as COPCs.

Table 3.5-1 lists the screening levels that are applied in the COPC screening process. Water concentrations were based on unfiltered (total fraction) samples. Surface and groundwater quality was compared to drinking water guidelines and standards for the protection of human health (**Table 3.5-1**). Soil quality was screened against CCME and BC CSR soil quality guidelines (SQGs) and standards for intake of contaminated soil for the following land uses: residential/parkland, agriculture, and wildlands (reverted) to account for land uses by Resident and Recreational Land Users in the LSA. Where available, the CCME SQG for the protection of human health was used, otherwise, the generic CCME SQG was used.

Table 3.5-1: Screening Criteria and Guidelines for Identifying Contaminants of Potential Concern to be included in the Human Health Risk Assessment

Environmental Media	Screening Criteria
Criteria Air Contaminants	1. BC ENV British Columbia Ambient Air Quality Objectives (BC AAQOs) (BC ENV 2020b)
Metals in Air	1. Ontario Ambient Air Quality Criteria (Ontario MOE 2012) 2. Texas Long-Term Effects Screening Levels (ESLs) (Texas CEQ 2016) 3. Washington State Acceptable Source Impact Levels (ASIL) (Washington State 2019)
Soil	1. CCME Environmental Quality Guidelines (AG and RP) (CCME 2021b) 2. BC CSR Schedule 3.1 – Intake of Contaminated Soil (AG and WL _R) (B.C. Reg. 375/96) 3. BC CSR Schedule 3.1 - Generic Numerical Soil Standards (AG and WL _R) (B.C. Reg. 375/96)
Groundwater	1. Health Canada Guidelines for Canadian Drinking Water Quality—Summary Table (Health Canada 2020) 2. BC CSR Schedule 3.2 – Drinking Water (B.C. Reg. 375/96) 3. BC ENV B.C. Source Drinking Water Quality Guidelines: Guideline Summary (BC ENV 2020a)
Surface Water	1. Health Canada Guidelines for Canadian Drinking Water Quality—Summary Table (Health Canada 2020) 2. BC CSR Schedule 3.2 – Drinking Water (B.C. Reg. 375/96) 3. BC ENV B.C. Source Drinking Water Quality Guidelines: Guideline Summary (BC ENV 2020a)

Environmental Media	Screening Criteria
Subsistence Foods	1. Comparison to back-calculated screening benchmarks based on the most conservative oral toxicity reference value (TRV) and receptor-specific subsistence foods consumption rates (Appendix C of this HHRA) 2. BC Ambient Water Quality Guidelines (mercury and selenium in fish tissues) (BC MOE 2001; BC ENV 2014a)

Notes:

BC ENV = British Columbia Ministry of Environment and Climate Change Strategy

CCME = Council of Canadian Ministers of the Environment

BC CSR = BC Contaminated Sites Regulation

AG = Agricultural Land Use

RP = Residential and Parkland Land Use

WLR = Wildlands, Reverted

US EPA = United States Environmental Protection Agency

TR = Threshold Risk

3.5.2 Results

3.5.2.1 Air

Criteria Air Contaminants

Baseline annual average and 98th Percentile of PM_{2.5} exceeded provincial AQOs at the BC ENV Telkwa Monitoring Station in 2014 and 2015 (Tables 3.4-1 and 3.4-2). Therefore, Baseline PM_{2.5} was included as a COPC.

CACs under Project conditions were modelled (**Appendix 4.1-B of the EAC Application**) and are shown in **Table 3.4-4** together with the relevant AAQOs. The maximum concentrations in the LSA (at the MPOI adjacent to the Project fence line) were predicted to exceed the AAQOs for Background plus Project Contributions for all CACs, except for SO₂. However, as described in Section 3.4.1.2, ROCs are not expected to spend extended periods of time at the MPOI location while hunting, gathering, or recreating. Therefore, this receptor location was not considered further for screening of COPCs. Instead, the maximum concentrations at the Back Country Horsemen Camp, the closest residence, and in Telkwa were used for COPC screening against AAQOs.

Based on the screening rationale outlined above, the following CACs were selected as COPCs for further assessment: **PM₁₀ (24-hour)** and **PM_{2.5} (24-hour and annual)**, both exceeding AAQOs in Telkwa.

Metals

The concentration of metals attached to PM₁₀ were screened against the Ontario Ambient Air Quality Criteria, the Texas State Effect Screening Levels (ESLs), and Washington State Acceptable Source Impact Levels (ASILs) (see references in **Table 3.5-1**) for chronic durations for metal concentrations in air as BC does not have such criteria. Based on the maximum metal concentrations bound to PM₁₀ exceeding chronic screening levels over an annual averaging period, no metal COPC was identified in air.

Chromium, although exceeding the guideline for hexavalent chromium, was initially not selected as a COPC in Baseline air, because it was measured as total chromium and the guideline for hexavalent chromium does not apply. Further, chromium was not detectable in dust samples collected during Baseline studies and the calculated Baseline exceedance is an artifact of the calculation, which substituted half of the detection limit as the concentration for chromium (0.000014 to 0.000023 mg/dm²-day). However, as there was a

measurable incremental change from Baseline for the Project Case, **chromium** was retained as a COPC. The COPC screening results are shown in **Appendix B to this HHRA, Table B-2**.

3.5.2.2 Soil

Based on the maximum concentrations in soils in the LSA exceeding the most stringent of applicable agriculture and parkland or wildlands CCME and BC CSR guidelines or standards in both the Baseline and predicted Project Case, **aluminum, arsenic, boron, cadmium, and iron** were selected as COPCs in soil (**Appendix B to this HHRA, Table B-4**).

3.5.2.3 Surface Water

Surface water quality parameters measured during Baseline included metals, phenols, PAHs, BTEX, and petroleum hydrocarbons. Of the measured organic parameters, only phenols, extractable petroleum hydrocarbons (EPH10-19), and light extractable petroleum hydrocarbons (LEPH) had detectable concentrations. Phenols were measured at a maximum concentration of 0.0199 mg/L (WQS08, Jan 2019), and EPH10-19 and LEPH were detected only once at WQS03-DS in July 2018 (both 0.39 mg/L). The BC CSR Drinking Water (DW) standards (B.C. Reg. 375/96, Schedule 3.2) for phenols (1mg/L) and EPH10-19 (5 mg/L) were not exceeded, and there is no standard for LEPH in water. Therefore, no organic parameters were identified as COPCs in surface water.

Concentrations of metals, metalloids, and nutrients in Baseline and predicted Project water quality datasets were screened against health-based screening benchmarks listed in Table 3.5-1 and shown in **Appendix B to this HHRA, Table B-3**. **Cobalt, lithium, and selenium** screened in as COPCs in surface water based on maximum concentrations exceeding the most conservative health-based screening benchmark in either the Baseline, Project Case, or both.

3.5.2.4 Groundwater

Maximum Baseline concentrations of the following metal parameters exceeded drinking water guidelines in groundwater sampled from residential wells downgradient of the Project (n = 8) and were, therefore, screened into the assessment: **arsenic, cobalt, iron, lithium, and manganese** (**Appendix B to this HHRA, Table B-3**).

The predicted worst-case (High Case) groundwater concentrations for residential wells (maximum horizontal hydraulic conductivity, bedrock background groundwater quality, winter months of the first 25 years of Post-closure period including discharges of pulse from the control pond) was used for screening COPCs in Project Case groundwater. Maximum predictions were not used, because seasonal signals in loading yielding maxima have a tendency to average out the longer a groundwater flow path is. Groundwater travel times from loading sources at the Project Minesite to residential wells are on the order of 300 to 400 years (i.e., a long time for seasonal loading signal to be dampened). Thus, instead of applying short-lived maximum peak loads to long-term estimates of downgradient groundwater quality, the High Case groundwater quality modelling results were used for COPC screening.

Concentrations of **cobalt** and **lithium** were predicted to exceed the BC CSR DW standard (B.C. Reg. 375/96, Schedule 3.2), and cobalt exceeded the BC source drinking water quality guidelines (BC ENV 2020a) in Post-closure. Although sodium concentrations were predicted to exceed the BC CSR standard, sodium was not selected as a COPC. This is because the BC CSR standard for sodium (200 µg/L) is based on a threshold for unacceptable taste (World Health Organization (WHO) 1993) and is not a health-based standard. Health effects of sodium are expected at concentrations much higher than the BC CSR standard (Bright and Addison 2002).

3.5.2.5 Fish Tissues

There are only two available guidelines against which metals in fish tissues can be screened for COPCs: selenium and mercury.

BC's tissue quality guideline for selenium (BC ENV 2014b) is based on whole-body concentration and provides 1.8 mg/kg ww (or 7.3 mg/kg dry weight), based on consumption of up to 220 g of fish per day as the human consumption screening value. Muscle tissue selenium concentrations collected from rainbow trout in the LSA ranged from 0.208 mg/kg to 0.710 mg/kg in 2017 and 0.176 mg/kg to 0.99 mg/kg in 2018. The average across all samples was 0.396 mg/kg in 2017 and 0.503 mg/kg in 2018. No fish tissue samples exceeded the BC tissue quality guideline for selenium.

Tissue mercury concentrations did not exceed BC ENVs guideline (0.1 mg/kg ww; BC MOE 2001) or Health Canada guidelines (0.5 mg/kg ww; Health Canada 2007a) for any of the samples tested. Mercury concentrations ranged from 0.0097 mg/kg to 0.0681 mg/kg in 2017 and 0.0117 mg/kg to 0.0629 mg/kg in 2018.

Based on a comparison with fish tissue guidelines as shown in **Appendix A to this HHRA, Tables A-11 and A-13**, there are no COPCs carried forward for risk assessment for the Baseline or Project case in fish tissues.

3.5.2.6 Subsistence Foods

Predicted concentrations of parameters in subsistence foods in Baseline, Operation, and Closure case were screened for COPCs as per guidance by BC MOH (2021). Screening was carried out by comparing predicted concentrations in subsistence foods to back-calculated risk-based screening benchmarks (or target concentrations [TC]) based on the most conservative (toddler) oral toxicity reference value (TRV) (Section 5) and receptor-specific subsistence foods consumption rates as described in **Appendix C to this HHRA**.

The screening table for subsistence foods is provided in **Appendix B to this HHRA, Table B-5**. The following parameters screened in as COPCs in subsistence foods: **aluminum, barium, cadmium, chromium, cobalt, iron, lithium, manganese, mercury, molybdenum, nickel, selenium, strontium, and thallium**.

3.5.2.7 Special Case Contaminants of Potential Concern

This step in the COPC screening process identifies chemicals that have the potential to bioaccumulate or to biomagnify in the food web (BC ENV 2019a). Thus, even if the concentrations of those metals in environmental media are lower than applicable guidelines, they were carried forward as COPCs as a conservative measure. The criteria used to assess bioaccumulation potential are typically bioconcentration factors (BCFs) and bioaccumulation factors (BAFs) (Health Canada 2019a). Site-specific BCFs from water to fish tissue and BCFs from soil to plant tissues were considered in this screening step. If the BCF was greater than 5000, then the parameter was considered to have bioaccumulative properties (Environment Canada 2003; Health Canada 2019a) and was retained as a COPC. If the BCF was less than 5000, the parameter was not identified as a special case COPC.

Appendix A to this HHRA, Table A-6 shows the BCF_{plant} calculated for COPCs in plants due to the uptake from soil, **Appendix A to this HHRA, Table A-12** shows the BCF_{fish} calculated for fish from water, and **Appendix D to this HHRA** shows the biotransfer factors (BTFs) for terrestrial mammals and birds. None of the BCF_{plant} or BTFs were greater than 5000. However, the BCF_{fish} exceeded 5000 for cadmium, mercury, phosphorus, potassium, and zinc. Phosphorus and potassium are unlikely to be detrimental to human health at concentrations present in the aquatic food chain and in fish and, thus, were not considered further for the assessment of human health. Selenium was included as a bioaccumulative

substance in the aquatic food chain (Beatty and Russo 2014). Final COPCs retained as special case COPCs were: **cadmium, mercury, selenium, and zinc**.

3.6 Problem Formulation Summary: Conceptual Site Model

The Conceptual Site Model (CSM) for human health is a graphical representation of the relationships between contaminant sources, transport pathways, exposure pathways, and people. The CSM is shown in **Figure 3.6-1**. A summary of all COPCs selected for further assessment is provided in **Table 3.6-1**.

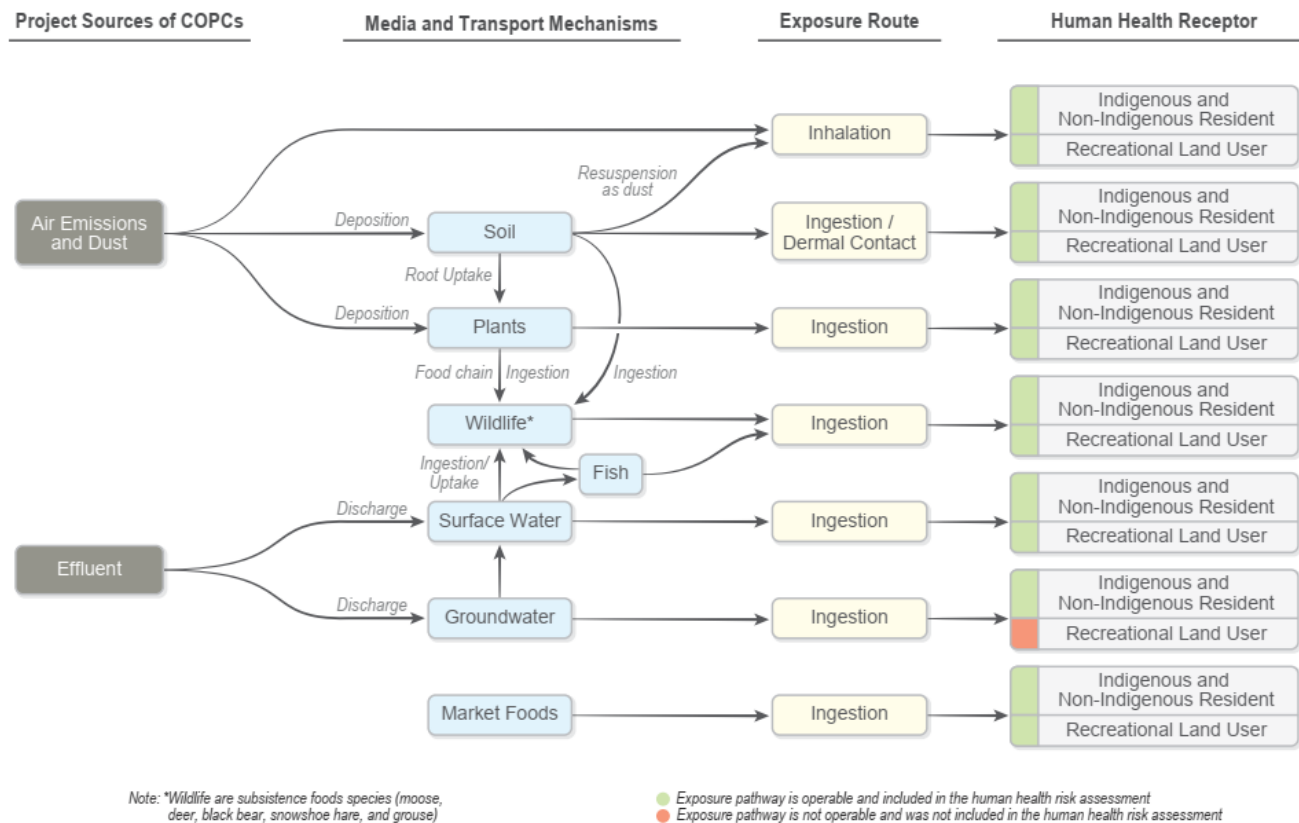


Figure 3.6-1: Conceptual Site Model

www.erm.com

Project No.: 0403488-702-0009

Client: Telkwa Coal Limited, a subsidiary of Allegiance Coal Limited

Graphics: TEN-21ERM-002

Figure 3.6-1: Conceptual Site Model

TEN-21ERM-002

8½x11"

Table 3.6-1: Final Selection of Contaminants of Potential Concern

Parameter	Screened in as Contaminant of Potential Concern in:														Final COPC Selection
	Groundwater			Surface Water			Air		Soil		Subsistence Food			Special Case	
	Baseline Measured	Baseline Predicted	Post-Closure Phase	Baseline Measured	Operation	Closure*	Baseline	Operation	Baseline	Operation	Baseline	Operation	Closure*		
Aluminum	-	-	-	-	-	-	-	-	YES	YES	YES	YES	YES	-	YES
Antimony	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic	YES	YES	-	-	-	-	-	-	YES	YES	-	-	-	-	YES
Barium	-	-	-	-	-	-	-	-	-	-	YES	YES	YES	-	YES
Beryllium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bismuth	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boron	-	-	-	-	-	-	-	-	YES	YES	-	-	-	-	YES
Cadmium	-	-	-	-	-	-	-	-	YES	YES	-	-	YES	YES	YES
Calcium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromium	-	-	-	-	-	-	-	YES	-	-	-	-	YES	-	YES
Cobalt	YES	YES	YES	YES	YES	YES	-	-	-	-	YES	YES	YES	-	YES
Copper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron	YES	-	-	-	-	-	-	-	YES	YES	YES	YES	YES	-	YES
Lead	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lithium	-	-	YES	-	YES	YES	-	-	-	-	-	YES	YES	-	YES
Magnesium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manganese	YES	YES	-	-	-	-	-	-	-	-	YES	YES	YES	-	YES
Mercury	-	-	-	-	-	-	-	-	-	-	YES	YES	YES	YES	YES
Molybdenum	-	-	-	-	-	-	-	-	-	-	-	-	YES	-	YES

Parameter	Screened in as Contaminant of Potential Concern in:														Final COPC Selection
	Groundwater			Surface Water			Air		Soil		Subsistence Food			Special Case	
	Baseline Measured	Baseline Predicted	Post-Closure Phase	Baseline Measured	Operation	Closure*	Baseline	Operation	Baseline	Operation	Baseline	Operation	Closure*		
Nickel	-	-	-	-	-	-	-	-	-	-	YES	YES	YES	-	YES
Potassium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium	-	-	-	-	-	YES	-	-	-	-	YES	YES	YES	YES	YES
Silver	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sodium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strontium	-	-	-	-	-	-	-	-	-	-	YES	YES	YES	-	YES
Thallium	-	-	-	-	-	-	-	-	-	-	-	YES	YES	-	YES
Tin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uranium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vanadium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zinc	-	-	-	-	-	-	-	-	-	-	-	-	-	YES	YES

Notes:

COPC = Contaminant of Potential Concern

"-" = COPC not selected in environmental medium and for the Project phase

* Closure includes Decommissioning and Reclamation and Post-closure phases

4. EXPOSURE ASSESSMENT

In the exposure assessment, the total dose of each COPC for human ROC is estimated. A dose is the amount of COPC that a person takes into the body daily, normalized to body weight. Exposure estimates (doses) for multiple pathways with the same intake route will be summed (e.g., soil ingestion, water ingestion, and ingestion of food). Pathways relevant for each ROC were explored and summarized in Sections 3.3 and 3.6.

Doses are estimated based on ROC characteristics and the concentration of the COPC that a person may be exposed to in environmental media or the food chain (i.e., exposure point concentrations, EPCs). The following subsections describe the ROC characteristics (Section 4.1) and the EPCs that were used to calculate total exposure doses. Exposure to CACs was considered separately since inhalation is the only exposure route for these parameters (Section 4.2). Exposure to non-carcinogens (threshold COPCs; Section 4.3) were also considered separately from carcinogens (non-threshold) COPCs (Section 4.4) as the methods used to calculate exposure doses to these two groups of COPCs are slightly different.

4.1 Human Receptor Characteristics

Receptor characteristics are based on Project-specific information, guidance documents, or literature. The following guidance documents from sources representative of the Canadian population were consulted:

- Health Canada. 2019. Guidance for Evaluating Human Health Impacts in Environmental Assessment: Human Health Risk Assessment.
- Health Canada. 2018. Guidance for Evaluating Human Health Impacts in Environmental Assessment: Country Foods.
- Health Canada. 2012. Federal Contaminated Sites Risk Assessment in Canada Part 1: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA).
- USEPA. 2004. Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment).
- Richardson, GM. 1997. Compendium of Canadian human exposure factors for risk assessment. O'Connor Associates Environmental Inc., Ottawa, ON.

Receptor characteristics are the factors that can influence or mediate the relationship between exposure and effect for each representative ROC group. Typical characteristics include body weight and surface area, ingestion rates for water, soil, and dietary items (i.e., what a person might eat). Many exposure characteristics are lifestyle dependent or may be a function of site-use and activities. Where possible, and reasonable, local conditions, habits, and site use patterns have been considered.

4.1.1 General Human Receptor Characteristics (applicable to all ROCs):

The human ROCs selected were toddlers (6 months up to 5 years of age) and adults (>20 years; Health Canada 2019a; Health Canada 2021a). Toddlers are often most susceptible to chemicals with a threshold response due to their ratio of body size to ingestion rates (IRs) compared to other life stages or their higher incidental soil ingestion rate (Health Canada 2010a, 2021b). Therefore, if an evaluation finds that COPC concentrations in exposure media are unlikely to pose a health risk to toddlers, all other life-stages would be considered protected. An adult ROC was also selected for both threshold and non-threshold response chemicals based on guidance provided by Health Canada (2021a).

The human ROC characteristics used to calculate the estimated daily dose of COPCs were body weight, ingestion (for food, soil, water, air), inhalation, and dermal uptake rates from water, and exposure duration and frequencies dependent on land use. The body weight for adults (70.7 kg) and toddlers (16.5 kg) as well as age group duration (4.5 and 60 years, respectively) were based on guidance provided by Health Canada (2019a). Body weights, age group durations, and age-dependant adjustment factors (ADAF) for infant, toddler, child, teen, and adult, and life expectancy (80 years) were incorporated into the calculation of the lifetime average daily dose (LADD) of carcinogens (i.e., arsenic) in air, water, soil, and food and were also obtained from Health Canada (Health Canada 2013) (Section 4.4).

4.1.2 *Receptor-specific Characteristics: Indigenous and Non-Indigenous Resident*

4.1.2.1 *Traditional Subsistence Food Harvester*

The primary objective when selecting subsistence foods for the HHRA was to identify the most relevant foods to include in exposure calculations because not every subsistence food can be evaluated. This is an accepted and standard approach in HHRA (Health Canada 2018). Key considerations when selecting the subsistence foods to evaluate included:

- which subsistence foods may be currently collected in the Human Health LSA;
- how the subsistence food is used (i.e., food, medicine, or both);
- what part(s) of the subsistence food may be consumed (i.e., specific organs, plant leaves or roots);
- what quantities of each subsistence food may be consumed; and
- what the consumption frequencies may be for each subsistence food.

The most frequently consumed subsistence food species from each of three categories (plants, wildlife, and fish) found within the Human Health LSA are then selected for evaluation.

The most recent subsistence foods consumption survey relevant to the Project was reported by Chan et al. (2011) for the Moricetown Band (Witset First Nation), combined with Nat'oot'en (Lake Babine), located approximately 130 km southeast of the Project. A total of 128 households participated in the Chan et al. (2011) surveys. Thus, not all responses were specific to Moricetown Band members. However, these data were assumed to represent the subsistence foods use by all Wet'suwet'en people in the LSA. The top 10 traditional foods identified by Chan et al. (2011) are listed in **Table 4.1-1**.

Table 4.1-1: Top Ten Traditional Subsistence Food Items Consumed by Moricetown and Nat'oot'en Peoples Living On-Reserve

Traditional Subsistence Food	Average Days per Year Consumed (Standard Error)
Salmon (any type)	63 (5)
Moose meat	50 (21)
Salmon, sockeye	41 (0)
Eulachon grease	16 (16)
Soapberries	16 (8)
Blue huckleberry	14 ((3)
Laver seaweed	7 (7)
Salmon, Chinook (King/Spring)	7 (6)

Traditional Subsistence Food	Average Days per Year Consumed (Standard Error)
Blueberries (Alaska, oval leaved, bog)	7 (1)
Trout (any type)	5 (4)

Source: Chan et al. (2011)

In March 2006, OW member Stefan Schug was interviewed to identify subsistence foods that were harvested from the project area for the Davidson Project west of Smithers. These data were incorporated into the Davidson Project Country Foods Baseline Assessment (Rescan 2008). Results from the interview included important plant, mammal, bird, and fish species harvested and consumed for subsistence food as well as quantitative consumption data (amounts, frequencies). Identified mammal and bird species that were reported as harvested and consumed by Wet'suwet'en people by Rescan (2008) are shown in **Table 4.1-2**.

Table 4.1-2: Important Mammals and Birds Consumed by Wet'suwet'en People for Nutritional Purposes

Common Animal Name	Scientific Name
Moose	<i>Alces alces</i>
Black bear	<i>Ursus americanus</i>
Beaver	<i>Castor Canadensis</i>
Lynx	<i>Lynx Canadensis</i>
Porcupine	<i>Erethizon dorsatum</i>
Muskrat	<i>Ondatra zibethicus</i>
Snowshoe hare	<i>Lepus americanus</i>
Hoary marmot/Groundhog	<i>Marmota caligata</i>
Squirrel	<i>Tamiasciurus sp.</i>
Ruffed, Spruce, and Blue grouse	<i>Phasianidae sp.</i>

Source: Adapted from Rescan (2008)

While salmon may be an important harvested fish species, to be conservative in an HHRA it is important to select a non-anadromous fish that obtains all or most of its food from aquatic habitats within the LSA throughout its lifecycle. This is because fish that spend some or all of their lifecycle outside of the LSA (e.g., salmon that spend the majority of their adult life stage in the marine environment) will not be affected by Project-related changes in the aquatic environment in the LSA or will be less affected than a non-anadromous, resident fish species. Thus, rainbow trout was preferentially assessed as a food fish species in this HHRA.

Based on the above information, and also taking into consideration non-Indigenous subsistence food use, and inclusion of important consumption-based links in the food-chain (e.g., plant eaters [herbivorous], meat-eaters [carnivorous], or omnivorous large and small animals), the following subsistence food species and groups were assessed in the HHRA:

- Moose and mule deer (selected as representatives for commonly consumed herbivorous large mammals, with moose having a greater exposure to the aquatic food chain than deer);
- American black bear (selected as representative for commonly consumed omnivorous large mammals);

- Snowshoe hare (selected as representative for commonly consumed small herbivorous mammals with a smaller foraging range than large mammals);
- Ruffed or Blue grouse (selected as representative for commonly consumed birds);
- Rainbow trout (selected as representative for commonly consumed non-anadromous fish species with extensive Baseline data);
- Berries (selected as commonly gathered and grown food with available Baseline data); and
- Above-ground plants (selected as commonly harvested leafy food, including from backyard gardens, with extensive Baseline data).

The final selection of traditional subsistence foods evaluated in this HHRA and the frequency and rate of their ingestion (serving sizes) are provided in **Table 4.1-3**. The most frequently consumed subsistence foods from each of three categories (plants, wildlife and fish) found within the LSA were selected for evaluation. Mule deer, snowshoe hare, and grouse were included as a large and small mammal, and as a bird, respectively, with smaller home ranges than moose, based on information provided in Rescan (2008). Animals with smaller home ranges located near the Project are preferable to evaluate potential Project-related effects on subsistence foods compared to animals with large home ranges and tendency to migrate further, such as moose. For selection of subsistence foods and organ meat, Rescan (2008) indicates that:

"The muscle tissue and major body parts (ribs, backbone and limbs) of each animal are the most frequently consumed. However, the liver, kidney, heart, stomach, intestine and brain of moose are also consumed on an infrequent basis (i.e., up to 10 times per year). Moose are the most frequently consumed mammal with a reasonable maximum consumption amount of 277 g at a frequency of 300 times per year. Grouse are the most frequently consumed bird species with a reasonable maximum consumption amount of 170 g at a frequency of 30 times per year." (Rescan 2008)

Table 4.1-3: Final Selection of Subsistence Foods Evaluated in this HHRA and the Frequency and Rate of their Ingestion

Subsistence Food	Percent of On-Reserve Indigenous People Consuming Subsistence Food (Ecozone 5) ⁽¹⁾	Serving Size (kg/serving) ⁽¹⁾		Average Consumption Frequency (Ecozone 5; Servings per Year) ⁽¹⁾
		Adult	Toddler ⁽⁵⁾	Adult and Toddler
Moose meat	93	0.155	0.775 ⁽³⁾	71
Deer meat	22	0.155	0.775 ⁽³⁾	8 ⁽²⁾
Moose liver	20	0.155	0.775 ⁽³⁾	8 ⁽²⁾
Moose kidney	9	0.155	0.775 ⁽³⁾	8 ⁽²⁾
Deer liver	3	0.155	0.775 ⁽³⁾	8 ⁽²⁾
Deer kidney	1	0.155	0.775 ⁽³⁾	8 ⁽²⁾
Black Bear meat	14	0.155	0.775 ⁽³⁾	8 ⁽²⁾
Grouse (Blue, Ruffed)	10	0.155	0.775	8 ⁽²⁾
Rabbit meat (Snowshoe Hare/Jackrabbit)	6	0.155	0.775 ⁽³⁾	8 ⁽²⁾
Trout (any type)	22	0.126	0.628	9
Berries ⁽⁴⁾	66	0.475	0.238	49

Subsistence Food	Non-Indigenous Resident	Serving Size (kg/serving)		Consumption Frequency (Average Days per Year Consumed)
		Adult	Toddler ⁽⁵⁾	Adult and Toddler
Garden Produce ⁽⁶⁾	NA	0.143	0.067	120 ⁽⁷⁾

Notes:

¹ Percent of On-Reserve FN people consuming subsistence foods and average (plus standard error) consumption frequency in Ecozone 5 was obtained from Table 7f (Chan 2011); Average (all genders and age groups) serving size was obtained from Table 27 (Chan 2011), except where indicated below.

² Average days per year consumed was based on Table 7f in Chan (2011) and best professional judgement. Days per year this food is consumed were assumed to be lower than days per year top ten traditional foods are consumed (between 9 and 71 days depending on type of traditional food).

³ Based on mean portion size for land mammal meat (Chan 2011, Table 27).

⁴ Consumption rates and average days per year consumed for berries are additive and consist of soapberries, blue huckleberries, and blueberries (Alaska, oval leaved, bog), which are the three most consumed berry species.

⁵ Toddler was assumed to have a consumption rate of 50% of adult consumption rate.

⁶ The daily consumption rate for garden produce was obtained from Richardson (1997, Table 5.4) and CCME (2006). The mean consumption rate for vegetables other than root vegetables is 143 g/day (adults) and 67 g/day (toddlers) and was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the rate in Richardson (1997) includes vegetables from store and garden sources.

⁷ Best professional judgement.

However, consumption amounts and frequencies reported in Chan et al. (2011) were relied on preferentially as they were more recent than Rescan (2008) and are representative of a larger population.

It was assumed that Indigenous Resident Land Users go up to eight times annually to hunt, fish, gather food, or visit traplines, each trip lasting seven days. While on the land, people are assumed to drink surface water. Consumption of subsistence foods was assumed to occur throughout the year. It was assumed that a toddler would eat subsistence foods at the same frequency as adults, since toddlers most likely consume the same meals together with adults. The assumed toddler serving sizes were calculated as 50% of the adult serving sizes (Health Canada 2007b). It is anticipated that this amount overestimates actual toddler serving sizes as Richardson (1997) suggests toddlers consume 43% of what adults do.

It was further assumed that the Indigenous Resident Land User lives in the LSA year-round and drinks groundwater from residential groundwater wells when not on the land. They were further assumed to consume store-bought foods when not relying on subsistence foods.

4.1.2.2 Non-traditional Subsistence Food Harvester

Non-Indigenous Resident Land Users live on their properties year-round and were assumed to drink groundwater from residential groundwater wells on their properties. They were assumed to consume store-bought foods and food grown on their properties or tenures.

Non-root vegetable consumption rates were obtained from Richardson (1997) as recommended by Health Canada (2019a, 2021a). Richardson (1997) provided consumption rates and distributions for the Canadian national average consumer and was assumed to be applicable to consumption rates of the Non-Indigenous Resident Land User in the LSA (average 67 g/day for children and 143 g/day for adults). These consumption rates represent a variety of foods from different sources including the grocery store. Consistent with guidance from the Canadian Council of Ministers of the Environment (CCME 2006), a fractional intake of 0.1 was then applied to represent amounts consumed as homegrown produce. It was

also assumed that garden produce may be similarly exposed to potential Project emissions as is leafy vegetation in the LSA. Although produce will likely be washed prior to consumption, the COPC concentrations in the HHRA were based on unwashed vegetation and predicted Project dustfall on vegetation, adding a layer of conservatism.

In addition to consuming garden- or farmed vegetables and pasture-raised meats, some Resident Land Users may also hunt or gather berries or other subsistence foods. Because subsistence food consumption data are far more readily available for Indigenous populations, and because it is assumed that Indigenous populations rely more heavily on subsistence foods than Non-Indigenous populations, the subsistence food ingestion rates of the Indigenous food harvester were also applied to the Non-Indigenous Resident Land User. It was further assumed that exposures of livestock (e.g., cattle) through the food chain was appropriately approximated by exposures of deer and moose within the LSA. This is a reasonable approximation, since BTFs obtained from beef from the literature are commonly applied to other ruminant animals.

4.1.3 *Receptor-specific Characteristics: Recreational Land User*

The Recreational Land User was assumed to not live in the LSA but may visit the LSA for recreational purposes. It was assumed that people would spend up to eight weeks per year in the LSA. Similar to the Indigenous food harvester, Recreational Land Users were assumed to drink surface water while on the land and consume berries, fish, or game they harvest within the LSA throughout the year. Because subsistence food consumption data are more readily available for Indigenous populations, and because it is assumed that Indigenous populations rely more heavily on subsistence foods than non-indigenous populations, the subsistence food ingestion rates of the Indigenous subsistence food harvester were conservatively applied to the Recreational Land User. In addition, Recreational Land Users were assumed to camp and swim in streams and lakes at recreational sites or provincial parks.

4.2 Inhalation of Criteria Air Contaminants

Base Case concentrations of PM₁₀ and PM_{2.5} were measured near the Project (at PM Kerr) and in Telkwa (BC ENV Telkwa) and were presented in Tables 3.4-1 and 3.4-2 in Section 3.4.1.1.

Project Case concentrations of CACs were predicted by the Air Quality Modelling Report (**Appendix 4.1-B of the EAC Application**). The EPCs of CACs are the concentrations for Background plus Project Contribution in air at the Back Country Horsemen camp, at the nearest rural residence, and at Telkwa, as presented in **Table 3.4-4** in Section 3.4.1.2.

4.3 Exposure Point Concentrations and Doses of Non-carcinogenic Contaminants of Potential Concern

The EPCs for parameters identified as COPCs (Section 3.5 and summarized in **Table 3.6-1**) were included in exposure dose equations to determine the estimated daily dose of each COPC through the various exposure pathways. Parameters identified as COPCs were included in calculations for each exposure pathway, even if that parameter was not a COPC identified for that exposure pathway, as recommended by BC Ministry of Health (2021) and Health Canada (2019). The calculations of dose are based on either measured COPC concentrations in media (e.g., air, soil) or modeled COPC concentration estimates for Baseline and for Project phases.

The 95% UCLM was generally used as the EPC for all exposure media, except as noted in the following subsections. The following subsections describe the EPC and dose calculations for each exposure pathway for Base Case and Project Case. Example calculations are provided in **Appendix C to this HHRA** and in subsections below.

4.3.1 Inhalation of Contaminants of Potential Concern in Air

The 95% UCLM of Base and Project Case COPC concentrations bound to PM₁₀ (Tables 4.3-1 and 4.3-2) were used to determine the daily dose of COPCs that humans receive via inhalation. Equation 6 was used to calculate the dose of COPCs (mg/kg BW-day) from inhalation of PM₁₀, as recommended by Health Canada (2019a):

$$Dose = \frac{C_{Air} \times UCF \times IR_A \times RAF_{Inh} \times D_1 \times D_2 \times D_3}{BW} \quad [\text{Equation 6}]$$

where:

<i>Dose</i>	= dose of COPC from inhalation (mg/kg BW-day)
<i>C_{Air}</i>	= concentration of COPC in air (µg/m ³)
<i>UCF</i>	= unit conversion factor (1 mg/1,000 µg)
<i>IR_A</i>	= receptor air intake (inhalation) rate (m ³ /d)
<i>RAF_{Inh}</i>	= relative absorption factor by inhalation (unitless)
<i>D₁</i>	= hours per day exposed/24 hours
<i>D₂</i>	= days per week exposed/7 days
<i>D₃</i>	= weeks per year exposed/52 weeks
<i>BW</i>	= body weight (kg BW)

A sample calculation for inhalation of aluminum by a Recreational Land User toddler in Base Case is:

$$Dose = \frac{0.0266 \frac{\mu g}{m^3} \times \frac{1 mg}{1000 \mu g} \times \frac{8.3 m^3}{day} \times 1 \times \frac{24 hours}{24 hours} \times \frac{7 days}{7 days} \times \frac{8 weeks}{52 weeks}}{16.5 kg BW}$$

$$Dose = 0.0000021 mg/kg BW \cdot day$$

The dose of COPCs via the inhalation exposure route for toddlers and adults in Base Case are presented in **Table 4.3-1** and for Project Case (Operation) in **Table 4.3-2**.

The assumptions used in the calculation of the dose of COPCs via inhalation were:

- For Base Case, the proportion of metals in dustfall under Baseline conditions are the same as the proportion of metals associated with PM₁₀.
- Toddlers have an inhalation rate of 8.3 m³/day (Health Canada 2019a);
- Adults have an inhalation rate of 16.6 m³/day (Health Canada 2019a);
- The exposure to COPCs in air was converted to an internal dose based on the relative absorption factor; this was done to make exposure via the inhalation route comparable to TRVs derived for the ingestion route. It also allows the summation of doses from all exposure routes.
- Concentrations of COPCs below the MDL were replaced with concentrations half of the MDL.
- For the Project Case, inhalation metals in PM₁₀ includes both contributions from Project operations and resuspended soils.
- Year 5 of the Operation phase, modelled in the Air Quality Model (**Appendix 4.1-B of the EAC Application**) is used as an input to the HHRA, and is representative of the Construction phase; and
- The Base Case is representative of Closure case conditions because Project-related air emissions are expected to be similar to Baseline conditions during Decommissioning and Reclamation and Post-closure phases.

Table 4.3-1: Dose of Contaminants of Potential Concern from Inhalation of Particulate Matter in Base Case

Exposure Characteristics		Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
		Toddler	Adult	Toddler	Adult
Hours/24 Hours		24	24	24	24
Days/7 Days		7	7	7	7
Weeks/52 Weeks		8	8	52	52
Inhalation Rate (m ³ /day)		8.3	16.6	8.3	16.6
Relative Absorption Factor (unitless)		1	1	1	1
Body Weight (kg)		16.5	70.7	16.5	70.7
COPC	Baseline Metal Concentration bound to PM ₁₀ (µg/m ³) ^a	Estimated Daily Intake (mg/kg BW-day)			
		Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
		Toddler	Adult	Toddler	Adult
Aluminum	0.0266	0.0000021	0.00000096	0.000013	0.0000062
Arsenic	0.000219	0.000000017	0.000000008	0.00000011	0.000000051
Barium	0.000770	0.000000060	0.000000028	0.00000039	0.00000018
Boron	0.00604	0.00000047	0.00000022	0.00000304	0.00000142
Cadmium	0.0000302	0.000000023	0.000000011	0.00000015	0.000000071
Chromium	0.000302	0.000000023	0.000000011	0.00000015	0.000000071
Cobalt	0.0000604	0.000000047	0.000000022	0.00000030	0.00000014
Iron	0.0293	0.0000023	0.0000011	0.000015	0.0000069
Lithium	0.00302	0.00000023	0.00000011	0.0000015	0.00000071
Manganese	0.00309	0.00000024	0.00000011	0.0000016	0.00000073
Mercury	0.0000302	0.000000023	0.000000011	0.00000015	0.000000071
Molybdenum	0.0000302	0.000000023	0.000000011	0.00000015	0.000000071
Nickel	0.000302	0.000000023	0.000000011	0.00000015	0.000000071
Selenium	0.000604	0.000000047	0.000000022	0.00000030	0.00000014
Strontium	0.00174	0.00000013	0.00000006	0.00000087	0.00000041
Thallium	0.0000604	0.000000047	0.000000022	0.00000030	0.00000014
Zinc	0.00445	0.00000034	0.00000016	0.0000022	0.0000010

Notes:

COPC = contaminant of potential concern

BW = body weight

PM₁₀ = particulate matter up to and including 10 µm in size

^a Values were converted to mg/m³ for input to the calculations.

Table 4.3-2: Dose of Contaminants of Potential Concern from Inhalation of Particulate Matter in Project Case (Operation)

Exposure Characteristics		Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
		Toddler	Adult	Toddler	Adult
Hours/24 Hours		24	24	24	24
Days/7 Days		7	7	7	7
Weeks/52 Weeks		8	8	52	52
Inhalation Rate (m ³ /day)		8.3	16.6	8.3	16.6
Relative Absorption Factor (unitless)		1	1	1	1
Body Weight (kg)		16.5	70.7	16.5	70.7
COPC	Operation Metal Concentration bound to PM ₁₀ (µg/m ³) ^a	Estimated Daily Intake (mg/kg BW-day)			
		Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
		Toddler	Adult	Toddler	Adult
Aluminum	0.0822	0.0000064	0.0000030	0.000041	0.000019
Arsenic	0.000257	0.000000020	0.0000000093	0.00000013	0.000000060
Barium	0.00147	0.00000011	0.000000053	0.00000074	0.00000035
Boron	0.00608	0.00000047	0.00000022	0.0000031	0.0000014
Cadmium	0.0000351	0.0000000027	0.0000000013	0.000000018	0.0000000082
Chromium	0.000401	0.000000031	0.000000014	0.00000020	0.000000094
Cobalt	0.0000952	0.0000000074	0.0000000034	0.000000048	0.000000022
Iron	0.108	0.0000084	0.0000039	0.000054	0.000025
Lithium	0.00302	0.00000023	0.00000011	0.0000015	0.00000071
Manganese	0.00480	0.00000037	0.00000017	0.0000024	0.0000011
Mercury	0.0000806	0.0000000062	0.0000000029	0.000000041	0.000000019
Molybdenum	0.0000433	0.0000000034	0.0000000016	0.000000022	0.000000010
Nickel	0.000387	0.000000030	0.000000014	0.00000019	0.000000091
Selenium	0.000606	0.000000047	0.000000022	0.00000031	0.00000014
Strontium	0.00189	0.00000015	0.000000068	0.00000095	0.00000044
Thallium	0.000162	0.000000013	0.0000000059	0.000000082	0.000000038
Zinc	0.00494	0.00000038	0.00000018	0.0000025	0.0000012

Notes:

COPC = contaminant of potential concern

BW = body weight

PM₁₀ = particulate matter up to and including 10 µm in size

^a Values were converted to mg/m³ for input to the calculations.

4.3.2 Water Ingestion

4.3.2.1 Exposure Point Concentrations in Groundwater

The EPC of COPCs from the ingestion of groundwater in Base Case is based on the 50th percentile concentration in overburden groundwater presented in Section 3.4.5, as provided by SRK Consulting (Canada) Inc. (SRK) (**Appendix 1.0-U** of the **EAC Application**).

It is not expected that groundwater quality will change in Operation phase, as the groundwater model predicted that particles would travel for more than 400 years in the base case and 300 years in the high case before reaching residential wells located in the groundwater flow path downgradient of the Project. Thus, the Baseline concentration based on the 50th percentile concentration in overburden groundwater is used as the EPC in Operation phase for the Project Case.

The EPC for the Project Case Closure is based on the long-term average winter groundwater concentrations (using overburden P50 groundwater concentrations as background), as provided by SRK (**Appendix 1.0-U**).

Groundwater was assumed to contribute to the Resident Land User's ingestion of drinking water for 309 days per year, while surface water was assumed to contribute 56 days a year (8 weeks) while Resident Land Users spend time on the land. The groundwater exposure pathway was not included for the Recreational Land Users as they do not reside in the LSA and are not expected to have access to groundwater for drinking water.

The assumptions used for the ingestion of groundwater pathway were:

- The 50th percentile concentration in overburden groundwater represents Base Case drinking water quality at residential wells within the human health LSA;
- Base Case groundwater quality is representative of the Project Case (Operation) groundwater quality in residential wells;

4.3.2.2 Exposure Point Concentrations in Surface Water

The Base Case surface water EPC was based on the average of the P50 base case concentration at 12 water quality model assessment nodes. These nodes were: Goathorn Creek (n = 2), Tenas Creek (n = 3), Four Creek (n = 4), Telkwa River (n = 1), and the Bulkley River (n = 2). The location of the water quality model assessment nodes are identified in **Appendix 4.3-A** of the **EAC Application**.

The reason for selecting the specific locations for inclusion in the calculation of the Base Case surface water EPC is to enable direct comparison of the Baseline water quality to predicted water quality at the exact same locations (i.e., water quality model node assessment locations). The modelling nodes are considered the most likely to experience Project-related effects on surface water quality because they are downstream of proposed Project infrastructure or influence. Other Baseline water quality monitoring sites located further away or upstream of the Project are not expected to be affected by the Project and water concentrations of COPCs at these locations would be expected to be the same as Baseline concentrations. By basing the assessment just on the sampling locations that match the modelling nodes where there is greatest potential for effects due to the Project, the assessment of Project-related effects is most conservative and comparison of Baseline conditions to predicted conditions is most conservative.

For the Operation and Closure phases, the annual 95% UCLM concentration of each parameter was calculated from the EA20 scenario monthly model predictions for the years that matched the Operation (22 years) and Closure (49 years) phases, as per the **Appendix 4.3-A**. The average of the maximum of the annual 95% UCLM concentrations from the 12 surface water quality assessment nodes was used as the Project Case EPC from drinking water ingestion by land users, as an input to the food chain model

(Appendix C to this HHRA), and to predict fish tissue concentrations. Using the maximum of the annual 95% UCLM concentration provides a conservatively high estimate of concentrations that a land user may experience while in the LSA.

The assumptions used for the ingestion of drinking water pathway were:

- Surface water quality at the 12 modelling nodes is representative of the surface water quality within the Human Health LSA.
- Toddlers have a water ingestion rate of 0.6 L/day (Health Canada 2019a).
- Adults have a water ingestion rate of 1.5 L/day (Health Canada 2019a).
- Surface water is assumed to be consumed untreated.

4.3.2.3 Dose from Drinking Water

Equation 7 was used to calculate human exposure to COPCs (mg/kg BW-day) from drinking groundwater and surface water, as recommended by (Health Canada 2021a):

$$Dose = \frac{C_W \times IR_W \times RAF_{Oral} \times D_2 \times D_3}{BW} \quad \text{[Equation 7]}$$

where:

- $Dose$ = dose of COPC from water ingestion (mg/kg BW-day)
- C_W = concentration of COPC in drinking water (mg/L)
- IR_W = receptor water intake rate (L/d)
- RAF_{Oral} = relative absorption factor from the gastrointestinal tract, assumed to be 1 (unitless)
- D_2 = days per week exposed/7 days
- D_3 = weeks per year exposed/52 weeks
- BW = body weight (kg BW)

A sample calculation for ingestion of aluminum with water by a Recreational Land User toddler in the Base Case using Equation 7 is:

$$Dose = \frac{\frac{0.098 \text{ mg}}{L} \times \frac{0.6 \text{ L}}{\text{day}} \times 1 \times \frac{7 \text{ days}}{7 \text{ days}} \times \frac{8 \text{ weeks}}{52 \text{ weeks}}}{16.5 \text{ kg BW}}$$

$$Dose = 0.00055 \text{ mg/kg BW} \cdot \text{day}$$

The COPC dose via drinking surface water for toddlers and adults for the Base Case is in **Table 4.3-3**, for the Project Case (Operation)s in **Table 4.3-4**, and for the Project Case (Closure) in **Table 4.3-5**.

Table 4.3-3: Dose of Contaminants of Potential Concern via the Drinking Water Ingestion Route in the Base Case

Exposure Characteristics	Recreational Land Users		Indigenous and Non-Indigenous Resident Land Users	
	Toddler	Adult	Toddler	Adult
Days/7 Days	7	7	7	7
Weeks/52 Weeks	8	8	52	52
Water Ingestion Rate (L/day)	0.6	1.5	0.6	1.5
Relative Absorption Factor (unitless)	1	1	1	1
Body Weight (kg)	16.5	70.7	16.5	70.7

Contaminant of Potential Concern	Baseline Water Concentration for Recreational Land Users (mg/L) ^a	Baseline Water Concentration for Resident Land Users (mg/L) ^b	Estimated Daily Dose (mg/kg BW-day)			
			Recreational Land Users		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Aluminum	0.098	0.0193	0.000549	0.000320	0.000702	0.000409
Arsenic	0.000465	0.000664	0.00000260	0.00000152	0.0000241	0.0000141
Barium	0.0495	0.0863	0.000277	0.000162	0.00314	0.00183
Boron	0.0098	0.0862	0.0000550	0.0000321	0.00313	0.00183
Cadmium	0.0000073	0.00001889	0.0000000406	0.0000000237	0.000000687	0.000000401
Chromium	0.000258	0.000886	0.00000145	0.000000843	0.0000322	0.0000188
Cobalt	0.0000500	0.000262	0.000000280	0.000000163	0.00000951	0.00000555
Iron	0.114	0.0428	0.000636	0.000371	0.00156	0.00091
Lithium	0.001	0.002	0.00000466	0.00000272	0.0000908	0.0000530
Manganese	0.0074	0.04524	0.0000414	0.0000242	0.00165	0.000960
Mercury	0.00000250	0.00000462	0.0000000140	0.00000000816	0.000000168	0.0000000979
Molybdenum	0.000291	0.000891	0.00000163	0.000000949	0.0000324	0.00001891
Nickel	0.000250	0.000885	0.00000140	0.000000816	0.0000322	0.0000188
Selenium	0.0000463	0.0001764	0.000000259	0.000000151	0.00000641	0.00000374
Strontium	0.109	0.109	0.000608	0.000355	0.00395	0.00231
Thallium	0.00000500	0.00000500	0.0000000280	0.0000000163	0.000000182	0.000000106
Zinc	0.00150	0.00446	0.00000839	0.00000490	0.000162	0.0000947

Notes:

COPC = contaminant of potential concern

BW = body weight

^a The Baseline water concentrations for recreational land users are the 95th percentile of base case concentrations used as inputs in the surface water quality model at water quality assessment nodes. These concentrations were used to ensure direct comparability of Baseline and predicted water concentrations.

^b Water COPC concentrations for resident land users were calculated as ((56 days x [COPC_{surface water}]) + (309 days x [COPC_{groundwater}]))/365 days, where [COPC_{surface water}] is the P50 base case concentrations used as inputs in the surface water quality model at water quality assessment nodes and [COPC_{groundwater}] is the 95th percentile Baseline groundwater concentration.

Table 4.3-4: Dose of Contaminants of Potential Concern via the Drinking Water Ingestion Route in the Project Case (Operation)

Exposure Characteristics			Recreational Land Users		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Days/7 Days			7	7	7	7
Weeks/52 Weeks			8	8	52	52
Water Ingestion Rate (L/day)			0.6	1.5	0.6	1.5
Relative Absorption Factor (unitless)			1	1	1	1
Body Weight (kg)			16.5	70.7	16.5	70.7
Contaminant of Potential Concern	Operations Phase Water Concentration for Recreational Land Users (mg/L)	Operations Phase Water Concentration for Resident Land Users (mg/L)	Estimated Daily Dose (mg/kg BW-day)			
			Recreational Land Users		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Aluminum	0.108	0.0208	0.000605	0.000353	0.000757	0.000442
Arsenic	0.000507	0.000670	0.00000283	0.00000165	0.0000244	0.0000142
Barium	0.0522	0.0867	0.000292	0.000170	0.00315	0.00184
Boron	0.0141	0.0868	0.0000786	0.0000459	0.00316	0.00184
Cadmium	0.00000905	0.0000192	0.0000000506	0.0000000295	0.000000697	0.000000407
Chromium	0.000316	0.000895	0.00000177	0.00000103	0.0000325	0.0000190
Cobalt	0.0000735	0.000265	0.000000411	0.000000240	0.00000965	0.00000563
Iron	0.141	0.0470	0.000787	0.000459	0.00171	0.00100
Lithium	0.00323	0.00287	0.0000180	0.0000105	0.000104	0.0000608
Manganese	0.00903	0.0455	0.0000505	0.0000295	0.00165	0.000965
Mercury	0.00000238	0.00000460	0.0000000133	0.00000000778	0.000000167	0.0000000976
Molybdenum	0.000361	0.000902	0.00000202	0.00000118	0.0000328	0.0000191
Nickel	0.000340	0.000899	0.00000190	0.00000111	0.0000327	0.0000191
Selenium	0.000153	0.000193	0.000000854	0.000000498	0.00000701	0.00000409
Strontium	0.127	0.127	0.000712	0.000415	0.00463	0.00270
Thallium	0.00000683	0.00000683	0.0000000382	0.0000000223	0.000000249	0.000000145
Zinc	0.00170	0.00449	0.00000949	0.00000554	0.000163	0.0000953

Notes:

COPC = contaminant of potential concern

BW = body weight

Table 4.3-5: Dose of Contaminants of Potential Concern via the Drinking Water Ingestion Route in the Project Case (Closure)

Exposure Characteristics			Recreational Land Users		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Days/7 Days			7	7	7	7
Weeks/52 Weeks			8	8	52	52
Water Ingestion Rate (L/day)			0.6	1.5	0.6	1.5
Relative Absorption Factor (unitless)			1	1	1	1
Body Weight (kg)			16.5	70.7	16.5	70.7
Contaminant of Potential Concern	Closure Phase Water Concentration for Recreational Land Users (mg/L)	Closure Phase Water Concentration for Resident Land Users (mg/L)	Estimated Daily Dose (mg/kg BW/day)			
			Recreational Land Users		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Aluminum	0.115	0.0251	0.000642	0.000375	0.000912	0.000532
Arsenic	0.000869	0.000873	0.00000486	0.00000284	0.0000317	0.0000185
Barium	0.0538	0.0845	0.000301	0.000176	0.00307	0.00179
Boron	0.0462	0.0956	0.000258	0.000151	0.00348	0.00203
Cadmium	0.0000332	0.0000318	0.000000186	0.000000108	0.00000116	0.000000675
Chromium	0.000585	0.000927	0.00000327	0.00000191	0.0000337	0.0000197
Cobalt	0.000813	0.000672	0.00000455	0.00000265	0.0000245	0.0000143
Iron	0.132	0.0460	0.000736	0.000429	0.00167	0.000976
Lithium	0.0253	0.00979	0.0001416	0.0000826	0.000356	0.000208
Manganese	0.0179	0.0456	0.0000999	0.0000583	0.00166	0.000967
Mercury	0.00000248	0.0000115	0.0000000139	0.00000000810	0.000000419	0.000000245
Molybdenum	0.00168	0.00161	0.00000942	0.00000549	0.0000585	0.0000341
Nickel	0.00156	0.00154	0.00000874	0.00000510	0.0000561	0.0000327
Selenium	0.00128	0.000753	0.00000715	0.00000417	0.0000274	0.0000160
Strontium	0.310	0.310	0.00174	0.00101	0.0113	0.00659
Thallium	0.000245	0.000245	0.00000137	0.000000799	0.00000890	0.00000519
Zinc	0.00245	0.00472	0.0000137	0.00000800	0.000172	0.000100

Notes:

COPC = contaminant of potential concern

BW = body weight

4.3.3 Inadvertent Soil Ingestion

The Baseline 95% UCLM concentrations of COPCs in soil from 30 sites located within the Human Health LSA (Table 4.3-6) were used as the EPC in Equation 8 to calculate the dose of COPCs humans receive

from incidental soil ingestion in the Base Case. Predicted Project Case soil concentrations based on COPCs in dustfall in Operation (**Table 4.3-7**) were used as the EPC in Equation 8 to calculate the dose of COPCs humans receive from incidental soil ingestion under the Project Case (Operation and Closure). Equation 8 was used to calculate human exposure to COPCs (mg/kg BW-day) from soil ingestion, as recommended by Health Canada (2019a):

$$Dose = \frac{C_S \times IR_S \times RAF_{Oral} \times D_2 \times D_3}{BW} \quad \text{[Equation 8]}$$

where:

- $Dose$ = dose of COPC from inadvertent soil ingestion (mg/kg BW-day)
- C_S = concentration of COPC in soil (mg/kg)
- IR_S = receptor soil ingestion rate (kg/d)
- RAF_{Oral} = relative absorption factor from the gastrointestinal tract, assumed to be 1 (unitless)
- D_2 = days per week exposed/7 days
- D_3 = weeks per year exposed/52 weeks
- BW = body weight (kg BW)

A sample calculation for inadvertent ingestion of aluminum with soil by a Recreational Land User toddler in Base Case using Equation 8 is:

$$Dose = \frac{\frac{19404 \text{ mg}}{\text{kg}} \times \frac{0.00008 \text{ kg}}{\text{day}} \times 1 \times \frac{7 \text{ days}}{7 \text{ days}} \times \frac{8 \text{ weeks}}{52 \text{ weeks}}}{16.5 \text{ kg BW}}$$

$$Dose = 0.014 \text{ mg/kg BW} \cdot \text{day}$$

The doses of COPCs via the soil ingestion exposure route for toddlers and adults for the Base Case is presented in **Table 4.3-6**, and for the Project Case (Operation and Closure) are presented in **Table 4.3-7**.

The assumptions used in the calculation of the dose of COPCs via inadvertent soil ingestion were:

- Baseline soil EPC concentrations are representative of Baseline soil quality within the Human Health LSA;
- Soil quality does not take into consideration garden soils that are commonly amended with external sources of soil, compost, mulch and/or fertilizers;
- Toddlers have a soil ingestion rate of 0.00008 kg/day (Health Canada 2019a).
- Adults have a soil ingestion rate of 0.00002 kg/day (Health Canada 2019a);
- COPC concentrations below the MDL were replaced with concentrations of half of the MDL.
- Project Case soil EPCs were based on dust deposition rates and associated assumptions listed in Section 3.4.1.2.

Table 4.3-6: Estimated Daily Dose of COPCs via Inadvertent Soil Ingestion in the Base Case

Exposure Characteristics		Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
		Toddler	Adult	Toddler	Adult
Days/7 Days		7	7	7	7
Weeks/52 Weeks		8	8	52	52
Soil Ingestion Rate (kg/day)		0.00008	0.00002	0.00008	0.00002
Relative Absorption Factor (unitless)		1	1	1	1
Body Weight (kg)		16.5	70.7	16.5	70.7
COPC	Baseline Soil Concentration (mg/kg) ^a	Dose from Incidental Ingestion of Soil (mg/kg BW/day)			
		Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
		Toddler	Adult	Toddler	Adult
Aluminum	19404	0.0145	0.000844	0.0941	0.00549
Arsenic	9.24	0.00000689	0.000000402	0.0000448	0.00000261
Barium	254	0.000189	0.0000111	0.00123	0.0000718
Boron	3.00	0.00000224	0.000000131	0.0000145	0.000000849
Cadmium	0.462	0.000000345	0.0000000201	0.00000224	0.000000131
Chromium	24.8	0.0000185	0.00000108	0.000120	0.00000702
Cobalt	12.5	0.00000933	0.000000544	0.0000606	0.00000354
Iron	36438	0.0272	0.00159	0.177	0.0103
Lithium	13.5	0.0000100	0.000000586	0.0000653	0.00000381
Manganese	1079	0.000805	0.0000470	0.00523	0.000305
Mercury	0.056	0.0000000419	0.00000000244	0.000000272	0.0000000159
Molybdenum	0.846	0.000000631	0.0000000368	0.00000410	0.000000239
Nickel	20.8	0.0000155	0.000000906	0.000101	0.00000589
Selenium	0.177	0.000000132	0.00000000771	0.000000859	0.0000000501
Strontium	59.4	0.0000443	0.00000258	0.000288	0.0000168
Thallium	0.0699	0.0000000522	0.00000000304	0.000000339	0.0000000198
Zinc	108	0.0000808	0.00000472	0.000525	0.0000307

Notes:

COPC = contaminant of potential concern

BW = body weight

^a This is the 95%UCLM Baseline soil concentration. Only sites that are modeled in the Air Quality model are included in the Baseline concentration.

Table 4.3-7: Estimated Daily Dose of COPCs via Inadvertent Soil Ingestion in Project Case (Operation and Closure)

Exposure Characteristics		Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
		Toddler	Adult	Toddler	Adult
Days/7 Days		7	7	7	7
Weeks/52 Weeks		8	8	52	52
Soil Ingestion Rate (kg/day)		0.00008	0.00002	0.00008	0.00002
Relative Absorption Factor (unitless)		1	1	1	1
Body Weight (kg)		16.5	70.7	16.5	70.7
COPC	Operation and Closure Soil Concentration (mg/kg) ^a	Dose from Incidental Ingestion of Soil (mg/kg BW-day)			
		Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
		Toddler	Adult	Toddler	Adult
Aluminum	19501	0.0145	0.000849	0.0946	0.00552
Arsenic	9.64	0.00000719	0.000000420	0.0000467	0.00000273
Barium	256	0.000191	0.0000111	0.00124	0.0000724
Boron	16.9	0.0000126	0.000000737	0.0000821	0.00000479
Cadmium	0.532	0.000000397	0.0000000232	0.00000258	0.000000151
Chromium	25.6	0.0000191	0.00000111	0.000124	0.00000724
Cobalt	12.7	0.00000945	0.000000551	0.0000614	0.00000358
Iron	36585	0.0273	0.00159	0.177	0.0103
Lithium	13.5	0.0000100	0.000000586	0.0000653	0.00000381
Manganese	1087	0.000811	0.0000473	0.00527	0.000308
Mercury	0.128	0.0000000953	0.00000000556	0.000000620	0.0000000361
Molybdenum	0.923	0.000000688	0.0000000402	0.00000447	0.000000261
Nickel	21.6	0.0000161	0.000000939	0.000105	0.00000611
Selenium	1.57	0.00000117	0.0000000682	0.00000760	0.000000444
Strontium	62.8	0.0000469	0.00000273	0.000305	0.0000178
Thallium	0.227	0.000000170	0.000000010	0.00000110	0.0000000643
Zinc	119	0.0000887	0.00000517	0.000577	0.0000336

Notes:

COPC = contaminant of potential concern

BW = body weight

^a This is the 95%UCLM Baseline soil concentration. Only sites that are modeled in the Air Quality model are included in the Baseline concentration.

4.3.4 Dermal Absorption from Soil

Soil EPCs for the Base Case and Project Case for the dermal absorption pathway are the same as described in Section 4.3.3 for inadvertent soil ingestion. Equation 9 was used to calculate the dose of COPCs (mg/kg BW-day) via dermal absorption from soil, as recommended by Health Canada (2019a):

$$Dose = \frac{[\sum(C_S \times SA \times SL)] \times RAF_{Derm} \times EF \times D_2 \times D_3}{BW} \quad \text{[Equation 9]}$$

where:

- $Dose$ = dose of COPC from dermal contact with soil (mg/kg BW-day)
- C_S = concentration of COPC in soil (mg/kg)
- SA = surface area of skin exposed to soil for hands and the body other than hands (cm²)
- SL = soil loading rate to exposed skin for hands and the body other than hands (kg/cm²-event)
- RAF_{Derm} = relative dermal absorption factor (unitless)
- EF = exposure frequency (events/day)
- D_2 = days per week exposed/7 days
- D_3 = weeks per year exposed/52 weeks
- BW = body weight (kg BW)

A sample calculation for the dose of aluminum via dermal contact with soil for a Recreational Land User toddler in Base Case using Equation 9 is:

$$Dose = \frac{\frac{19404 \text{ mg}}{\text{kg}} \times \left\{ \left(430 \text{ cm}^2 \times \frac{1 \times 10^{-7} \text{ kg}}{\text{cm}^2 \cdot \text{event}} \right) + \left(5700 \text{ cm}^2 \times \frac{1 \times 10^{-8} \text{ kg}}{\text{cm}^2 \cdot \text{event}} \right) \right\} \times 0.01 \times \frac{1 \text{ event}}{\text{day}} \times \frac{7 \text{ days}}{7 \text{ days}} \times \frac{8 \text{ weeks}}{52 \text{ weeks}}}{16.5 \text{ kg BW}}$$

$$Dose = 0.000181 \text{ mg/kg BW} \cdot \text{day}$$

The assumptions listed for the soil ingestion pathway were also used in the calculation of the dose via dermal soil contact, plus additional assumptions:

- The entire body is exposed to soil.
- Skin surface areas for hands and areas other than hands and associated soil loading rates were obtained from Health Canada (2019a).
- Exposure frequency (events) is once a day.
- Dermal absorption factors were obtained from (Health Canada 2021b), US EPA (1995), and EBRC (2007). Where metal-specific dermal absorption factors were unavailable, a RAF_{Derm} of 0.01 (1%) was assumed as per guidance from US EPA Region 3 (US EPA 2020).

The dose of COPCs via the dermal soil contact exposure route for toddlers and adults are presented in **Table 4.3-8** for the Base Case and **Table 4.3-9** for the Project Case (Operation and Closure).

Table 4.3-8: Dose of Contaminants of Potential Concern via Dermal Soil Contact in Base Case

Exposure Characteristics	Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
	Toddler	Adult	Toddler	Adult
Events/day	1	1	1	1
Days/7 Days	7	7	7	7
Weeks/52 Weeks	8	8	52	52
Surface area of hands exposed for soil loading (cm ²) ^a	430	890	430	890
Surface area of body, other than hands, exposed for soil loading (cm ²) ^a	5700	16750	5700.0	16750

Exposure Characteristics			Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Soil loading rate to exposed skin of hands (kg/cm ² -event) ^a			0.00000010	0.00000010	0.00000010	0.00000010
Soil loading rate to exposed skin of body, other than hands (kg/cm ² -event) ^a			0.00000001	0.00000001	0.00000001	0.00000001
Body weight (kg)			16.5	70.7	16.5	70.7
COPC	Baseline Soil Concentration (mg/kg) ^b	Relative Dermal Absorption Factor (unitless)	Estimated Daily Dose (mg/kg BW/day)			
			Recreational Land User		Indigenous and Non-indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Aluminum	19404	0.01 ^d	0.000181	0.000108	0.00118	0.000704
Arsenic	9.24	0.03 ^{c,e}	0.000000258	0.000000155	0.00000168	0.00000101
Barium	254	0.10 ^e	0.0000237	0.0000142	0.000154	0.0000921
Boron	3.00	0.01 ^e	0.0000000280	0.0000000167	0.000000182	0.000000109
Cadmium	0.462	0.001 ^c	0.000000000431	0.000000000258	0.00000000280	0.00000000168
Chromium	24.8	0.10 ^e	0.00000231	0.00000138	0.0000150	0.00000900
Cobalt	12.5	0.01 ^d	0.000000117	0.0000000698	0.000000758	0.000000454
Iron	36438	0.01 ^d	0.000340	0.000203	0.00221	0.00132
Lithium	13.5	0.01 ^d	0.000000126	0.0000000752	0.000000816	0.000000489
Manganese	1079	0.01 ^d	0.0000101	0.00000602	0.0000654	0.0000391
Mercury	0.0562	1.00 ^e	0.0000000524	0.0000000314	0.000000340	0.000000204
Molybdenum	0.846	0.01 ^e	0.00000000789	0.00000000472	0.0000000513	0.0000000307
Nickel	21	0.091 ^e	0.000001766	0.00000106	0.0000115	0.00000687
Selenium	0.177	0.01 ^e	0.00000000165	0.000000000989	0.0000000107	0.00000000643
Strontium	59.4	0.01 ^d	0.000000554	0.000000331	0.00000360	0.00000215
Thallium	0.0699	0.01 ^d	0.000000000652	0.000000000390	0.00000000424	0.00000000254
Zinc	108.4	0.10 ^e	0.0000101	0.00000605	0.0000657	0.0000393

Notes:

COPC = contaminant of potential concern

BW = body weight

^a Values from Health Canada (2019).

^b This is the 95%UCLM Baseline soil concentration. Only sites that are modeled in the Air Quality model are included in the Baseline concentration.

^c US EPA (2004) Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Washington, DC. July 2004. Exhibit 3-4.

^d US EPA (1995) Assessing Dermal Exposure from Soil - December 1995. US EPA Region 3, Technical Guidance Manual, Risk Assessment. Available at <https://www.epa.gov/risk/assessing-dermal-exposure-soil>. Accessed September 2020.

^e Health Canada (2021) Federal Contaminated Sites Risk Assessment in Canada: Toxicological Reference Values (TRVs), Version 3.0., Ottawa, ON.

Table 4.3-9: Dose of Contaminants of Potential Concern via Dermal Soil Contact in Project Case (Operation and Closure)

Exposure Characteristics			Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Events/day			1	1	1	1
Days/7 Days			7	7	7	7
Weeks/52 Weeks			8	8	52	52
Surface area of hands exposed for soil loading (cm ²) ^a			4.56	9.53	4.56	9.53
Surface area of body, other than hands, exposed for soil loading (cm ²) ^a			28.0	89.1	28.0	89.1
Soil loading rate to exposed skin of hands (kg/cm ² -event) ^a			0.0000001	0.0000001	0.0000001	0.0000001
Soil loading rate to exposed skin of body, other than hands (kg/cm ² -event) ^a			0.00000001	0.00000001	0.00000001	0.00000001
Body weight (kg)			16.5	70.7	16.5	70.7
COPC	Operations Phase Soil Concentration (mg/kg) ^b	Relative Dermal Absorption Factor (unitless)	Estimated Daily Dose (mg/kg BW-day)			
			Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Aluminum	19501	0.01 ^d	0.000182	0.000109	0.00118	0.000707
Arsenic	9.64	0.03 ^{c,e}	0.000000270	0.000000161	0.00000175	0.00000105
Barium	256	0.10 ^e	0.0000239	0.0000143	0.000155	0.0000929
Boron	16.9	0.01 ^e	0.000000158	0.0000000945	0.00000103	0.000000614
Cadmium	0.532	0.001 ^c	0.000000000496	0.000000000297	0.00000000323	0.00000000193
Chromium	25.6	0.10 ^e	0.00000239	0.00000143	0.0000155	0.00000929
Cobalt	12.7	0.01 ^d	0.000000118	0.0000000707	0.000000768	0.000000460
Iron	36585	0.01 ^d	0.000341	0.000204	0.00222	0.00133
Lithium	13.5	1.00 ^e	0.000000126	0.0000000752	0.000000816	0.000000489
Manganese	1087	0.01 ^e	0.0000101	0.00000607	0.0000659	0.0000394
Mercury	0.128	0.091 ^e	0.000000119	0.0000000713	0.000000774	0.000000464
Molybdenum	0.923	0.01 ^e	0.00000000860	0.00000000515	0.0000000559	0.0000000335
Nickel	22	0.01 ^e	0.00000183	0.00000110	0.0000119	0.00000713

COPC	Operations Phase Soil Concentration (mg/kg) ^b	Relative Dermal Absorption Factor (unitless)	Estimated Daily Dose (mg/kg BW-day)			
			Recreational Land User		Indigenous and Non-Indigenous Resident Land Users	
			Toddler	Adult	Toddler	Adult
Selenium	1.57	0.01 ^d	0.0000000146	0.000000009	0.0000000950	0.0000000569
Strontium	62.8	0.01 ^d	0.000000586	0.000000351	0.000000381	0.000000228
Thallium	0.227	0.10 ^e	0.00000000212	0.00000000127	0.0000000138	0.000000008
Zinc	119	0.01 ^d	0.0000111	0.00000664	0.0000721	0.0000431

Notes:

COPC = contaminant of potential concern

BW = body weight

^a Values from Health Canada (2019).

^b This is the 95%UCLM Baseline soil concentration. Only sites that are modeled in the Air Quality model are included in the Baseline concentration.

^c US EPA (2004) Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Washington, DC. July 2004. Exhibit 3-4.

^d US EPA (1995) Assessing Dermal Exposure from Soil - December 1995. US EPA Region 3, Technical Guidance Manual, Risk Assessment. Available at <https://www.epa.gov/risk/assessing-dermal-exposure-soil>. Accessed September 2020.

^e Health Canada (2021) Federal Contaminated Sites Risk Assessment in Canada: Toxicological Reference Values (TRVs), Version 3.0., Ottawa, ON.

4.3.5 Subsistence Foods Ingestion

4.3.5.1 Exposure Point Concentrations in Fish

The sources of Base Case and Project Case data for fish tissue concentrations were described in Section 3.4.6. The 95% UCLM fish tissue COPC concentrations measured in Baseline studies were used as the EPCs for the Base Case and the 95% UCLM fish tissue COPC concentration predicted based on the BCFs were used as the Project Case EPCs (**Appendix A to this HHRA, Table A-13**).

4.3.5.2 Exposure Point Concentrations in Vegetation

EPCs for the Base Case and Project Case in berries and farm produce (leaves and stem vegetation) were calculated as described in Section 3.4.3 using soil-to-plant BCFs and Baseline and predicted soil concentrations. The 95% UCLM concentrations were used in both cases. Baseline EPCs are shown in **Appendix A to this HHRA, Tables A-7 and A-8**, and Project Case (Operation and Closure) EPCs are shown in **Table A-9**.

4.3.5.3 Exposure Point Concentrations in Terrestrial Wildlife Tissue

No terrestrial wildlife species from the Human Health LSA were harvested to obtain tissue samples. Rather, COPC concentrations in moose, deer, black bear, snowshoe hare, and grouse tissue were estimated using a food chain model described in Golder Associates (2005) and recommended by Health Canada (2018). **Appendix D to this HHRA** describes the food chain model used to predict the tissue concentrations. The model used the Base Case or Project Case 95% UCLM concentrations of COPCs in water, soil, vegetation (leaves/stems and berries), and fish tissue, in addition to wildlife ingestion rates and COPC-specific BTFs. The model also takes into account foraging time in the LSA to enable evaluation of COPC uptake associated with exposures occurring within the LSA.

Each terrestrial wildlife species was assumed to take up COPCs from the environmental medium (soil, water, fish, and vegetation) based on information known about the species' life histories. Tables in **Appendix D to this HHRA** present the modelled deer, moose, black bear, snowshoe hare, and grouse COPC concentrations in tissue for the Base Case and Project Case (Operation and Closure).

For calculations of dose for arsenic, the arsenic concentration in subsistence food items was adjusted to account for the amount of inorganic arsenic that is likely to be present, as that is the most toxic form. The inorganic arsenic fraction was used in the calculation of the dose from subsistence foods. For deer, moose, black bear, and snowshoe hare it was assumed that 70% of the total arsenic was inorganic and for grouse it was assumed that 50% of the total arsenic was inorganic (EFSA 2009, 2014). For berries and leaves/stem vegetation it was assumed that 74% of the arsenic was inorganic (JECFA 2011a). For fish it was assumed that 10% of the arsenic was inorganic (Phillips 1990; Slejkovec, Bajc, and Doganoc 2004; Rosemond, Xie, and Liber 2008; Rahman, Haseqawa, and Lim 2012). For soil and water ingestion, it was assumed that 100% of the arsenic was inorganic.

4.3.5.4 Dose from Subsistence Foods Ingestion

The dose of each COPC for toddlers and adults was based on the EPCs for each subsistence food and the human ROC characteristics. Equation 10 was used to calculate dose of COPCs (mg/kg BW-day) from subsistence food consumption, as recommended by Health Canada (2019a):

$$Dose = \frac{(\sum [C_{food\ i} \times IR_{food\ i} \times RAF_{oral\ i} \times D_i])}{BW \times 365} \quad \text{[Equation 10]}$$

where:

<i>Dose</i>	= dose of COPC from ingestion with subsistence foods (mg/kg BW-day)
<i>C_{food i}</i>	= concentration of COPC in food (mg/kg wwt)
<i>IR_{food i}</i>	= receptor ingestion rate of food (kg wwt/day; see Table 4.1-3)
<i>RAF_{oral i}</i>	= relative absorption factor from the gastrointestinal tract for COPC, assumed to be 1 (unitless)
<i>D_i</i>	= days per year during which consumption of food will occur (days/year; Table 4.1-3)
<i>BW</i>	= body weight (kg BW)
<i>365</i>	= total days per year (days/year)

Assumptions used in the calculation of the dose of COPCs via ingestion of subsistence foods were:

- COPC concentrations below the MDL were replaced with concentrations of half of the MDL;
- Only one serving per day is consumed;
- Since BTFs for wildlife species are not currently available, the BTFs for moose, deer, black bear, and snowshoe hare were assumed to be equivalent to published BTFs for cattle (Staven et al. 2003; RAIS 2020) and the BTFs for grouse were assumed to be equivalent to published BTFs for chicken (Staven et al. 2003; US EPA 2005b);

- The cattle and poultry BTFs are for uptake from food-to-tissue and it was assumed that the same BTFs would apply to uptake from water-to-tissue. BTFs from soil to tissue were calculated based on guidance by US EPA (2007). The BTFs also assume that animals are in a steady state and that their chemical intake rates are constant.
- The diets of moose, deer, black bear, snowshoe hare, and grouse include only the vegetation species that were collected in Baseline field studies and in the proportions used in the food chain model (95% UCLM concentrations from each species pooled);
- All subsistence foods consumed by people in a year came from within the Human Health LSA;
- Animals consume water, soil, and vegetation at the rates and frequencies used in the food chain model.
- The consumption rates of subsistence foods described in Section 4.1.1 and 4.1.2 are representative of land users who may harvest subsistence foods within the LSA.
- Moose, deer, black bear, snowshoe hare, grouse, and berries represent the subsistence foods that land users consume.

A sample calculation of the estimated daily dose of aluminum for toddlers from ingestion of snowshoe hare in the Base Case using Equation 11 is provided below. Similar calculations for each of the other subsistence foods were also completed using Equation 11:

$$Dose_{hare} = \frac{C_{hare} \times IR \times RAF \times D}{BW \times 365} \quad [\text{Equation 11}]$$

$$Dose_{hare} = \frac{\frac{0.00664 \text{ mg}}{\text{kg}} \times \frac{0.0775 \text{ kg}}{\text{day}} \times 1 \times \frac{8 \text{ days}}{\text{year}}}{16.5 \text{ kg BW} \times \frac{365 \text{ days}}{\text{year}}}$$

$$Dose_{hare} = 6.83 \times 10^{-7} \text{ mg/kg BW} \cdot \text{day}$$

A sample calculation of the dose of aluminum from ingestion of all subsistence foods ($Dose_{food}$) is provided below for toddlers for Baseline conditions. The dose of aluminum for each subsistence food item was calculated first (see sample calculation using Equation 11) and then the dose from all species was summed using Equation 12.

$$Dose_{food} = Dose_{moose \text{ meat}} + Dose_{moose \text{ organs}} + Dose_{deer \text{ meat}} + Dose_{deer \text{ organs}} + Dose_{bear} + Dose_{hare} + Dose_{grouse} + Dose_{trout} + Dose_{berries}$$

[Equation 12]

$$Dose_{food} = (0.000127 + 0.0000129 + 0.0000143 + 0.0000128 + 0.00000912 + 0.000114 + 0.000000688 + 0.00495 + 0.000154) \text{ mg/kg BW} \cdot \text{day}$$

$$Dose_{food} = 0.00540 \text{ mg/kg BW} \cdot \text{day}$$

The dose of each COPC for toddler and adult ROCs is presented for the Base Case in **Table 4.3-10**, for the Project Case (Operation) in **Table 4.3-11**, and for the Project Case (Closure) in **Table 4.3-12**.

4.3.6 Market Foods Ingestion

Contaminants of potential concern may also be present in foods in the market (retail or commercial) food system. As per guidance from the BC Ministry of Health (BC MOH 2021) and Health Canada (2018, 2019), dose from ingestion of market foods is included in the HHRA to estimate the overall exposure to COPCs from food ingestion. The doses from market foods are independent of the Project phase as it is assumed that people will consume the same amount of market foods every year (in addition to

subsistence foods). Thus, the same dose of POCs from market foods is applied to the Base Case and Project Case (Operation and Closure) (**Tables 4.3-10 to 4.3-12**).

The calculation of the daily dose for non-carcinogenic (threshold) parameters and for carcinogenic (non-threshold POC – arsenic) from ingestion of market foods is presented in **Appendix E to this HHRA**.

Table 4.3-10: Dose of Contaminants of Potential Concern from the Ingestion of Subsistence Food by Human Receptors in the Base Case

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)							
	Dose from Moose Meat		Dose from Moose Organs		Dose from Mule Deer Meat		Dose from Mule Deer Organs	
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.000127	0.0000590	0.0000129	0.00000597	0.0000143	0.00000662	0.0000128	0.00000593
Arsenic	0.00000836	0.00000388	0.00000285	0.00000132	0.000000951	0.000000441	0.00000287	0.00000133
Barium	0.000177	0.0000821	0.0000558	0.0000259	0.00000498	0.00000231	0.0000139	0.00000646
Boron	0.000383	0.000178	0.0000863	0.0000400	0.0000109	0.00000507	0.0000219	0.0000101
Cadmium	0.00000577	0.00000268	0.00000249	0.00000115	0.000000653	0.000000303	0.00000250	0.00000116
Chromium	0.0000341	0.0000158	0.00000619	0.00000287	0.000000956	0.000000443	0.00000154	0.000000714
Cobalt	0.0000438	0.0000203	0.0000797	0.0000370	0.00000123	0.000000569	0.0000198	0.00000919
Iron	0.0270	0.0125	0.00608	0.00282	0.000759	0.000352	0.00152	0.000704
Lithium	0.0000435	0.0000202	0.00000757	0.00000351	0.00000130	0.000000601	0.00000200	0.000000929
Manganese	0.00111	0.000517	0.000173	0.0000804	0.0000317	0.0000147	0.0000438	0.0000203
Mercury	0.00000939	0.00000435	0.00000687	0.00000319	0.00000124	0.000000576	0.00000806	0.00000374
Molybdenum	0.0000787	0.0000365	0.0000587	0.0000273	0.00000229	0.00000106	0.0000152	0.00000703
Nickel	0.000139	0.0000643	0.00306	0.00142	0.00000397	0.00000184	0.000778	0.000361
Selenium	0.000127	0.0000590	0.0000347	0.0000161	0.0000145	0.00000674	0.0000352	0.0000163
Strontium	0.0113	0.00525	0.0238	0.0111	0.000317	0.000147	0.00593	0.00275
Thallium	0.00000190	0.000000883	0.000000437	0.000000203	0.0000000558	0.0000000259	0.000000114	0.0000000527
Zinc	0.0237	0.0110	0.00237	0.00110	0.00284	0.00132	0.00253	0.00117

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)							
	Dose from American Black Bear		Dose from Grouse		Dose from Snowshoe Hare		Dose from Rainbow Trout	
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.00000912	0.00000423	0.000114	0.0000528	0.000000688	0.000000319	0.00496	0.00230
Arsenic	0.0000000149	0.000000007	0.0000000786	0.0000000365	0.000000001	0.000000000	0.000000860	0.000000399
Barium	0.00000207	0.000000960	0.00000217	0.00000101	0.000000192	0.0000000892	0.000201	0.0000931
Boron	0.00000503	0.00000233	0.000137	0.0000636	0.000000422	0.000000196	0.0000107	0.00000495
Cadmium	0.0000000242	0.0000000112	0.000000775	0.000000359	0.000000002	0.000000001	0.00000686	0.00000318
Chromium	0.000000409	0.000000190	0.000000204	0.0000000945	0.0000000369	0.0000000171	0.00000846	0.00000393
Cobalt	0.000000556	0.000000258	0.00000118	0.000000545	0.0000000474	0.0000000220	0.00000962	0.00000446
Iron	0.000371	0.000172	0.000367	0.000170	0.0000293	0.0000136	0.00914	0.00424
Lithium	0.000000783	0.000000363	0.00000142	0.000000660	0.0000000500	0.0000000232	0.00000545	0.00000253
Manganese	0.0000144	0.00000666	0.0000316	0.0000147	0.00000123	0.000000569	0.000865	0.000401
Mercury	0.00000115	0.000000534	0.000000002	0.000000001	0.0000000532	0.0000000247	0.00000305	0.00000142
Molybdenum	0.00000118	0.000000547	0.000000715	0.000000332	0.0000000883	0.0000000410	0.00000147	0.000000684
Nickel	0.00000189	0.000000878	0.000000007	0.000000003	0.000000153	0.0000000712	0.00000785	0.00000364
Selenium	0.00000132	0.000000612	0.00000527	0.00000245	0.0000000330	0.0000000153	0.000227	0.000105
Strontium	0.000130	0.0000603	0.0000304	0.0000141	0.0000123	0.00000569	0.000451	0.000209
Thallium	0.0000000355	0.0000000165	0.0000000119	0.000000006	0.000000002	0.000000001	0.000000391	0.000000181
Zinc	0.000865	0.000401	0.00114	0.000530	0.0000646	0.0000300	0.00209	0.000969

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)						Total Dose from Subsistence Foods only (not including Garden Produce) - Recreational Receptor (mg/kg BW/day)	
	Dose from Berries		Dose from Garden Produce (Leaves) ⁽¹⁾		Background Dose from Market Food [mg/kg BW/day]			
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.000154	0.0000715	0.00143	0.000710	0.0642	0.0251	0.00540	0.00251
Arsenic	0.000000458	0.000000212	0.00000164	0.000000812	0.00316	0.00105	0.0000164	0.00000763
Barium	0.000512	0.000237	0.00296	0.00146	0.0318	0.0122	0.000968	0.000449
Boron	0.000663	0.000308	0.00151	0.000749	NA	NA	0.00132	0.000611
Cadmium	0.00000286	0.00000133	0.0000115	0.00000571	0.00108	0.000438	0.0000219	0.0000102
Chromium	0.00000141	0.000000652	0.0000129	0.00000636	0.00101	0.000426	0.0000533	0.0000247
Cobalt	0.000000735	0.000000341	0.00000745	0.00000369	0.000446	0.000179	0.000157	0.0000727
Iron	0.000780	0.000362	0.00451	0.00223	0.423	0.177	0.0460	0.0213
Lithium	0.0000164	0.00000759	0.0000113	0.00000560	0.00134	0.000539	0.0000784	0.0000364
Manganese	0.00265	0.00123	0.00715	0.00354	0.206	0.0833	0.00493	0.00229
Mercury	0.000000546	0.000000253	0.000000528	0.000000261	0.000187	0.0000661	0.0000304	0.0000141
Molybdenum	0.0000305	0.0000142	0.0000386	0.0000191	0.0108	0.00422	0.000189	0.0000876
Nickel	0.0000363	0.0000168	0.0000721	0.0000357	0.00936	0.00401	0.00403	0.00187
Selenium	0.00000392	0.00000182	0.00000597	0.00000295	0.00472	0.00199	0.000449	0.000208
Strontium	0.000517	0.000240	0.00480	0.00238	NA	NA	0.0426	0.0197
Thallium	0.000000136	0.0000000631	0.000000134	0.0000000665	0.0000325	0.0000129	0.00000309	0.00000143
Zinc	0.000443	0.000206	0.00196	0.000971	0.417	0.173	0.0360	0.0167

Notes:

¹ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

NA = Literature data were not available for COPC in market foods.

Grey shading indicates background doses.

Metal COPCs	Total Dose from Subsistence Foods only (including Garden Produce) - Residential Receptor (mg/kg BW/day)		Total Dose from Subsistence and Background Market Foods (not including Garden Produce) - Recreational Receptor (mg/kg BW/day)		Total Dose from Subsistence and Background Market Foods (including Garden Produce) - Residential Receptor (mg/kg BW/day)	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.00684	0.00322	0.0696	0.0276	0.0711	0.0284
Arsenic	0.0000181	0.00000844	0.00317	0.00105	0.00317	0.00105
Barium	0.00393	0.00191	0.0328	0.0126	0.0357	0.0141
Boron	0.00283	0.00136	0.00132	0.000611	0.00283	0.00136
Cadmium	0.0000335	0.0000159	0.00110	0.000448	0.00111	0.000454
Chromium	0.0000662	0.0000311	0.00107	0.000450	0.00108	0.000457
Cobalt	0.000164	0.0000764	0.000603	0.000252	0.000610	0.000255
Iron	0.0505	0.0236	0.469	0.198	0.474	0.201
Lithium	0.0000897	0.0000420	0.00142	0.000575	0.00143	0.000581
Manganese	0.0121	0.00583	0.210	0.0856	0.218	0.0891
Mercury	0.0000309	0.0000144	0.000218	0.0000802	0.000218	0.0000804
Molybdenum	0.000227	0.000107	0.0110	0.00431	0.0110	0.00433
Nickel	0.00410	0.00190	0.0134	0.00587	0.0135	0.00591
Selenium	0.000455	0.000211	0.00517	0.00220	0.00518	0.00220
Strontium	0.0474	0.0221	0.0426	0.0197	0.0474	0.0221
Thallium	0.00000322	0.00000150	0.0000355	0.0000144	0.0000357	0.0000144
Zinc	0.0380	0.0177	0.453	0.190	0.455	0.191

Notes:

Grey shading indicates inclusion of background doses.

Table 4.3-11: Dose of Contaminants of Potential Concern from the Ingestion of Subsistence Food by Human Receptors in the Project Case (Operation)

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)							
	Dose from Moose Meat		Dose from Moose Organs		Dose from Mule Deer Meat		Dose from Mule Deer Organs	
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.000156	0.0000723	0.0000158	0.00000731	0.0000176	0.00000817	0.0000158	0.00000733
Arsenic	0.000000163	0.0000000754	0.0000000554	0.0000000257	0.00000105	0.000000487	0.00000317	0.00000147
Barium	0.000178	0.0000826	0.0000561	0.0000260	0.00000501	0.00000232	0.0000140	0.00000650
Boron	0.00109	0.000504	0.000245	0.000114	0.0000319	0.0000148	0.0000639	0.0000296
Cadmium	0.00000612	0.00000284	0.00000264	0.00000122	0.000000694	0.000000322	0.00000265	0.00000123
Chromium	0.0000365	0.0000170	0.00000663	0.00000308	0.00000103	0.000000477	0.00000165	0.000000767
Cobalt	0.0000453	0.0000210	0.0000824	0.0000382	0.00000127	0.000000590	0.0000205	0.00000952
Iron	0.0304	0.0141	0.00685	0.00318	0.000859	0.000399	0.00172	0.000797
Lithium	0.0000439	0.0000204	0.00000765	0.00000355	0.00000131	0.000000607	0.00000202	0.000000938
Manganese	0.00112	0.000520	0.000174	0.0000809	0.0000319	0.0000148	0.0000440	0.0000204
Mercury	0.0000180	0.00000834	0.0000132	0.00000611	0.00000238	0.00000111	0.0000155	0.00000719
Molybdenum	0.0000821	0.0000381	0.0000613	0.0000285	0.00000239	0.00000111	0.0000158	0.00000735
Nickel	0.000142	0.0000658	0.00313	0.00145	0.00000407	0.00000189	0.000797	0.000370
Selenium	0.000548	0.000254	0.000150	0.0000695	0.0000642	0.0000298	0.000156	0.0000722
Strontium	0.0116	0.00537	0.0244	0.0113	0.000325	0.000151	0.00607	0.00282
Thallium	0.00000831	0.00000385	0.00000191	0.000000884	0.000000244	0.000000113	0.000000497	0.000000231
Zinc	0.0246	0.0114	0.00246	0.00114	0.00296	0.00137	0.00263	0.00122

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)							
	Dose from American Black Bear		Dose from Grouse		Dose from Snowshoe Hare		Dose from Rainbow Trout	
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.0000115	0.00000534	0.000143	0.0000665	0.000000850	0.000000394	0.00594	0.00275
Arsenic	0.0000000173	0.0000000805	0.0000000874	0.0000000405	0.00000000115	0.00000000535	0.00000100	0.000000465
Barium	0.00000209	0.000000968	0.00000218	0.00000101	0.000000193	0.0000000898	0.000234	0.000109
Boron	0.0000186	0.00000861	0.000426	0.000198	0.00000123	0.000000573	0.0000333	0.0000154
Cadmium	0.0000000268	0.0000000124	0.000000829	0.000000384	0.00000000223	0.00000000104	0.00000930	0.000000431
Chromium	0.000000462	0.000000214	0.000000220	0.000000102	0.0000000397	0.0000000184	0.0000159	0.00000737
Cobalt	0.000000602	0.000000279	0.00000122	0.000000567	0.0000000491	0.0000000228	0.0000142	0.00000660
Iron	0.000438	0.000203	0.000420	0.000195	0.0000332	0.0000154	0.0126	0.00584
Lithium	0.000000971	0.000000450	0.00000143	0.000000663	0.0000000503	0.0000000233	0.0000751	0.0000348
Manganese	0.0000145	0.00000671	0.0000318	0.0000147	0.00000123	0.000000572	0.000994	0.000461
Mercury	0.00000183	0.000000847	0.000000003	0.000000002	0.000000102	0.0000000475	0.00000303	0.00000141
Molybdenum	0.00000129	0.000000601	0.000000749	0.000000347	0.0000000923	0.0000000428	0.0000337	0.0000156
Nickel	0.00000195	0.000000905	0.000000007	0.000000003	0.000000157	0.0000000729	0.00000962	0.00000446
Selenium	0.00000342	0.00000159	0.0000246	0.0000114	0.000000146	0.0000000677	0.000227	0.000105
Strontium	0.000135	0.0000626	0.0000312	0.0000145	0.0000125	0.00000582	0.000617	0.000286
Thallium	0.000000147	0.0000000680	0.0000000521	0.0000000242	0.00000000943	0.00000000438	0.00000107	0.000000497
Zinc	0.000885	0.000411	0.00119	0.000554	0.0000672	0.0000312	0.00245	0.00114

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)						Total Dose from Subsistence Foods only (not including Garden Produce) - Recreational Receptor(mg/kg BW/day)	
	Dose from Berries		Dose from Garden Produce (Leaves) ⁽¹⁾		Background Dose from Market Food [mg/kg BW/day]			
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.000734	0.000340	0.00193	0.000955	0.0642	0.0251	0.00722	0.00335
Arsenic	0.000000709	0.000000329	0.00000186	0.000000919	0.00316	0.00105	0.00000625	0.00000290
Barium	0.000520	0.000241	0.00297	0.00147	0.0318	0.0122	0.00101	0.000469
Boron	0.000674	0.000313	0.00154	0.000761	NA	NA	0.00258	0.00120
Cadmium	0.00000289	0.00000134	0.0000116	0.00000574	0.00108	0.000438	0.0000251	0.0000117
Chromium	0.00000274	0.00000127	0.0000140	0.00000695	0.00101	0.000426	0.0000652	0.0000303
Cobalt	0.00000112	0.000000518	0.00000780	0.00000386	0.000446	0.000179	0.000167	0.0000774
Iron	0.00181	0.000840	0.00539	0.00267	0.423	0.177	0.0551	0.0256
Lithium	0.0000164	0.00000759	0.0000113	0.00000560	0.00134	0.000539	0.000149	0.0000690
Manganese	0.00268	0.00124	0.00719	0.00356	0.206	0.0833	0.00509	0.00236
Mercury	0.000000899	0.000000417	0.000000848	0.000000420	0.000187	0.0000661	0.0000549	0.0000255
Molybdenum	0.0000308	0.0000143	0.0000389	0.0000193	0.0108	0.00422	0.000228	0.000106
Nickel	0.0000372	0.0000173	0.0000730	0.0000362	0.00936	0.00401	0.00412	0.00191
Selenium	0.00000395	0.00000183	0.00000601	0.00000298	0.00472	0.00199	0.00118	0.000546
Strontium	0.000520	0.000241	0.00482	0.00239	NA	NA	0.0437	0.0203
Thallium	0.000000803	0.000000372	0.000000714	0.000000353	0.0000325	0.0000129	0.0000130	0.00000605
Zinc	0.000447	0.000207	0.00197	0.000975	0.417	0.173	0.0377	0.0175

Notes:

¹ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

NA = Literature data were not available for COPC in market foods.

Grey shading indicates inclusion of background doses.

Metal COPCs	Total Dose from Subsistence Foods only (including Garden Produce) – Residential Receptor(mg/kg BW/day)		Total Dose from Subsistence and Background Market Foods (not including Garden Produce) – Recreational Receptor(mg/kg BW/day)		Total Dose from Subsistence and Background Market Foods (including Garden Produce) – Residential Receptor(mg/kg BW/day)	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.00915	0.00430	0.0715	0.0285	0.0734	0.0294
Arsenic	0.00000811	0.00000382	0.00316	0.00105	0.00316	0.00105
Barium	0.00398	0.00194	0.0328	0.0126	0.0358	0.0141
Boron	0.00412	0.00196	0.00258	0.00120	0.00412	0.00196
Cadmium	0.0000367	0.0000174	0.00111	0.000450	0.00112	0.000455
Chromium	0.0000792	0.0000372	0.00108	0.000456	0.00109	0.000463
Cobalt	0.000175	0.0000812	0.000613	0.000256	0.000620	0.000260
Iron	0.0605	0.0282	0.479	0.203	0.484	0.205
Lithium	0.000160	0.0000746	0.00149	0.000608	0.00150	0.000613
Manganese	0.0123	0.00592	0.211	0.0857	0.218	0.0892
Mercury	0.0000557	0.0000259	0.000242	0.0000915	0.000243	0.0000920
Molybdenum	0.000267	0.000125	0.0110	0.00432	0.0110	0.00434
Nickel	0.00419	0.00195	0.0135	0.00592	0.0136	0.00595
Selenium	0.00118	0.000549	0.00590	0.00253	0.00590	0.00254
Strontium	0.0485	0.0226	0.0437	0.0203	0.0485	0.0226
Thallium	0.0000138	0.00000640	0.0000455	0.0000190	0.0000462	0.0000193
Zinc	0.0397	0.0185	0.455	0.191	0.457	0.192

Notes:

Grey shading indicates inclusion of background doses.

Table 4.3-12: Dose of Contaminants of Potential Concern from the Ingestion of Subsistence Food by Human Receptors in the Project Case (Closure)

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)							
	Dose from Moose Meat		Dose from Moose Organs		Dose from Mule Deer Meat		Dose from Mule Deer Organs	
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.000128	0.0000593	0.0000129	0.00000599	0.0000143	0.00000665	0.0000128	0.00000596
Arsenic	0.00000861	0.00000400	0.00000293	0.00000136	0.000000979	0.000000454	0.00000296	0.00000137
Barium	0.000178	0.0000825	0.0000560	0.0000260	0.00000500	0.00000232	0.0000140	0.00000649
Boron	0.00109	0.000505	0.000245	0.000114	0.0000320	0.0000148	0.0000639	0.0000297
Cadmium	0.00000611	0.00000284	0.00000263	0.00000122	0.000000693	0.000000322	0.00000265	0.00000123
Chromium	0.0000347	0.0000161	0.00000629	0.00000292	0.000000972	0.000000451	0.00000157	0.000000726
Cobalt	0.0000444	0.0000206	0.0000807	0.0000375	0.00000124	0.000000577	0.0000201	0.00000931
Iron	0.0271	0.0126	0.00610	0.00283	0.000761	0.000353	0.00152	0.000707
Lithium	0.0000484	0.0000224	0.00000842	0.00000391	0.00000142	0.000000658	0.00000219	0.00000102
Manganese	0.00112	0.000520	0.000174	0.0000807	0.0000319	0.0000148	0.0000440	0.0000204
Mercury	0.0000166	0.00000769	0.0000121	0.00000563	0.00000220	0.00000102	0.0000143	0.00000663
Molybdenum	0.0000822	0.0000381	0.0000614	0.0000285	0.00000239	0.00000111	0.0000159	0.00000735
Nickel	0.000141	0.0000655	0.00311	0.00145	0.00000405	0.00000188	0.000793	0.000368
Selenium	0.000550	0.000255	0.000150	0.0000696	0.0000643	0.0000298	0.000156	0.0000723
Strontium	0.0116	0.00539	0.0244	0.0113	0.000326	0.000151	0.00608	0.00282
Thallium	0.00000493	0.00000229	0.00000113	0.000000525	0.000000145	0.0000000670	0.000000294	0.000000136
Zinc	0.0246	0.0114	0.00246	0.00114	0.00296	0.00137	0.00263	0.00122

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)							
	Dose from American Black Bear		Dose from Grouse		Dose from Snowshoe Hare		Dose from Rainbow Trout	
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.00000969	0.00000449	0.000114	0.0000530	0.000000691	0.000000320	0.00634	0.00294
Arsenic	0.0000000210	0.000000010	0.0000000807	0.0000000374	0.00000000107	0.000000000498	0.00000226	0.00000105
Barium	0.00000208	0.000000967	0.00000218	0.00000101	0.000000193	0.0000000896	0.000235	0.000109
Boron	0.0000186	0.00000861	0.000426	0.000198	0.00000123	0.000000573	0.0000506	0.0000235
Cadmium	0.0000000306	0.0000000142	0.0000000828	0.0000000384	0.00000000223	0.00000000104	0.0000356	0.0000165
Chromium	0.000000451	0.000000209	0.000000207	0.0000000962	0.0000000375	0.0000000174	0.0000225	0.0000105
Cobalt	0.00000111	0.000000516	0.00000119	0.000000551	0.0000000479	0.0000000222	0.000115	0.0000532
Iron	0.000392	0.000182	0.000369	0.000171	0.0000294	0.0000136	0.0130	0.00603
Lithium	0.00000170	0.000000787	0.00000147	0.000000684	0.0000000532	0.0000000247	0.000333	0.000154
Manganese	0.0000148	0.00000686	0.0000317	0.0000147	0.00000123	0.000000571	0.00359	0.00167
Mercury	0.00000172	0.000000797	0.00000000315	0.00000000146	0.0000000944	0.0000000438	0.00000305	0.00000142
Molybdenum	0.00000133	0.000000615	0.000000749	0.000000347	0.0000000923	0.0000000428	0.0000532	0.0000247
Nickel	0.00000198	0.000000919	0.00000000683	0.00000000317	0.000000156	0.0000000725	0.0000350	0.0000162
Selenium	0.00000342	0.00000159	0.0000246	0.0000114	0.000000146	0.0000000677	0.000227	0.000105
Strontium	0.000137	0.0000637	0.0000313	0.0000145	0.0000126	0.00000583	0.00167	0.000777
Thallium	0.000000497	0.000000231	0.0000000304	0.0000000141	0.00000000552	0.00000000256	0.0000394	0.0000183
Zinc	0.000919	0.000426	0.00119	0.000554	0.0000672	0.0000312	0.00378	0.00175

Metal COPCs	Dose from Ingestion of Subsistence Foods (mg/kg BW/day)						Total Dose from Subsistence Foods Only (not including Garden Produce) – Recreational Receptor(mg/kg BW/day)	
	Dose from Berries		Dose from Garden Produce (Leaves) ⁽¹⁾		Background Dose from Market Food [mg/kg BW/day]			
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.000155	0.0000717	0.00144	0.000713	0.0642	0.0251	0.00679	0.00315
Arsenic	0.000000459	0.000000213	0.00000165	0.000000815	0.00316	0.00105	0.0000183	0.00000849
Barium	0.000513	0.000238	0.00297	0.00147	0.0318	0.0122	0.00101	0.000466
Boron	0.000673	0.000312	0.00154	0.000761	NA	NA	0.00260	0.00121
Cadmium	0.00000287	0.00000133	0.0000116	0.00000573	0.00108	0.000438	0.0000514	0.0000238
Chromium	0.00000141	0.000000656	0.0000129	0.00000640	0.00101	0.000426	0.0000681	0.0000316
Cobalt	0.000000738	0.000000342	0.00000748	0.00000370	0.000446	0.000179	0.000264	0.000123
Iron	0.000783	0.000363	0.00452	0.00224	0.423	0.177	0.0500	0.0232
Lithium	0.0000164	0.00000759	0.0000113	0.00000560	0.00134	0.000539	0.000413	0.000191
Manganese	0.00266	0.00123	0.00717	0.00355	0.206	0.0833	0.00767	0.00356
Mercury	0.000000727	0.000000337	0.000000702	0.000000348	0.000187	0.0000661	0.0000508	0.0000236
Molybdenum	0.0000307	0.0000143	0.0000389	0.0000192	0.0108	0.00422	0.000248	0.000115
Nickel	0.0000364	0.0000169	0.0000724	0.0000358	0.00936	0.00401	0.00413	0.00191
Selenium	0.00000394	0.00000183	0.00000600	0.00000297	0.00472	0.00199	0.00118	0.000547
Strontium	0.000519	0.000241	0.00482	0.00239	NA	NA	0.0448	0.0208
Thallium	0.000000251	0.000000117	0.000000248	0.000000123	0.0000325	0.0000129	0.0000467	0.0000217
Zinc	0.000444	0.000206	0.00197	0.000974	0.417	0.173	0.0390	0.0181

Notes:

¹ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

NA = Literature data were not available for COPC in market foods.

Grey shading indicates inclusion of background doses.

Metal COPCs	Total Dose from Subsistence Foods only (including Garden Produce) - Residential Receptor(mg/kg BW/day)		Total Dose from Subsistence and Background Market Foods (not including Garden Produce) - Recreational Receptor(mg/kg BW/day)		Total Dose from Subsistence and Background Market Foods (including Garden Produce) - Residential Receptor(mg/kg BW/day)	
	Toddler	Adult	Toddler	Adult	Toddler	Adult
Aluminum	0.00823	0.00386	0.0710	0.0283	0.0725	0.0290
Arsenic	0.0000200	0.00000931	0.00317	0.00105	0.00318	0.00106
Barium	0.00397	0.00194	0.0328	0.0126	0.0358	0.0141
Boron	0.00413	0.00197	0.00260	0.00121	0.00413	0.00197
Cadmium	0.0000630	0.0000296	0.00113	0.000462	0.00114	0.000468
Chromium	0.0000811	0.0000380	0.00108	0.000457	0.00110	0.000464
Cobalt	0.000272	0.000126	0.000710	0.000301	0.000718	0.000305
Iron	0.0545	0.0254	0.473	0.200	0.478	0.203
Lithium	0.000424	0.000197	0.00175	0.000730	0.00177	0.000736
Manganese	0.0148	0.00711	0.213	0.0869	0.220	0.0904
Mercury	0.0000515	0.0000239	0.000238	0.0000897	0.000239	0.0000900
Molybdenum	0.000287	0.000134	0.0110	0.00433	0.0111	0.00435
Nickel	0.00420	0.00195	0.0135	0.00592	0.0136	0.00596
Selenium	0.00118	0.000550	0.00590	0.00254	0.00590	0.00254
Strontium	0.0496	0.0232	0.0448	0.0208	0.0496	0.0232
Thallium	0.0000470	0.0000218	0.0000792	0.0000346	0.0000794	0.0000347
Zinc	0.0410	0.0191	0.456	0.191	0.458	0.192

Notes:

Grey shading indicates inclusion of background doses.

4.3.7 Total Dose of Non-carcinogenic Contaminants from all Pathways

To calculate the Hazard Quotient (HQ) for each COPC the total estimated daily dose ($Dose_{total}$ in mg/kg BW-day) of COPCs from all exposure routes was calculated:

$$Dose_{total} = Dose_{inhalation} + Dose_{water\ ingestion} + Dose_{soil\ ingestion} + Dose_{soil\ contact} + Dose_{S-food} + Dose_{M-food}$$

[Equation 13]

Where:

$Dose_{inhalation}$	= estimated daily dose of COPC from inhalation (mg/kg BW-day)
$Dose_{water\ ingestion}$	= estimated daily dose of COPC from water ingestion (mg/kg BW-day)
$Dose_{water\ contact}$	= estimated daily dose of COPC from dermal water contact (mg/kg BW-day)
$Dose_{soil\ ingestion}$	= estimated daily dose of COPC from incidental ingestion of soil (mg/kg BW-day)
$Dose_{soil\ contact}$	= estimated daily dose of COPC from dermal soil contact (mg/kg BW-day)
$Dose_{S-food}$	= estimated daily dose of COPC from subsistence food ingestion (mg/kg BW-day)
$Dose_{M-food}$	= estimated daily dose of COPC from market food ingestion (mg/kg BW-day)

An example calculation for the total dose of aluminum for the Recreational Land User toddler in the Base Case using [Equation 13] is:

$$Dose_{total} = (0.0000021 + 0.00055 + 0.014 + 0.00018 + 0.0054 + 0.064) \text{ mg/kg BW} \cdot \text{day}$$

$$Dose_{total} = 0.085 \text{ mg/kg BW} \cdot \text{day}$$

The dose from each exposure pathway and total doses for all human ROCs in the Base Case and Project Cases are presented in **Appendix G, Tables G-2 to G-13**. Background doses from ingestion of market foods are generally in the same order of magnitude or higher compared to doses from subsistence foods or other exposure pathways for most COPCs.

4.4 Dose for Non-threshold Contaminants of Potential Concern

4.4.1 Inhalation Exposure Route

Carcinogenic COPCs in air (arsenic, cadmium, chromium, and nickel) were assessed by using COPC concentrations in air ($\mu\text{g}/\text{m}^3$; **Table 4.3-1** and **Table 4.3-2**), the exposure duration (ED; years) for each life stage and the ADAF to calculate the LADD using Equation 14, and then compared against TRVs expressed as cancer unit risk factors (UR) for each individual life stage.

Exposure to carcinogens may not be constant throughout a ROC's life as receptor characteristics such as inhalation/ingestion rates and body weights vary with life stage. To account for exposures during more sensitive life stages, which are typically younger life stages, the LADD is calculated for a "composite" adult ROC. The composite receptor uses life stage-specific exposure characteristics to calculate the exposure dose for each life stage and then the exposures the adult has experienced to carcinogens during the different life stages are incorporated by summing individual life stage doses.

Table 4.4-1 presents the LADD for each life stage from inhalation of COPCs in the LSA. An example calculation for inhalation of arsenic by an infant Residential Land User in the Base Case using Equation 14 and a summation across age groups (infant, toddler, child, teen, and adult) using Equation 15 are provided below.

$$Dose = \sum_i (C \times TR_i \times ADAF_i \times D_1 \times D_2 \times D_3)$$

[Equation 14]

Where:

$Dose$ = lifetime average daily dose of COPC from air inhalation ($\mu\text{g}/\text{m}^3$)

- C = Concentration of metal in air bound to PM_{10} (mg/m^3)
 TR_i = Fraction of time exposed for lifestage i (ED in years / 80 years)
 $ADAF_i$ = Age-dependent adjustment factor for lifestage i (unitless)
 D_1 = hours per day exposed (24 hours / 24 hours)
 D_2 = days per week exposed/7 days
 D_3 = weeks per year exposed/52 weeks

$$Dose_{infant} = \frac{0.000219 \mu g}{m^3} \times \frac{0.5 \text{ years}}{80 \text{ years}} \times 10 \times \frac{24 \text{ hours}}{24 \text{ hours}} \times \frac{7 \text{ days}}{7 \text{ days}} \times \frac{52 \text{ weeks}}{52 \text{ weeks}}$$

$$Dose_{infant} = 1.37 \times 10^{-5} \mu g/m^3$$

$$Dose = Dose_{infant} + Dose_{toddler} + Dose_{child} + Dose_{teen} + Dose_{Adult} \quad [\text{Equation 15}]$$

$$Dose = (1.37 \times 10^{-5} + 6.16 \times 10^{-5} + 5.75 \times 10^{-5} + 4.38 \times 10^{-5} + 1.64 \times 10^{-4}) \mu g/m^3$$

$$Dose = 3.41 \times 10^{-4} \mu g/m^3$$

Table 4.4-1: Lifetime Average Daily Dose of Contaminants of Potential Concern from Inhalation of Non-threshold Metals ($\mu g/m^3$)

	Infant	Toddler	Child	Teen	Adult
ED (Health Canada, 2013)	0.5	4.5	7	8	60
ADAF (Health Canada 2013)	10	5	3	2	1
Base Case					
Recreational Land User					
Arsenic LADD	2.10×10^{-6}	9.47×10^{-6}	8.84×10^{-6}	6.74×10^{-6}	2.53×10^{-5}
Cadmium LADD	2.90×10^{-7}	1.31×10^{-6}	1.22×10^{-6}	9.29×10^{-7}	3.48×10^{-6}
Chromium LADD	2.90×10^{-6}	1.31×10^{-5}	1.22×10^{-5}	9.29×10^{-6}	3.48×10^{-5}
Nickel LADD	2.90×10^{-6}	1.31×10^{-5}	1.22×10^{-5}	9.29×10^{-6}	3.48×10^{-5}
Indigenous and Non-Indigenous Resident Land Users					
Arsenic LADD	1.37×10^{-5}	6.16×10^{-5}	5.75×10^{-5}	4.38×10^{-5}	1.64×10^{-4}
Cadmium LADD	1.89×10^{-6}	8.49×10^{-6}	7.93×10^{-6}	6.04×10^{-6}	2.26×10^{-5}
Chromium LADD	1.89×10^{-5}	8.49×10^{-5}	7.93×10^{-5}	6.04×10^{-5}	2.26×10^{-4}
Nickel LADD	1.89×10^{-5}	8.49×10^{-5}	7.93×10^{-5}	6.04×10^{-5}	2.26×10^{-4}
Project Case (Operation)					
Recreational Land Users					
Arsenic LADD	2.47×10^{-6}	1.11×10^{-5}	1.04×10^{-5}	7.91×10^{-6}	2.97×10^{-5}
Cadmium LADD	3.37×10^{-7}	1.52×10^{-6}	1.42×10^{-6}	1.08×10^{-6}	4.05×10^{-6}
Chromium LADD	3.86×10^{-6}	1.74×10^{-5}	1.62×10^{-5}	1.23×10^{-5}	4.63×10^{-5}
Nickel LADD	3.72×10^{-6}	1.67×10^{-5}	1.56×10^{-5}	1.19×10^{-5}	4.47×10^{-5}
Indigenous and Non-Indigenous Resident Land Users					
Arsenic LADD	1.61×10^{-5}	7.23×10^{-5}	6.75×10^{-5}	5.14×10^{-5}	1.93×10^{-4}
Cadmium LADD	2.19×10^{-6}	9.86×10^{-6}	9.20×10^{-6}	7.01×10^{-6}	2.63×10^{-5}
Chromium LADD	2.51×10^{-5}	1.13×10^{-4}	1.05×10^{-4}	8.02×10^{-5}	3.01×10^{-4}

	Infant	Toddler	Child	Teen	Adult
Nickel LADD	2.42×10^{-05}	1.09×10^{-04}	1.02×10^{-04}	7.74×10^{-05}	2.90×10^{-04}
Project Case (Closure)					
Recreational Land Users					
Arsenic LADD	2.10×10^{-06}	9.47×10^{-06}	8.84×10^{-06}	6.74×10^{-06}	2.53×10^{-05}
Cadmium LADD	2.90×10^{-07}	1.31×10^{-06}	1.22×10^{-06}	9.29×10^{-07}	3.48×10^{-06}
Chromium LADD	2.90×10^{-06}	1.31×10^{-05}	1.22×10^{-05}	9.29×10^{-06}	3.48×10^{-05}
Nickel LADD	2.90×10^{-06}	1.31×10^{-05}	1.22×10^{-05}	9.29×10^{-06}	3.48×10^{-05}
Indigenous and Non-Indigenous Resident Land Users					
Arsenic LADD	1.37×10^{-05}	6.16×10^{-05}	5.75×10^{-05}	4.38×10^{-05}	1.64×10^{-04}
Cadmium LADD	1.89×10^{-06}	8.49×10^{-06}	7.93×10^{-06}	6.04×10^{-06}	2.26×10^{-05}
Chromium LADD	1.89×10^{-05}	8.49×10^{-05}	7.93×10^{-05}	6.04×10^{-05}	2.26×10^{-04}
Nickel LADD	1.89×10^{-05}	8.49×10^{-05}	7.93×10^{-05}	6.04×10^{-05}	2.26×10^{-04}

Notes:

ED = Age Group Duration (years)

ADAF = Age-dependent adjustment factor for lifestage (unitless)

LADD = Lifetime average daily dose

4.4.2 Ingestion Exposure Route

Of the COPCs, only arsenic is a carcinogen via the ingestion exposure pathway. Doses for arsenic as a carcinogen are based on the LADD, which is calculated using the same dose equations as for non-carcinogens except there is an additional term in the equation to account for exposure duration across a lifetime.

The LADD was calculated based on the 95% UCLM dose for the Base Case, Project Case (Operation,) and Project Case (Closure) over the lifetime of a human receptor (80 years; Health Canada 2019a). This essentially represents a lifetime exposure rather than exposure over the duration of the Project and, thus, dose averaging is a reasonable approach.

The LADD is defined by the following equation (Health Canada 2013):

$$LADD = [ER \times ED] / LE$$

[Equation 16]

where:

LADD = lifetime average daily dose from ingestion (mg/kg BW-day)

ER = exposure rate (mg/kg BW-day) as calculated for threshold COPCs in Sections 4.3.2 to 4.3.6

ED = exposure duration (years)

LE = life expectancy (80 years)

4.4.2.1 Dose from Drinking Water

Equation 16 was used to calculate human exposure to arsenic (mg/kg BW-day) from drinking groundwater and surface water.

A sample calculation for ingestion of arsenic with water by a Recreational Land User toddler for the Base Case is:

$$LADD = \frac{0.000465 \text{ mg}}{L} \times \frac{0.6 L}{\text{day}} \times 1 \times \frac{7 \text{ days}}{7 \text{ days}} \times \frac{8 \text{ weeks}}{52 \text{ weeks}} \times 4.5 \text{ years}$$

$$LADD = \frac{16.5 \text{ kg BW} \times 80 \text{ years}}{LADD = 1.46 \times 10^{-7} \text{ mg/kg BW} \cdot \text{day}}$$

The dose of arsenic via drinking surface water for each life stage for the Base Case and for Project Cases (Operation and Closure) are in **Table 4.4-2**.

Table 4.4-2: Lifetime Average Daily Dose of Arsenic from Ingestion with Drinking Water

	Infant	Toddler	Child	Teen	Adult
Water IR (HC 2019)	0.3	0.6	0.8	1	1.5
ED (HC, 2019)	0.5	4.5	7	8	60
BW (HC 2019)	8.2	16.5	32.9	59.7	70.7
Base Case					
LADD, Recreational Land User	1.64×10^{-08}	1.46×10^{-07}	1.52×10^{-07}	1.20×10^{-07}	1.14×10^{-06}
LADD, Residential Land User	1.52×10^{-07}	1.36×10^{-06}	1.41×10^{-06}	1.11×10^{-06}	1.06×10^{-05}
Project Case (Operation)					
LADD, Recreational Land User	1.78×10^{-08}	1.59×10^{-07}	1.66×10^{-07}	1.31×10^{-07}	1.24×10^{-06}
LADD, Residential Land User	1.53×10^{-07}	1.37×10^{-06}	1.43×10^{-06}	1.12×10^{-06}	1.07×10^{-05}
Project Case (Closure)					
LADD, Recreational Land User	3.06×10^{-08}	2.74×10^{-07}	2.85×10^{-07}	2.24×10^{-07}	2.13×10^{-06}
LADD, Residential Land User	2.00×10^{-07}	1.78×10^{-06}	1.86×10^{-06}	1.46×10^{-06}	1.39×10^{-05}

Assumptions listed under Section 4.3.2 also apply to the calculation of the LADD.

4.4.2.2 Inadvertent Soil Ingestion

Equation 16 was used to calculate human exposure to arsenic (mg/kg BW-day) from incidental ingestion of soil.

A sample calculation for ingestion of arsenic with soil by a Recreational Land User toddler for Base Case is:

$$LADD = \frac{9.24 \text{ mg}}{\text{kg}} \times \frac{0.00008 \text{ kg}}{\text{day}} \times 1 \times \frac{7 \text{ days}}{7 \text{ days}} \times \frac{8 \text{ weeks}}{52 \text{ weeks}} \times 4.5 \text{ years}$$

$$LADD = \frac{16.5 \text{ kg BW} \times 80 \text{ years}}{LADD = 3.88 \times 10^{-7} \text{ mg/kg BW} \cdot \text{day}}$$

The dose of arsenic via ingestion of soil for each life stage for the Base Case and for Project Cases (Operation and Closure) are in **Table 4.4-3**.

Table 4.4-3: Lifetime Average Daily Dose of Arsenic from Incidental Ingestion with Soil

	Infant	Toddler	Child	Teen	Adult
Water IR (HC 2019)	0.3	0.6	0.8	1	1.5
ED (HC, 2019)	0.5	4.5	7	8	60
BW (HC 2019)	8.2	16.5	32.9	59.7	70.7

	Infant	Toddler	Child	Teen	Adult
Base Case					
LADD, Recreational Land User	2.17×10^{-08}	3.88×10^{-07}	7.56×10^{-08}	4.76×10^{-08}	3.02×10^{-07}
LADD, Residential Land User	1.41×10^{-07}	2.52×10^{-06}	4.91×10^{-07}	3.10×10^{-07}	1.96×10^{-06}
Project Case (Operation)					
LADD, Recreational Land User	2.26×10^{-08}	4.05×10^{-07}	7.89×10^{-08}	4.97×10^{-08}	3.15×10^{-07}
LADD, Residential Land User	1.47×10^{-07}	2.63×10^{-06}	5.13×10^{-07}	3.23×10^{-07}	2.05×10^{-06}
Project Case (Closure)					
LADD, Recreational Land User	2.26×10^{-08}	4.05×10^{-07}	7.89×10^{-08}	4.97×10^{-08}	3.15×10^{-07}
LADD, Residential Land User	1.47×10^{-07}	2.63×10^{-06}	5.13×10^{-07}	3.23×10^{-07}	2.05×10^{-06}

Assumptions listed under Section 4.3.3 also apply to the calculation of the LADD.

4.4.2.3 Dermal Absorption from Soil

Soil EPCs for the Base Case and Project Case for the dermal absorption pathway are the same as for inadvertent soil ingestion. Equation 9 was used to calculate LADD of arsenic (mg/kg BW-day) via dermal absorption from soil, as recommended by Health Canada (2019a):

$$LADD = \frac{[\sum(C_s \times SA \times SL)] \times RAF_{Derm} \times EF \times D_2 \times D_3 \times D_4}{BW \times LE} \quad [\text{Equation 17}]$$

where:

- $LADD$ = lifetime average daily dose of arsenic from dermal contact with soil (mg/kg BW-day)
- C_s = concentration of arsenic in soil (mg/kg)
- SA = surface area of skin exposed to soil for hands and the body other than hands (cm^2)
- SL = soil loading rate to exposed skin for hands and the body other than hands ($\text{kg}/\text{cm}^2\text{-event}$)
- RAF_{Derm} = relative dermal absorption factor (unitless)
- EF = exposure frequency (events/day, assumed to be 1)
- D_2 = days per week exposed/7 days
- D_3 = weeks per year exposed/52 weeks
- D_4 = years exposed during lifetime
- BW = body weight (kg BW)
- LE = life expectancy (80 years)

A sample calculation for the LADD of arsenic via dermal contact with soil for a Recreational Land User toddler in Base Case using Equation 17 is:

$$Dose = \frac{\frac{9.24 \text{ mg}}{\text{kg}} \times \left\{ \left(430 \text{ cm}^2 \times \frac{1 \times 10^{-7} \text{ kg}}{\text{cm}^2 \cdot \text{event}} \right) + \left(5700 \text{ cm}^2 \times \frac{1 \times 10^{-8} \text{ kg}}{\text{cm}^2 \cdot \text{event}} \right) \right\} \times 0.01 \times \frac{1 \text{ event}}{\text{day}} \times \frac{7 \text{ days}}{7 \text{ days}} \times \frac{8 \text{ weeks}}{52 \text{ weeks}} \times 4.5 \text{ years}}{16.5 \text{ kg BW} \times 80 \text{ years}}$$

$$Dose = 1.45 \times 10^{-8} \text{ mg/kg BW} \cdot \text{day}$$

The dose of arsenic via dermal contact with soil for each life stage for the Base Case and for Project Cases (Operation and Closure) are in **Table 4.4-4**.

Table 4.4-4: Lifetime Average Daily Dose of Arsenic from Dermal Contact with Soil

	Infant	Toddler	Child	Teen	Adult
Water IR (HC 2019)	0.3	0.6	0.8	1	1.5
ED (HC, 2019)	0.5	4.5	7	8	60
BW (HC 2019)	8.2	16.5	32.9	59.7	70.7
Base Case					
LADD, Recreational Land User	2.11×10^{-09}	1.45×10^{-08}	1.75×10^{-08}	1.62×10^{-08}	1.16×10^{-07}
LADD, Residential Land User	1.37×10^{-08}	9.45×10^{-08}	1.14×10^{-07}	1.05×10^{-07}	7.54×10^{-07}
Project Case (Operation)					
LADD, Recreational Land User	2.20×10^{-09}	1.52×10^{-08}	1.83×10^{-08}	1.69×10^{-08}	1.21×10^{-07}
LADD, Residential Land User	1.43×10^{-08}	9.86×10^{-08}	1.19×10^{-07}	1.10×10^{-07}	7.87×10^{-07}
Project Case (Closure)					
LADD, Recreational Land User	2.20×10^{-09}	1.52×10^{-08}	1.83×10^{-08}	1.69×10^{-08}	1.21×10^{-07}
LADD, Residential Land User	1.43×10^{-08}	9.86×10^{-08}	1.19×10^{-07}	1.10×10^{-07}	7.87×10^{-07}

Assumptions listed under Section 4.3.4 also apply to the calculation of the LADD.

4.4.2.4 Dose from Subsistence and Market Foods Ingestion

Equation 18 was used to calculate human exposure to arsenic (mg/kg BW-day) from ingestion of subsistence foods and market foods.

The dose of arsenic was based on the EPCs for each subsistence food and the human ROC characteristics.

$$LADD = \frac{(\sum [C_{food\ i} \times IR_{food\ i} \times RAF_{oral\ i} \times D_i]) \times D_4}{BW \times 365 \times LE} \quad [\text{Equation 18}]$$

where:

<i>LADD</i>	= average lifetime daily dose of arsenic from ingestion with foods (mg/kg BW-day)
<i>C_{food i}</i>	= concentration of arsenic in food (mg/kg wwt)
<i>IR_{food i}</i>	= receptor ingestion rate of food (kg wwt/day; see Table 4.1-3)
<i>RAF_{oral i}</i>	= relative absorption factor from the gastrointestinal tract for arsenic, assumed to be 1 (unitless)
<i>D_i</i>	= days per year during which consumption of food will occur (days/year; Table 4.1-3)
<i>D₄</i>	= years exposed during lifetime
<i>BW</i>	= body weight (kg BW)
<i>365</i>	= total days per year (days/year)
<i>LE</i>	= life expectancy (80 years)

A sample calculation for ingestion of arsenic with subsistence foods (Rainbow trout) by a Recreational Land User toddler for the Base Case using Equation 18 is:

$$LADD_{trout} = \frac{\frac{0.00911 \text{ mg}}{\text{kg}} \times \frac{0.0628 \text{ kg}}{\text{day}} \times 1 \times \frac{9 \text{ days}}{\text{year}} \times 4.5 \text{ years}}{16.5 \text{ kg BW} \times \frac{365 \text{ days}}{\text{year}} \times 80 \text{ years}}$$

$$LADD_{trout} = 4.8 \times 10^{-8} \text{ mg/kg BW} \cdot \text{day}$$

A sample calculation of the total dose of arsenic from ingestion of all subsistence foods ($Dose_{food}$) is provided below for toddlers for the Base Case using Equation 12. The dose of arsenic for each subsistence food item was calculated first (see sample calculation using Equation 18) and then the dose from all species was summed using Equation 12.

$$LADD_{food} = ((4.7 \times 10^{-7}) + (1.6 \times 10^{-7}) + (5.3 \times 10^{-8}) + (1.6 \times 10^{-7}) + (8.4 \times 10^{-10}) + (4.4 \times 10^{-9}) + (5.9 \times 10^{-11}) + (4.8 \times 10^{-8}) + (2.6 \times 10^{-8})) \text{mg/kg BW} \cdot \text{day}$$

$$LADD_{food} = 5.2 \times 10^{-7} \text{ mg/kg BW} \cdot \text{day}$$

The dose of each COPC for toddler and adult ROCs is presented for the Base Case in **Table 4.4-5**, for the Project Case (Operation) in **Table 4.4-6**, and for the Project Case (Closure) in **Table 4.4-7**.

Assumptions listed under Section 4.3.5 also apply to the calculation of the LADD.

Table 4.4-5: Lifetime Average Daily Dose of Arsenic from the Ingestion of Subsistence and Market Food by Human Receptors in the Base Case

Lifestage	Duration in Years	Lifetime Average Daily Dose for Age Group from Ingestion of Subsistence Foods (mg/kg BW/day)				
		Dose from Moose Meat	Dose from Moose Organs	Dose from Mule Deer Meat	Dose from Mule Deer Organs	Dose from American Black Bear
Infant ¹	0.5					
Toddler	4.5	4.70×10^{-07}	1.60×10^{-07}	5.35×10^{-08}	1.62×10^{-07}	8.41×10^{-10}
Child ²	7	3.65×10^{-07}	1.24×10^{-07}	4.15×10^{-08}	1.25×10^{-07}	6.52×10^{-10}
Teen ³	8	4.59×10^{-07}	1.56×10^{-07}	5.22×10^{-08}	1.58×10^{-07}	8.21×10^{-10}
Adult	60	2.91×10^{-06}	9.91×10^{-07}	3.31×10^{-07}	1.00×10^{-06}	5.20×10^{-09}

Lifestage	Duration in Years	Lifetime Average Daily Dose for Age Group from Ingestion of Subsistence Foods (mg/kg BW/day)				
		Dose from Grouse	Dose from Snowshoe Hare	Dose from Rainbow Trout	Dose from Berries	Dose from Garden Produce (Leaves) ⁴
Infant ¹	0.5				5.72×10^{-09}	2.05×10^{-08}
Toddler	4.5	4.42×10^{-09}	5.88×10^{-11}	4.84×10^{-08}	2.57×10^{-08}	9.22×10^{-08}
Child ²	7	3.43×10^{-09}	4.56×10^{-11}	3.75×10^{-08}	2.00×10^{-08}	7.15×10^{-08}
Teen ³	8	4.32×10^{-09}	5.74×10^{-11}	4.73×10^{-08}	2.51×10^{-08}	9.61×10^{-08}
Adult	60	2.74×10^{-08}	3.64×10^{-10}	2.99×10^{-07}	1.59×10^{-07}	6.09×10^{-07}

Notes:

¹ Infants are assumed to not be eating meat and therefore only berries and vegetables were used to calculate LADD.

² Children are assumed to have the same consumption rate and frequencies as toddlers.

³ Teens are assumed to have the same consumption rate and frequency as adults.

⁴ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

Lifestage	Duration in Years	Lifetime Average Daily Dose for Age Group from Ingestion of Subsistence Foods (mg/kg BW/day)	Total Dose from Subsistence Foods only (not including Garden Produce) - Recreational Receptor (mg/kg BW/day)	Total Dose from Subsistence Foods Only (including Garden Produce) - Residential Receptor (mg/kg BW/day)	Total Dose from Subsistence and Background Market Foods (not including Garden Produce) - Recreational Receptor (mg/kg BW/day)	Total Dose from Subsistence and Background Market Foods (including Garden Produce) - Residential Receptor (mg/kg BW/day)
		Background Dose from Market Food [mg/kg BW/day]				
Infant ¹	0.5	1.30×10^{-06}	5.72×10^{-09}	2.62×10^{-08}	1.31×10^{-06}	1.33×10^{-06}
Toddler	4.5	3.49×10^{-05}	9.25×10^{-07}	1.02×10^{-06}	3.59×10^{-05}	3.59×10^{-05}
Child ²	7	3.21×10^{-05}	7.17×10^{-07}	7.89×10^{-07}	3.29×10^{-05}	3.29×10^{-05}
Teen ³	8	2.38×10^{-05}	9.04×10^{-07}	1.00×10^{-06}	2.48×10^{-05}	2.48×10^{-05}
Adult	60	1.59×10^{-04}	5.72×10^{-06}	6.33×10^{-06}	1.65×10^{-04}	1.65×10^{-04}

Notes:

¹ Infants are assumed to not be eating meat and therefore only berries and vegetables were used to calculate LADD.

² Children are assumed to have the same consumption rate and frequencies as toddlers.

³ Teens are assumed to have the same consumption rate and frequency as adults.

⁴ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

Table 4.4-6: Lifetime Average Daily Dose of Arsenic from the Ingestion of Subsistence and Market Food by Human Receptors in the Project Case (Operation)

Lifestage	Duration in Years	Lifetime Average Daily Dose for Age Group from Ingestion of Subsistence Foods (mg/kg BW-day)				
		Dose from Moose Meat	Dose from Moose Organs	Dose from Mule Deer Meat	Dose from Mule Deer Organs	Dose from American Black Bear
Infant ¹	0.5					
Toddler	4.5	5.17×10^{-07}	1.76×10^{-07}	5.90×10^{-08}	1.79×10^{-07}	9.75×10^{-10}
Child ²	7	4.02×10^{-07}	1.37×10^{-07}	4.57×10^{-08}	1.38×10^{-07}	7.56×10^{-10}
Teen ³	8	5.05×10^{-07}	1.72×10^{-07}	5.76×10^{-08}	1.74×10^{-07}	9.53×10^{-10}
Adult	60	3.20×10^{-06}	1.09×10^{-06}	3.65×10^{-07}	1.10×10^{-06}	6.03×10^{-09}

Lifestage	Duration in Years	Lifetime Average Daily Dose for Age Group from Ingestion of Subsistence Foods (mg/kg BW-day)				
		Dose from Grouse	Dose from Snowshoe Hare	Dose from Rainbow Trout	Dose from Berries	Dose from Garden Produce (Leaves) ⁴
Infant ¹	0.5				8.86×10^{-09}	2.32×10^{-08}
Toddler	4.5	4.92×10^{-09}	6.49×10^{-11}	4.65×10^{-08}	3.99×10^{-08}	1.04×10^{-07}
Child ²	7	3.81×10^{-09}	5.03×10^{-11}	4.38×10^{-08}	3.09×10^{-08}	8.10×10^{-08}
Teen ³	8	4.80×10^{-09}	6.33×10^{-11}	5.51×10^{-08}	3.90×10^{-08}	1.09×10^{-07}
Adult	60	3.04×10^{-08}	4.01×10^{-10}	3.49×10^{-07}	2.47×10^{-07}	6.89×10^{-07}

Notes:

¹ Infants are assumed to not be eating meat and therefore only berries and vegetables were used to calculate LADD.

² Children are assumed to have the same consumption rate and frequencies as toddlers.

³ Teens are assumed to have the same consumption rate and frequency as adults.

⁴ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

Lifestage	Duration in Years	Background Dose from Market Food [mg/kg BW/day]	Total Dose from Subsistence Foods only (not including Garden Produce) - Recreational Receptor (mg/kg BW/day)	Total Dose from Subsistence Foods only (including Garden Produce) - Residential Receptor (mg/kg BW/day)	Total Dose from Subsistence and Background Market Foods (not including Garden Produce) - Recreational Receptor (mg/kg BW/day)	Total Dose from Subsistence and Background Market Foods (including Garden Produce) - Residential Receptor (mg/kg BW/day)
Infant ¹	0.5	1.30×10^{-06}	8.86×10^{-09}	3.21×10^{-08}	1.31×10^{-06}	1.33×10^{-06}
Toddler	4.5	3.49×10^{-05}	1.03×10^{-06}	1.14×10^{-06}	3.60×10^{-05}	3.61×10^{-05}
Child ²	7	3.21×10^{-05}	8.01×10^{-07}	8.82×10^{-07}	3.29×10^{-05}	3.30×10^{-05}
Teen ³	8	2.38×10^{-05}	1.01×10^{-06}	1.12×10^{-06}	2.49×10^{-05}	2.50×10^{-05}
Adult	60	1.59×10^{-04}	6.39×10^{-06}	7.08×10^{-06}	1.65×10^{-04}	1.66×10^{-04}

Notes:

¹ Infants are assumed to not be eating meat and therefore only berries and vegetables were used to calculate LADD.

² Children are assumed to have the same consumption rate and frequencies as toddlers.

³ Teens are assumed to have the same consumption rate and frequency as adults.

⁴ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

Table 4.4-7: Lifetime Average Daily Dose of Arsenic from the Ingestion of Subsistence and Market Food by Human Receptors in the Project Case (Closure)

Lifestage	Duration in Years	Lifetime Average Daily Dose for Age Group from Ingestion of Subsistence Foods (mg/kg BW/day)				
		Dose from Moose Meat	Dose from Moose Organs	Dose from Mule Deer Meat	Dose from Mule Deer Organs	Dose from American Black Bear
Infant ¹	0.5					
Toddler	4.5	4.84×10^{-07}	1.65×10^{-07}	5.51×10^{-08}	1.66×10^{-07}	1.18×10^{-09}
Child ²	7	3.76×10^{-07}	1.28×10^{-07}	4.27×10^{-08}	1.29×10^{-07}	9.14×10^{-10}
Teen ³	8	4.73×10^{-07}	1.61×10^{-07}	5.38×10^{-08}	1.63×10^{-07}	1.15×10^{-09}
Adult	60	3.00×10^{-06}	1.02×10^{-06}	3.41×10^{-07}	1.03×10^{-06}	7.29×10^{-09}

Lifestage	Duration in Years	Lifetime Average Daily Dose for Age Group from Ingestion of Subsistence Foods (mg/kg BW/day)				
		Dose from Grouse	Dose from Snowshoe Hare	Dose from Rainbow Trout	Dose from Berries	Dose from Garden Produce (Leaves) ⁴
Infant ¹	0.5				5.74×10^{-09}	2.06×10^{-08}
Toddler	4.5	4.54×10^{-09}	6.04×10^{-11}	1.27×10^{-07}	2.58×10^{-08}	9.26×10^{-08}
Child ²	7	3.52×10^{-09}	4.68×10^{-11}	9.86×10^{-08}	2.00×10^{-08}	7.18×10^{-08}
Teen ³	8	4.43×10^{-09}	5.90×10^{-11}	1.24×10^{-07}	2.52×10^{-08}	9.65×10^{-08}
Adult	60	2.81×10^{-08}	3.73×10^{-10}	7.87×10^{-07}	1.60×10^{-07}	6.11×10^{-07}

Notes:

¹ Infants are assumed to not be eating meat and therefore only berries and vegetables were used to calculate LADD.

² Children are assumed to have the same consumption rate and frequencies as toddlers.

³ Teens are assumed to have the same consumption rate and frequency as adults.

⁴ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

Lifestage	Duration in Years	Background Dose from Market Food [mg/kg BW/day]	Total Dose from Subsistence Foods only (not including Garden Produce) - Recreational Receptor (mg/kg BW/day)	Total Dose from Subsistence Foods only (including Garden Produce) - Residential Receptor (mg/kg BW/day)	Total Dose from Subsistence and Background Market Foods (not including Garden Produce) - Recreational Receptor (mg/kg BW/day)	Total Dose from Subsistence and Background Market Foods (including Garden Produce) - Residential Receptor (mg/kg BW/day)
Infant ¹	0.5	1.30×10^{-06}	5.74×10^{-09}	2.63×10^{-08}	1.31×10^{-06}	1.33×10^{-06}
Toddler	4.5	3.49×10^{-05}	1.03×10^{-06}	1.12×10^{-06}	3.60×10^{-05}	3.61×10^{-05}
Child ²	7	3.21×10^{-05}	7.99×10^{-07}	8.70×10^{-07}	3.29×10^{-05}	3.30×10^{-05}
Teen ³	8	2.38×10^{-05}	1.01×10^{-06}	1.10×10^{-06}	2.49×10^{-05}	2.50×10^{-05}
Adult	60	1.59×10^{-04}	6.98×10^{-06}	6.98×10^{-06}	1.65×10^{-04}	1.66×10^{-04}

Notes:

¹ Infants are assumed to not be eating meat and therefore only berries and vegetables were used to calculate LADD.

² Children are assumed to have the same consumption rate and frequencies as toddlers.

³ Teens are assumed to have the same consumption rate and frequency as adults.

⁴ The ingestion rate (IR) of vegetables in Richardson (1997) was adjusted by a factor of 0.1 to account for garden produce only, as per CCME (2006), as the IR in Richardson (1997) includes vegetables from store and garden sources.

5. TOXICITY ASSESSMENT

5.1 Introduction

The toxicity assessment step is to identify applicable toxicity benchmarks to incorporate in the risk characterization step. The toxicity benchmark, known as the TRV, is the level of exposure that is associated with no adverse effects or an acceptable risk threshold.

Toxicity information is typically derived from laboratory studies, where dose-response information is extrapolated from animal test subjects to humans by applying uncertainty or safety factors. In most cases, uncertainty factors (UFs) of 100 to 1,000 are applied by regulatory authorities to the laboratory-derived no observed adverse effect levels (NOAELs). The NOAELs are the highest concentration used in a toxicity test that results in no observed or measured chronic health effects. These UFs account for interspecies extrapolation and the protection of the most susceptible individuals in the population (e.g., children and the elderly). Therefore, TRVs based on animal studies generally have large margins of safety to ensure that the toxicity or risk of a substance to people is not underestimated. Lowest observed adverse effect levels (LOAEL) or NOAELs from human studies have smaller UFs because no extrapolation from animals to humans is required.

5.2 Selection of Regulatory Thresholds for Risk Characterization

For non-carcinogenic chemicals, the TRV is the daily dose that is deemed tolerable or acceptable (i.e., safe). For carcinogenic chemicals, the TRV is referred to as slope factor (SF; relating to exposure dose) or unit risk (UR; relating to exposure concentration). Examples of types of TRVs identified by different regulatory agencies include tolerable daily intake (TDI), acceptable daily intake (ADI), reference dose (RfD), reference concentration (RfC), minimum risk level (MRL), among others. The TDI, ADI, RfD, MRL, and SF are typically used for oral/dermal exposures, while RfC and UR are used for inhalation exposures.

The selection of human health-based AAQOs for the criteria air contaminants (CACs) used the following selection hierarchy:

1. BC Ministry of Environment and Climate Change Strategy;
2. Canadian Council of Ministers for the Environment;
3. United States Environmental Protection Agency; and
4. World Health Organization.

The ambient air quality criteria for the CACs used in this HHRA are summarized in **Table 5.5-1**.

Table 5.5-1: Ambient Air Quality Criteria for Criteria Air Contaminants

CAC	Averaging Period	AAQO ($\mu\text{g}/\text{m}^3$)
PM _{2.5}	24-hour	25
	Annual	8
PM ₁₀	24-hour	50

Notes:

PM_{2.5} = particulate matter equal or less than 2.5 μm in diameter; PM₁₀ = particulate matter equal or less than 10 μm in diameter

AAQO = ambient air quality objective, based on the most conservative BC AAQO (BC ENV 2020b) or CAAQS (CCME 2021a, including standards anticipated for 2025).

For metal COPCs, Health Canada (2019a) states that the preferred TRV source is Health Canada (2010) (recently replaced by Health Canada, 2021); however, TRVs can also be obtained from other regulatory agencies such as:

1. US EPA's Integrated Risk Information System (IRIS);
2. United Nation World Health Organization (WHO; INCHEM database);
3. National Institute for Public Health and the Environment (Netherlands);
4. US Agency for Toxic Substances and Disease Registry (ATSDR); and
5. California Environmental Protection Agency (CalEPA) – Toxic Criteria Database.

BC ENV (2017) states that the province's preferred TRV source is its own, US EPA IRIS, Health Canada (2010; recently replaced by Health Canada 2021), and the WHO followed by the following hierarchy of sources if toxicity factors are not available from USEPA IRIS, Health Canada, or the WHO, as follows:

1. US ATSDR;
2. CalEPA – Toxic Criteria Database;
3. National Institute for Public Health and the Environment (Netherlands);
4. US EPA Regional Screening Levels;
5. Oak Ridge National Laboratory Risk Assessment Information System (RAIS); and
6. other documents or databases published by Canadian or US government agencies.

To be conservative, the most stringent TRV from these sources was selected for each COPC.

Appendix F to this HHRA provides TRVs for all COPCs for each route of exposure, and key cancer and non-cancer health concerns associated with exposure to elevated levels of each COPC.

Tables 5.5-2 and 5.3-3 list the SFs, URs, and TRVs applied to this assessment. Rationale for selection of each TRV, SF, or UR is provided in **Appendix F to this HHRA**.

Table 5.5-2: Slope Factors and Unit Risks Used in the Human Health Risk Assessment.

Contaminant of Potential Concern	Carcinogenic TRV	Source
Ingestion Exposure Route, Slope Factor in (mg/kg BW-day)⁻¹		
Arsenic	1.8	Health Canada (2021b)
Inhalation Exposure Route, Inhalation Unit Risk in (mg/m³)⁻¹		
Arsenic	6.4	Health Canada (2021b)
Cadmium	4.2	Health Canada (2021b)
Chromium	12	US EPA (2022)
Nickel	1.3	Health Canada (2021b)

Table 5.5-3: Toxicity Reference Values Used in the Human Health Risk Assessment.

Contaminant of Potential Concern	Toxicity Reference Value (mg/kg BW-day)	Target Organ or System for Critical Effect	Source
Aluminum	0.29	Renal system	JECFA (2011b)
Arsenic	0.0003	Skin and cardiovascular system	US EPA (2022)
Barium	0.2	Kidney	Health Canada (2021b)
Boron	0.2	Developmental system	US EPA (2022)
Cadmium	0.0008	Kidney	Health Canada (2021b)
Chromium (VI)	0.0022	Gastrointestinal system	Health Canada (2021b)
Cobalt	0.0014	Cardiomyopathy	Oak Ridge National Laboratory (2021)
Iron	0.7	Gastrointestinal system	US EPA (2022)
Lithium	0.002	Nervous system	Oak Ridge National Laboratory (2021)
Manganese	0.025	Nervous and developmental system	Health Canada (2021b)
Mercury	0.0003	Immune system, Kidney	Health Canada (2021b)
Molybdenum	0.005	Urinary System	US EPA (2022)
Nickel	0.0013	Reproductive system	Health Canada (2021b)
Selenium	0.0060 (toddlers) 0.0057 (adults)	Nervous system, Skin (selenosis), blood	Health Canada (2021b)
Strontium	0.6	Musculoskeletal system	US EPA (2022)
Thallium	0.000088 (toddler) 0.0000025 (adult)	Not applicable (average dietary intake)	(Health Canada 2011a)
Zinc	0.48 (toddler) 0.57 (adult)	Blood	Health Canada (2021b)

6. RISK CHARACTERIZATION

6.1 Introduction

Using the results of the exposure assessment and toxicity assessment, human health risks were quantified using either concentration ratios (CRs) or hazard quotients (HQs). The CR is the ratio between the concentration (in air) and the TRV, and is applied to CACs. The HQ is the ratio between the dose and the TRV and provides an overall risk estimate for a metal COPC through various exposure pathways (ingestion, inhalation, dermal contact). In addition, the incremental lifetime cancer risk (ILCR) was determined for COPCs that may be associated with carcinogenic potential via inhalation (i.e., arsenic, cadmium, chromium, and nickel) or ingestion (i.e., arsenic).

6.2 Estimation of Non-carcinogenic Risks Using Concentration Ratios: Inhalation of Criteria Air Contaminants

Concentration ratios were calculated for the Base Case and Project Case at receptor locations. Maximum CRs at key receptor locations are provided in **Table 6.2-1**. Results for all individual receptor locations are provided in **Appendix G to this HHRA, Table G-1**.

Table 6.2-1: Concentration Ratios for Criteria Air Contaminants at Receptor Locations in the Base Case and Project Case (Operations)

CAC	Averaging Period	Telkwa ^a	Backcountry Horsemen Camp	Rural Residence
Maximum CR for Project Contribution				
PM ₁₀	24-hour	0.03	0.50	0.22
PM _{2.5}	24-hour	0.02	0.17	0.09
	Annual	0.01	0.06	0.05
Maximum CR for Project plus Base Case				
PM ₁₀	24-hour	1.16	0.80	0.52
PM _{2.5}	24-hour	1.38	0.58	0.50
	Annual	1.41	0.41	0.40
CAC	Averaging Period	BC ENV- Telkwa ^a	PM-Kerr	Rural Residence
Minimum CR for Base Case				
PM ₁₀	24-hour	NA	0.11 ^b	NA
PM _{2.5}	24-hour	1.36	0.17 ^b	NA
	Annual	1.34	0.27 ^b	NA

Notes:

Bold and highlighted numbers indicate a CR higher than the acceptable threshold of 1.

CR = Concentration Ratio.

NA = Not applicable, no measurement available for Base Case (see Tables 3.4-1 and 3.4-2), and Appendix 4.1-C of the EAC Application.

^a Telkwa refers to sensitive receptor locations within the Village of Telkwa in the air quality model domain. BC ENV Telkwa refers to the BC Ministry of Environment and Climate Change Strategy ambient air quality monitoring station.

^b Data recorded from January 1 to 16, 2020.

Because the MPOI (maximum concentration in LSA) is located adjacent to the fence line of the Project where human ROCs are not expected to be present, the likelihood of a person being exposed to CACs at the location of the maximum ground level concentration where and when the maximum concentrations may happen is expected to be negligible and health risks are not expected. Potential risks are evaluated for locations where people currently reside and likely recreate, as these are the locations where exposure would occur.

Because PM_{2.5} and PM₁₀ concentrations experienced in the Project Case were calculated to include concentrations experienced during the Base Case, the CR, and hence the potential risk associated with human exposure to particular matter, generated for the Project Case incorporates the potential risks associated with human exposure to background contamination while in the LSA. Therefore, the risk threshold for CRs is 1. Concentration ratios below 1 indicate that there is no risk to human health from the CAC for the referenced averaging period. Concentration ratios above 1 indicate that there may be a potential for risks to human health from inhalation of CACs for the referenced averaging period that should be investigated further.

Calculated CRs for the Base Case and predicted Project Case plus background for PM₁₀ and PM_{2.5} are less than 1 for all averaging periods at the Horsemen Camp, at PM Kerr and at the closest rural residence. Thus, no human health risks from the inhalation of fine particulate matter are expected at these receptor locations.

Calculated CRs for the Base Case and predicted Project Case plus background for PM_{2.5} and PM₁₀ (Project plus background only) are greater than 1 for all averaging periods in Telkwa. As evident from the CRs for PM₁₀ and PM_{2.5} presented in **Table 6.2-1**, the CRs are not significantly different between the Base Case and predicted Project Case, and the contributions from the Project are predicted to be less than 1.5%. Thus, potential human health risk from inhalation of fine PM exists already in the Base Case and is likely related to air emissions from vehicles and smoke from wood burning. The Project is not expected to contribute to human health risks from the inhalation of fine PM in Telkwa.

6.3 Estimation of Non-carcinogenic Risks Using Hazard Quotients

The $Dose_{total}$ of COPCs from all routes ((in mg/kg BW/day; Section 4.3.7) was divided by the TRV (in mg/kg BW/day; Section 5.2) to obtain the existing conditions HQ (unitless) using Equation 19:

$$HQ = Dose_{Total}/TRV \quad \text{[Equation 19]}$$

Appendix G to this HHRA, Tables G-2 to G-13 show exposure route-specific and total HQs for each COPC for ROCs for the Base Case, Project Case (Operation), and Project Case (Closure). **Table 6.3-1** presents a summary of total HQs as well as the incremental change (in percent) between the Base Case and Project Case.

Because doses in the Project Case were calculated to include doses in the Base Case, the HQ, and hence the potential risk associated with human exposure to COPCs, generated for the Project Case incorporates the potential risks associated with human exposure to background COPC concentration in air, water, soil, and subsistence foods within the LSA. Background exposures also include exposure to metal COPCs in retail (or market) food products, which contributes the majority of exposure for all COPCs (**Appendix G to this HHRA**).

As per guidance by Health Canada (2019a), Residential Land Users were assumed to be present within the LSA boundaries full time; hence, an acceptable risk threshold HQ of 1 was deemed appropriate for non-carcinogenic COPCs assessed in this HHRA. Exposures for Recreational Land Users do not include exposure to media (air, water, soil) when outside of the LSA (i.e., when not recreating in the LSA). Therefore, a threshold HQ of 0.2 was deemed appropriate and conservative for the Recreational Receptor for non-carcinogenic COPCs.

Table 6.3-1: Total Hazard Quotients (from all Exposure Pathways) in the Base Case, Project Case (Operation), and Project Case (Closure), and Incremental Change between the Base Case and Project Case for Contaminants of Potential Concern

Contaminant of Potential Concern	Recreational Land User Toddler ¹					Indigenous and non-Indigenous Resident Land User Toddler ²					Recreational Land User Adult ¹					Indigenous and non-Indigenous Resident Land User Adult ²				
	Base Case	Operation	Closure	%X OP	%X CL	Base Case	Operation	Closure	%X OP	%X CL	Base Case	Operation	Closure	%X OP	%X CL	Base Case	Operation	Closure	%X OP	%X CL
Aluminum	0.29	0.29	0.30	-1%	1%	0.58	0.57	0.58	-2%	1%	0.100	0.099	0.10	0%	2%	0.12	0.12	0.12	0%	2%
Arsenic	11	11	11	0%	0%	11	11	11	0%	0%	3.5	3.5	3.5	0%	0%	3.6	3.6	3.6	0%	1%
Barium	0.17	0.17	0.17	0%	0%	0.20	0.20	0.20	0%	0%	0.064	0.064	0.064	0%	0%	0.080	0.081	0.080	0%	0%
Boron	0.0069	0.013	0.014	94%	109%	0.030	0.037	0.038	23%	29%	0.0032	0.0062	0.0068	93%	111%	0.016	0.019	0.020	19%	25%
Cadmium	1.1	1.1	1.1	0%	3%	1.1	1.1	1.1	0%	3%	0.45	0.45	0.46	0%	3%	0.45	0.46	0.47	0%	3%
Chromium	0.54	0.55	0.55	1%	2%	0.62	0.63	0.63	1%	2%	0.23	0.23	0.23	1%	2%	0.25	0.25	0.25	1%	2%
Cobalt	0.44	0.44	0.52	2%	18%	0.49	0.49	0.57	2%	18%	0.18	0.18	0.22	2%	21%	0.19	0.19	0.23	2%	22%
Iron	0.71	0.72	0.72	2%	1%	0.93	0.95	0.94	2%	1%	0.29	0.29	0.29	2%	1%	0.30	0.31	0.31	2%	1%
Lithium	0.72	0.76	0.95	6%	33%	0.79	0.84	1.1	5%	38%	0.29	0.31	0.41	7%	41%	0.32	0.34	0.47	6%	49%
Manganese	8.5	8.5	8.6	0%	1%	9.0	9.0	9.1	0%	1%	3.4	3.4	3.5	0%	2%	3.6	3.6	3.7	0%	1%
Mercury	0.73	0.81	0.79	11%	9%	0.73	0.82	0.80	12%	10%	0.27	0.31	0.30	14%	12%	0.27	0.31	0.30	15%	12%
Molybdenum	2.2	2.2	2.2	0%	1%	2.2	2.2	2.2	0%	1%	0.86	0.87	0.87	0%	1%	0.87	0.87	0.88	0%	1%
Nickel	10	10	10	1%	1%	10	11	11	1%	1%	4.5	4.6	4.6	1%	1%	4.6	4.6	4.6	1%	1%
Selenium	0.86	0.98	0.98	14%	14%	0.86	0.99	0.99	14%	15%	0.39	0.44	0.45	15%	16%	0.39	0.45	0.45	15%	16%
Strontium	0.072	0.074	0.078	3%	8%	0.086	0.089	0.10	4%	19%	0.033	0.034	0.036	3%	9%	0.041	0.042	0.050	4%	22%
Thallium	0.41	0.52	0.92	28%	126%	0.41	0.54	1.0	31%	146%	0.58	0.76	1.4	32%	145%	0.59	0.78	1.6	34%	173%
Zinc	0.94	0.95	0.95	0%	1%	0.95	0.95	0.96	0%	1%	0.33	0.33	0.34	0%	1%	0.33	0.34	0.34	0%	1%

Notes:

¹ Hazard quotients greater than 0.2 are bolded and shaded grey.

² Hazard quotients greater than 1 are bolded and shaded grey.

%X OP = Incremental percent change between the Base Case and Project Case (Operation).

%X CL = Incremental percent change between the Base Case and Project Case (Closure).

Incremental percent change of >20% for %X OP and %X CL is bolded and shaded grey.

Hazard quotients for each exposure pathway are presented in Appendix G.

Tabloid verso

A HQ less than the acceptable risk threshold HQ indicates that the exposure does not pose a significant health risk to human ROCs. A HQ value greater than the threshold does not necessarily indicate that adverse health effects will occur since the TRVs are conservative (i.e., protect human health by including several UFs) and many of the assumptions made in the exposure assessment (Section 4) were conservative. A HQ of greater than the threshold does suggest that the potential risk to human health may require a more detailed evaluation.

However, in an environmental assessment, the purpose of conducting a HHRA is to quantitatively identify the incremental change in risk to human health due to the proposed Project, rather than the absolute risk. Therefore, the incremental change in HQs (in %) between the Base Case and Project Case provides the basis for determining the relevance and potential for change in human health due to the Project. An incremental change in HQ of less than 20% can be considered not significant as it is within the range of variability and margin of analytical error for measurable COPC concentrations in air, water, soil, and foods and is unlikely to be detectable in environmental monitoring programs. Given the conservative assumptions used in the risk assessment (e.g., all subsistence foods eaten by a person in a year come from within the LSA, TRVs with safety factors of up to 1,000 fold), environmental media variability, and the inherent uncertainties in risk assessment (see Section 7), for the COPCs where the HQ was higher than 0.2 or 1, but the Project-related incremental change in HQ was less than 20%, measurable changes in human health due to the Project are unlikely.

Contaminants of potential concern with total HQs greater than 0.2 for the Recreational Land Users are: aluminum (toddler only), arsenic, cadmium, chromium, cobalt, iron, lithium, manganese, mercury, molybdenum, nickel, selenium, thallium, and zinc. Contaminants of potential concern with HQs greater than 1 for the Residential Land Users are: arsenic, cadmium, lithium (in Closure only), manganese, molybdenum, nickel, and thallium (in Closure only) for toddlers; and arsenic, manganese, nickel (and thallium in Closure only) for adults. However, as stated above, the largest contributions to these HQs are from market food exposures and the focus of the assessment is on the potential for incremental change in human health due to the Project.

6.3.1 *Contaminants of Potential Concern with Incremental Increase Greater than 20%*

As presented in **Table 6.3-1**, only boron and thallium change more than 20% in the Project Case (Operation) compared to the Base Case. Contaminants of potential concern that change significantly in the Project Case (Closure) from the Base Case include boron, cobalt (for adults only), lithium, strontium, and thallium.

6.3.1.1 *Boron and Strontium*

Although the incremental increase in HQs for boron and strontium are greater than 20% (i.e., up to 22% for strontium and 23% to 103% for boron), the HQs remain well below the threshold of 0.2 or 1 (**Table 6.3-1**). Thus, it is concluded that exposure to boron and strontium do not pose a health risk to human ROCs. The incremental increase is a result of a predicted increase in concentrations of boron in surface water and soil, and a predicted increase in strontium in drinking water.

6.3.1.2 *Thallium*

The incremental increase in total HQ for thallium in the Operation and Closure phases (28% to 173%) are due to the contribution of thallium from subsistence foods, especially rainbow trout (**Table 4.3-10 to Table 4.3-12**). Thallium concentration may increase in fish because thallium concentrations are predicted to increase in surface water downstream of the Project. However, drinking water HQs remain well below

threshold HQs of 0.2 or 1 in Operation and Closure and, therefore, drinking water from creeks and streams in the LSA is not predicted to result in health risks to people.

Considering the magnitude of the total HQ (0.4 to 1.4 for Recreational and 0.4 and 1.6 for Resident land users), the level of incremental change in HQs is not likely to result in measurable effects on people.

This conclusion is based on the following considerations:

- Environment and Climate Change Canada and Health Canada (2020) state that food is the primary source of thallium exposure for the Canadian population. Both market foods and country foods were fully accounted for in the risk calculations for Recreational and Resident land users and the total HQs for Residents were below the threshold of 1, except for adults in Closure. Using a HQ threshold of 0.2 for the Recreational land user is very conservative as the highest contribution to the HQ from background market foods exposures is accounted for and background contributions from air inhalation or contact/ingestion with soil and water are likely insignificant relative to food ingestion.
- Based on partition coefficients for water to suspended particles of 4.28 and for water to sediment of 1.48 (summarized by Harvey et al. 2007), thallium is predicted to be moderately mobile from water to sediment and highly adsorbent to particulate matter in surface water (Environment and Climate Change Canada and Health Canada 2020). Another mechanism for removing thallium from water is the precipitation of Tl(III) hydroxide followed by reduction to Tl(I) by organic rich anaerobic sediment or bound to sediment with sulfide ion to form insoluble thallium(I) sulfide (International Programme on Chemical Safety 1996; Laforte et al. 2004; Gao et al. 2007; Turner et al. 2010). Thus, thallium may partition from water to sediment indicating that dissolved thallium concentrations, and thus HQs, downstream of the Project are likely over-estimated as these attenuation mechanisms are not included in the surface water quality model.
- The derivation of the EPC for thallium in water in the Closure phase was highly conservative because the maximum (worst year) thallium concentration was chosen for each phase and each water quality modelling node and then assumed to persist over the entire duration of the phase. However, thallium concentrations vary over time in the Closure phase, increasing in year 2045 to year 2070, and then decreasing at a slower rate until the end of the modelling period. Thus, while thallium concentrations in fish tissues will also vary with time, the highest concentration was assumed to persist throughout the entire Closure phase and are likely to overestimate actual fish tissue concentrations.
- The percent change in fish thallium concentrations may be unrealistically high between the Base Case and Project Case, as they are modeled based on the change in thallium water concentrations using a linear relationship between water concentration and fish tissue concentration that may overestimate the uptake relationship as uptake rates often have an inverse relationship with water concentrations (McGeer et al. 2003; Carriquiriborde, Handy, and Davies 2004; DeForest, Brix, and Adams 2007; Adams 2011). Thallium uptake and bioaccumulation by aquatic animals and plants, transfer along aquatic food chains, as well as environmental behavior and toxicity of thallium ion species [Tl(III) and Tl(I)] remain poorly understood (Couture et al. 2011).
- The derivation of the EPC for thallium in fish tissues in the Operation and Closure phases was based on WQS02 (Tenas Creek), WQS05 (Goathorn Creek), WQS09 (Telkwa River), and WQS11 and WQS12 (Bulkley River), with the highest increases predicted for Tenas and Goathorn creeks. However, people are more likely to obtain fish from the Bulkley River and the Telkwa River, where thallium concentrations are predicted to be 10 to 100-times lower than in Tenas and Goathorn creeks, which are not known as popular fishing locations (Section 3.1.3.3). Also, salmon, rather than rainbow trout, are a favorite fish for anglers. Because salmon spend their adult lives in the marine environment and don't eat during their spawning migrations, their tissue concentrations are not likely to be significantly affected by freshwater quality during their migration. Therefore, the health risks to people from consuming thallium in fish caught in the LSA are overestimated.

- Biomonitoring data from Canada and the U.S demonstrate that thallium-containing substances are of low concern at the current levels of exposure found in the general public (Environment and Climate Change Canada and Health Canada 2020). The conclusion was based on comparing monitoring data of total thallium in urine of the Canadian population to a human biomonitoring guidance value, which is typically derived from existing health-based exposure values (Umweltbundesamt [Federal Environment Agency] 2011). Health Canada stated that food intake is the primary route of exposure to thallium, with an average dietary intake for all age groups of 0.029 µg/kg BW-day and for toddlers of 0.088 µg/kg BW-day (based on Health Canada 2011a), and that biomonitoring data of total thallium urinary creatinine adjusted concentrations are more than an order of magnitude below the human biomonitoring guidance value. Based on the foregoing information and on the maximum Project Case total dose of 0.040 µg/kg BW-day for adults and 0.089 µg/kg BW-day for toddlers (for Resident land users in Closure), health risks to people from thallium are expected to be negligible.

However, due to the uncertainties in the risk assessment for thallium, it should be included in future monitoring programs to confirm that future measured concentrations remain within the range predicted in surface waters.

6.3.1.3 *Lithium and Cobalt*

Moderate increases in total HQ for cobalt (for adults only) and lithium (toddlers and adults) in the Closure phase (22% to 49%) are due to a doubling in HQs for these COPCs in subsistence foods, especially rainbow trout. As with thallium, this is due to a predicted increase in cobalt and lithium concentrations in surface water in the Closure phase. Drinking water HQs for cobalt and lithium remain well below threshold HQs of 0.2. The background HQs from ingestion of market foods are higher compared to risks from drinking water or from subsistence foods ingestion for these COPCs. Therefore, it is unlikely that the predicted increases in risks will result in measurable effects to people.

In addition, Health Canada's recently updated TRVs (Health Canada 2021b) do not include a TRV for lithium. The chronic TRV for lithium is a provisional peer-reviewed toxicity value (PPRTV; US EPA 2008; RAIS 2021) and is highly conservative. The PPRTV that was used as a TRV in the assessment (0.002 mg/kg-day or 0.14 mg/person-day) is lower than the EDI for American adults (0.65 to 3.1 mg/person-day) and was much lower than the EDI (10 mg/person-day) in places like Chile where lithium-rich salinas occur without evidence of adverse effects to the local population. Lithium is often used to treat certain psychiatric disorders and the PPRTV is equivalent to the lower bound of therapeutic doses of lithium.

Nevertheless, cobalt and lithium should be included in future monitoring programs to confirm that future measured concentrations remain within the range predicted in surface waters.

6.3.1.4 *Other Considerations*

For the Resident Land Users, the estimated daily dose of COPCs was assumed to come from air, water, and soil contact throughout the human health LSA during the entire year. However, Resident Land Users may not reside in the LSA for the entire year and therefore the HHRA may overestimate exposures for Resident Land Users. In addition, not all of the subsistence foods that an individual will eat will come from the Human Health LSA, as was assumed in the assessment.

Conservative assumptions made throughout the HHRA that lead to an overestimation of risk are the use of upper-bound estimates of environment media concentrations, i.e., 95% UCLM concentrations, the use of worst-case years and locations with maximum concentrations, in the calculations. Risk levels would likely be lower if other statistics of more central tendency were used (e.g., medians, means). The use of highly conservative TRVs will further contribute to an overestimation of risk.

6.3.2 Organ System Toxicity

Non-carcinogenic risks for COPCs with similar target organs or similar target effects were summed to derive a Hazard Index (HI), as their risk is assumed to be additive (Health Canada 2019a; BC MOH 2021). As with HQs in Section 6.3.1, where the estimated HI is less than or equal to 0.2 for the Recreational Land Users or 1 for Residential Land Users, these risks were deemed negligible (Health Canada 2019a; BC MOH 2021). Incremental changes between the Base Case and Project Case of less than 20% were considered to be insignificant as this percentage is within the range of variability and margin of analytical error of measuring COPC concentrations in environmental media. **Table 6.3-2** shows the target organ system toxicity for the COPCs evaluated in this HHRA. The resulting HIs and their incremental changes between the Base Case and Project Case are presented in **Table 6.3-3** and **Table 6.3-4**, respectively.

Table 6.3-2: Target Organ System Toxicity of Contaminants of Potential Concern

Parameter of Concern	Target Organ System								
	Cardiovascular	Blood	Nervous system	Development	Kidney	Gastrointestinal	Skin	Reproductive	Musculoskeletal
Aluminum					x				
Arsenic	x						x		
Barium					x				
Boron				x					
Cadmium					x				
Chromium						x			
Cobalt	x								
Iron						x			
Lithium			x						
Manganese	x		x	x					
Mercury			x		x				
Molybdenum					x				
Nickel								x	
Selenium							x		
Strontium									x
Thallium									
Zinc		x							

Table 6.3-3: Hazard Indices for Each Target Organ System for the Baseline and Project Phases

Receptor and Age Group	Phase	Hazard Index for Target Organ Effect								
		Cardiovascular	Blood	Nervous system	Development	Kidney	Gastrointestinal	Skin	Reproductive	Musculoskeletal
Recreational Land User Toddler ¹	Baseline	19.5	1.8	10.8	8.5	4.5	1.3	11.5	10.3	0.07
	Operation	19.5	1.9	11.0	8.5	4.6	1.3	11.6	10.4	0.07
	Closure	19.7	1.9	11.3	8.6	4.6	1.3	11.6	10.4	0.08
Indigenous and non-Indigenous Resident Land User Toddler ²	Baseline	20.3	1.8	11.4	9.0	4.8	1.6	11.7	10.5	0.09
	Operation	20.3	1.9	11.6	9.0	4.9	1.6	11.8	10.5	0.09
	Closure	20.5	1.9	12.0	9.1	5.0	1.6	11.8	10.6	0.10

Receptor and Age Group	Phase	Hazard Index for Target Organ Effect								
		Cardiovascular	Blood	Nervous system	Development	Kidney	Gastrointestinal	Skin	Reproductive	Musculoskeletal
Recreational Land User Adult ¹	Baseline	7.1	0.7	4.4	3.4	1.7	0.5	3.9	4.5	0.03
	Operation	7.1	0.8	4.5	3.4	1.8	0.5	4.0	4.6	0.03
	Closure	7.2	0.8	4.6	3.5	1.8	0.5	4.0	4.6	0.04
Indigenous and non-Indigenous Resident Land User Adult ²	Baseline	7.4	0.72	4.6	3.6	1.8	0.55	4.0	4.6	0.04
	Operation	7.4	0.78	4.7	3.6	1.8	0.56	4.0	4.6	0.04
	Closure	7.5	0.79	4.9	3.7	1.9	0.56	4.0	4.6	0.05

Notes:

¹ Hazard quotients greater than 0.2 are bolded and shaded grey.

² Hazard quotients greater than 1 are bolded and shaded grey.

Table 6.3-4: Incremental Change in Hazard Indices for Each Target Organ System for the Baseline and Project Phases

Receptor and Age Group	Phase	Incremental Change in Hazard Index Between Base Case and Project Cases for Target Organ System								
		Cardiovascular	Blood	Nervous system	Development	Kidney	Gastrointestinal	Skin	Reproductive	Musculoskeletal
Recreational Land User Toddler ¹	Operation	0%	7%	2%	0%	2%	2%	1%	1%	3%
	Closure	1%	7%	5%	1%	3%	1%	1%	1%	8%
Indigenous and non-Indigenous Resident Land User Toddler ²	Operation	0%	7%	2%	0%	2%	2%	1%	1%	4%
	Closure	1%	7%	5%	1%	3%	1%	1%	1%	19%
Recreational Land User Adult ¹	Operation	0%	8%	3%	0%	2%	2%	2%	1%	3%
	Closure	1%	9%	6%	2%	3%	1%	2%	1%	9%
Indigenous and non-Indigenous Resident Land User Adult ²	Operation	0%	8%	3%	0%	2%	2%	2%	1%	4%
	Closure	2%	9%	7%	2%	3%	1%	2%	1%	22%

Notes:

Incremental change larger than 20% is bolded and shaded grey.

While Health Canada (2019a) and BC MOH (2021) recommend that HQs for COPCs with similar target organs or systems be summed into an HI, caution should be used in interpreting these results. In many

cases, the type of effect caused by different parameters on the same target organ or system is different and may not be caused by the same mechanism of action. Thus, effects may not be additive and summing the already conservative HQs into an HI could further overestimate the risk.

The HIs in the Base Case for all target organs or systems (except for the musculoskeletal system) were higher than 0.2 for the Recreational Land User toddler and adult and higher than 1.0 for the Resident Land User toddler. For these ROCs, the results were similar for the Base Case and Project Cases with no or insignificant increases in the magnitude of the HI. For the Resident Land User adult, the Base Case and Project Case (Operation) HIs exceeded the threshold of 1.0 for the cardiovascular, nervous system and development, kidney, skin, and reproductive system (but not gastrointestinal system or blood).

The highest HI of 20.5 was for COPCs that had a critical effect on the cardiovascular system, almost entirely associated with arsenic and manganese in market foods. The incremental change between the Base Case and Project Case (Operation and Closure) was 2% or less, which does not represent a measurable change.

The only incremental change that was approaching or larger than 20% was between Baseline and Project Case (Closure) for the Resident Land User for the musculoskeletal system (19% and 22% for toddler and adult, respectively). This increase is at the threshold and is attributable to increases in strontium in surface water but the HIs, just like the HQs, are well below 0.2 for the Recreational and Residential Land Users and, thus, strontium is not of a health concern.

6.4 Estimation of Incremental Lifetime Cancer Risks

The ILCR is the increase in lifetime cancer risk above the normal risks associated with background exposures. In the context of an EA, it is the increase in the lifetime cancer risk due to Project activities. It is calculated by multiplying the LADD of a carcinogenic substance with the appropriate SF or UR (Section 5.2) to derive a conservative estimate of the potential ILCR associated with that exposure dose. The acceptable risk threshold for the ILCR is 1×10^{-5} (or 1 in 100,000) as determined by BC MOH (2021) and Health Canada (Health Canada 2013, 2019a).

6.4.1 Incremental Lifetime Cancer Risk via the Inhalation Exposure Route

Arsenic, cadmium, chromium, and nickel are considered to be carcinogens via the inhalation route; thus, the ILCR was calculated with a UR value in units of $(\text{mg}/\text{m}^3)^{-1}$ using Equation 20 (Health Canada 2019a):

$$ILCR = \sum (C_{air} \times TR_i \times UR \times ADAF_i) \quad [\text{Equation 20}]$$

Where:

$ILCR$	= incremental lifetime cancer risk (unitless)
C_{air}	= concentration of COPC in air (mg/m^3)
TR_i	= fraction of time exposed for life stage i (exposure duration in years/80 years)
UR	= unit risk (mg/m^3) ⁻¹
$ADAF_i$	= age-dependent adjustment factor for life stage i

For non-threshold carcinogens acting through a mutagenic mode of action, an age-dependant adjustment factor (ADAF) was applied to the ILCR calculation. The use of the ADAF accounts for the potential for increased sensitivity of younger life stages to mutagenic carcinogens. Default ADAFs have been developed by Health Canada (2013) and were used in this assessment.

The inhalation cancer unit risk for arsenic is $0.0064 (\mu\text{g}/\text{m}^3)^{-1}$, for cadmium $0.0042 (\mu\text{g}/\text{m}^3)^{-1}$, for chromium $0.012 (\mu\text{g}/\text{m}^3)^{-1}$, and for nickel $0.0013 (\mu\text{g}/\text{m}^3)^{-1}$ (Table 5.2-2 of this HHRA; Health Canada 2021b). Since arsenic, cadmium, chromium, and nickel can cause lung cancer, the risks are assumed to

be additive and are summed (Health Canada 2019a). The predicted concentrations of arsenic, cadmium, chromium, and nickel bound to PM₁₀ in the Base Case and Project Case (Operation) were used in the ILCR calculations.

Since carcinogenic risks are expressed in incremental terms, presenting ILCRs for the Project-Only scenario allows for the evaluation of risks due to the Project independent of background exposure. The Project-Only ILCR was calculated by subtracting the Base Case ILCR from the Project Case ILCR.

Tables 6.4-1 and 6.4-2 present the ILCRs from inhalation for the Baseline and Project Case (Operation), respectively. It was assumed that during Closure, EPCs of COPCs in air are similar to the Base Case. **Table 6.4-3** presents the Project-Only ILCR.

Table 6.4-1: Incremental Lifetime Cancer Risk for Inhalation of Carcinogenic Metals in Air for Each Life Stage in the Base Case

	Infant	Toddler	Child	Teen	Adult
ED (HC, 2019)	0.5	4.5	7	8	60
ADAF	10	5	3	2	1
Recreational Land Users					
Arsenic ILCR	1.3×10^{-08}	6.1×10^{-08}	5.7×10^{-08}	4.3×10^{-08}	1.6×10^{-07}
Cadmium ILCR	1.2×10^{-09}	5.5×10^{-09}	5.1×10^{-09}	3.9×10^{-09}	1.5×10^{-08}
Chromium ILCR	3.5×10^{-08}	1.6×10^{-07}	1.5×10^{-07}	1.1×10^{-07}	4.2×10^{-07}
Nickel ILCR	3.8×10^{-09}	1.7×10^{-08}	1.6×10^{-08}	1.2×10^{-08}	4.5×10^{-08}
Summed Metal ILCR	6.0×10^{-08}	2.7×10^{-07}	2.5×10^{-07}	1.9×10^{-07}	7.2×10^{-07}
Age-adjusted Metal ILCR	6.0×10^{-08}	3.3×10^{-07}	5.8×10^{-07}	7.8×10^{-07}	1.5×10^{-06}
Indigenous and Non-Indigenous Resident Land Users					
Arsenic ILCR	8.8×10^{-08}	3.9×10^{-07}	3.7×10^{-07}	2.8×10^{-07}	1.1×10^{-06}
Cadmium ILCR	7.9×10^{-09}	3.6×10^{-08}	3.3×10^{-08}	2.5×10^{-08}	9.5×10^{-08}
Chromium ILCR	2.3×10^{-07}	1.0×10^{-06}	9.5×10^{-07}	7.2×10^{-07}	2.7×10^{-06}
Nickel ILCR	2.5×10^{-08}	1.1×10^{-07}	1.0×10^{-07}	7.9×10^{-08}	2.9×10^{-07}
Summed Metal ILCR	3.9×10^{-07}	1.8×10^{-06}	1.6×10^{-06}	1.3×10^{-06}	4.7×10^{-06}
Age-adjusted Metal ILCR	3.9×10^{-07}	2.2×10^{-06}	3.8×10^{-06}	5.1×10^{-06}	9.8×10^{-06}

Notes:

ED = Age Group Duration (years)

ADAF = Age-dependant adjustment factor (unitless)

ILCR = Incremental lifetime cancer risk; $ILCR = \sum (C * TR * UR * ADAF)$

Table 6.4-2: Incremental Lifetime Cancer Risk for Inhalation of Carcinogenic Metals in Air for Each Life Stage for the Project Case (Operation)

	Infant	Toddler	Child	Teen	Adult
ED (HC, 2019)	0.5	4.5	7	8	60
ADAF	10	5	3	2	1
Recreational Land Users					
Arsenic ILCR	1.6×10^{-08}	7.1×10^{-08}	6.6×10^{-08}	5.1×10^{-08}	1.9×10^{-07}
Cadmium ILCR	1.4×10^{-09}	6.4×10^{-09}	5.9×10^{-09}	4.5×10^{-09}	1.7×10^{-08}

Chromium ILCR	4.6×10^{-08}	2.1×10^{-07}	1.9×10^{-07}	1.5×10^{-07}	5.6×10^{-07}
Nickel ILCR	4.8×10^{-09}	2.2×10^{-08}	2.0×10^{-08}	1.5×10^{-08}	5.8×10^{-08}
Summed Metal ILCR	7.5×10^{-08}	3.4×10^{-07}	3.2×10^{-07}	2.4×10^{-07}	9.0×10^{-07}
Age-adjusted Metal ILCR	7.5×10^{-08}	4.1×10^{-07}	7.3×10^{-07}	9.7×10^{-07}	1.9×10^{-06}

Indigenous and Non-Indigenous Resident Land Users

Arsenic ILCR	1.0×10^{-07}	4.6×10^{-07}	4.3×10^{-07}	3.3×10^{-07}	1.2×10^{-06}
Cadmium ILCR	9.2×10^{-09}	4.1×10^{-08}	3.9×10^{-08}	2.9×10^{-08}	1.1×10^{-07}
Chromium ILCR	3.0×10^{-07}	1.4×10^{-06}	1.3×10^{-06}	9.6×10^{-07}	3.6×10^{-06}
Nickel ILCR	3.1×10^{-08}	1.4×10^{-07}	1.3×10^{-07}	1.0×10^{-07}	3.8×10^{-07}
Summed Metal ILCR	4.9×10^{-07}	2.2×10^{-06}	2.1×10^{-06}	1.6×10^{-06}	5.9×10^{-06}
Age-adjusted Metal ILCR	4.9×10^{-07}	2.7×10^{-06}	4.8×10^{-06}	6.3×10^{-06}	1.2×10^{-05}

Notes:

ED = Age Group Duration (years)

ADAF = Age-dependant adjustment factor (unitless)

ILCR = Incremental lifetime cancer risk; $ILCR = \sum (C * TR * UR * ADAF)$

Table 6.4-3: Incremental Lifetime Cancer Risk for Inhalation of Carcinogenic Metals in Air for Each Life Stage for the Project-Only Case (Operation)

	Infant	Toddler	Child	Teen	Adult
ED (HC, 2019)	0.5	4.5	7	8	60
ADAF	10	5	3	2	1

Recreational Land Users

Arsenic ILCR	2.9×10^{-09}	1.1×10^{-08}	9.9×10^{-09}	7.9×10^{-09}	2.8×10^{-08}
Cadmium ILCR	2.0×10^{-10}	8.8×10^{-10}	8.3×10^{-10}	6.3×10^{-10}	2.4×10^{-09}
Chromium ILCR	1.1×10^{-08}	5.2×10^{-08}	4.8×10^{-08}	3.7×10^{-08}	1.4×10^{-07}
Nickel ILCR	1.1×10^{-09}	4.8×10^{-09}	4.5×10^{-09}	3.4×10^{-09}	1.3×10^{-08}
Summed Metal ILCR	1.5×10^{-08}	6.8×10^{-08}	6.3×10^{-08}	4.8×10^{-08}	1.8×10^{-07}
Age-adjusted Metal ILCR	1.5×10^{-08}	8.3×10^{-08}	1.5×10^{-07}	1.9×10^{-07}	3.8×10^{-07}

Indigenous and Non-Indigenous Resident Land Users

Arsenic ILCR	1.5×10^{-08}	6.9×10^{-08}	6.4×10^{-08}	4.9×10^{-08}	1.8×10^{-07}
Cadmium ILCR	1.3×10^{-09}	5.7×10^{-09}	5.4×10^{-09}	4.1×10^{-09}	1.5×10^{-08}
Chromium ILCR	7.4×10^{-08}	3.4×10^{-07}	3.1×10^{-07}	2.4×10^{-07}	8.9×10^{-07}
Nickel ILCR	6.9×10^{-09}	3.1×10^{-08}	2.9×10^{-08}	2.2×10^{-08}	8.3×10^{-08}
Summed Metal ILCR	9.8×10^{-08}	4.4×10^{-07}	4.1×10^{-07}	3.1×10^{-07}	1.2×10^{-06}
Age-adjusted Metal ILCR	9.8×10^{-08}	5.4×10^{-07}	9.5×10^{-07}	1.3×10^{-06}	2.4×10^{-06}

Notes:

ED = Age Group Duration (years)

ADAF = Age-dependant adjustment factor (unitless)

ILCR = Incremental lifetime cancer risk; $ILCR = \sum (C * TR * UR * ADAF)$

For Recreational and Residential Land Users, the Base Case, Project Case (Operation), and Project-Only ILCRs are below the ILCR threshold of 1 in 10,000 (1.0×10^{-5}) for individual age groups (summed metal ILCR). For age-adjusted metal ILCRs, where age groups are added consecutively, the ILCR for adult

Resident Land User for Base Case plus Project Case is marginally above the threshold of 1.0×10^{-5} (i.e., 1.2×10^{-5}). However, Base Case contributes the larger proportion of this ILCR (9.8×10^{-6}), while the Project-Only contribution is 2.4×10^{-6} (Table 6.4-3). Thus, based on the Project-Only ILCR, there is no risk predicted from inhalation of metals due to the Project as the Project-Only ILCR is less than the acceptable risk threshold of 1.0×10^{-5} .

6.4.2 Incremental Lifetime Cancer Risk due to Arsenic via the Ingestion Exposure Route

Arsenic is carcinogenic via the ingestion route (i.e., water, inadvertent soil ingestion, and food ingestion). Risk characterization for arsenic via the ingestion exposure route using ILCRs is based on only the increase in exposure that results from project activities (i.e., Project alone scenario, or the incremental difference between the Project Case and Base Case).

While the evidence is mixed that arsenic is a mutagenic carcinogen (see Section 5.2 and **Appendix F to this HHRA**), to be conservative it was assumed that arsenic does act with a mutagenic mechanism of action and the ADAF (Section 6.4.1) was applied to the ILCR calculation. Thus, the ILCR was calculated using Equation 21 (Health Canada 2019a).

$$ILCR = \sum(LADD_i \times ADAF_i \times SF) \quad \text{[Equation 21]}$$

Where:

$ILCR$	= incremental lifetime cancer risk (unitless)
SF	= slope factor (mg/kg BW-day) ⁻¹
$LADD_i$	= lifetime average daily dose during life stage i (mg/kg BW-day)
$ADAF_i$	= age-dependant adjustment factor for life stage i

Calculated LADDs and ILCRs for the ingestion pathway are presented in **Appendix G to this HHRA (Tables G-14 to G-24)**. The ILCRs are summarized for all ROCs in the Base Case and Project Case (Operations and Closure) in **Table 6.4-4**. **Table 6.4-5** presents the Project-Only ILCR for both Project Case phases, which were calculated as Project Case minus Base Case ILCRs.

Except for the adult Resident Land Users, incremental changes between the Base Case and Project Case in ILCR (i.e., Project-Only) from drinking water are less than 1.0×10^{-5} and, thus, considered negligible. For the adult Resident Land Users, a Project-Only ILCR of 1.4×10^{-5} is predicted for the Project Case (Closure). Although this is above the acceptable risk threshold, it is unlikely that the change will adversely affect human health as the estimate assumes that an adult would live in the LSA and drink surface water (in addition to groundwater) from streams and rivers downstream of and close to the Project their entire lifetime. Tenas and Goathorn creeks, which are predicted to have greater increases in arsenic concentrations in Closure compared to other rivers, are unlikely to be used as a constant source of drinking water. Also, the surface water concentrations of arsenic in the Project Case (Closure) were assumed to be the maximum of the annual 95% UCLM concentration during the entire Decommissioning and Reclamation and Post-closure phases, which further overestimates risk from ingestion of arsenic, as arsenic concentrations are expected to change over time (increase to a maximum and then decrease) (**Appendix 1.0-U of the EAC Application**). However, arsenic should be included in future monitoring programs to confirm that future measured concentrations remain within the range predicted in surface waters.

The Project-Only ILCR from inadvertent ingestion of arsenic with soil is less than 1.0×10^{-5} (**Table 6.4-5**) and, thus, risks due to arsenic in soil from the Project are considered negligible.

The Project-Only ILCR from ingestion of arsenic with subsistence foods is less than 1×10^{-5} (**Table 6.4-5**) and, thus, risks due to arsenic in subsistence foods from the Project are considered negligible.

The calculated background ILCRs for the ingestion of market foods pathway exceed the acceptable risk threshold of 10^{-5} for all ROCs by more than an order of magnitude, based on assumptions and data considered in this HHRA (**Table 6.4-4**). The toddler and adult ILCR were 3.4×10^{-4} and 8.8×10^{-4} , respectively. However, since the Project will not affect this background exposure to market foods, the Project-Only ILCR is zero (**Table 6.4-5**) and market foods do not contribute to risk due to the Project.

6.4.3 Incremental Lifetime Cancer Risk due to Arsenic via Dermal Contact with Soil

Arsenic is also considered to be carcinogenic via the dermal contact route; thus, the ILCR was calculated using Equation 16 (Health Canada 2019a). The calculated LADD and ILCRs for arsenic via dermal contact with soil are presented in **Appendix G to this HHRA (Tables 25 and 26)** and summarized in **Table 6.4-4**. The Project-Only ILCR due to dermal contact with arsenic in soil for both the Project Case phases (Operation and Closure) is below the threshold of 1×10^{-5} .

6.4.4 Summary: Incremental Change in the Incremental Lifetime Cancer Risk due to Arsenic between Project Case and Base Case

The ILCRs for ingestion of water, soil, subsistence foods, market foods, and dermal contact with soil were summed as per guidance by (Health Canada 2019a) and presented in **Table 6.4-4** as total ILCR. Total ILCRs range from 3.5×10^{-4} to 1.0×10^{-3} , but this magnitude is entirely driven by the contribution from market foods.

Incremental increases in ILCR due to the Project do not exceed the Health Canada threshold of 1.0×10^{-5} except for the adult Residential Land User in the Project Case (Closure), where the Project-Only ILCR is slightly above the acceptable risk threshold (1.9×10^{-5}). The highest amount of incremental change in Project-Only ILCRs is contributed by the drinking water exposure pathway, due to arsenic in surface water. All other exposure pathways that are under the influence of the Project (ingestion and dermal contact with soil, ingestion of subsistence foods) contribute negligible amounts to the change in the total Project-Only ILCR from exposure to arsenic.

Table 6.4-4: Summary of Incremental Lifetime Cancer Risk from Arsenic in the Base Case and Project Case (Operation and Closure) from All Exposure Pathways

Pathway	Base Case ILCR				Project Case (Operation) ILCR				Project Case (Closure) ILCR			
	Recreational Land User		Indigenous and Non-indigenous Resident Land User		Recreational Land User		Indigenous and Non-Indigenous Resident Land User		Recreational Land User		Indigenous and Non-indigenous Resident Land User	
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Water and Soil												
Drinking Water ⁽¹⁾	1.6 x 10 ⁻⁰⁶	4.9 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰⁵	4.6 x 10 ⁻⁰⁵	1.8 x 10 ⁻⁰⁶	5.4 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰⁵	4.6 x 10 ⁻⁰⁵	3.0 x 10 ⁻⁰⁶	9.2 x 10 ⁻⁰⁶	2.0 x 10 ⁻⁰⁵	6.0 x 10 ⁻⁰⁵
Soil Ingestion ⁽¹⁾	3.9 x 10 ⁻⁰⁶	5.0 x 10 ⁻⁰⁶	2.5 x 10 ⁻⁰⁵	3.3 x 10 ⁻⁰⁵	4.0 x 10 ⁻⁰⁶	5.2 x 10 ⁻⁰⁶	2.6 x 10 ⁻⁰⁵	3.4 x 10 ⁻⁰⁵	4.0 x 10 ⁻⁰⁶	5.2 x 10 ⁻⁰⁶	2.6 x 10 ⁻⁰⁵	3.4 x 10 ⁻⁰⁵
Soil Dermal Contact ⁽¹⁾	1.7 x 10 ⁻⁰⁷	5.3 x 10 ⁻⁰⁷	1.1 x 10 ⁻⁰⁶	3.4 x 10 ⁻⁰⁶	1.8 x 10 ⁻⁰⁷	5.5 x 10 ⁻⁰⁷	1.1 x 10 ⁻⁰⁶	3.6 x 10 ⁻⁰⁶	1.8 x 10 ⁻⁰⁷	5.5 x 10 ⁻⁰⁷	1.1 x 10 ⁻⁰⁶	3.6 x 10 ⁻⁰⁶
Subsistence Foods												
Moose Meat	4.2 x 10 ⁻⁰⁶	1.3 x 10 ⁻⁰⁵	4.2 x 10 ⁻⁰⁶	1.3 x 10 ⁻⁰⁵	4.7 x 10 ⁻⁰⁶	1.4 x 10 ⁻⁰⁵	4.7 x 10 ⁻⁰⁶	1.4 x 10 ⁻⁰⁵	4.4 x 10 ⁻⁰⁶	1.3 x 10 ⁻⁰⁵	4.4 x 10 ⁻⁰⁶	1.3 x 10 ⁻⁰⁵
Moose Liver + Kidney	1.4 x 10 ⁻⁰⁶	4.5 x 10 ⁻⁰⁶	1.4 x 10 ⁻⁰⁶	4.5 x 10 ⁻⁰⁶	1.6 x 10 ⁻⁰⁶	4.9 x 10 ⁻⁰⁶	1.6 x 10 ⁻⁰⁶	4.9 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰⁶	4.6 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰⁶	4.6 x 10 ⁻⁰⁶
Deer Meat	4.8 x 10 ⁻⁰⁷	1.5 x 10 ⁻⁰⁶	4.8 x 10 ⁻⁰⁷	1.5 x 10 ⁻⁰⁶	5.3 x 10 ⁻⁰⁷	1.6 x 10 ⁻⁰⁶	5.3 x 10 ⁻⁰⁷	1.6 x 10 ⁻⁰⁶	5.0 x 10 ⁻⁰⁷	1.5 x 10 ⁻⁰⁶	5.0 x 10 ⁻⁰⁷	1.5 x 10 ⁻⁰⁶
Deer Liver + Kidney	1.5 x 10 ⁻⁰⁶	4.5 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰⁶	4.5 x 10 ⁻⁰⁶	1.6 x 10 ⁻⁰⁶	5.0 x 10 ⁻⁰⁶	1.6 x 10 ⁻⁰⁶	5.0 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰⁶	4.6 x 10 ⁻⁰⁶	1.5 x 10 ⁻⁰⁶	4.6 x 10 ⁻⁰⁶
Black Bear	7.6 x 10 ⁻⁰⁹	2.3 x 10 ⁻⁰⁸	7.6 x 10 ⁻⁰⁹	2.3 x 10 ⁻⁰⁸	8.8 x 10 ⁻⁰⁹	2.7 x 10 ⁻⁰⁸	8.8 x 10 ⁻⁰⁹	2.7 x 10 ⁻⁰⁸	1.1 x 10 ⁻⁰⁸	3.3 x 10 ⁻⁰⁸	1.1 x 10 ⁻⁰⁸	3.3 x 10 ⁻⁰⁸
Grouse	4.0 x 10 ⁻⁰⁸	1.2 x 10 ⁻⁰⁷	4.0 x 10 ⁻⁰⁸	1.2 x 10 ⁻⁰⁷	4.4 x 10 ⁻⁰⁸	1.4 x 10 ⁻⁰⁷	4.4 x 10 ⁻⁰⁸	1.4 x 10 ⁻⁰⁷	4.1 x 10 ⁻⁰⁸	1.3 x 10 ⁻⁰⁷	4.1 x 10 ⁻⁰⁸	1.3 x 10 ⁻⁰⁷
Snowshoe Hare	5.3 x 10 ⁻¹⁰	1.6 x 10 ⁻⁰⁹	5.3 x 10 ⁻¹⁰	1.6 x 10 ⁻⁰⁹	5.8 x 10 ⁻¹⁰	1.8 x 10 ⁻⁰⁹	5.8 x 10 ⁻¹⁰	1.8 x 10 ⁻⁰⁹	5.4 x 10 ⁻¹⁰	1.7 x 10 ⁻⁰⁹	5.4 x 10 ⁻¹⁰	1.7 x 10 ⁻⁰⁹
Rainbow Trout ⁽¹⁾	4.4 x 10 ⁻⁰⁷	1.3 x 10 ⁻⁰⁶	4.4 x 10 ⁻⁰⁷	1.3 x 10 ⁻⁰⁶	5.1 x 10 ⁻⁰⁷	1.6 x 10 ⁻⁰⁶	5.1 x 10 ⁻⁰⁷	1.6 x 10 ⁻⁰⁶	1.1 x 10 ⁻⁰⁶	3.5 x 10 ⁻⁰⁶	1.1 x 10 ⁻⁰⁶	3.5 x 10 ⁻⁰⁶
Berries ⁽²⁾	3.3 x 10 ⁻⁰⁷	8.2 x 10 ⁻⁰⁷	3.3 x 10 ⁻⁰⁷	8.2 x 10 ⁻⁰⁷	5.2 x 10 ⁻⁰⁷	1.3 x 10 ⁻⁰⁶	5.2 x 10 ⁻⁰⁷	1.3 x 10 ⁻⁰⁶	3.4 x 10 ⁻⁰⁷	8.2 x 10 ⁻⁰⁷	3.4 x 10 ⁻⁰⁷	8.2 x 10 ⁻⁰⁷
Garden Produce ⁽²⁾			1.2 x 10 ⁻⁰⁶	3.0 x 10 ⁻⁰⁶	-	-	1.4 x 10 ⁻⁰⁶	3.4 x 10 ⁻⁰⁶	-	-	1.2 x 10 ⁻⁰⁶	3.0 x 10 ⁻⁰⁶
Background Market Foods												
Market Foods	3.4 x 10 ⁻⁰⁴	8.8 x 10 ⁻⁰⁴	3.4 x 10 ⁻⁰⁴	8.8 x 10 ⁻⁰⁴	3.4 x 10 ⁻⁰⁴	8.8 x 10 ⁻⁰⁴	3.4 x 10 ⁻⁰⁴	8.8 x 10 ⁻⁰⁴	3.4 x 10 ⁻⁰⁴	8.8 x 10 ⁻⁰⁴	3.4 x 10 ⁻⁰⁴	8.8 x 10 ⁻⁰⁴
Total ILCR	3.5 x 10 ⁻⁰⁴	9.2 x 10 ⁻⁰⁴	3.9 x 10 ⁻⁰⁴	9.9 x 10 ⁻⁰⁴	3.5 x 10 ⁻⁰⁴	9.2 x 10 ⁻⁰⁴	3.9 x 10 ⁻⁰⁴	1.0 x 10 ⁻⁰³	3.5 x 10 ⁻⁰⁴	9.3 x 10 ⁻⁰⁴	4.0 x 10 ⁻⁰⁴	1.0 x 10 ⁻⁰³

Notes:

ILCR = incremental lifetime cancer risk

¹ assuming that 100% of soil, water, and fish values are inorganic arsenic

² assuming that up to 74% of total arsenic is inorganic arsenic (JECFA 2011)

JECFA. 2011. Arsenic (addendum). WHO Food Additives Series: 63. FAO JECFA Monographs 8. Prepared by the Seventy-second meeting of the Joint FAO/ WHO Expert Committee on Food Additives (JECFA). Geneva and Rome, 2011.

Table 6.4-5: Incremental Changes between Incremental Lifetime Cancer Risk for the Base Case and Project Cases (Project-Only ILCR)

Pathway	Incremental Change between Operation and Base Case ILCR				Incremental Change between Closure and Base Case ILCR			
	Recreational Land User		Indigenous and Non-Indigenous Resident Land User		Recreational Land User		Indigenous and Non-Indigenous Resident Land User	
	Toddler	Adult	Toddler	Adult	Toddler	Adult	Toddler	Adult
Water and Soil								
Drinking Water ⁽¹⁾	1.4 x 10 ⁻⁰⁷	4.4 x 10 ⁻⁰⁷	1.4 x 10 ⁻⁰⁷	4.4 x 10 ⁻⁰⁷	1.4 x 10 ⁻⁰⁶	4.3 x 10 ⁻⁰⁶	4.7 x 10 ⁻⁰⁶	1.4 x 10⁻⁰⁵
Soil Ingestion ⁽¹⁾	1.7 x 10 ⁻⁰⁷	2.2 x 10 ⁻⁰⁷	1.1 x 10 ⁻⁰⁶	1.4 x 10 ⁻⁰⁶	1.7 x 10 ⁻⁰⁷	2.2 x 10 ⁻⁰⁷	1.1 x 10 ⁻⁰⁶	1.4 x 10 ⁻⁰⁶
Soil Dermal Contact ⁽¹⁾	7.3 x 10 ⁻⁰⁹	2.3 x 10 ⁻⁰⁸	4.8 x 10 ⁻⁰⁸	1.5 x 10 ⁻⁰⁷	7.3 x 10 ⁻⁰⁹	2.3 x 10 ⁻⁰⁸	4.8 x 10 ⁻⁰⁸	1.5 x 10 ⁻⁰⁷
Subsistence Foods								
Moose Meat	4.2 x 10 ⁻⁰⁷	1.3 x 10 ⁻⁰⁶	4.2 x 10 ⁻⁰⁷	1.3 x 10 ⁻⁰⁶	1.3 x 10 ⁻⁰⁷	4.0 x 10 ⁻⁰⁷	1.3 x 10 ⁻⁰⁷	4.0 x 10 ⁻⁰⁷
Moose Liver + Kidney	1.4 x 10 ⁻⁰⁷	4.4 x 10 ⁻⁰⁷	1.4 x 10 ⁻⁰⁷	4.4 x 10 ⁻⁰⁷	4.4 x 10 ⁻⁰⁸	1.3 x 10 ⁻⁰⁷	4.4 x 10 ⁻⁰⁸	1.3 x 10 ⁻⁰⁷
Deer Meat	4.9 x 10 ⁻⁰⁸	1.5 x 10 ⁻⁰⁷	4.9 x 10 ⁻⁰⁸	1.5 x 10 ⁻⁰⁷	1.4 x 10 ⁻⁰⁸	4.4 x 10 ⁻⁰⁸	1.4 x 10 ⁻⁰⁸	4.4 x 10 ⁻⁰⁸
Deer Liver + Kidney	1.5 x 10 ⁻⁰⁷	4.6 x 10 ⁻⁰⁷	1.5 x 10 ⁻⁰⁷	4.6 x 10 ⁻⁰⁷	4.3 x 10 ⁻⁰⁸	1.3 x 10 ⁻⁰⁷	4.3 x 10 ⁻⁰⁸	1.3 x 10 ⁻⁰⁷
Black Bear	1.2 x 10 ⁻⁰⁹	3.7 x 10 ⁻⁰⁹	1.2 x 10 ⁻⁰⁹	3.7 x 10 ⁻⁰⁹	3.0 x 10 ⁻⁰⁹	9.4 x 10 ⁻⁰⁹	3.0 x 10 ⁻⁰⁹	9.4 x 10 ⁻⁰⁹
Grouse	4.4 x 10 ⁻⁰⁹	1.4 x 10 ⁻⁰⁸	4.4 x 10 ⁻⁰⁹	1.4 x 10 ⁻⁰⁸	1.0 x 10 ⁻⁰⁹	3.2 x 10 ⁻⁰⁹	1.0 x 10 ⁻⁰⁹	3.2 x 10 ⁻⁰⁹
Snowshoe Hare	5.4 x 10 ⁻¹¹	1.7 x 10 ⁻¹⁰	5.4 x 10 ⁻¹¹	1.7 x 10 ⁻¹⁰	1.4 x 10 ⁻¹¹	4.3 x 10 ⁻¹¹	1.4 x 10 ⁻¹¹	4.3 x 10 ⁻¹¹
Rainbow Trout ⁽¹⁾	7.2 x 10 ⁻⁰⁸	2.2 x 10 ⁻⁰⁷	7.2 x 10 ⁻⁰⁸	2.2 x 10 ⁻⁰⁷	7.1 x 10 ⁻⁰⁷	2.2 x 10 ⁻⁰⁶	7.1 x 10 ⁻⁰⁷	2.2 x 10 ⁻⁰⁶
Berries ⁽²⁾	1.8 x 10 ⁻⁰⁷	4.5 x 10 ⁻⁰⁷	1.8 x 10 ⁻⁰⁷	4.5 x 10 ⁻⁰⁷	1.3 x 10 ⁻⁰⁹	3.2 x 10 ⁻⁰⁹	1.3 x 10 ⁻⁰⁹	3.2 x 10 ⁻⁰⁹
Garden Produce ⁽²⁾	-	-	1.6 x 10 ⁻⁰⁷	4.0 x 10 ⁻⁰⁷	-	-	4.7 x 10 ⁻⁰⁹	1.2 x 10 ⁻⁰⁸
Background Market Foods								
Market Foods	0	0	0	0	0	0	0	0
Total ILCR	1.3 x 10 ⁻⁰⁶	3.7 x 10 ⁻⁰⁶	2.5 x 10 ⁻⁰⁶	5.5 x 10 ⁻⁰⁶	2.5 x 10 ⁻⁰⁶	7.4 x 10⁻⁰⁶	6.8 x 10 ⁻⁰⁶	1.9 x 10⁻⁰⁵

Notes:

ILCR = incremental lifetime cancer risk

Changes in ILCR between Baseline and Project greater than 1.0 x 10⁻⁵ are bolded and shaded grey.

7. UNCERTAINTIES AND CONSERVATISM IN THE RISK ASSESSMENT

The process of evaluating human health risks from exposure to environmental media involves several steps, each containing inherent uncertainties that ultimately affect the final risk estimates. These uncertainties exist in numerous areas, including the collection of samples, laboratory analysis, estimation of potential exposures, and derivation of TRVs, resulting in either an over- or underestimation of risk. However, where uncertainties existed a conservative approach was taken to compensate for uncertainties to ultimately overestimate, rather than underestimate, potential risks.

Some of the uncertainties have been mentioned in the preceding report sections. The following uncertainty analysis is a qualitative discussion of the key sources of uncertainty in this HHRA and the anticipated effect of the uncertainty on the conclusions of the HHRA. There may be sources of uncertainty other than those evaluated here; however, their effect on the calculation of CRs, HQs, HIs, and ILCRs, are considered to be less significant.

7.1 Contaminants of Potential Concern

The COPCs selected for this assessment were mostly metals, since metals naturally occur in environmental media (i.e., soil, sediment, water, and plant and animal tissue) and were monitored during Baseline studies to support Project development. By screening maximum measured Baseline metal concentrations in the different media against environmental quality guidelines and considering bioaccumulation, it is expected that all relevant metal COPCs have been selected for inclusion in the HHRA.

However, there exists a possibility that other COPCs (e.g., other metals, organic chemicals, etc.) could be associated with Project activities in the future, but do not occur or were not measured under existing conditions, or were not predicted in the Project Case. While the omission of other COPCs might tend to underestimate total risks, this is not a significant source of uncertainty that would affect the results of the HHRA because:

- The COPCs that were excluded were known to be present at concentrations that are well below a level of concern. For instance, PAHs were found to be significantly below guidelines in Baseline studies and potential risk from exposure to PAHs in coal dust deposits was considered negligible and was not carried forward in the risk assessment (Section 3.5.1).
- Some COPCs, like those found in petroleum hydrocarbons or other chemicals used by the Project, are expected to be present within the Minesite but are not expected to be present in areas outside of the Minesite where there is public access. Their storage, handling, and disposal is subject to specific management plans to prevent spills, accidents, or malfunctions. Additionally, any COPCs present within the Minesite will be addressed during the Decommissioning and Reclamation phase so that the potential for exposure and risks to human health will not remain in the Post-closure phase.
- The COPCs that were excluded were considered to be innocuous (e.g., calcium, magnesium, potassium).

7.2 Estimated Environmental Concentrations

7.2.1 Predictive Modelling

The HHRA relies on predictive modelling of COPC concentrations in air, surface- and groundwater, and soil. As with all modelling, especially when predicting over long periods of time in the future or over large study areas, model limitations and assumptions can result in uncertainties in numerical concentration estimates. Models are generally based on limited datasets and historical records, a thorough but ultimately limited understanding of confounding current environmental conditions (e.g., variability in flows

or geological formations), and long-term assumptions and predictions for future environmental conditions (e.g., extent of the effects of climate change on predictions). Base Case models can be calibrated using existing datasets, whereas Project Case models can only be verified by monitoring future conditions during Project development.

The HHRA has used upper-bound estimates of modelled COPC concentrations (e.g., the 90th percentile dust concentration, the maximum of the annual 95% UCLM surface water concentration, that are the worst-year predictions) to ensure that overall predictions of risk to people from Project activities are not underestimated. Risk levels would likely be lower if other statistics of more central tendency were used (e.g., medians, means).

7.2.2 *Terrestrial Subsistence Food Species*

Concentrations of COPCs in the tissue of moose, deer, bear, hare, and grouse were estimated using a food chain model. As with all models, the results are highly dependent on the accuracy of input parameters and the quality of the model itself. Standard methodologies for modelling have been used and described throughout this report and in **Appendix D to this HHRA**.

The main uncertainty in the food chain model was in the selection of BTFs. For animal exposure routes, BTFs from food-to-tissue were used also for water-to-tissue, and soil-to-tissue BTFs were calculated based on US EPA (2007). However, it is unlikely that the BTFs from water-to-tissue are the same as food-to-tissue, and calculated soil-to-tissue BTFs introduce further uncertainty. In addition, the mammalian BTFs were based on published values for beef, as BTFs are not available specifically for moose, deer, bear, and hare. This is a reasonable approximation, since BTFs obtained from beef from the literature are commonly applied to other animals. Similarly, values for grouse were based on available avian species information (chickens). This is the accepted method to model the uptake of COPCs into animals when empirical data are not available and uses the best available data to enable the assessment.

To compensate for the uncertainties associated with the food chain modelling, modelled tissue concentrations in moose and deer were calibrated with publicly available tissue chemistry data from the literature to increase the accuracy of the predictions. Data were not readily available for other subsistence foods species so those models were not calibrated. However, because these other foods (bear, hare, and grouse) are consumed at a much lower frequency than moose and deer, the implications associated with uncertainty in the uncalibrated model predictions of tissue concentrations for these foods on the overall exposure estimates or risk estimates is likely to be low.

The ingestion rates for moose, deer, bear, hare, and grouse used for food, soil, and water were based on guidance for estimating wildlife exposure characteristics provided by Environment Canada (2012) and allometric equations provided in Sample et al. (1997). Wherever possible, conservative assumptions have been made to ensure that potential risks are not underestimated. Bears can have a foraging range larger than the study area; however, the food chain model assumed bears would spend 100% of their time in the LSA. This introduces another layer of uncertainty that results in an over-estimation of exposure to bear from Project-related activities.

Not all vegetation diet species consumed by wildlife or people can be collected during Baseline studies. Thus, the food chain model relies on a limited number of plant species, which may over- or underestimate exposures. Some plants, such as willows, can hyper-accumulate metals and thus are likely to have tissue concentrations higher than other plants that might be consumed by wildlife or people. By including plants such as willow in the Baseline sampling program, it is less likely that the overall concentrations in plants is underestimated.

Vegetation tissue samples were used to model the ingestion of COPCs from garden produce. This is expected to overestimate potential risks because garden produce is customarily washed during preparation

of food, but Baseline vegetation samples were not washed prior to laboratory analysis of metals. It was further assumed that garden produce may be similarly exposed to potential Project emissions as is leafy vegetation in the LSA located closer to the Project. This assumption is also conservative as residents' gardens and farms are located further away from the Project than locations where vegetation was collected during Baseline studies. The assessment is thus overly conservative for this exposure pathway and ROC.

Predicted Project plant tissue concentrations for subsistence foods were based on predicted soil concentrations based on predicted dust fall. Predicted soil and vegetation EPCs in the entire LSA were based on the 90th percentile of the worst-case annual amount of metals in dustfall modelled to occur during the Project Case (Operation). This is conservative and likely overestimates exposures that would actually occur throughout the LSA, especially at sites located further away from the Project where it is more likely that people will collect subsistence foods. It is unlikely that EPCs for soil and vegetation have been underestimated and, thus, this has resulted in exposure and risk estimates that are biased high. This would also result in an overestimate of the terrestrial subsistence food EPCs.

7.2.3 Fish

Consumption of COPCs in fish is one of the main pathways causing Baseline and future risk to human ROCs. For this Project, it was assumed to be due to consumption of rainbow trout from the Bulkley River, Telkwa River, Goathorn Creek, and Tenas Creek. However, anecdotal information and available studies indicate that the traditional Wet'suwet'en fish catches are Chinook and sockeye salmon and a variety of other important food fish species (Section 3.1.2). The main species of fish caught in the area by non-Indigenous fishermen are salmon and Steelhead trout, particularly on the Bulkley River (Section 3.1.3).

The Food Nutrition & Environment Study by Chan et al. (2011) lists over 200 traditional foods that are consumed by Aboriginal Groups in British Columbia and rainbow trout are only eaten by approximately 14% of the Aboriginal population in the area, whereas 99% consume salmon. Furthermore, even among those who eat trout, people generally reported eating eight times more salmon as they do trout. However, salmon spend most of their adult lives in the marine environment and their muscle tissue composition reflects the food obtained from the marine environment, whereas rainbow trout are resident fish species that spend most of their time in the creeks and rivers of the LSA. The assumption that people eat significant amounts of rainbow trout is unlikely, resulting in a more conservative (higher) estimate of potential human health risk associated with fish consumption.

Estimates of fish EPCs are affected by BCF estimates, which were calculated for the Project on a site-by-site basis. This minimizes the uncertainties associated with the BCFs since the data are site-specific and not derived from literature. The BCF was calculated as a simple linear metric (tissue concentration divided by water concentration); however, available literature suggests that there is an inverse relationship between water concentrations and tissue concentrations in fish (McGeer et al. 2003; Carriquiriborde, Handy, and Davies 2004; DeForest, Brix, and Adams 2007; Adams 2011). The use of a linear BCF model in this risk assessment is expected to overestimate the tissue concentrations of most metals.

7.3 Human Exposure Pathways

7.3.1 Locations of Subsistence Foods Harvested

Accurate calculation of risk values requires accurate estimates of the level of human exposure that is occurring. Many of the required exposure parameters are not known with certainty and must be estimated from limited data or knowledge. For example, little information was available about specific locations or frequency of use of the LSA for recreation and for subsistence food collection. The risk assessment approach relies heavily on these types of quantitative data but can only take limited account of other

(non-Western) approaches, like the Wet'suwet'en concept of *Yintah*, where everything is connected to the land and exposures at special locations should not be seen in isolation.

In general, when quantitative exposure data were limited or absent, the exposure parameters were chosen in a way that was intended to be conservative. For instance, for all of the subsistence foods evaluated it was assumed that 100% consumed by people each year came from the Human Health LSA. This is an overestimate, given the large area available for harvesting regionally, outside of the LSA. This overestimation provides conservatism in the risk predictions.

Based on the availability of Baseline vegetation data and the uncertainty regarding traditional or popular subsistence food collection areas, berry collection sites were located near forestry roads. It is unlikely that people will collect berries exclusively from these sites once the Project is developed due to access restrictions (refer to the **PAMP**), or that they would consume berries unwashed. Therefore, the estimation of future Project vegetation COPC concentrations, which takes into account the Base Case concentrations at these locations, provides a conservative approach and results in an over-estimation of risk.

Public access to the areas of the Minesite and Bypass Road will be reinstated during Post-closure. At that time, dust due to the Project will be reduced to Base Case levels and will not affect inhalation or ingestion of metals from subsistence foods beyond Base Case levels. However, dust accumulated over time in soils will still be available for plant uptake and this was accounted for in the future predictions of plant and berry tissue quality.

7.3.2 *Subsistence Foods Consumption Quantity and Frequency*

The Indigenous consumption amount and frequency data used in this assessment were based on values provided by Chan et al. (2011). The frequency of consumption was amortized over a year. Indigenous subsistence food amount and frequency of consumption was also applied to non-Indigenous subsistence food users, as Indigenous populations commonly rely more heavily on subsistence foods than non-Indigenous populations. This provides a level of conservatism to the non-Indigenous subsistence food user.

7.3.3 *Bioavailability*

It was assumed that the bioavailability of most COPCs via the ingestion and inhalation routes of exposure was 100 percent. This assumption would likely result in a conservatively high dose for the COPCs.

7.4 Toxicity Reference Values

Toxicity information for many chemicals is often limited and based on either animal exposure studies or epidemiological studies. Therefore, there are varying degrees of uncertainty associated with TRVs and these uncertainties are common to all risk assessments. Uncertainties can arise from:

- Limited availability of toxicity studies;
- Extrapolation from animal studies to humans;
- Extrapolation from high dose to low dose;
- Extrapolation from continuous exposure to intermittent exposure;
- Extrapolation from non-linear to linear toxicity relationships; and
- Variation in intra-species (between different people) sensitivities.

Uncertainty in TRVs is one of the largest sources of uncertainty in risk estimates. Because of the conservative methods Health Canada and other agencies use in dealing with uncertainties it is much more likely that uncertainty in TRV values results in an overestimation rather than an underestimation of risk. For instance, large UFs are incorporated into the derivation of TRVs which, in the case of thallium, the TRV is considered temporary by Health Canada and the UF is in the range of 3,000 (US EPA 2009).

Since the TRV is applied to the exposure estimates for both the Base Case and Project Case (Operations and Closure) in the denominator of the HQs, the main implication for the uncertainty in TRVs is in the absolute value of the HQ (e.g., a HQ of 1 vs a HQ of 10). The uncertainty in TRVs has minimal implications for the relative incremental change between the Base Case and Project Case since the same TRV value is used in HQ calculations for both cases, which means that the relative incremental change will be the same regardless of the TRV value used in the HQ calculation.

7.5 Uncertainties in Risk Estimates

Because risk estimates for a COPC are derived by combining uncertain estimates of exposure and toxicity (see Sections 7.2, 7.3, and 7.4), the risk estimates for each COPC are more uncertain than either the exposure or toxicity estimates alone. Additional uncertainty arises from the issue of how to combine risk estimates across different chemicals (Section 6.3.2). In some cases, the effects caused by one COPC do not influence the effects caused by other COPCs. In other cases, the effects of one chemical may interact with effects of other COPCs, causing responses that are approximately additive, greater than additive (synergistic), or less than additive (antagonistic). Where information on target organs and toxic effects were available and similar, additive effects were assumed and calculated. In most cases, available toxicity data are not sufficient to define what type of interaction is expected, so Health Canada assumes effects are additive for non-carcinogens that act on the same target organ.

7.6 Definitions of Health

Health is defined as “A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO 1948). Although this definition implies that all aspects of well-being should be considered when assessing human health, including physical, social, emotional, spiritual, and environmental effects on health, the established HHRA methodology for toxicological effects only addresses physical and environmental effects due to contamination in environmental media (water, soil, air) and subsistence foods. This may underestimate overall effects on health due to development of the Project from other (e.g., emotional) effects. However, socio-economic effects, effects on community well-being, and effects from noise are addressed in other relevant sections in the EAC Application.

8. CONCLUSIONS

This HHRA was prepared in accordance with current guidelines for HHRA in environmental assessment in Canada and British Columbia. Human Health was identified as a VC in the EAC Application for the Project and this HHRA was conducted to determine whether incremental changes in risk to Human Health can be expected as a result of the Project from exposure to COPCs within the Human Health LSA.

Human receptors of concern assessed in the HHRA were Indigenous and non-Indigenous Residents and Recreational Land Users. The types, sources, and transport pathways of COPCs were identified and complete exposure pathways between sources and receptors were presented in a CSM for the Project. Project activities that could affect air, water, soil, vegetation, and subsistence foods quality have the potential to cause a change in Human Health. Predictive models were developed to estimate EPCs of COPCs in air, water, soil, vegetation, and subsistence foods. The results of the predictive modelling were used as inputs to estimate predicted future risks in the Project Case (Operations and Closure) and compared to the Base Case risk estimates.

Human health risks from the inhalation of fine particulate matter are not expected at receptors located closest to the Project (i.e., Horsemen Camp, PM Kerr, and the closest rural residence). The Project is not expected to contribute to human health risks from the inhalation of fine particulate matter.

Incremental changes in surface water concentrations and, thus, incremental changes in subsistence foods COPC concentrations of cobalt, lithium, and thallium due to the Project are predicted to increase HQs for Resident and Recreational Land Users in the Operation phase (thallium only) and the Closure phase (cobalt, lithium, and thallium). However, there is uncertainty in the assessment due to highly conservative assumptions made throughout the HHRA and background risks from ingestion of market foods are generally in the same order of magnitude compared to risks from subsistence foods for these COPCs. Therefore, it is unlikely that the predicted increases in risks will adversely affect human health.

The Project-Only ILCR (Project Case minus Base Case) from inhalation of carcinogenic metals was below the acceptable risk threshold of 1×10^{-5} and, thus, considered negligible. Similarly, the Project-Only ILCR due to dermal contact with arsenic in soil and due to ingestion of arsenic in subsistence foods and soil were below this threshold and, thus, considered negligible.

The HHRA predicted a Project-Only ILCR of 1.9×10^{-5} in the Project Case (Closure) relative to the Base Case from ingestion of arsenic in drinking water for the adult Resident Land User, but not for other receptors. Although this is above the acceptable risk threshold of 1×10^{-5} , it is unlikely that the change will adversely affect human health as the prediction assumes that an adult would live in the LSA and drink surface water from within the LSA their entire lifetime. Surface water arsenic concentrations were assumed to be the maximum of the annual 95% UCLM concentration during the entire Decommissioning and Reclamation and Post-closure phases where arsenic concentrations are predicted to decrease, which further overestimates risk from ingestion of arsenic.

The risk estimates incorporate multiple conservative assumptions, which suggests that risks under both the Base Case and predicted Project Case scenarios are likely overestimated, in particular those associated with consumption of subsistence foods and water. Risks from consumption of water and subsistence foods are comparable or lower than background risks calculated for consumption of market foods. The potential for adverse health effects resulting from the Project is considered negligible.

Monitoring of concentrations of arsenic, cobalt, lithium, and thallium in air, soil, surface water, groundwater, fish tissue, and plant tissue should be completed during all phases of the Project (i.e., Construction, Operation, Decommissioning and Reclamation, and Post-closure phases) to confirm key exposure assumptions made in the HHRA.

9. REFERENCES

- British Columbia Contaminated Sites Regulation, B.C. Reg. 375/96.
- Achten, C., C. Shubo, K. L. Straub, and T. Hofmann. 2011. The lack of microbial degradation of polycyclic aromatic hydrocarbons from coal-rich soils. *Environmental Pollution*, 159: 623-29.
- Adams, W. J. 2011. *Bioaccumulation of Metal Substances by Aquatic Organisms Part 1*.
<https://www.oecd.org/env/ehs/risk-assessment/48720690.pdf> (accessed November 2020).
- BC ENV. 2014a. *Ambient Water Quality Guidelines for Selenium. Technical Report Update*. Water Protection and Sustainability Branch, Environmental Sustainability and Strategic Policy Division, British Columbia Ministry of Environment. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_moe_se_wqg.pdf (accessed October 2020).
- BC ENV. 2014b. *Companion Document to: Ambient Water Quality Guidelines for Selenium Update*. Water Protection and Sustainability Branch, Environmental Sustainability and Strategic Policy Division, British Columbia Ministry of Environment. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_moe_se_wqg_companion_document.pdf (accessed October 2020).
- BC ENV. 2017. *Technical Guidance on Contaminated Sites 7: Supplemental Guidance for Risk Assessments. Version 5 November 2017*. Victoria, BC.
- BC ENV. 2019a. *Fact Sheet: Parameters of Concern. Defining Parameters of Concern for Mine Effluent Discharge Authorization Applications*. Victoria, BC.
- BC ENV. 2019b. *Protocol 13 for Contaminated Sites: Screening Level Risk Assessment Version 3.1*. Victoria, BC.
- BC ENV. 2020a. *B.C. Source Drinking Water Quality Guidelines: Guideline Summary. Water Quality Guideline Series, WQG-01*. Province of B.C.: Victoria, B.C.
- BC ENV. 2020b. *Provincial Air Quality Objective Information Sheet - British Columbia Ambient Air Quality Objectives*. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/air/reports-pub/prov_aqo_fact_sheet.pdf (accessed November 2020).
- BC MOE. 2001. *Ambient Water Quality Guidelines for Mercury: Overview Report - First Update*. <http://www.env.gov.bc.ca/wat/wq/BCguidelines/mercury/mercury.html> (accessed June 2016).
- BC MOH. 2021. *British Columbia Guidance for Prospective Human Health Risk Assessment. Version 1.0. April 2021*. BC Ministry of Health (BC MOH). Health Protection Branch, Population and Public Health Division: Victoria, BC.
- Beatty, J. M. and G. A. Russo. 2014. *Ambient water quality guidelines for selenium: Technical report update*. British Columbia Ministry of Environment. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_moe_se_wqg.pdf (accessed May 2021).
- Bright, D. and J. Addison. 2002. *Derivation of Matrix Soil Standards for Salt under the British Columbia Contaminated Sites Regulation*. British Columbia Ministry of Water, Land and Air Protection, Ministry of Transportation and Highways, British Columbia Buildings Corporation, and the Canadian Association of Petroleum Producers: Victoria, BC.

- British Columbia Ministry of Energy, M. a. L. C. I. B. M. 2021. *Health, Safety and Reclamation Code for Mines in British Columbia*. Victoria, BC. 364 pp. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/mineral-exploration-mining/documents/health-and-safety/code-review/health_safety_and_reclamation_code_apr2021.pdf (accessed October 2021).
- BVLD. 2012. *BVLD Airshed Management Plan: A Community Action Plan for Clean Air*. Bulkley Valley Lakes District Airshed Management Society (BVLD AMS):
- Carriquiriborde, P., R. D. Handy, and S. J. Davies. 2004. Physiological modulation of iron metabolism in rainbow trout (*Oncorhynchus mykiss*) fed low and high iron diets. *J Exp Biol*, 207 (Pt 1): 75-86.
- CCME. 2020. *DRAFT - Scientific Criteria Document for the Development of the Canadian Soil Quality Guidelines for the Protection of Human Health: Lead*. Canadian Council of Ministers of the Environment: Winnipeg, Manitoba.
- CCME. 2021a. *Canada's Air*. <https://www.ccme.ca/en/air-quality-report#slide-7> (accessed May 2021).
- CCME. 2021b. *Canadian environmental quality guidelines - summary table*. Canadian Council of Ministers of the Environment. <https://ccme.ca/en/summary-table> (accessed August 2016).
- Chan, L., O. Receveur, D. Sharp, H. Schwartz, A. Ing, and C. Tikhonov. 2011. *First Nations Food, Nutrition & Environment Study (FNFNES): Results from British Columbia (2008/2009)*. University of Northern British Columbia: Prince George, BC.
- Chapman, P. M., J. Downie, A. Maynard, and L. A. Taylor. 1996. Coal and deodorizer residues in marine sediments - contaminants or pollutants? *Environmental Toxicology and Chemistry*, 15 (5): 638-42.
- Couture, P., C. Fortin, L. Hare, D. Lapointe, and D. Pitre. 2011. *Critical Review of Thallium in Aquatic Ecosystems. Research Report No R-1272. April 2011*. R-1272. Inorganics Unit, Ecological Assessment Division, Science and Technology Branch, Environment Canada: Québec, QC.
- Cowherd, J., C. 2008. *Transportability Assessment of PM Emissions*. 10.3155/2008ACE08.573. Midwest Research Institute: Kansas City, MO.
- Crossroads Cultural Resource Management. 2020. *Cultural Use Study*.
- CSAP. 2012. *CSAP Technical Guidance for Risk Assessment COPC Screening*. Society of Contaminated Sites Approved Professionals of British Columbia:
- Deepthike, H. U., R. Tecon, G. Van Kooten, I. R. Van Der Meer, H. Harms, M. Wells, and J. Short. 2009. Unlike PAHs from Exxon Valdez crude oil, PAHs from Gulf of Alaska coals are not readily bioavailable. *Environmental Science and Technology*, 43: 5864-70.
- DeForest, D. K., K. V. Brix, and W. J. Adams. 2007. Assessing metal bioaccumulation in aquatic environments: The inverse relationship between bioaccumulation factors, trophic transfer factors and exposure concentration. *Aquatic Toxicology*, 84: 236-46.
- EBRC. 2007. *Health Risk Assessment Guidance for Metals - Fact sheet 1: Assessment of occupational dermal exposure and dermal absorption for metals and inorganic metal compounds. Report prepared for International Council on Mining & Metals*.
- EFSA. 2009. Scientific opinion on arsenic in food. *European Food Safety Authority Journal*, 7 (10): 1351.
- EFSA. 2014. Dietary exposure to inorganic arsenic in the European population. *European Food Safety Authority Journal*, 12 (3): 3597-665.
- Environment and Climate Change Canada and Health Canada. 2020. *Draft Screening Assessment - Thallium and its compounds. September 2020*. <https://www.canada.ca/en/environment-climate->

- [change/services/evaluating-existing-substances/draft-screening-assessment-thallium-compounds.html](https://www.ec.gc.ca/ceac/evaluating-existing-substances/draft-screening-assessment-thallium-compounds.html) (accessed October 2021).
- Environment Canada. 2003. *Guidance Manual for the Categorization of Organic and Inorganic Chemicals on Canada's Domestic Substances List (DSL): Determining Persistence, Bioaccumulation Potential, and Inherent Toxicity to Non-human Organisms*. Existing Chemicals Branch:
- Environment Canada. 2012. *Federal Contaminated Sites Action Plan (FCSAP) Ecological Risk Assessment Guidance. Module 3: Standardization of Wildlife Receptor Characteristics*. Government of Canada, Environment Canada: Gatineau, QC.
- Gao, Y., M. Leermakers, M. Elskens, G. GBillon, B. Ouddane, J.-C. Fischer, and W. Baeyens. 2007. High resolution profiles of thallium, manganese and iron assessed by DET and DGT techniques in riverine sediment pore waters. *Sci Total Environ*, 373: 526-33.
- Ghosh, U., J. W. Talley, and R. G. Luthy. 2001. Particle-scale investigation of PAH desorption kinetics and thermodynamics from sediment. *Environmental Science and Technology*, 35 (17): 3468-75.
- Golder Associates. 2005. *Guidance Document for Country Foods Surveys for the Purpose of Human Health Risk Assessment*. Prepared for Health Canada.
- Gottesfeld, L. M. J. 1994a. Conservation, territory, and traditional beliefs: An analysis of Gitksan and Wet'suwet'en subsistence, Northwest British Columbia, Canada. *Human Ecology*, 22 (4): 443-65.
- Gottesfeld, L. M. J. 1994b. Wet'suwet'en Ethnobotany: Traditional Plant Uses. *Journal of Ethnobiology*, 14 (2): 185-210.
- Gottesfeld, L. M. J. 1999. *Plants, Land and People, A Study of Wet'suwet'en Ethnobotany*. diss., University of Alberta.
- Health Canada. 2000. *Decision-Making Framework for Identifying, Assessing, and Managing Health Risks*. Health Canada. <https://www.canada.ca/en/health-canada/corporate/about-health-canada/reports-publications/health-products-food-branch/health-canada-decision-making-framework-identifying-assessing-managing-health-risks.html> (accessed October 26, 2020).
- Health Canada. 2007a. *Human health risk assessment of mercury in fish and health benefits of fish consumption*. November 20, 2011. Bureau of Chemical Safety, Food Directorate, Health Products and Food Branch: Ottawa, ON.
- Health Canada. 2007b. *Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption*. Bureau of Chemical Safety, Food Directorate, Health Products and Food Branch: Ottawa, ON.
- Health Canada. 2010a. *Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRA chem)*. Health Canada: Ottawa, ON.
- Health Canada. 2010b. *Federal Contaminated Site Risk Assessment in Canada, Supplemental Guidance on Human Health Risk Assessment for Country Foods (HHRA foods)*. Health Canada: Ottawa, ON.
- Health Canada. 2010c. *Useful Information for Environmental Assessments*. Health Canada: Ottawa, On.
- Health Canada. 2011a. *Dietary Intakes of Contaminants and Other Chemicals for Different Age-Sex Groups of Canadians - Canadian Total Diet Study*. https://www.canada.ca/content/dam/hc-sc/migration/hc-sc/fn-an/alt_formats/hpfb-dgpsa/pdf/surveill/metal_intake-plomb_apport_93-99-eng.pdf (accessed February 2022).

- Health Canada. 2011b. *Toxicological reference values, estimated daily intakes or dietary reference values for trace elements*. Obtained from Chemical Health Hazard Revised March 2011, unpublished: Ottawa, ON.
- Health Canada. 2013. *Federal Contaminated Site Risk Assessment in Canada: Interim Guidance on Human Health Risk Assessment for Short-Term Exposure to Carcinogens at Contaminated Sites*. Contaminated Sites Division, Safe Environments Directorate: Ottawa, ON.
- Health Canada. 2016a. *Guidance for Evaluating Human Health Impacts in Environmental Assessment: Air Quality*. Ottawa, ON.
- Health Canada. 2016b. *Guidance for Evaluating Human Health Impacts in Environmental Assessment: Drinking and Recreational Water Quality*. Ottawa, ON.
- Health Canada. 2016c. *Human Health Risk Assessment for Diesel Exhaust*. Ottawa, ON.
- Health Canada. 2017. *Federal Contaminated Site Risk Assessment in Canada: Supplemental Guidance on Human Health Risk Assessment of Air Quality, Version 2.0*. March 2017. Ottawa, ON.
- Health Canada. 2018. *Guidance for Evaluating Human Health Impacts in Environmental Assessment: Country Foods*. Ottawa, ON.
- Health Canada. 2019a. *Guidance for Evaluating Human Health Impacts in Environmental Assessment: Human Health Risk Assessment*. Ottawa, ON.
- Health Canada. 2019b. *Guidelines for Canadian Drinking Water Quality. Guideline Technical Document - Uranium*. Ottawa, ON.
- Health Canada. 2020. *Guidelines for Canadian Drinking Water Quality. Summary Table*. Prepared by Health Canada in collaboration with the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment: Ottawa, ON.
- Health Canada. 2021a. *Federal Contaminated Site Risk Assessment in Canada: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 3.0*. Ottawa, ON.
- Health Canada. 2021b. *Federal Contaminated Site Risk Assessment in Canada: Toxicological Reference Values (TRVs), Version 3.0*. Health Canada: Ottawa, ON.
- International Programme on Chemical Safety. 1996. *Environmental Health Criteria 182: Thallium*. World Health Organization. <https://incchem.org/documents/ehc/ehc/ehc182.htm> (accessed October 2021).
- JECFA. 2011a. *Arsenic (addendum). WHO Food Additives Series: 63. FAO JECFA Monographs 8*. Prepared by the Seventy-second Meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA): Geneva, CH.
- JECFA. 2011b. *Evaluations of the Joint FAO/WHO Expert Committee on Food Additives (JECFA): Aluminum*. Presented at Joint FAO/WHO Expert Committee on Food Additives (JECFA),
- Laforte, L., A. Tessier, C. Gobeil, and R. Carignan. 2004. Thallium diagenesis in lacustrine sediments. *Geochim Cosmochim Acta*, 69 (22): 5295-306.
- McGeer, J. C., K. V. Brix, J. M. Skeaff, D. K. DeForest, S. I. Brigham, W. J. Adams, and A. Green. 2003. Inverse relationship between bioconcentration factor and exposure concentration for metals: Implications for hazard assessment of metals in the aquatic environment. *Environmental Toxicology and Chemistry*, 22 (5): 1017-37.

- Neff, J. M., S. A. Stout, and D. G. Gunster. 2005. Ecological Risk Assessment of Polycyclic Aromatic Hydrocarbons in Sediments: Identifying Sources and Ecological Hazard. *Integrated Environmental Assessment and Management*, 1 (1): 22-33.
- Northern Health. 2015a. *Guidance on Human Health Risk Assessment*. Version 1.0. September 2015.
- Northern Health. 2015b. *Standard Working Group Comments and Recommendations for Provincial Environmental Assessments in Northern British Columbia*. Version 2.1. April 29, 2015. Office of Health and Resource Development:
- Oak Ridge National Laboratory. 2021. *Provisional Peer-Reviewed Toxicity Values. PPRTV Assessments Electronic Library*. <https://hhpprtv.ornl.gov/> (accessed May 2021).
- Phillips, D. J. H. 1990. Arsenic in aquatic organisms: a review, emphasizing chemical speciation. *Aquatic Toxicology*, 16: 151-86.
- Rahman, M. A., H. Haseqawa, and R. P. Lim. 2012. Bioaccumulation, biotransformation and trophic transfer of arsenic in the aquatic food chain. *Environmental Research*, 116: 118-35.
- RAIS. 2020. <https://rais.ornl.gov/index.html> (Chemical Parameters - Beef Transfer Coefficient. The Risk Assessment Information System. accessed July 2020).
- RAIS. 2021. *Chemical Parameters*. Risk Assessment Information System. <https://rais.ornl.gov/> (accessed January 2022).
- Regional District of Bulkley-Nechako. 2012. *Agriculture Plan*. Burns Lake, BC.
- Rescan. 2008. *Davidson Project Country Foods Baseline Assessment*. Prepared by Rescan Environmental Services Ltd. for Blue Pearl Mining Ltd.: Vancouver.
- Richardson, G. M. 1997. *Compendium of Canadian Human Exposure Factors for Risk Assessment* O'Connor Associates Environmental Inc.: Ottawa, ON.
- Rosemond, S. D., Q. Xie, and K. Liber. 2008. Arsenic concentration and speciation in fish freshwater fish species from Back Bay near Yellowknife, NT, Canada. *Environmental Monitoring and Assessment*, 147: 199-210.
- Sample, B. E., M. S. Aplin, R. A. Efroymsen, G. W. Suter II, and C. J. E. Welsh. 1997. *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*. ORNL/TM-13391. Oak Ridge National Laboratory, US Department of Energy: Oak Ridge, TN.
- Sartorelli, P., A. Cenni, G. Matteucci, L. Montomoli, M. T. Novelli, and S. Palmi. 1999. Dermal exposure assessment of polycyclic aromatic hydrocarbons: in vitro percutaneous penetration from lubricating oil. *International Archives of Occupational and Environmental Health*, 72: 528-32.
- Sartorelli, P., L. Montomoli, A. G. Sisinni, R. Bussani, D. Cavallo, and V. Foa. 2001. Dermal exposure assessment of polycyclic aromatic hydrocarbons: in vitro percutaneous penetration from coal dust. *Toxicology and Industrial Health*, 17: 17-21.
- Slejkovec, Z., Z. Bajc, and D. Z. Doganoc. 2004. Arsenic speciation patterns in freshwater fish. *Talanta*, 62 (5): 931-36.
- Staven, L. H., K. Rhoads, B. A. Napier, and D. L. Streng. 2003. *A Compendium of Transfer Factors for Agricultural and Animal Products*. PNNL-13421. Richland, WA.
- Telkwa Coal Ltd. 2018. *Tenas Project. Project Description. November 2018 Final Version. Submitted to BC EAO by Telkwa Coal Ltd.*

- Texas CEQ. 2016. Effects Screening Levels (ESL) Lists Used in the Review of Air Permitting Data (November 2016 update). http://www.tceq.texas.gov/toxicology/esl/list_main.html#esl_1 (accessed September 2020).
- Thorsen, W. A., W. G. Cope, and D. Shea. 2004. Bioavailability of PAHs: Effects of soot carbon and PAH source. *Environmental Science and Technology*, 38: 2029-37.
- Turner, A., A. Cabon, G. A. Glegg, and A. S. Fisher. 2010. Sediment–water interactions of thallium under simulated estuarine conditions. *Geochim Cosmochim Acta*, 74: 6779-87.
- US EPA. 1991. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part B, Development of Risk Based Preliminary Remediation Goals), Interim.
- US EPA. 1995. *Assessing Dermal Exposure from Soil - December 1995. US EPA Region 3, Technical Guidance Manual, Risk Assessment*.
- US EPA. 2004. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Final. EPA/540/R/99/005*. Office of Emergency and Remedial Response. Office of Superfund Remediation and Technology Innovation: Washington, DC.
- US EPA. 2005a. *Guidelines for Carcinogen Risk Assessment*. EPA/630/P-03/001F. United States Environmental Protection Agency, Risk Assessment Forum: Washington, DC.
- US EPA. 2005b. *Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities*. EPA520-R-05-006. US EPA Office of Solid Waste and Emergency Response: Washington, DC.
- US EPA. 2007. Attachment 4-1 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs) Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLsd. In
- US EPA. 2008. *Provisional Peer Reviewed Toxicity Values for Lithium (CASRN 7439-93-2)*. Superfund Health Risk Technical Support Center, National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency: Cincinnati, OH.
- US EPA. 2009. *Toxicological Review of Thallium and Compounds (CAS No. 7440-28-0). In Support of Summary Information on the Integrated Risk Information System (IRIS)*. U.S. Environmental Protection Agency. https://ofmpub.epa.gov/eims/eimscomm.getfile?p_download_id=530222 (accessed May 2021).
- US EPA. 2020. *Assessing Dermal Exposure from Soil. Region 3 Technical Guidance Manual, Risk Assessment*.
- US EPA. 2022. Integrated Risk Information System (IRIS). https://iris.epa.gov/AtoZ/?list_type=alpha (IRIS Assessments accessed February 2022).
- Washington State. 2019. Washington Administrative Code (WAC 173-460-150): Table of ASIL, SQER, and de minimis emission values. <http://apps.leg.wa.gov/WAC/default.aspx?cite=173-460-150> (accessed September 2020).
- WHO. 1948. *Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 states (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948*. World Health Organization: New York, NY.
- WHO. 1984. *Health Promotion: A Discussion Paper on the Concept and Principles*. World Health Organization Regional Office for Europe: Copenhagen, Denmark.

- World Health Organization (WHO). 1993. *Guidelines for drinking-water quality, 2nd ed. Vol. 1. Recommendations. Geneva, World Health Organization. p. 55.*
- Yang, J. J., T. A. Roy, A. J. Krueger, W. Neil, and C. R. Mackerer. 1989. In vitro and In vivo percutaneous absorption of benzo(a)pyrene from petroleum crude-fortified soil in the rat. *Bull Environ Contam Toxicol*, 43: 207-14.
- Yang, J. J., T. A. Roy, and C. R. Mackerer. 1986a. Percutaneous absorption of anthracene in the rat: Comparison of in vivo and in vitro results. *Toxicology and Industrial Health*, 2 (1): 79-84.
- Yang, J. J., T. A. Roy, and C. R. Mackerer. 1986b. Percutaneous absorption of benzo(a)pyrene in the rat: Comparison of in vivo and in vitro results. *Toxicology and Industrial Health*, 2 (4): 409-16.

ERM has over 160 offices across the following countries and territories worldwide

Argentina	The Netherlands
Australia	New Zealand
Belgium	Norway
Brazil	Panama
Canada	Peru
Chile	Poland
China	Portugal
Colombia	Puerto Rico
France	Romania
Germany	Russia
Ghana	Senegal
Guyana	Singapore
Hong Kong	South Africa
India	South Korea
Indonesia	Spain
Ireland	Sweden
Italy	Switzerland
Japan	Taiwan
Kazakhstan	Tanzania
Kenya	Thailand
Malaysia	UAE
Mexico	UK
Mozambique	US
Myanmar	Vietnam

ERM's Vancouver Office
#1000 - 1100 Melville Street
Vancouver, BC
Canada V6E 4A6

T: +1 604 689 9460
F: +1 604 687 4277

www.erm.com