Appendix A

Detailed Quantitative Environmental Risk Assessment

Crown Mountain Coking Coal Project, British Columbia

Prepared by: AECOM Canada Ltd.
Prepared for: NWP Coal Canada Ltd.

Detailed Quantitative Environmental Risk Assessment

Crown Mountain Coking Coal Project, British Columbia

NWP Coal Canada Ltd.

Project number: 60590462

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EXECUTIVE SUMMARY

NWP Coal Canada Ltd (NWP) is proposing to develop the Crown Mountain Coking Coal Project (the Project), which is intended as an open pit metallurgical coal mine. The Project area is located approximately 30 km by road from Sparwood, BC, within the Elk Valley coal field in the East Kootenay Region of southeastern British Columbia. The Project comprises ten coal licenses, located in the Elk Valley and Crowsnest coal fields. The anticipated production capacity of the Project is up to 4.0 million run-of-mine tonnes per annum for a production duration of approximately 15 years. Exploration activities have indicated that the coal at the Project site is typical of coking coals produced from existing mines in the Elk Valley. The high-quality metallurgical coal would be transported via railway to coastal BC, where it would be shipped overseas to be used in steelmaking.

This report focuses on characterizing potential risks arising from the exposure of human and ecological receptors to chemical contaminants predicted to influence environmental quality based on interactions between proposed Project activities and the natural environment. Health risk assessment is a systematic and well-documented process to define and quantify potential health risks, which serve as surrogate measure of potential impacts from the Project. The present risk assessment was conducted in accordance with Provincial and Federal risk assessment guidance, including:

- Health Canada. Federal Contaminated Sites Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment.
- Health Canada. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals.
- Canadian Council of Ministers of Environment. Ecological Risk Assessment Guidance Document.
- British Columbian, Contaminated sites Regulation, Protocol 1 for Contaminated Sites – Detailed Risk Assessment.

Methods

Risk assessments typically include a variety of conservative assumptions to avoid underestimation of potential risks. The present risk assessment uses site-specific data paired with conservative models and assumptions to predict the toxicological risk to humans and wildlife during the operational phase of the Project, which is also considered to be an acceptable and conservative basis for inference of health risks during the mine construction phase. As this is a prospective assessment of toxicological risk (i.e. the assessment of a proposed/future Project), the current risk assessment relies on a combination of baseline data, conservative assumptions including predicted air quality, long-term particulate deposition, and surface water quality predictions, as well as documented receptor characteristics in order to arrive at quantitative estimates of future health risk.

Scope and Spatial Boundary: The present risk assessment is based primarily on information obtained through engagement with the Ktunaxa Nation Council to identify locations which are known to be of importance to local Indigenous communities for traditional land use activities (refereed to as critical receptor locations). The identified locations were incorporated into the local study areas of other discipline teams, namely air quality modelling and surface water quality modelling, as these two pathways were identified as the most likely pathways connecting proposed Project activities with the surrounding environment.

Project Linkages to Environment: Predicted changes in concentrations of contaminants of potential concern in environmental media are conservatively based on a conservative or worst-case modelled scenario. In the case of airborne emissions, air quality and particulate deposition are modelled for the year of highest production (project year 11), and in the case of surface water quality the assessment is based on the maximum 30-day rolling average through the project lifecycle. The calculated risk estimates are inferred to adequately describe toxicological health risk through all stages of the Project, including construction, decommissioning, and post-closure.

Aquatic Health Risks: Health risk to aquatic valued components are assessed based on modelled surface water quality at key locations in the watershed, and ecologically relevant toxicity data for the identified contaminants of potential concern. Risk estimates were calculated as “hazard quotients” (HQ) and are the ratio between the estimated exposure and ecologically relevant toxicity reference values protective of the receptors being assessed. Aquatic valued components were identified and drawn from the Application Information Requirements.

Wildlife Health Risk: Exposure and consequent risk for wildlife receptors assessed as part of the wildlife health valued component is conducted using a multimedia food web model. Predicted changes to environmental quality are modelled through the foodweb and estimated daily exposure of contaminants to ecological receptors is calculated based on active routes of exposure. Wildlife receptors of concern are assessed based on species specific characteristics to estimate exposure from surface water, dietary intake, incidental soil ingestion, etc. Risk estimates were calculated as “hazard quotients” (HQ) and are the ratio between the estimated exposure and ecologically relevant toxicity reference values protective of the receptors being assessed. Wildlife receptors are conservatively assumed to spend 100% of their time at critical receptor locations in the local study area where exposure concentrations would be biased high. This may be plausible for sessile receptors or receptors with small home ranges but may be highly conservative for receptors with a larger foraging range.

Human Health Risk: The local study area is likely visited by a variety of peoples, including recreational visitors, hunters, trappers, community residents, and Indigenous groups engaging in their traditional lifestyle. Of the various groups of people who may visit the study area in the future, people engaged in traditional land uses are expected to have the greatest potential exposure based on duration and frequency of visit and the activities they engage in while in the study area. Based on information provided through engagement with the KNC, the current risk assessment assesses potential risk to Indigenous people engaged in a traditional lifestyle for both a current land use scenario and a more intensive rights-based land use scenario. These Indigenous traditional lifestyle scenarios are considered sufficiently conservative to infer maximal potential risk to non-Indigenous peoples also frequenting the study area.

Human receptors of all age groups are conservatively assumed to be present at critical receptor locations 365 days a year for the duration of their life, and that modelled environmental conditions associated with the year of greatest flux is characteristic of the conditions encountered through the receptors lifetime. Additionally, it is assumed that 100% of the annual exposure is derived from the critical receptor location, including 100% of dietary intake and drinking water intake. Human exposures associated with dietary intake were modelled based on a site-specific multimedia foodweb model to predict the concentration of contaminants of potential concern in food items. Depending upon the type of health hazard presented by COPCs to humans, risk estimates were calculated either as “hazard quotients” or as the “incremental lifetime cancer risk” (ILCR).

Risk Assessment Results and Conclusions

Conclusions of the risk assessment are as follows:

Aquatic Health Risk: Sediment and water quality predictions and quantitative assessment of risks to aquatic valued components drew the following conclusions:

1. Predicted surface water and sediment quality identified cadmium, cobalt, and selenium as contaminants of potential concern (COPCs) to be carried forward for quantitative assessment.

2. The proposed Project and its activities are predicted to result **in a low potential risk to aquatic community health.**

   a. Hazard quotients in exceedance of target thresholds were calculated for project assessment nodes for cadmium, cobalt, and selenium.

   b. *Cadmium:* Risk estimates in exceedance of target threshold are calculated for benthic invertebrates associated with direct sediment contact. Risk estimates in exceedance of target thresholds are limited to the lower reach of West Alexander Creek before the confluence of Alexander Creek. Maximum calculated HQ is 2.7 suggestive of a low magnitude of effect.

c. *Cobalt:* HQs associated with surface water direct contact suggested exceedance of target risk thresholds in West Alexander Creek, prior to its confluence with Alexander Creek. The calculated HQ is suggestive of a moderate potential magnitude of effect in the lower reach of West Alexander Creek. Calculated HQ in Alexander Creek immediately after the confluence with West Alexander Creek is suggestive of a low potential magnitude of effect. Calculated HQs quickly decrease below target thresholds as one moves downstream.

d. Selenium: HQs in exceedance of the target risk threshold are conservatively predicted for benthic invertebrates associated with direct sediment contact as well as aquatic invertebrates associated with direct contact with surface water. Risk estimates in exceedance of target thresholds are limited to the lower reach of West Alexander Creek before the confluence of Alexander Creek. Maximum calculated HQs are suggestive of a low potential magnitude of effect. The calculated HQs with higher potential magnitude in the Harmer Creek watershed are reflective of historical and ongoing mining activities in Elk Valley and are not related to the proposed Project.

3. Proposed Project activities are predicted to result in no significant a health risk to sensitive amphibian species. The overall potential health **risk to amphibians as a result of the Project are considered to be negligible.**

4. Calculated hazard quotients associated with surface water exposure to sensitive fish species were below the target threshold for all COPCs, at all key water quality locations with the exception of those affected by surface water discharge from Harmer Creek. **Project related health risk to sensitive fish species is considered to be negligible.**

   a. Release from the waste rock sedimentation pond to lower West Alexander Creek, and subsequently to Alexander Creek is the principal pathway affecting surface water quality. Calculated hazard quotients for water quality stations along the effluent flow pathway are below target thresholds for all COPCs.

   b. Calculated hazard quotients for waterbird exposure to selenium in surface water are below target thresholds at all water quality stations. **The potential health risk to waterbirds as a result of the Project are considered to be negligible.**

5. Overall the proposed Project and associated activities are considered to present a **low risk to aquatic health.**

6. Risk estimates at cumulative assessment nodes suggest a potentially high magnitude of effect associated with surface water quality and predicted sediment quality in the Grave Creek watershed below the confluence with Harmer Creek. It must be noted water quality within Harmer Creek is impacted by historical and existing mining activity upstream of the Project. According to the Water Quality Modelling Report the **proposed Project activities do not appreciably affect the Grave Creek watershed, and the risk predictions associated with the cumulative assessment nodes are indicative of current baseline conditions.**

Wildlife Health Risk

7. The following COPCs were identified for wildlife and carried forward for quantitative assessment: arsenic, cadmium, chromium, cobalt, selenium, and thallium.

8. Predicted concentrations of COPCs in soil as a result if incremental changes to soil chemistry associated with total particulate deposition present a **negligible risk to plant health** based on conservative assumptions and toxicity reference values.

9. Predicted concentrations of COPCs in soil as a result if incremental changes to soil chemistry associated with total particulate deposition present a **negligible risk to soil invertebrate health** based on conservative assumptions and toxicity reference values.

10. The overall Project related **wildlife health risk associated with exposure to all COPCs is considered to be low and likely negligible for mammalian receptors for the Application and Cumulative assessment cases.**

11. The overall Project related **wildlife health risk associated with exposure to all COPCs is considered to be low or low and likely negligible for avian receptors for the Application and Cumulative assessment cases.**

Human Health Risk

12. COPCs identified for inclusion in assessment of human health risk included arsenic, benzo(a)pyrene, cadmium, chromium, cobalt, nickel, selenium, and thallium.

13. For Arsenic, calculated hazard quotients for human exposure under current and rights-based land use scenarios were below target thresholds (HQ<1) for the Base, Application, and Current assessment cases. Threshold non-cancer human health risks associated with arsenic exposure are therefore considered to be **negligible**. Calculated incremental lifetime cancer risks for the current and rights-based human receptors exceeded the target threshold of 1E-05 at all critical receptor locations, resulting in a high magnitude of risk (i.e. ILCR >1E-04). Predicted ILCRs at all critical receptor locations are reported to have a small (<10%) increase relative to the Base Case for the high consuming rights-based receptor under the Application and Cumulative assessment cases. Considering the above information, the overall Project related cancer risk associated with arsenic exposure is considered to be **low and likely negligible** for current and rights-based land use scenarios for the Application and Cumulative assessment cases.

14. For Cadmium, calculated hazard quotients for human exposure under current and rights-based land use scenarios exceeded the target threshold at seven critical receptor locations exposure. Critical receptor locations along Alexander Creek, downstream of proposed activities have calculated HQs ranging from 1.3 to 1.8 for the Application and Cumulative assessment cases. Project related risk from threshold effects associated with cadmium exposure is considered to be low for current and rights-based receptors for the Application and Cumulative assessment cases. Calculated ILCRs for the current and rights-based human receptors exceeded the target threshold at 7 of 14 critical receptor locations outside the Project exclusion area, with a high magnitude of risk (i.e. ILCR >1E-04). Critical receptor locations with unacceptable ILCRs are primarily confined to critical receptor locations located in the immediate vicinity of mine related infrastructure, such as the haul road and rail loadout. It is considered implausible that these locations would be used in a way that reflects with the exposure scenario assessed (i.e. full time, year-round occupancy for the duration of the Project lifecycle). The overall Project related cancer risk associated with inhalation exposure to cadmium is considered to be **low and likely negligible** for current and rights-based land use scenarios for the Application and Cumulative assessment cases.

15. For Chromium, calculated hazard quotients for human exposure under current and rights-based land use scenarios exceeded the target threshold at all locations for the Base, Application, and Cumulative assessment cases. Calculated HQs are essentially unchanged between Base and Application and Cumulative cases at several critical receptor locations. The overall Project related threshold risk associated with chromium exposure is considered **low and likely negligible** for current and rights-based land use scenarios for the Application and Cumulative assessment cases. Calculated ILCRs for the current and rights-based human receptors exceeded the target at 5 of 14 critical receptor locations outside the Project exclusion area, with a high magnitude of risk. Critical receptor locations with unacceptable ILCRs are limited to locations in the immediate vicinity of mine infrastructure, such as the haul road and rail loadout. It is considered implausible that these locations would be used in a way that reflects with the exposure scenario assessed (i.e. full time, year-round occupancy for the duration of the Project lifecycle). The overall Project related cancer risk associated with inhalation exposure to chromium is considered to be **low** for current and rights-based land use scenarios.

16. For Cobalt, calculated hazard quotients for human exposure under current and rights-based land use scenarios exceeded the target threshold at all locations for the Base, Application, and

Cumulative assessment cases. Calculated HQs are essentially unchanged between Base and Application and Cumulative cases at all but 5 critical receptor locations. Incremental calculated HQs exceeding target thresholds are limited to locations directly influenced by physical works (CRID-4 and CRID12) and three critical receptor locations (CRID-10, -11 & -14) which are downstream but in close proximity to the confluence between West Alexander Creek and Alexander Creek. Incremental HQs at these locations (CRID-10, -11, and -14) range between 1.7 and 4.4 suggestive of a low potential magnitude of effect. Uncertainty and conservative assumptions in the modelled surface water quality, as well as conservatism in the TRV used in the present assessment likely overestimate threshold non-cancer health risks associated with oral exposure to cobalt. The overall Project related threshold risk associated with cobalt exposure is considered to be **low** for current and rights-based receptors for the Application and Cumulative assessment cases.

17. For Nickel, calculated hazard quotients for human exposure the current and rights-based land use scenarios exceeded the target threshold at one location within Alexander. Incremental increase in calculated hazard quotients is reported at critical receptor locations downstream of the confluence between West Alexander Creek (which carried mine effluent discharge) and Alexander Creek (incremental hazard quotients range between 0.3 and 0.7). Uncertainty and conservative assumptions in the modelled surface water quality, as well as conservatism in the TRV used in the present assessment likely overestimate threshold non-cancer health risks associated with oral exposure to nickel. The overall Project related threshold risk associated with nickel exposure is considered to be l**ow and likely negligible**. Calculated incremental lifetime cancer risk due to nickel exposure for the current and rights-based land use scenarios exceeded the acceptable threshold at a single location (CRID-4) located at the rail load-out, with a low magnitude of risk. It is considered implausible that this location would be used in a way that reflects with the exposure scenario assessed (i.e. full time, year-round occupancy for the duration of the Project lifecycle). The overall Project related cancer risk associated with inhalation exposure to nickel is considered to be **low and likely negligible**.

18. For Selenium, calculated hazard quotients for human exposure to current and rights-based land use scenarios were below target thresholds (HQ<1) for the Base, Application, and Current assessment cases. Threshold non-cancer human health risks associated with selenium exposure are therefore considered to be **negligible**.

19. Benzo(a)pyrene was assessed as a non-threshold inhalation carcinogen only. Calculated ILCRs for exposure to benzo(a)pyrene to current and rights-based receptors were below target thresholds for the Base, Application, and Current assessment cases. Non-threshold cancer human health risks associated with benzo(a)pyrene inhalation exposures are therefore considered to be **negligible**.

ABBREVIATIONS AND ACRONYMS

CCME – Canadian Council of Ministers of the Environment
CEAA – Canadian Environmental Assessment Act
CEM -Conceptual Exposure Model
COPC – Contaminant of Potential Concern
CRL – Critical Receptor Location
EA – Environmental Assessment
EAC – Environmental Assessment Certificate
EAO – BC Environmental Assessment Office
EDD – Estimated Daily Dose
EPC – Exposure Point Concentration
HHERA – Human Health and Ecological Risk Assesement
HHRA – Human Health Risk Assessment
HQ – Hazard Quotient
ILCR – Incremental Lifetime Cancer Risk
Kd – Water-to-sediment partition coefficient
KQ – Key Question
KNC - Ktunaxa Nation Council
LADD – Lifetime Amortized Daily Dose
LSA – Local Study Area
MAC – Maximum Acceptable Concentration
NOAEL – No Observed Adverse Effects Level
NWP - NWP Coal Canada Ltd.
RfC – Reference Concentration
RfD – Reference Dose
ROC – Receptor of Concern
TDI – Tolerable Daily Intake
TRV – Toxicity Reference Value
VC – Valued Components

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1. Introduction

The following presents the methodology and results of a prospective detailed quantitative environmental risk assessment (HHERA) for the proposed NWP Coal Canada Ltd. (NWP) Crown Mountain Coking Coal Project (the Project).

Major mining projects, such as the Project, have a potential to emit chemical contaminants to the environment through controlled or uncontrolled emission such as permitted effluent discharge, surface water runoff, fugitive dust, and emissions from vehicle traffic or other direct facility emissions. These emissions in turn have the potential to alter environmental quality of local and regional landscapes which could potentially expose humans and wildlife (including plants, and animals in the terrestrial and aquatic environment) to chemical emissions from the Project. The degree of exposure and significance of potential risks to human or ecological health is of concern to local residents, communities, and regulatory agencies, and is the focus of this technical support document.

The following quantitative assessment provides a basis for the understanding of potential risks to human and ecological health posed by the Project. HHERA is a systematic and well-documented process to define and quantify potential health risks, which serve as surrogate measure of potential impacts from the Project. The HHERA uses site-specific data and conservative models and assumptions to predict the toxicological risk potential to humans and wildlife during the operational phase of the Project. Through a combination of conservative assumptions including predicted air quality, long-term particulate deposition, and surface water quality predictions through the operational phase the calculated risk estimates are inferred to adequately describe toxicological health risk through all stages of the Project, including construction, decommissioning, and post-closure.

1.1 Project Description

NWP Coal Canada Ltd (NWP) is proposing to develop the Crown Mountain Coking Coal Project (the Project), which is intended as an open pit metallurgical coal mine located within the Elk Valley coal field in the East Kootenay Region of southeastern British Columbia, BC (**Figure 1-1**). NWP is a jointly owned subsidiary of Jameson Resources Limited and Bathurst Resources Limited (Canada). The Project comprises ten coal licenses. The Project is located between several existing metallurgical coal mines in the Elk Valley and Crowsnest coal fields, with Teck Resources Limited's (Teck) Elkview mine located approximately 8 kilometres (km) southwest of the Project area and Teck's Line Creek mine located approximately 12 km north of the Project area. The Project area is located approximately 30 km by road from Sparwood, BC and is accessible by several Forest Service Roads, including Grave Creek Road in the northwest and Alexander Creek Road from the south.

The anticipated production capacity of the Project is up to 4.0 million run-of-mine tonnes per annum for a production duration of approximately 15 years. This equates to a coal production capacity of approximately 10,150 tonnes per day. Exploration activities have indicated that the coal at the Project site is typical of coking coals produced from existing mines in the Elk Valley. The high-quality metallurgical coal would be transported via railway to coastal BC, where it would be shipped overseas to be used in steelmaking.

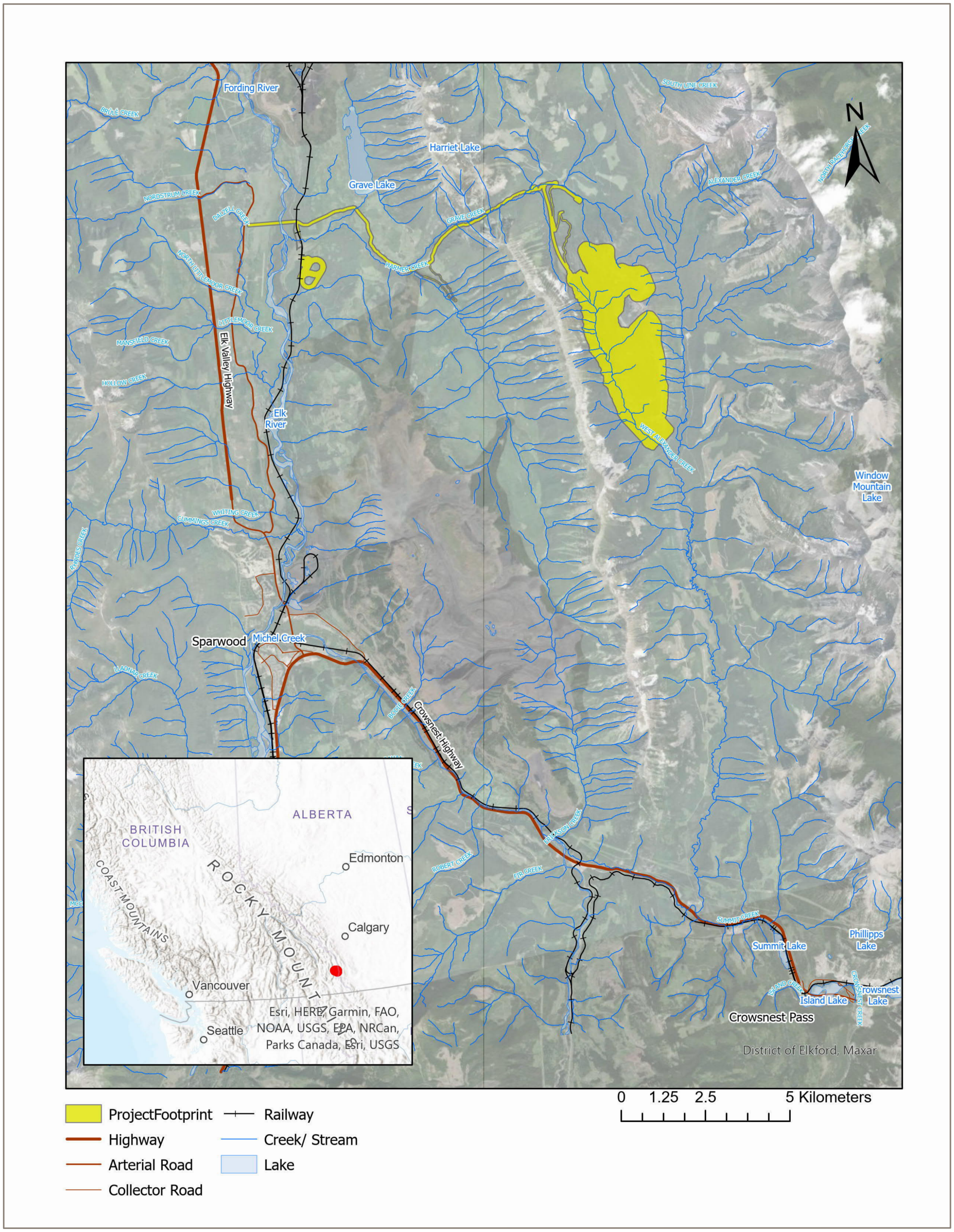

Figure 1-1: Project Location

Key components of the proposed Project include:

- Surface extraction areas (3 pits – north pit, east pit, and south pit);
- Waste rock management areas;
- Plant area (includes raw coal stockpile area, a processing plant, and site support facilities);
- Clean coal transportation route (via an overland conveyor and haul road);
- Rail load-out facility and rail siding (includes various auxiliary facilities);
- Power and natural gas supply;
- Explosives and fuel storage; and
- Water supply and sewage treatment.

1.2 Regulatory Context

Since the proposed Project is a coal mine with a proposed capacity greater than 250,000 tonnes per year of clean coal and will result in a disturbance greater than 750 hectares (ha) that was not previously permitted for disturbance, it is subject to a provincial environmental assessment under Part 3 of the Reviewable Projects Regulation (BC Reg 370/02) of the Act.

The BC Environmental Assessment Office (EAO) issued a Section 10 Order to the Proponent on October 30, 2014 confirming that the proposed Project requires an Environmental Assessment Certificate (EAC), pursuant to Section 10(1)(c) of the *BCEAA*, before it may receive provincial permits to construct and operate the proposed Project.

The proposed Project is also subject to the *Canadian Environmental Assessment Act* (CEAA) 2012. Federally, the Project is considered a Designated Project under the CEAA 2012 Regulations Designating Physical Projects as the mine will have a production capacity of more than 3,000 tonnes per day.

The Project will undergo a coordinated provincial - federal review.

1.3 General Approach and Risk Assessment Framework

This report focuses on characterizing potential risks arising from the exposure of human and ecological receptors to chemical contaminants predicted to influence environmental quality based on interactions between proposed project activities and the natural environment.

All chemical substances/stressors (from both anthropogenic and natural sources) have the potential to cause environmental effects. The magnitude of risk depends on the receptor being present (person or wildlife), an exposure pathway being present, and a contaminant of potential concern (COPC) being present at a concentration sufficient to be hazardous (its degree of “hazard”).

Where all components are present, the possibility of a risk exists (**Illustration 1**). This basic principle forms the basis of risk assessment Problem Formulation and applies in the present evaluation. If one or more of these three components is absent, then risk is negated. For example, a receptor could be exposed to a chemical, but if that chemical has negligible toxicity and/or is present at only very low (i.e., non-hazardous) levels, then no unacceptable risk would be expected. Alternatively, an extremely hazardous material may be present; however, if there is no way for a receptor to be exposed, then the risk is negated (i.e., receptor is not at risk).

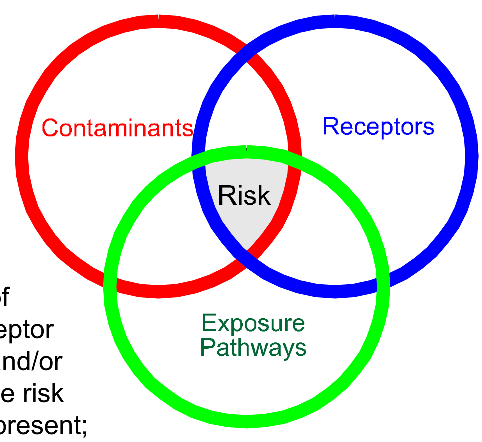

Illustration 1: Components of a Toxicological Risk

The major components of the risk assessment framework include the following:

- **Problem Formulation:** A review and compilation of existing data and a summary of past activities. Identification of the environmental hazards that may pose a human health or ecological risk (i.e., contaminant of potential concern in excess of applicable guidelines), potential receptors, and relevant exposure pathways.
- **Exposure Assessment:** Qualitative or quantitative evaluation of the likelihood or degree to which the receptors are exposed to the hazard.
- **Risk Characterization:** Qualitative or quantitative assessment of the human health or ecological risk of each potential COPC to each receptor. Risk characterization integrates the exposure with potential effects.
- **Uncertainty Assessment:** Review of the assumptions and uncertainties associated with the risk estimation, along with an evaluation of the extent to which conclusions about risks are sensitive to assumptions and limitations.

The HHERA was conducted in general accordance with the following federal and provincial guidance documents:

- Health Canada. 2010a. Federal Contaminated Sites Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. Revised 2012. Available at www.healthcanada.gc.ca
- Health Canada. 2010b. Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals ($DQRA_{Chem}$). Ontario 2010. Available at www.healthcanada.gc.ca
- Canadian Council of Ministers of Environment (CCME). 2020. Ecological Risk Assessment Guidance Document. Available at https://ccme.ca/en/res/eraguidance_e.pdf
- BC CSR Protocol 1 for Contaminated Sites – Detailed Risk Assessment. Version 3.0, Revised May 2021. Available from https://www2.gov.bc.ca/gov/content/environment/air-land-water/site-remediation/legislation-and-protocols

2. Scope of Assessment

2.1 Study Objectives

The primary objective of the present HHERA is to address concerns related to project interactions with identified valued components (VCs) with respect to chemical toxicity and potential impact to health. VCs were identified through stakeholder consultation and are presented in the Crown Mountain Coking Coal Project – Valued Components for Environmental Assessment submitted to (BC EAO 2018). VCs to which the present assessment relate primarily include:

Aquatic Health – Benthic invertebrates, fish species, amphibians, and aquatic feeding wildlife such as waterbirds.

Wildlife Health – Wildlife species including but not limited to American Robin, little brown bat, masked shrew, White-tailed Ptarmigan, least chipmunk, snowshoe hare, bighorn sheep, elk, Common Raven, deer mouse, grizzly bear, Northern Goshawk, American badger, American marten, Canada lynx, American Dipper, Canada Goose, moose, common merganser, and river otter.

Human Health – People, including local communities, First Nations, and temporary residents at recreation areas.

Specifically, the study objectives are expressed in the following Key Question (KQ) respecting potential impacts to the VCs of human and ecological health:

- KQ1: What will be the *collective effect of changes to water, air, soil, and food* to (i) human and (ii) ecological health?

Figure 2-1 is provided to help visualize the relationship of the key question. Data analyses and modelled scenarios were structured around these key questions. It was assumed that potential health risk associated with optimal production during the mine Operation phase would be more significant than the Construction and Closure phases, hence the HHERA focused on Operational scenarios.

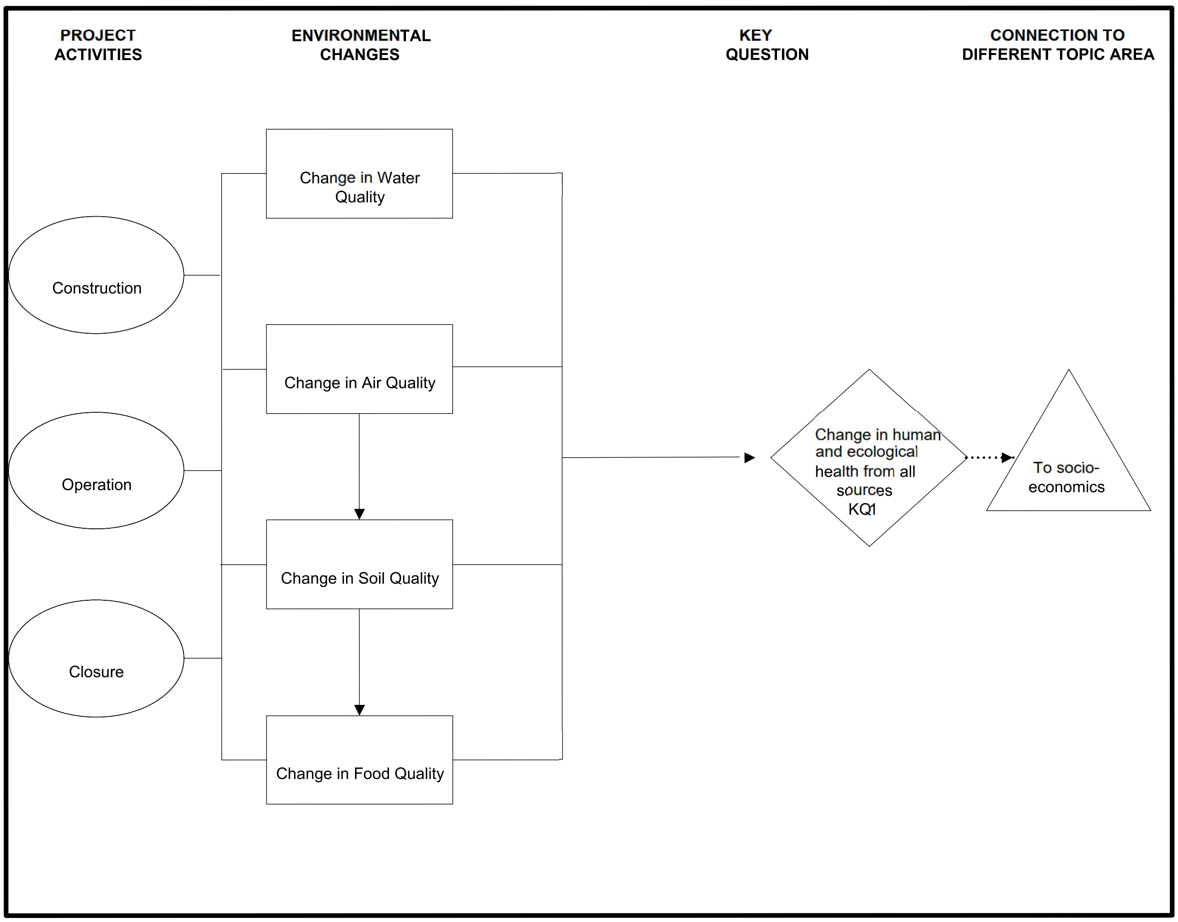

Figure 2-1: Linkage Diagram with interrelationships of general key questions for HHERA

2.2 Sources of Site-Specific Biophysical Data and Information

This document is one of a series of reports prepared to support the application process. Documents from which information and data were obtained relevant to the development of the quantitative HHERA are as follows:

- Baseline Soil Data: *Baseline Soil and Vegetation Chemistry Report – Crown Mountain Coking Coal Project* (Keefer Ecological Services Ltd. 2021)
- Baseline Water Quality: *Surface Water Quality Baseline Report – Crown Mountain Coking Coal Project* (Dillon Consulting Ltd. 2021)
- Baseline Vegetation Quality: *Baseline Soil and Vegetation Chemistry Report – Crown Mountain Coking Coal Project* (Keefer Ecological Services Ltd. 2021)

- Baseline Sediments Quality: *Crown Mountain Coking Coal Project – Aquatic Health Baseline Sampling Report.* (Lotic Environmental., 2019)
- Baseline Fish Tissue Quality: *Crown Mountain Coking Coal Project – Aquatic Health Baseline Sampling Report.* (Lotic Environmental., 2019)
- Air Quality Modelling: *Air Quality Prediction Model Report - Crown Mountain Coking Coal Project.* (Dillon Consulting Ltd. 2021)
- Surface Water Quality Modelling: *Water Quality Prediction Model Report - Crown Mountain Coking Coal Project.* (SRK Consulting, Inc. 2021)

2.2.1 Indigenous and Stakeholder Consultation

Throughout the EA process, NWP engaged with Indigenous groups and conducted consultation with public stakeholders and regulators. Consultation and engagement activities are summarized and discussed in Section 4 of the Application.

Prior to development of the present HHERA additional engagement took place with the Ktunaxa Nation Council (KNC) to provide traditional use and knowledge with respect to identification of critical receptor locations and characteristics to be included in the assessment of Human Health. A summary of feedback from the KNC specific to the HHERA is presented in **Table 2-1**.

Input from the KNC led to the human health risk assessment (HHRA) adopting two fundamental indigenous lifestyle profiles that reflect:

- (i) current land and resource usage ("Current Use"); and
- (ii) indigenous rights-based land and resource usage ("Rights-Based Use").

Most importantly, in both receptor scenarios, these considerations recognized KNC perspectives concerning frequency of traditional harvesting and hunting, dietary profiles, and interaction with environmental components of study area and this was integrated within exposure models for the human health risk assessment process.

Table 2-1: Summary of Engagement and Consultation Feedback on HHERA Input Parameters

Topic	Feedback Received*:				Consultation Feedback	Feedback Source	Response or Actions Identified
	IG	G	P/S	O			
Indigenous Human Receptor Age Groupings and Physiological Metrics	✓				Requirement for consideration of all members of societal composition (i.e., infant to elders)	Ktunaxa Nation Council (Sept. 9 2020)	Adoption of human receptor age groupings and physiological parameters per Health Canada (2010b)
Indigenous Human Receptor Traditional Dietary Profiles, and Critical Locations of Natural Resource Use	✓				HHRA needs to account for KNC to practice full rights-based traditional land based lifestyle including, location presence, frequency, traditional diet, and resource utilization.	Ktunaxa Nation Council (Oct. 29 2020)	Adoption of two indigenous receptor groups for risk assessment: • Current Use • Rights-Based Use

Note:

**IG = Indigenous Group (group specified in column); G = Government (provincial or federal agencies); P/S = Public/Stakeholder (Interest group, local government, tenure and license holders, members of the public); O = Other*

2.3 Assessment Boundaries

2.3.1 Spatial Boundaries

The spatial boundaries of the present HHERA are dictated by the primary pathways potentially affecting environmental quality associated with Project related emissions. These include air quality and particulate deposition, as well as changes to surface water quality. The spatial boundaries for the HHERA were therefore selected to incorporate relative portions of the Regional Study Area study area where modelling of changes to air and surface water quality were available. In addition, the spatial boundary of the assessment was informed by input from the KNC in order to incorporate identified areas of human traditional land use or occupation. These locations, henceforth referred to as critical receptor locations are explicitly considered for exposure assessment to human and ecological receptors. Similarly, surface water quality at prediction nodes are explicitly considered for assessment of potential health risks to aquatic receptors.

In summary, the spatial boundaries of the study area for the HHERA are based principally on the information provided through engagement with Indigenous peoples, and portions of the local study areas from a variety of other discipline teams. The combined/overlapping dataset of predicted environmental conditions due to proposed Project from other discipline teams in concert with the selection of locations know to be used by ecological receptors and important to human traditional land use means that the spatial boundary of the present HHERA includes the anticipated range of exposure conditions, including potential worst case conditions.

The spatial boundaries of the HHERA as well as the critical receptor location, the water quality prediction nodes, and the Project exclusion zone (described below) are presented in **Figure 2-2**. The spatial boundary of the assessment was consistent between the human and wildlife receptors.

2.3.1.1 Project Exclusion Zone

Areas of industrial mining and resource extraction activities are not considered to be available for future use as wildlife habitat, or suitable for human occupation or traditional land use activities. The Project footprint includes the all mine related infrastructure. For the present HHERA, the area within the Project footprint in the vicinity of open pit mining and waste rock disposition is considered to represent the Project exclusion zone. Areas within the Project exclusion zone are considered to be off limits to human receptors not engaged in industrial resource extraction activities. As indicated on **Figure 2-2**, critical receptor location CRID-15 is located in the Project exclusion zone. This location will cease to be available to human receptors.

Similarly, the Project exclusion zone is considered to be unattractive as functioning ecological habitat and it is assumed the area would be actively avoided by mobile ecological receptors. Based on the above rationale, potential health risks to human and wildlife receptors within the Project exclusion zone are not quantitatively assessed, as the nature of the physical activities within the Project exclusion zone is assumed to preclude the presence of human or ecological receptors of concern.

Critical receptor locations located along haul roads, in the vicinity of the rail load-out loop, and at the location of the clean coal transfer station are included in the present assessment in order to capture the breadth of plausible exposure scenarios. It is important to acknowledge however that these locations are presently impacted by physical disturbance, and are not considered to be valued habitat which would support ecological receptors either now or in the future after Project development. Additionally, these locations are unlikely to be attractive locations capable of supporting full-time occupancy of human land users.

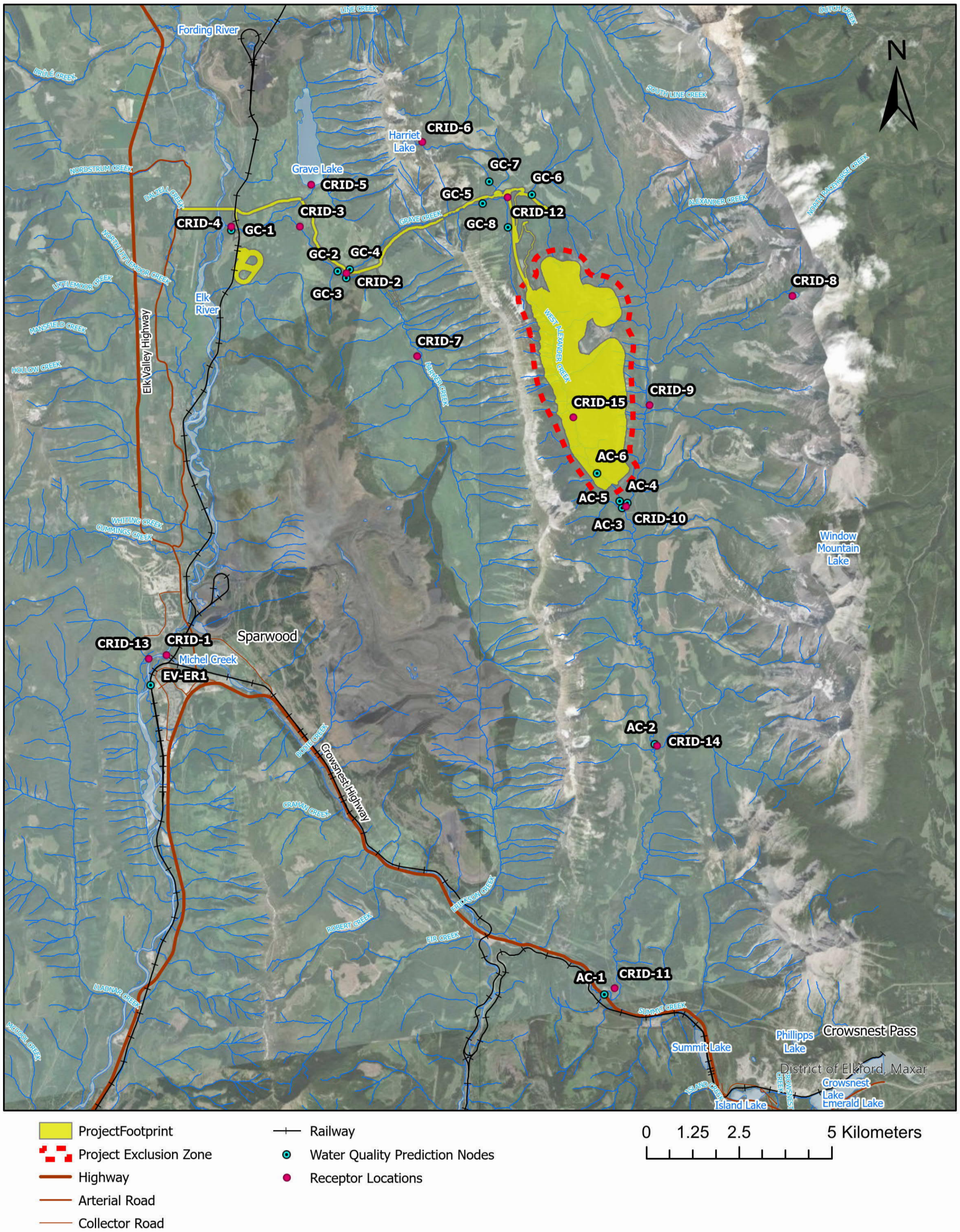

Figure 2-2: Spatial boundaries of the human and ecological risk assessment, critical receptor locations, and water quality prediction nodes.

2.3.2 Temporal Boundaries

The anticipated production capacity of the Project is up to 4.0 million run-of-mine tonnes per annum for a production duration of approximately 15 years. The following key model phases have been used in the assessment and form the basis for the temporal boundaries:

- Operations Phase: Mine Year 0 - 15
- Closure Phase: Mine Year 16
- Post-closure Phase: Mine Year 17 - 34

The temporal boundaries for the present HHERA cover the life of the Project through construction, operation, decommissioning and post closure. The HHERA was conducted using conservative estimates of emissions as follows:

- For the air quality modelling (Dillon, 2021) on which the HHERA relies, emissions were modelled based on a 5-year meteorological record and emissions estimates for the year of highest production (year 11). This emission rate was assumed to persist for the entire construction and operational phase of the Project (i.e. the entire 15-year project lifespan). Emissions are assumed to cease at the conclusion of the operational phase.
- For the surface water quality modelling (SRK Consulting, Inc. ,2021) on which the HHERA relies, predictions were developed for the entire 34-year Project lifecycle, including construction, operation, closure, and post closure phases. The surface water quality model was parameterized based on anticipated mine production rates and disposition of waste rock during the operational phase. The outputs of the water quality model carried forward for the present HHERA are based on the upper bound of source term concentrations (95th percentile), assuming the Waste Rock Dump (WRD) layering approach is successful at reducing oxidation of pyrite, thereby minimising the release of sulphate, acidity and trace elements including selenium and other metals.

For the human health risk assessment, it was conservatively assumed that people lived their entire lives within the local study area, spending 100% of their time at critical receptor locations. Since the air quality modelling and resultant incremental impacts to soil quality were developed based on the years of highest production (and therefore highest potential emissions) this is considered to be a conservative approach in line with Health Canada (2010a) guidance. Impacts associated with changes to surface water quality were assessed based on predicted annual peak concentrations (30-day rolling average) from the modelled time-series.

For wildlife receptors, the risk assessment was conducted based on conservative predictive modelling of emissions. The wildlife risk assessment evaluates chronic effects to wildlife receptors, assuming 100% of time is spent within the spatial bounds of the assessment, and that receptors would be exposed to conservative emissions estimates in the form of cumulative particulate deposition to soil, for their lifetime.

2.4 Assessment Cases

To understand the potential health effects of the Project the assessment was conducted considering three assessment cases: (i) existing conditions (Base Case), (ii) the Project-induced conditions (Application Case) and (iii) cumulative effects associated with ongoing emissions from existing or reasonably foreseeable future developments (Cumulative Case), as described below.

Health risks were evaluated in accordance with the Key Questions respecting potential changes from the Base Case in quality of surface water, air, soil, and food during the far future operations phase (i.e., after 15 years of operations and accrued dust deposition) and inferred to apply to construction and the post-closure phases of the Project. Though the scenarios differed, the exposure modeling methods were fundamentally the same for the Base, Application, and Cumulative assessment cases. The process followed basic principles of human risk assessment frameworks endorsed by Health Canada (2010a). Additional details are provided in subsequent sections and in Appendices D1 and D2, which describe the food chain model and the computational model, respectively.

2.4.1 Base Case

The Base Case represents existing conditions and characterizes potential for health risk to human ecological receptors. The Base Case incorporates effects of all existing development in the local study area such as existing mining operations, forestry, oil & gas exploration, etc. Crucially, the Base Case considers current effects from operating mining operations.

The Base Case assessment relies primarily on measured biophysical data, especially baseline studies of concentrations of contaminants of concern in environmental media, and is conducted in order to establish current benchmark risk estimates. This benchmark is subsequently used in the Application Case and Cumulative Case to examine the “incremental” risk resulting from releases associated with the Project and Reasonably Foreseeable Developments (RFD).

2.4.2 Application Case

The Application Case represents cumulative effects from Project-induced changes to the environment and current conditions as represented in the Base Case.

For the Application Case effects are evaluated based on the summation of exposure or risk presented by the Base case plus the Project. The “incremental risk” from the Project is therefore the difference between the Application Case and the Base Case.

Risks estimated for the Application Case are based on predicted concentrations of contaminants in environmental media (air quality, particulate deposition, and surface water quality) provided from other assessments conducted as part of the EAC application. Predicted changes to environmental quality are propagated through the assessment through the use of multimedia contaminant transport models (i.e. predicted incremental soil concentration and concentrations of contaminants of concern in wild food tissues).

2.4.3 Cumulative Case

The Cumulative Case assesses the potential effects associated with the proposed Project in addition to incremental changes associated with ongoing or reasonably foreseeable future development. The Cumulative Case is based on whatever reasonably foreseeable projects included in the assessments conducted by the air and water quality disciplines, as predictions from these sources form the basis for the human health and ecological risk assessment.

The risks estimated for this case are based on:

1. Predicted changes to air quality, particulate deposition, and surface water quality provided by other assessments as part of the current EAC application;
2. Predicted changes to soil and subsequent changes to vegetation and wildlife tissue associated with 15 years of additional particulate deposition assuming baseline dust fall data represents predicted ongoing cumulative dust fall from sources aside from the proposed Project; and
3. For surface water quality, some water quality locations (nodes) are considered to be representative of the Cumulative Case in that the predicted water quality is influenced by primarily by surface waters source terms originating from other existing resource extraction projects.

3. Preliminary Problem Formulation

3.1 Project Activities and Linkages to Environmental Quality

This HHERA quantifies potential health impacts of the Project to human, wildlife and aquatic VCs. Risk is an abstract concept that embraces (i) a hazard or hazardous event existing with a certain likelihood, and (ii) the adverse consequence and severity that arises from the hazard. *Health* risks are plausible to the extent that a contaminant exists, there are receptors present, and exposure or contaminant transport pathways exist that connect the human receptors with the contaminants/stressors of concern.

As a first qualitative step Project activities which have potential to cause substantive change in environmental condition which may affect health are identified. This preliminary qualitative assessment step aids to focus the assessment and identify pathways and environmental media of particular significance to the application. To this end, linkages were made between Project activities and potential effect to environmental media, as described below.

3.1.1 Activities potentially affecting Air Quality:

Particulate emissions with adsorbed contaminants are associated with land disturbance, coal handling, hauling, and combustion emissions associated with vehicle traffic and other emission sources associated with the Project. In addition, regulated air quality parameters can be potentially altered because of combustion emissions associated with Project activities (Dillon, 2021).

Community residents, Indigenous peoples, or temporary residents and seasonal land users (hunting/harvesting or recreational land use) spending time within the local study area may be exposed to chemical constituents associated with fugitive air release from Project activities through direct inhalation.

Since this pathway represents a defined uncontrolled release from the Project it is considered to be of primary importance to the overall quantitative environmental health assessment and is evaluated further in the human health risk assessment.

This pathway was not evaluated directly for wildlife; however, it was assessed indirectly through assessment of incremental changes to soil quality as a result of dust deposition and multimedia food web uptake by wildlife.

3.1.2 Activities potentially affecting Soil Quality:

It is expected that particulate emissions will be associated with land disturbance, coal handling, hauling, and combustion emissions associated with vehicle traffic and other emission sources associated with the Project. Chemical constituents associated with Project derived particulate emissions have the potential to accumulate in soils within the local study area as a result of particulate deposition and mixing with surficial soil horizons.

Community residents, Indigenous peoples, or temporary residents and seasonal land users (hunting/harvesting or recreational land use) may be exposed to chemical constituents through direct contact and incidental ingestion of soils. Wildlife may be exposed to chemical constituents through incidental soil ingestion (e.g. incidental ingestion with consumption of vegetation).

Since this pathway represents a defined uncontrolled release from the Project it is considered to be of primary importance to the overall quantitative environmental health assessment and is evaluated further in the human health and wildlife health risk assessments through the multimedia food web exposure model.

3.1.3 Activities potentially affecting Surface Water Quality:

Residual effects to surface water quality, specifically within Alexander Creek which will be a receiver of treatment pond effluent, are predicted as a result of Project activities (SRK, 2021). Community residents, first nations traditional land users, or temporary residents and seasonal land users (hunting/harvesting or recreational land use) may be exposed to chemical constituents through direct contact and ingestion of surface water.

Effluent discharge from the Project site is predicted to have a measurable effect on surface water quality and as such this pathway is considered to be of primary importance to the overall quantitative environmental risk assessment and is the basis for the aquatic health risk assessment. In addition, predicted changes to surface water quality have been incorporated into the multimedia human health and wildlife health risk assessments.

3.1.4 Activities potentially affecting Sediment Quality

Changes to surface water quality can potentially influence sediment chemistry in receiving waterbodies, however detectable change in sediment quality as a result of changes to air quality and surface water quality are expected to be negligible. Changes to sediment quality is a function of predicted changes to surface water quality, and as such is considered as a secondary pathway.

Community residents, first nations traditional land users, or temporary residents and seasonal land users (hunting/harvesting or recreational land use) may be exposed to chemical constituents through direct contact and incidental ingestion of sediments.

Wildlife that rely primarily on aquatic food sources are expected to use local watercourses and waterbodies for foraging, and may be exposed to chemical constituents through incidental ingestion of sediment.

3.1.5 Activities potentially affecting Groundwater Quality

According to the groundwater effects assessment (SRK, 2020b) the predicted effect of the Project activities to groundwater quality is considered to be not significant. In addition, impacts to groundwater quality are not anticipated to have a measurable impact on water quality where people obtain drinking water.

Impacts to groundwater quality are therefore considered as a secondary pathway and are not specifically assessed as part of this HHERA.

3.1.6 Activities potentially affecting Traditional Food Quality:

Residual effects to soil quality associated with particulate deposition and predicted effects to surface water quality have the potential to induce changes in the concentration of chemical constituents in the tissues of plants and animals in the local study area.

Community residents, first nations traditional land users, or temporary residents and seasonal land users (hunting/harvesting or recreational land use) may be exposed to chemical constituents through ingestion of plant and animal tissues within the local study area. Similarly, wildlife receptors may be exposed to chemical constituents through ingestion of plant and prey items.

Potential changes in food quality are assessed as part of the human health and wildlife health risk assessments using the multimedia food web exposure model developed for this HHERA. Pathways affecting traditional food quality include:

- Uptake and accumulation of Project related chemical constituents in vegetation (e.g., berries, plants) from soil after incremental changes to soil condition following prolonged air particulate deposition.
- Uptake and accumulation of Project related chemical constituents in terrestrial feeding wildlife from soil impacts through trophic transfer.
- Uptake and accumulation of Project related chemical constituents in aquatic feeding wildlife (including fish) as a result of changes to surface water quality and trophic transfer.

3.2 Multimedia Food-web Model

Prospective quantitative risk assessment for human and ecological receptors relies heavily on predictive modelling to identify Project related effects and distribute COPCs within abiotic and biotic media where linkages with Project activities exist.

Numerical modelling of surface water quality, air quality, and particulate deposition developed by other disciplines in the environmental assessment are incorporated into the multimedia food web model in order to predict concentrations of chemical constituents in abiotic compartments (i.e., soil, surface water, sediment, etc.).

The multimedia food web model relies on these predicted abiotic media concentrations for the prediction of COPC concentrations in the tissues of living organisms; this is accomplished using concentration ratios between organisms and their environment or dietary intake and trophic transfer factors.

Additional details of the multimedia food web and exposure models are provided in Section 4 *Wildlife Health Risk Assessment*, Section 6 *Human Health Risk Assessment* and **Appendix A**.

3.2.1 Elk Valley Selenium Bioaccumulation Model

Residual selenium released from Project activities and largely removed through the mitigative waste rock and water management strategy is anticipated to transfer to organic matter at the base of food web and then transfer to higher trophic levels. Uptake directly from water is not significant, however the dissolved selenium concentration is the primary factor driving tissue concentration of selenium in the foodweb, particularly for higher trophic level receptors.

The Elk Valley selenium bioaccumulation model[1] has been developed as a one-, two-, or three-phase model to simulate the processes of residual selenium transferred from water through the trophic levels. AECOM used the two-phase version of the selenium bioaccumulation model for the prediction of tissue concentration of invertebrates, fish eggs, and bird eggs through the present HHERA.

3.3 Overview of Approach to Exposure Modelling

Table 3-1 provides an overview of the approach and rationale for prospective exposure assessments conducted as part of the present ERA. The information in **Table 3-1** reflects content of subsequent chapters and appendices and is cross-referenced accordingly.

[1] Detailed information on the derivation and parameterization of the Elk Valley Selenium Bioaccumulation Model can be found in Annex E Benchmark Derivation Report for Selenium (Appendix C) of the Elk Valley Area Based Management Plan https://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/mining-smelt-energy/area-based-man-plan/annexes/e_benchmark_derivation_report__selenium.pdf

Table 3-1: Fundamental Exposure Assessment Approach and Assumptions

Parameter	Base Case	Application Case	Cumulative Case
Soil Quality	Not modelled; based on statistics of empirical baseline monitoring data	Calculated as the sum of the 95th percentile of baseline soil concentration and the predicted incremental soil concentration associated with particulate deposition over the 15 year mine lifecycle at each critical receptor location. Particulate deposition was modelled using the total particulate deposition to the ground surface Critical receptor location specific incremental soil concentration is calculated using US EPA methods for estimating incremental soil concentration (see **Appendix B**).	Cumulative case calculated an incremental soil concentration based on Project total particulate deposition, plus an additional 15 years of pre-project deposition data calculated using the current baseline particulate deposition data as an estimate of integrated effects of resource extraction activities. This impacts all components which are related to soil quality
Surface Water Quality	Not modelled; based on statistics of empirical baseline monitoring data	Application case uses the predicted concentrations of substances of interest as predicted by the surface water quality model (SRK, 2021) rolling average concentration over the annual model duration.	Surface water is assumed to be the same as the application case. No reasonably foreseeable projects are located in the Alexander Creek watershed, and as such Cumulative effects are anticipated to be equal to the Application case.
Air Quality	Calculated assuming baseline PM10 concentrations of 28 ug/m3 and chemical composition equal to average chemical composition of total particulate matter reported in baseline air quality monitoring program.	Air quality modelling was conducted using a three-year meteorological time-series dataset and Project activities characteristics of the maximum production period. Exposure point concentrations (deterministic and probabilistic) were generated for each Critical Receptor Location using location-specific 365d time-series of predicted PM_{10} concentrations and chemical composition associated with individual emission sources.	Air quality is assumed to be the same as the Application case. No reasonably foreseeable new air emissions were identified or modelled, and as such Cumulative effects are anticipated to be equal to the Application case.
Sediment Quality	95th percentile of baseline sediment dataset	Prospective sediment quality is modelled using water-to-sediment partition coefficients (Kd) as determined from baseline data for each of Upper Alexander Creek, Lower Alexander Creek, and Upper Grave Creek. Sediment concentrations are calculated based on annual average surface water concentration at water quality prediction nodes (**Appendix A**).	Sediment concentrations assumed to be the same as the Application case. No reasonably foreseeable projects are located in Alexander Creek watershed, and as such Cumulative effects are anticipated to be equal to the Application case.
Biological Tissues			
Fish Tissue	Baseline fish tissues for potentially affected stream reaches were modelled based on derived concentration ratios in conjunction with measured baseline water quality data. This approach was necessary to characterize baseline fish tissue concentrations in impacted stream reaches where fish tissue was not collected as part of the baseline assessment. For selenium, concentrations modelled based on the Elk Valley selenium bioaccumulation model (Teck, 2014).	Modelled based on maximum 30-day rolling average of critical receptor location specific predicted water quality (SRK) and derived water-to-fish concentrations ratios (**Appendix C**).	Fish muscle tissue quality not modelled for Cumulative scenario because surface water is assumed to be the same as the application case. No reasonably foreseeable projects are located in the Alexander creek watershed, and as such Cumulative effects mediated through fish tissue quality are anticipated to be equal to the Application case.
Fish Eggs	Calculated as a function of surface water concentration. Concentration ratios assumed to be equivalent to water-to-fish concentration ratios with the exception of selenium. Selenium concentration in fish eggs predicted based on Elk Valley selenium bioaccumulation model.	Modelled based on critical receptor location specific predicted surface water quality and water-to-fish concentration ratios. Selenium concentration predicted as a function of site-specific predicted surface water concentration using the elk valley selenium bioaccumulation model.	Fish egg tissue residues not modelled for Cumulative scenario because surface water is assumed to be the same as the application case. No reasonably foreseeable projects are located in the Alexander creek watershed, and as such Cumulative effects mediated through fish egg quality are anticipated to be equal to the Application case.
Shellfish Tissue	Calculated as a function of baseline surface water concentration and literature derives water-to-crustacean concentration ratios (**Appendix C**).	Calculated as a function of baseline surface water concentration and literature derives water-to-crustacean concentration ratios (**Appendix C**).	Shellfish tissue (e.g. freshwater mussels, clams, etc.) residues not modelled for Cumulative scenario because surface water is assumed to be the same as the application case. No reasonably foreseeable projects are located in the Alexander creek watershed, and as such Cumulative effects mediated through shellfish tissue quality are anticipated to be equal to the Application case.

Parameter	Base Case	Application Case	Cumulative Case
Large Mammals	Modelled using intake calculated from food web model and literature derived transfer factor.	Calculated from intake based on are weighted average accounting for overlap between foraging range and Project footprint. Concentration calculated using multimedia food web incorporating calculated Project incremental soil quality and feed-to-large mammal transfer factors (**Appendix C**). Further details provided in **Appendix D**.	Calculated from intake based on are weighted average accounting for overlap between foraging range and Project footprint. Concentration calculated using multimedia food web incorporating calculated cumulative incremental soil quality and feed-to-large mammal transfer factors (**Appendix C**). Further details provided in **Appendix D.**
Small Mammal Tissue	Modelled using 95th percentile of baseline soil data and literature derived soil-to-whole organism concentration ratios for temperate small mammals.	Modelled using critical receptor specific predicted incremental soil concentration and literature derived soil-to-whole organism concentration ratios for temperate small mammals.	Modelled using critical receptor specific predicted cumulative incremental soil concentration and literature derived soil-to-whole organism concentration ratios for temperate small mammals.
Bird Tissue	Modelled using 95th percentile of baseline soil data and literature derived soil-to-whole organism concentration ratios for temperate avian receptors.	Modelled using critical receptor specific predicted incremental soil concentration and literature derived soil-to-whole organism concentration ratios for temperate avian receptors.	Modelled using critical receptor specific predicted cumulative incremental soil concentration and literature derived soil-to-whole organism concentration ratios for temperate avian receptors.
Bird Eggs	With the exception of selenium, concentration of COPCs in bird eggs is assumed to approximate the concentration in bird tissue and is calculated as a function of the 95th percentile of baseline soil quality dataset and soil-to-bird concentration ratios. Selenium concentration in bird eggs modelled using the Elk Valley selenium bioaccumulation model (Teck, 2014) and the baseline surface water selenium concentration **(Appendix E)**.	Modelled using critical receptor location specific predicted incremental soil quality and soil-to-bird concentration ratios, with the exception of selenium which is modelled based on receptor location specific predicted surface water quality data using the elk valley selenium bioaccumulation model.	Modelled using critical receptor location specific predicted cumulative incremental soil quality and soil-to-bird concentration ratios, with the exception of selenium which is modelled based on receptor location specific predicted surface water quality data using the elk valley selenium bioaccumulation model.
Berries	Modelled based on 95th percentile of baseline soil dataset and soil-to-berry concentration ratios (**Appendix C**)	Modelled using critical receptor location specific predicted incremental soil concentration and soil-to-berry concentration ratios.	Modelled using critical receptor location specific predicted cumulative incremental soil concentration and soil-to-berry concentration ratios.
Plant Roots	Modelled based on 95th percentile of baseline soil dataset and soil-to-shrub concentration ratios.	Modelled using critical receptor location specific predicted incremental soil concentration and soil-to-shrub concentration ratio.	Modelled using critical receptor location specific predicted cumulative incremental soil concentration and soil-to-shrub concentration ratio.
Other Plants	Modelled based on 95th percentile of baseline soil quality dataset and soil-to-plant concentration ratios (**Appendix C**)	Modelled using critical receptor location specific predicted incremental soil concentration and soil-to-plant concentration ratios.	Modelled using critical receptor location specific predicted cumulative incremental soil concentration and soil-to-plant concentration ratios.
Lichens + Mushrooms	Modelled based on critical receptor location specific predicted incremental soil concentration and soil-to-plant concentration ratios.	Modelled using critical receptor location specific predicted incremental soil concentration and soil-to-mushroom/lichen concentration ratios.	Modelled using critical receptor location specific predicted cumulative incremental soil concentration and soil-to-mushroom/lichen concentration ratios.

4. Wildlife Health Risk Assessment

The following section presents the methods and results of a quantitative assessment of toxicological health risks to terrestrial and aquatic feeding wildlife species identifies as receptors of concern (ROCs) and assumed to be present in the study area.

4.1 Supplemental Problem Formulation

4.1.1 Receptors of Concern

Pursuant to the approved Applications Information Requirements for the Project (EAO 2018), the valued components (VCs) requiring consideration have were reviewed for context within the wildlife risk assessment receptors of concern (ROCs). Based on defined rationale, specific surrogate receptors were assigned to facilitate subsequent risk estimation processes (**Table 4-2**).

4.1.2 Identification of Exposure Pathways

Based on the ecology and feeding guilds of the surrogate wildlife receptors and the linkages of Project activities anticipated to release substances to the environment, an inventory of exposure pathways was documented (**Table 4-1**) to develop the conceptual exposure model (**Figure 4-1**).

Table 4-1: Exposure pathway assessment for wildlife receptors.

Receptor Group	Exposure Pathway	Included (Yes/No)	Rationale
Primary Producer and Soil Invertebrates	Direct Contact (soil)	**Yes**	Terrestrial plants are rooted in soil and soil invertebrates live in the rooting depth of soil.
Wildlife (Mammal/Avian)	Water Ingestion	**Yes**	Potential for surface water runoff to carry contaminants from soil to surface waterbodies is considered. Wildlife are considered likely to ingest surface water from local waterbodies.
	Food Ingestion	**Yes**	Wildlife exposure model will include dietary uptake.
	Incidental Soil Ingestion	**Yes**	Mammals/birds are assumed to ingest soil incidentally through grooming and feeding.
	Dermal Exposure	No	This pathway is expected to be negligible as the presence of fur/feathers limits dermal contact with soil. Data necessary to evaluate dermal contact exposure is often lacking.
	Inhalation	No	Inhalation not typically considered for ecological receptors.

4.1.3 Contaminants of Potential Concern

Screening of COPCs for inclusion in assessment of wildlife health risk was accomplished by comparing predicted concentrations of chemical constituents in abiotic and biotic compartments as a result of Project activities to applicable environmental quality objectives protective of ecological health.

All COPCs identified regardless of media are have been assessed for all exposure pathways in the wildlife health risk assessment. Details of the COPC screening are presented in **Appendix F**.

The screening process identified arsenic, cadmium, chromium, cobalt, selenium, and thallium as COPCs to be carried forward for quantitative assessment.

Table 4-2: Values components, receptors of concern, and surrogate receptors assessed in the wildlife health risk assessment.

Receptor Group	Receptor Type	Included in ERA? (Yes/No)	Rationale	Receptors of Concern (ROCs)*	Surrogate ROC(s) (if applicable)
Primary Producer	Moss/Grass/ Shrub/Tree/ Forb	**Yes**	A range of vegetation is present within the study area including lichen, mosses, grasses, wildflowers, willow, and ground shrubs.	Lichens, Mosses, Grasses, Wildflowers, Willow, Ground shrubs	Terrestrial Plants (community)
Invertebrate	Ground-dwelling	**Yes**	Ground-dwelling invertebrates are expected to be present in areas of accumulated soil and are an important dietary component for higher trophic level receptors.	Soil Invertebrates	Soil Invertebrates (community)
	Aerial	**No**	Aerial invertebrates are likely present at the Site. However, their contact with soil COCs is considered negligible. (Larval form will be considered with ground-dwelling invertebrates.)	Not Applicable	Not Applicable
Mammal	Herbivorous	**Yes**	Herbivorous mammals have the potential to be found throughout the study area, including ungulates, hares, and small rodents. Ungulate Winter Range occurs across valley bottoms and warm aspect hillsides and are important for Elk. Bighorn Sheep are blue-listed in BC.	Bighorn Sheep Mountain Goat Deer Mouse Elk Least Chipmunk Moose Snowshoe Hare	Bighorn Sheep Deer Mouse Elk Least Chipmunk Moose Snowshoe Hare
	Insectivorous	**Yes**	Insectivorous mammals, such as bats, have the potential to be found within the study area. The Little Brown Bat, Northern Myotis, and Eastern Red Bat are of special conservation concern and have been impacted by White Nose Syndrome. Both the Northern Myotis and Little Brown Bat are listed as Endangered by COSEWIC and blue and yellow-listed provincially. The Eastern Red Bat is red-listed in BC.	Little Brown Bat Northern Myotis Eastern Red Bat	Little Brown Bat

Receptor Group	Receptor Type	Included in ERA? (Yes/No)	Rationale	Receptors of Concern (ROCs)*	Surrogate ROC(s) (if applicable)
	Carnivorous	**Yes**	Carnivorous mammals have the potential to be found within the study area, including furbearing mammals and shrews. Some furbearers have a high proportion of their diet coming from fish ingestion, which is a potential pathway for selenium uptake. American Badger is on the provincial red-list, and listed as endangered under COSEWIC and SARA. Presence of Canada Lynx is an indicator of ecosystem health.	American Badger Canadian Lynx Masked Shrew Northern River Otter	American Badger Canadian Lynx Masked Shrew Northern River Otter
	Omnivorous	**Yes**	Omnivorous mammals have the potential to be found within the study area, including American Marten and Grizzly Bear. Grizzly Bear were documented within the Project LSA during baseline surveys and are considered an important species both ecologically and socially. Grizzly Bear is blue-listed in BC, and listed as Special Concern under COSEWIC and SARA. Baseline studies indicated that few American Marten were found within the LSA.	American Marten Grizzly Bear	American Marten Grizzly Bear
Avian	Herbivorous	**Yes**	Herbivorous avian receptors may be present within the study area. White-tailed Ptarmigan forage primarily on the ground increasing the likelihood of exposure to potential substances of interest.	White-tailed ptarmigan	White-tailed ptarmigan
	Carnivorous / Piscivorous / Insectivorous	**Yes**	Carnivorous / piscivorous / insectivorous birds have potential to be present within the study area. Several of these are waterbird species. Northern Goshawk is blue-listed in BC.	American Dipper Common Merganser Harlequin Duck Northern Goshawk	American Dipper Common Merganser Harlequin Duck Northern Goshawk
	Omnivorous / Insectivorous	**Yes**	Omnivorous / insectivorous birds have potential to be present within the study	Canada Goose Common Raven	Canada Goose Common Raven

Receptor Group	Receptor Type	Included in ERA? (Yes/No)	Rationale	Receptors of Concern (ROCs)*	Surrogate ROC(s) (if applicable)
			area. Several of these are waterbird species.	Mallard Red-winged Blackbird Spotted Sandpiper American Robin	Mallard Red-winged Blackbird Spotted Sandpiper
Reptile	Carnivorous	No	Sensitive reptile species, such as the western painted turtle, have a low potential of occurring within the Project footprint and LSA.	Not Applicable	Not Applicable

Notes:

** As defined in Applications Information Requirements for the Project (BC EAO 2018)*

4.1.4 Assessment Endpoints and Measurement Indicators

Assessment endpoints are explicit expressions of the actual environmental value, resource or ecological service to be protected and may be perceived as an environmental characteristic. If these endpoints are found to be significantly affected, they may warrant consideration of mitigative action.

Measurement endpoints are measurable changes in an attribute of an assessment endpoint that allow an evaluation of whether the ecological resource is being sufficiently protected. Measurement endpoints are typically considered from two perspectives: measures of exposure and measures of adverse effect. In the current ecological risk assessment, several major lines of evidence for measurement endpoints were pursued:

(i) Hazard Quotients predicated on measured (empirical) baseline exposure concentrations in water, soil and select dietary tissues of receptors

(ii) Hazard Quotients predicated on modelled exposure concentrations in sediment, water, soil, and dietary tissues of receptors

In accordance with Canadian regulatory guidance (Environment Canada 2014), hazard quotients <1.0 are considered to be indicative of negligible risk for the specific measurement and assessment endpoints. Calculated hazard quotients >1 require interpretation with consideration of conservatism, effect endpoint, level of effect and probabilities to fully characterize their significance relative to their assessment endpoint.

Table 4-3 summarizes the assessment and measurement endpoints that were selected for the ecological receptors:

Table 4-3: Assessment Endpoints and Measurement Indicators for Aquatic Health Assessment of Valued Components.

Valued Components	Assessment Endpoint	Measurement Indicators
Primary Producers	Protection of plant health to foster sustained growth, reproduction and populations.	Hazard Quotient using exposure input from predicted and/or measured soil quality.
Soil Invertebrate	Protection of invertebrate community health to foster sustained growth, reproduction and populations.	Hazard Quotient using exposure input from predicted and/or measured soil quality.
Wildlife (Mammalian)	Protection of wildlife health to foster sustained growth, reproduction and populations.	Hazard Quotient using exposure input from predicted and/or measured soil quality, surface water quality, sediment quality, and food quality.
Wildlife (Avian)	Protection of wildlife health to foster sustained growth and reproduction.	Hazard Quotient with input from predicted and/or measured soil quality, surface water quality, sediment quality, and food quality.

4.1.5 Conceptual Exposure Model

A conceptual exposure model is a written description and/or a visual representation of the relationships between the source of contaminants, receiving environment and processes by which receptors may become directly or indirectly exposed to contaminants (Barnthouse and Brown 1994). That is, CEMs indicate how a contaminant source and receptor are connected by an operable exposure pathway. Only those pathways assessed as being significant and operable are carried forward and quantitatively assessed in the evaluation of toxicological risk. A CEM for terrestrial and aquatic ROCs considered in the present HHERA is illustrated in **Figure 6-3**.

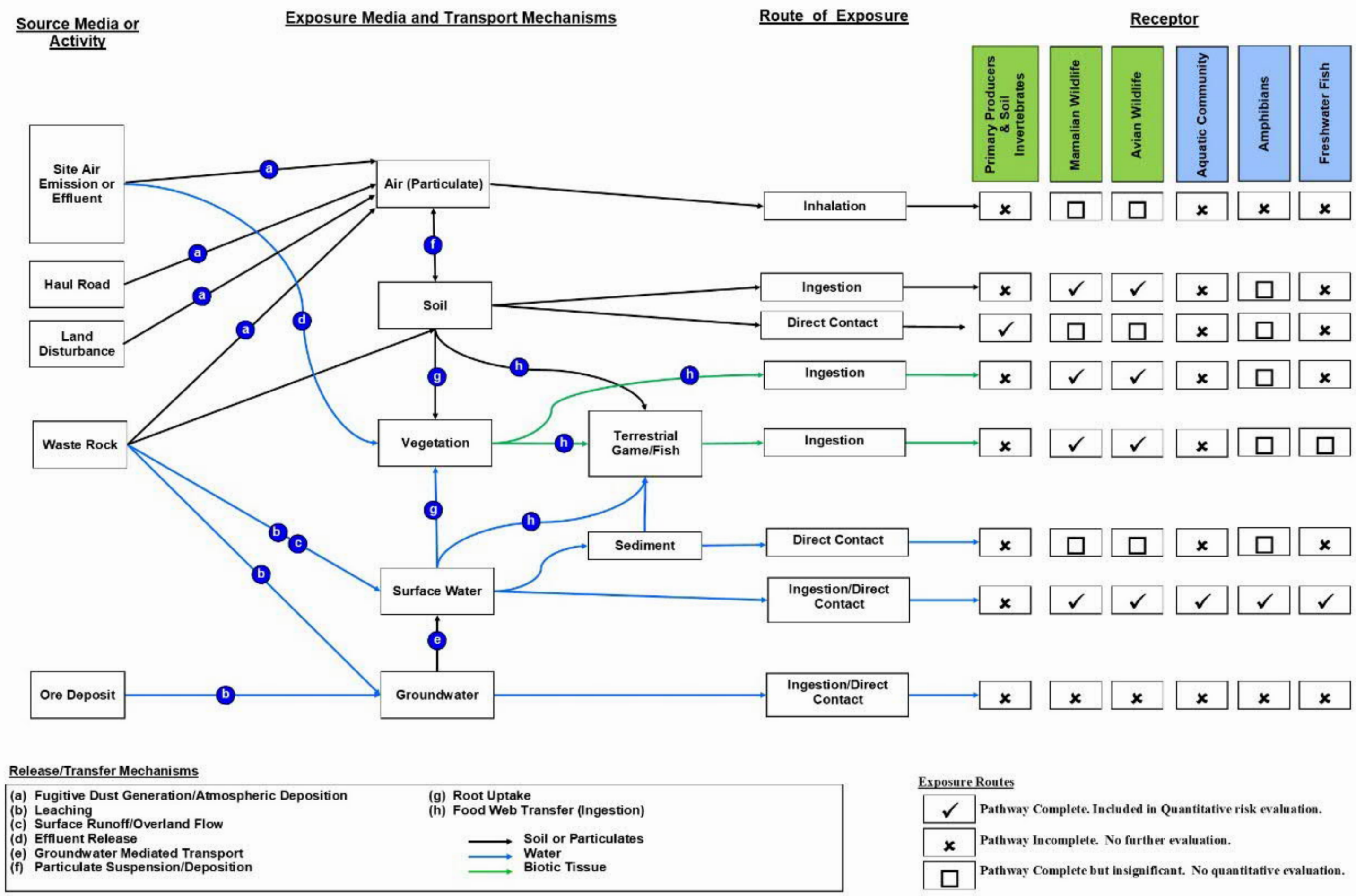

Figure 4-1: Conceptual Exposure Model for Ecological Risk Evaluation

4.2 Exposure Assessment

4.2.1 Terrestrial and Aquatic Feeding Wildlife

Exposure assessment for terrestrial and aquatic feeding wildlife is conducted by calculating average daily dose of contaminants to wildlife receptors as a result of intake and assimilation into biological organisms through common intake pathways (i.e. ingestion of food, water, sediment, biological tissues, etc.). Average daily dose is calculated following standard multimedia exposure equations (CCME, 2020). Details of the exposure assessment, including receptor specific characteristics of intake rates, dietary preferences, modelling algorithms (GoldSim) and the calculated average daily dose are provided in **Appendix A** and **Appendix G.**

Briefly, exposure assessment for terrestrial and aquatic feeding wildlife is executed though the following major steps:

1. Establishing predictive equations for transfer of contaminants *between abiotic media* (e.g., water to sediment, air particulates to soil) to predict future exposure point concentration of COPCs;
2. Establishing predictive equations for transfer of contaminants from *environmental abiotic media* (e.g., soil, water, sediment, air) *to internal tissue* of ecological receptors;
3. Establishing predictive equations to simulate transfer of contaminants *from prey tissue to predator tissue* and to predict average daily dose (intake rate) of COPCs for surrogate receptors;
4. Use of *baseline monitoring data* to support baseline exposure assessment and for seeding equations in steps 1 to 3 for the Application case and Cumulative case;
5. Use of *modelled air quality, water quality and sediment* quality data for exposure assessment and seeding equations in steps 1 to 3 for the Application case and Cumulative case; and
6. Integrating toxicity refence values for the contaminants and receptors of concern with their associated exposure metrics to calculate hazard quotients as measurement endpoints of risk.

4.3 Hazard Assessment

4.3.1 Assessment and Measurement Endpoints

For continuity with other local projects within the Elk Valley coal field and their regulatory review, the present quantitative risk assessment considers wildlife toxicity reference values which align with previously submitted and reviewed risk assessments of similar projects within the Elk Valley. Toxicity reference values employed in previously submitted quantitative wildlife risk assessments were reviewed, and prior to selection were cross checked with the current state of the science to confirm their adequacy for inclusion.

Toxicity reference values selected to assess potential effects to plants and soil invertebrates are presented in **Table 4-4**. Toxicity reference values selected to assess potential effects to mammals and birds identified as ROCs are presented in **Table 4-5.**

Table 4-4: Toxicity Reference Values for Assessment of Plants and Soil Invertebrates.

COPC	Plants	Endpoint	Critical Effect	Source	Soil Invertebrates	Endpoint	Effect	Source
Arsenic	18	MATC	G	US EPA 2005a	60	unknown	G,S,R	Efroymson et al. (1997)
Cadmium	32	MATC	G	US EPA 2005c	140	MATC or EC_{50}	G,R,P	US EPA 2005c
Chromium [(a)]	42[(b)]	NOAEL		US EPA 2008	57[(c)]	MATC	R	US EPA 2008
Cobalt	13	EC_{20}	G	USEPA 2005	40	unknown		OMOE 2004
Selenium	0.52	MATC or EC_{20}	G	US EPA 2007b	4.1	EC_{20}	R	US EPA 2007b
Thallium	1	unknown	G	Efroymson et al. (1997)	NA			

Notes:

TRVs expressed in units of mg/kg dry weight of soil

Endpoints: NOAEL = No observed adverse effects level; NOAEC = no observable effects concentration

Critical Effects: G = growth; R = reproduction; P = population; S = survival

a) TRV for trivalent chromium.

b) Toxicity data presented in US EPA 2005c. Eco SSL not derived as the data did not meet data quality objectives. AECOM have used the geomean of the NOAECs for the growth endpoint presented in Table 3.1 of US EPA

c) Toxicity data presented in US EPA 2005c. US EPA did not derive an Eco SSL for chromium to soil invertebrates due to insufficient data.

Table 4-5: Toxicity Reference Values for Assessment of Terrestrial Mammalian and Avian Species.

COPC	Avian TRV	Endpoint	Effect	Source	Mammalian TRV	Endpoint	Effect	Source
Arsenic	2.24	NOAEL	G,R	US EPA 2005a	1.04	NOAEL	G,R,S	US EPA 2005a
Cadmium	1.47	NOAEL	G,R	US EPA 2005c	0.77	NOAEL	R,G,S	US EPA 2005c
Chromium [(a)]	2.66	NOAEL	G,R	US EPA 2008	2.4	NOAEL	G,R	US EPA 2008
Cobalt	7.61[(b)]	NOAEL	G	USEPA 2005	7.33[(c)]	NOAEL	G,R	USEPA 2005
Selenium	0.29[(c)]	NOAEL	G,R	US EPA 2007b	0.143[(c)]	NOAEL	G,R	US EPA 2007b
Thallium	0.35[(d)]	LOAEL	S	USA CHPPM 2007	0.015	NOAEL	R	USA CHPPM 2007

Notes:

TRVs expressed inn units of mg/kg bw/day)

Endpoints: NOAEL = No observed adverse effects level;

Critical Effects: G = growth; R = reproduction; S = survival

a) TRV for trivalent chromium.

b) NOAEL was lower than the lowest bounded LOAEL for either growth or mortality results. The avian TRV is therefore protective of growth and mortality endpoints.

c) NOAEL was lower than the lowest bounded LOAEL for either reproduction, growth, or survival results. The TRV is therefore considered to be protective of growth, reproduction, and survival.

d) The thallium TRV selected for this ERA model for avian species is based on an acute LD50 (34.6 mg/kg) value cited in Schafer et al. (1972; as cited in USA CHPPM (2007). Because the study considered only acute exposures, the 34.6 mg/kg dose is assigned an uncertainty factor of 100 for the conversion from an acute LD50 to a chronic LOAEL, resulting in a chronic LOAEL of 0.346 mg/kg/day.

4.3.2 Risk Estimation

Risk characterization for exposures of wildlife entailed the calculation of HQs for each receptor and COPC. Risk characterization for metals is focused on calculated HQs at critical receptor locations, as these are considered representative of the likely range of conditions that may be encountered by wildlife within the study area. The HQs were calculated as:

$$HQ = \frac{TDD\ or\ EPC}{TRV}$$

Where:
HQ = hazard quotient (unitless)
TDD = total daily dose from all exposure routes (mg/kg day-1)
EPC = Exposure Point Concentration (mg/kg in soil or mg/L in water)
TRV = toxicity reference value (mg/kg day-1) or (mg/kg soil) or (mg/L water)

4.3.3 Defining Negligible Wildlife Health Risk

Ecological risk assessment hazard quotients are calculated using TRVs that are intended to be protective of the receptors of concern and in consideration of the identified protection goals. As such, HQ values below one (1.0) indicate negligible potential for harm, whereas HQ values above one indicate that an adverse response is possible and that more precise or accurate evaluation of risks may be warranted to address uncertainty.

4.3.4 Criteria Used for Interpretation of Project Risk

To provide interpretive insight on the risk levels and conservative assumptions employed to offset various sources of uncertainty normally encountered in wildlife health risk assessment, the categories provided in **Table 4-6** were used to describe the risk magnitudes for wildlife exposure to COPCs.

Table 4-6: Categories of Magnitude of Effect in Wildlife Health Risk Assessment

Risk Estimate	Negligible	Low	Moderate	High
Hazard Quotient	No change, below applicable guidelines, or HQ<1	1.0 < HQ ≤ 5	5 < HQ ≤ 10	HQ > 10

4.4 Predicted Risk Estimates

Detailed risk estimates, including hazard quotients for each receptor/location/COC are presented in **Appendix G**.

As described in Section 4.3.4, calculated hazard quotients which are below unity (i.e. HQ≤1) are indicative of negligible health risk. Maximum calculated hazard quotients for each COPC at each critical receptor location considering all potential wildlife receptors have been initially screened to identify COPCs for where a predicted HQ exceeds 1 (**Figure 4-2**). This screening process provides a coarse snapshot of the calculated risk estimates under the Base, Application, and Cumulative assessment cases. COPCs with a calculated HQ>1 are examined in detail in Section 4.5.

Mamalian Receptors

	American Badger			American Marten			Bighorn Sheep			Canada Lynx			Deer Mouse		
	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative
As															
Cd					2.0	2.0							1.8	4.8	4.8
Co					2.6	2.6									
Cr															
Se				4.2	4.2	4.3							11	12	12
Tl															

	Elk			Grizzly Bear			Least Chipmunk			Little Brown Myotis			Masked Shrew		
	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative
As													7.9	7.9	8.0
Cd								1.3	1.3		2.1	2.1	22	58	58
Co														7.7	7.7
Cr													3.4	3.5	3.5
Se							3.5	3.5	3.6	5.0	5.0	5.0	138	138	141
Tl													10	10	10

	Moose			Northern River Otter			Snowshoe Hare		
	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative
As									
Cd									
Co									
Cr									
Se				1.3	7.4	7.4			
Tl									

Avian Receptors

	American Dipper			Canada Goose			Common Merganser			Common Raven			Mallard			Northern Goshawk			Whitetailed Ptarmigan		
	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative	Baseline	Application	Cumulative
As																					
Cd	2.4	6.6	6.6																		
Co		2.5	2.5														1.2	1.2			
Cr																					
Se		Aquatic			2.7	2.7		Aquatic		1.7	1.7	1.7		Aquatic					1.2	1.2	1.2
Tl																					

Calculated HQ for Base Case >1 (purple)
Calculated HQ for Application Case >1 (blue)
Calculated HQ for Cumulative Case >1 (orange)
Aquatic = Waterbird risk assessed in Aquatic Health Risk Assessment Section

Figure 4-2: HQ Screening for terrestrial wildlife

4.5 Risk Characterization and Uncertainty Analysis

The following section provides risk characterization of those COPCs identified as exceeding target thresholds in at least a single receptor at critical receptor locations (CRLs) identified as being outside of the Project exclusion zone.

Risk characterization determines potential for negative health effects or risks to ROCs by considering the findings of the exposure and effects assessment, and also includes consideration of the ecological consequences of risk estimates and associated uncertainties.

4.5.1 Arsenic

Magnitude

Calculated HQs are below target thresholds for protection of plants and soil invertebrates at all critical receptor locations (**Appendix G**). Additionally calculated HQs are below target thresholds for all mammalian and avian ROCs at all critical receptor locations with the exception of the masked shrew. Maximum calculated HQs for the masked shrew were 7.9 under Baseline, Application and Cumulative assessment cases, suggesting a potential for moderate magnitude of effect.

Context

Calculated HQs for the masked shrew are unchanged (<1%) between the Base, Application, and Cumulative assessment cases. Calculated risk estimates are driven by baseline conditions, and are not indicative of a Project related risk.

Pathways

Primary exposure pathways to the masked shrew include dietary intake (70%) and incidental soil ingestion (29%).

Overall Significance of the Calculated Quantitative Risk Estimate

Predicted HQs in exceedance of the target threshold were limited to a single species. Predicted HQs for the masked shrew exceed target thresholds at all critical receptor locations assessed. Maximum calculated HQ was 7.9 suggesting a potential moderate magnitude of effect.

However, it is important to note that there is no predicted change in the dose or calculated HQs for the masked shrew between the Base, Application or Cumulative assessment cases, and calculated HQs are consistent regardless of the geographic location (i.e. critical receptor location) being assessed. The calculated HQs in exceedance of target thresholds are therefore considered to have low significance.

Considering the above information, the overall Project related wildlife health risk associated with arsenic exposure is considered to be **low and likely negligible** for the Application and Cumulative assessment cases.

4.5.2 Cadmium

Magnitude

Calculated HQs are below target thresholds for the protection of plants and soil invertebrates at all critical receptor locations.

Calculated HQs exceed threshold benchmarks for American Marten (Max HQ=2.0), Deer Mouse (Max HQ=4.8), Least Chipmunk (Max HQ=1.3), Little Brown Bat (Max HQ=2.1), Masked Shrew (Max HQ=58), and American Dipper (Max HQ=6.6). Calculated HQs suggest low to moderate potential magnitude of effect, with the exception of a high potential magnitude of effect for the masked shrew.

Geographic Distribution

Cadmium risk to mammalian wildlife are geographically limited to critical receptor locations within the Project footprint and along mine infrastructure (i.e. the haul roads). Predicted HQs in exceedance of the target threshold are limited to CRLs 2, 4, and 12 with maximum calculated HQs for mammalian ROCs at CRL12. These locations are not considered to be valued habitat which would support ecological receptors either now or in the future after project development. Calculated HQs for areas of ecological habitat (i.e. not located within roadways) were below target thresholds for the Application and Cumulative assessment cases (**Figure 4-3**).

Calculated HQs for American dipper were observed to be above target thresholds in the Application and Cumulative assessment cases at a subset of CRLs located downstream of the confluence of West Alexander Creek and Alexander Creek. Predicted surface water quality values indicate that Alexander Creek is influenced by effluent discharge from the proposed Project. Calculated HQs in exceedance of target threshold in American Dipper are predicted for CRL10 immediately after the confluence of West Alexander Creek and Alexander Creek south as far as CRL11, the furthest downstream prediction node Alexander Creek (**Figure 4-4**).

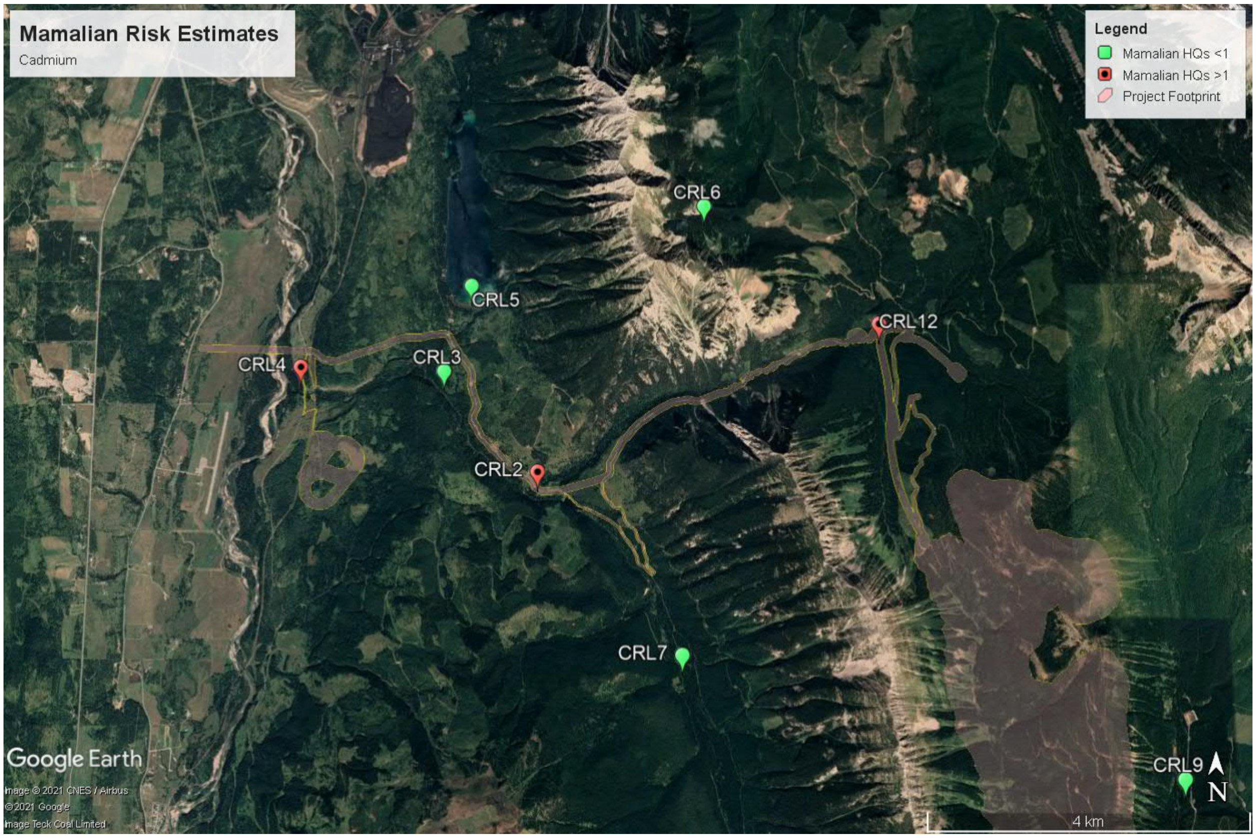

Figure 4-3: Spatial distribution of cadmium HQs > 1 for mammalian ROCs.

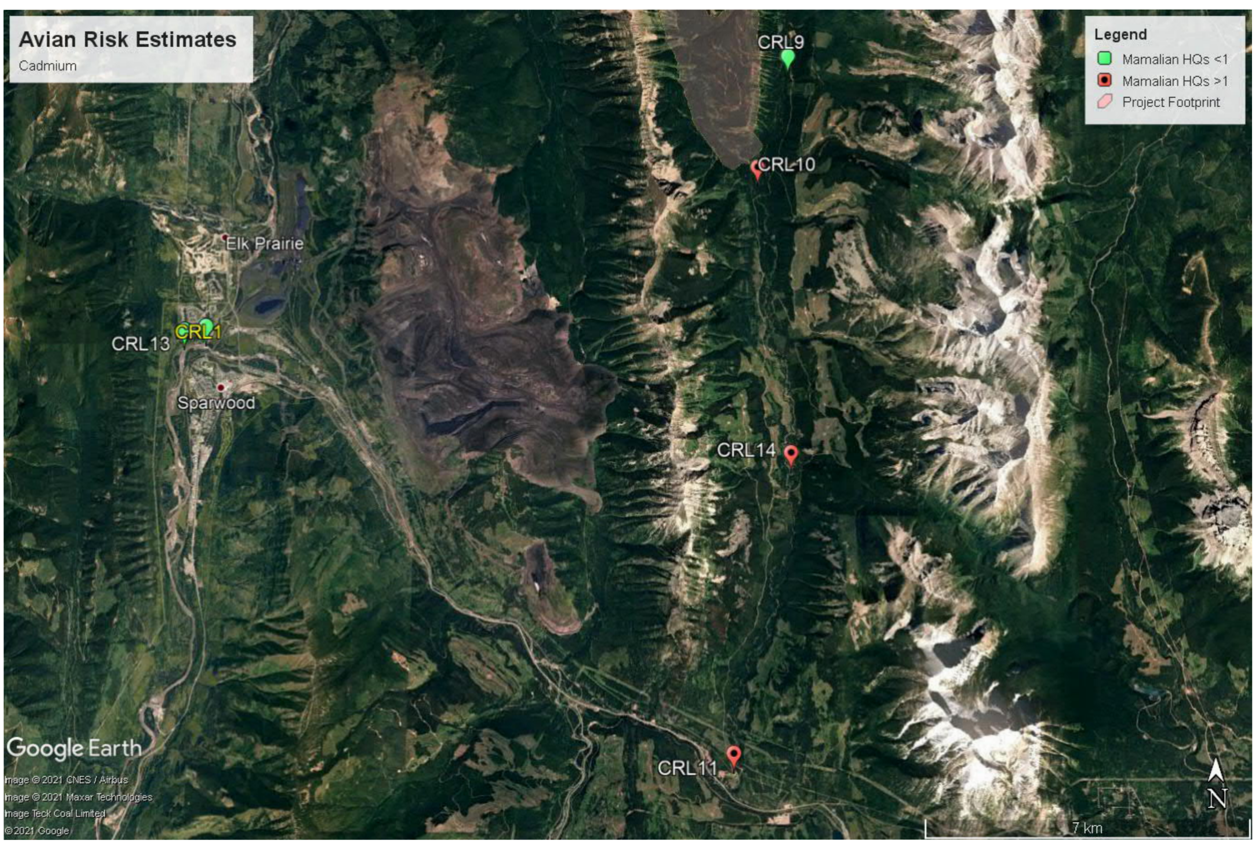

Figure 4-4: Spatial distribution of cadmium HQs > 1 for American Dipper.

Conservatism in the Toxicity Reference Values

The TRVs used for the assessment of mammalian receptors is a NOAEL protective of reproduction, growth and survival. The use of the NOAEL is considered to be a conservative endpoint for assessment of community health, and is likely to overestimate risks to many of the mammalian receptors identified as having HQs >1. The use of the NOAEL as a TRV is supported for the assessment of endangered or species of special concern, such as bat species assumed to be present.

Similarly, the TRV used for the assessment of the American Dipper is a conservative NOAEL protective of growth and reproduction. American Dipper is listed as provincially ranked as an S4 apparently secure species by the BC Conservation Data Centre[2]. The use of a NOAEL is considered to be conservative when assessing the risks to the American Dipper, and is considered to likely overestimate risks. None of the other aquatic feeding avian receptors were calculated to have HQs>1.

Overall Significance of the Calculated Quantitative Risk Estimate

Predicted HQs in exceedance of the target threshold were identified for mammalian and avian species. Maximum calculated HQs were identified for the Masked Shrew (HQ=58), however this result is considered to be of low significance since the HQ is predicted at a location within the Project footprint, and will not provide valued ecological habitat.

Other mammalian species with elevate HQs were predicted to have a low potential magnitude of effect 1.0 < HQ ≤ 5. Critical receptor locations where calculated mammalian HQs exceed target thresholds are limited to locations within the Project footprint along the haul road and do not represent valued ecological habitat.

Calculated HQs for American Dipper exceed target thresholds at CRLs located along Alexander Creek, downstream of the confluence with West Alexander Creek, indicating a low to moderate magnitude of effect. American Dipper is the only waterbird calculated to exceed target thresholds. The TRV used is a conservative NOAEL that may overestimate risks to the American Dipper relative to identified protection goals for this apparently stable population.

Considering the above information, the overall Project related wildlife health risk associated with cadmium exposure is considered to be low and likely negligible to mammalian receptors under the Application and Cumulative assessment cases. Overall Project risks are considered to be low for avian receptors under the Application and Cumulative assessment cases.

4.5.3 Cobalt

Magnitude

Calculated HQs are below target thresholds for protection of plants and soil invertebrates at all critical receptor locations.

Calculated HQs exceed threshold benchmarks for American Marten (Max HQ=3), Masked Shrew (Max HQ=8), Northern Goshawk (Max HQ=1.2) and American Dipper (Max HQ=1.4). Calculated HQs suggest low potential magnitude of effect, with the exception of a moderate potential magnitude of effect for the masked shrew.

Geographic Distribution

Cobalt risks to mammalian wildlife are geographically limited to critical receptor locations within the Project footprint and along mine infrastructure (i.e. the haul roads). Predicted HQs in exceedance of the target threshold are limited to CRLs 4, and 12 with maximum calculated HQs for mammalian ROCs at CRL12. These locations are not considered to be valued habitat which would support ecological

2 https://a100.gov.bc.ca/pub/eswp/speciesSummary.do;jsessionid=1d1a139b45391d8ebad85577824736e31bf8f603f7fd1f11b010efc2f12ca5d3.e3uMah8KbhmLe3aOchqKaNuOci1ynknvrkLOlQzNp65In0?id=15068

receptors either now or in the future after Project development. Calculated HQs for areas of ecological habitat (i.e. not located within roadways) were below target thresholds for the Application and Cumulative assessment cases.

Calculated HQs for American dipper were observed to be above target thresholds in the Application and Cumulative assessment cases at a subset of CRLs located downstream of the confluence of West Alexander Creek and Alexander Creek. Predicted surface water quality values indicate that Alexander Creek is influenced by effluent discharge from the proposed Project. Calculated HQs in exceedance of target threshold in American Dipper are predicted for CRL10 immediately after the confluence of West Alexander Creek and south as far as CRL11, the furthest downstream prediction node Alexander Creek.

Conservatism the Toxicity Reference Values

The toxicity reference values used for the assessment of mammalian receptors is a NOAEL protective of reproduction, growth and survival. The use of the NOAEL is considered to be a conservative endpoint for assessment of community health, and is likely to overestimate risks to many of the mammalian receptors identified as having HQs >1. The use of the NOAEL as a TRV is supported for the assessment of endangered or species of special concern, such as bat species assumed to be present in the study area.

Similarly, the TRV used for the assessment of the American Dipper is a conservative NOAEL protective of growth and reproduction. American Dipper is listed as provincially ranked as an S4 apparently secure species by the BC Conservation Data Centre. The use of a NOAEL is considered to be conservative when assessing the risks to the American Dipper, and is considered to likely overestimate risks. None of the other aquatic feeding avian receptors were calculated to have HQs>1.

Overall Significance of the Calculated Quantitative Risk Estimate

Predicted HQs in exceedance of the target threshold were identified for mammalian and avian species. Maximum calculated HQs were identified for the Masked Shrew (HQ=8), however this result is considered to be of low significance since the HQ is predicted at a location within the Project footprint, and will not provide valued ecological habitat.

Other mammalian species with elevate HQs were predicted to have a low potential magnitude of effect $1.0 < HQ \leq 5$. Critical receptor locations where calculated mammalian HQs exceed target thresholds are limited to locations within the Project footprint along the haul road and do not represent valued ecological habitat.

Calculated HQs for American Dipper exceed target thresholds at CRLs located along Alexander Creek, downstream of the confluence with West Alexander Creek, indicating a low potential magnitude of effect. American Dipper is the only waterbird calculated to exceed target thresholds. The TRV used is a conservative NOAEL that may overestimate risks to the American Dipper relative to identified protection goals for this apparently stable population.

Considering the above information, the overall Project related wildlife health risk associated with cobalt exposure is considered to be low and likely negligible mammalian receptors under the Application and Cumulative assessment cases. Overall Project risks are considered to be low for avian receptors under the Application and Cumulative assessment cases.

4.5.4 Chromium

Magnitude

Calculated HQs are below target thresholds for protection of plants and soil invertebrates at all critical receptor locations.

Calculated HQs are below target thresholds for all mammalian and avian ROCs at all critical receptor locations with the exception of the masked shrew. Maximum calculated HQs for the masked shrew were HQ=3.5 for the Application and Cumulative assessment cases, suggesting a potential for low magnitude of effect.

Context

Calculated HQs (3.4) for the masked shrew are exceed target thresholds in the Base Case assessment. Calculated HQs show negligible change (<1%) from the Base Case to the Application or Cumulative assessment cases. Calculated HQs are driven by baseline conditions and are not influenced by proposed Project activities.

Overall Significance of the Calculated Quantitative Risk Estimate

Predicted HQs in exceedance of the target threshold were limited to a single species. Predicted HQs for the masked shrew exceed target thresholds at all critical receptor locations assessed. Maximum calculated HQ was 3.5 suggesting a low magnitude of effect.

There is no significant predicted change in the dose or calculated HQs for the masked shrew between the Base, Application or Cumulative assessment cases, and calculated HQs are consistent regardless of the geographic location (i.e. critical receptor location) being assessed. The calculated HQs in exceedance of target thresholds are therefore considered to have low significance.

Considering the above information, the overall Project related wildlife health risk associated with arsenic exposure is considered to be **low and likely negligible** for the Application and Cumulative assessment cases.

4.5.5 Selenium

Magnitude

Calculated HQs are below target thresholds for protection of plants and soil invertebrates at all critical receptor locations.

Calculated HQs exceed threshold benchmarks suggesting a low potential magnitude of effect for a variety of mammalian and avian receptors ROCs (**Figure 4-2**).

Calculated HQs for the Deer Mouse (max. HQ=12) and Masked Shrew (max. HQ=141) suggest a moderate and high potential magnitude of effect for these ROCs respectively.

Context

Calculated HQs for terrestrial mammalian receptors were generally unchanged for the Application and Cumulative case relative to the Base Case. Calculated HQs for terrestrial mammalian receptors are driven by baseline conditions and suggest a negligible risk associated with Project activities.

Calculated HQs for terrestrial avian receptors (Common Raven and Whitetailed Ptarmigan) were unchanged for the Application and Cumulative case relative to the Base Case. Calculated HQs for terrestrial avian receptors are driven by baseline conditions and suggest a negligible risk associated with Project activities.

Calculated HQs for the Northern River Otter and the Canada Goose are predicted to increase in the Application and Cumulative assessment cases relative to the Base Case.

Geographic Distribution

Predicted HQs in exceedance of the target threshold for the Norther River Otter and the Canada Goose are limited to CRLs which are located along Lower Grave Creek, and in direct proximity to the Project footprint or mine related infrastructure (CRL2, SRL3, and CRL4). These critical receptor locations are considered to be cumulative assessment locations for the water quality assessment. Exposures to the Northern River Otter and the Canada Goose, both of which are intimately tied to the aquatic environment are driven primarily by water quality effects associated with Harmer Creek and the Elkview operations.

An additional point to consider is that these locations are not considered to be valued habitat which would support ecological receptors either now or in the future after Project development. HQs for areas of ecological habitat (i.e. not located within roadways) were below target thresholds for the Application and Cumulative assessment cases.

Conservatism the Toxicity Reference Values

The TRVs used for the assessment of mammalian receptors is a NOAEL protective of reproduction, growth and survival. The use of the NOAEL is considered to be a conservative endpoint for assessment of community health, and is likely to overestimate risks to many of the mammalian receptors identified as having HQs >1. The use of the NOAEL as a TRV is supported for the assessment of endangered or species of special concern, such as bat species assumed to be present in the LSA.

Overall Significance of the Calculated Quantitative Risk Estimate

Predicted HQs in exceedance of the target threshold were identified for mammalian and avian species.

Calculated HQs for terrestrial mammalian receptors were unchanged for the Application and Cumulative case relative to the Base Case. Calculated HQs for terrestrial mammalian receptors are driven by baseline conditions and suggest a negligible risk associated with Project activities.

Calculated HQs for terrestrial avian receptors (Common Raven and Whitetailed Ptarmigan) were unchanged for the Application and Cumulative case relative to the Base Case. Calculated HQs for terrestrial avian receptors are driven by baseline conditions and suggest a negligible risk associated with Project activities.

Calculated HQs for Northern River Otter and Canada Goose in exceedance of target thresholds are limited to areas of direct Project influence (i.e. on haul roads) and are not representative of values ecological habitat that would support these receptors in the future.

Considering the above information, the overall Project related wildlife health risk (exclusive of the potential aquatic health risks addressed in Section 5) associated with selenium are considered to be low and likely negligible under the Application and Cumulative assessment cases.

4.5.6 Thallium

Magnitude

Calculated HQs are below target thresholds for protection of plants at all critical receptor locations. No applicable TRV protective of soil invertebrates was identified.

Calculated HQs are below target thresholds for all mammalian and avian ROCs at all critical receptor locations with the exception of the masked shrew. Maximum calculated HQs for the masked shrew were HQ=10 under Application and Cumulative assessment cases, suggesting a potential for high magnitude of effect.

Context

Calculated HQs for the masked shrew are unchanged (<1%) between the Base, Application, and Cumulative assessment cases. Calculated risk estimates are driven by baseline conditions and are not indicative of a Project related risk.

Pathways

Primary exposure pathways to the masked shrew include incidental soil ingestion (78%) and dietary intake (22%).

Overall Significance of the Calculated Quantitative Risk Estimate

Predicted HQs in exceedance of the target threshold were limited to a single species. Predicted HQs for the masked shrew exceed target thresholds at all critical receptor locations assessed. Maximum calculated HQ was 10 suggesting a moderate magnitude of effect.

However, there is no predicted change in the dose or calculated HQs for the masked shrew between the Base, Application or Cumulative assessment cases, and calculated HQs are consistent regardless of the geographic location (i.e. critical receptor location) being assessed. The calculated HQs in exceedance of target thresholds are therefore considered to have low significance.

Considering the above information, the overall Project related wildlife health risk associated with thallium exposure is considered to be low and likely negligible for the Application and Cumulative assessment cases.

4.6 Conclusions of Wildlife Health Risk Assessment

Overall conclusions to the Wildlife Health Risk Assessment are drawn in consideration of the Key Question identified in Section 2.1 Study Objectives, specifically: ***What will be the collective potential effect of changes to water, air, soil, and food to ecological health?***

Conclusions of the Wildlife Health Risk Assessment are as follows:

What will be the collective potential effect of changes to air and soil to plant health?

- Predicted concentrations of COPCs in soil as a result if incremental changes to soil chemistry associated with total particulate deposition present a negligible risk to plant health for the Application and Cumulative assessment cases based on conservative assumptions and toxicity reference values.

What will be the collective potential effect of changes to air and soil to soil invertebrate health?

- Predicted concentrations of COPCs in soil as a result if incremental changes to soil chemistry associated with total particulate deposition present a negligible risk to soil invertebrate health for the Application and Cumulative assessment cases based on conservative assumptions and toxicity reference values.

What will be the collective potential effect of changes to water, air, soil, and food to the health of terrestrial mammalian species?

- Arsenic
  - Calculated HQs are below target thresholds for all mammalian and avian ROCs at all critical receptor locations with the exception of the masked shrew. Maximum calculated HQs for the masked shrew were 7.9 under Application and Cumulative assessment cases and are unchanged from the Base Case. Calculated risk estimates are driven by baseline conditions and are not indicative of a Project related risk.
  - The overall Project related wildlife health risk associated with arsenic exposure is considered to be **low and likely negligible** for the Application and Cumulative assessment cases.
- Cadmium
  - Calculated HQs exceed threshold benchmarks for American Marten (Max HQ=2.0), Deer Mouse (Max HQ=4.8), Least Chipmunk (Max HQ=1.3), Little Brown Bat (Max HQ=2.1), Masked Shrew (Max HQ=58), and American Dipper (Max HQ=6.6).
  - Cadmium risk to mammalian wildlife are geographically limited to critical receptor locations within the Project footprint and along mine infrastructure. These locations are not considered to be valued habitat capable of supporting ecological receptors after Project development. Calculated HQs for areas of ecological habitat are below target thresholds for the Application and Cumulative assessment cases.
  - The overall Project related wildlife health risk associated with cadmium exposure is considered to be **low and likely negligible** mammalian receptors under the Application and Cumulative assessment cases.

- Cobalt
  - Calculated HQs exceed threshold benchmarks for American Marten (Max HQ=3), Masked Shrew (Max HQ=8), Northern Goshawk (Max HQ=1.2) and American Dipper (Max HQ=1.4). Calculated HQs suggest low potential magnitude of effect, with the exception of a moderate potential magnitude of effect for the masked shrew.
  - Cobalt risks to mammalian wildlife are geographically limited to critical receptor locations within the Project footprint and along mine infrastructure (i.e. the haul roads). Calculated HQs for areas of ecological habitat (i.e. not located within roadways) were below target thresholds for the Application and Cumulative assessment cases.
  - The overall Project related wildlife health risk associated with cobalt exposure is considered to be **low and likely negligible** mammalian receptors under the Application and Cumulative assessment cases.
- Chromium
  - Calculated CRs are below target thresholds for all mammalian and avian ROCs at all critical receptor locations with the exception of the masked shrew. Maximum calculated HQs for the masked shrew were HQ=3.5 for the Application and Cumulative assessment cases, suggesting a potential for low magnitude of effect.
  - Calculated HQs (3.4) for the masked shrew are exceed target thresholds in the Base Case assessment. Calculated HQs show negligible change (<1%) from the Base Case to the Application or Cumulative assessment cases. Calculated HQs are driven by baseline conditions and are not influenced by proposed Project activities.
  - The overall Project related wildlife health risk associated with arsenic exposure is considered to be **low and likely negligible** for the Application and Cumulative assessment cases.
- Selenium
  - Calculated HQs for terrestrial mammalian receptors exceed target thresholds for a variety of ROCs, however HQs were unchanged for the Application and Cumulative case relative to the Base Case. Calculated HQs for terrestrial mammalian receptors are driven by baseline conditions a suggest a negligible risk associated with Project activities.
  - Calculated HQs for Northern River Otter exceeded target thresholds critical receptor locations in areas of direct Project influence (i.e. on haul roads) and are not representative of valued ecological habitat that would support these receptors in the future
  - The overall Project related wildlife health risk associated with selenium are considered to be **low and likely negligible** for terrestrial mammalian receptors under the Application and Cumulative assessment cases.
- Thallium
  - Calculated HQs are below target thresholds for all mammalian and avian ROCs at all critical receptor locations with the exception of the masked shrew. Maximum calculated HQs for the masked shrew were HQ=10 under Application and Cumulative assessment cases, suggesting a potential for high magnitude of effect.
  - Calculated HQs for the masked shrew are unchanged (<1%) between the Base, Application, and Cumulative assessment cases. Calculated risk estimates are driven by baseline conditions, and are not indicative of a Project related risk.
  - The overall Project related risk associated with thallium exposure is considered to be **low and likely negligible** for the Application and Cumulative assessment cases.

What will be the collective effect of changes to water, air, soil, and food to the health of terrestrial avian species?

- Arsenic
  - All calculated HQs for avian receptors were below target thresholds under the Application and Cumulative assessment cases. Risk to avian health are considered **negligible**.
- Cadmium
  - Calculated HQs exceed threshold benchmarks American Dipper (Max HQ=6.6). Calculated HQs suggest moderate potential magnitude of effect.
  - Calculated HQs for American Dipper exceed target thresholds at CRLs located along Alexander Creek, downstream of the confluence with West Alexander Creek, indicating a low to moderate magnitude of effect. American Dipper is the only waterbird calculated to exceed target thresholds. The TRV used is a conservative NOAEL that may overestimate risks to the American Dipper relative to identified protection goals for this apparently stable population.
  - Overall Project risks are considered to be **low** for avian receptors under the Application and Cumulative assessment cases.
- Cobalt
  - Calculated HQs marginally exceed threshold benchmarks for Northern Goshawk (Max HQ=1.2) and American Dipper (Max HQ=1.4). Calculated HQs suggest low potential magnitude of effect. In consideration of the conservatism of the assessment and the limited geographic extent of predicted impact, the overall Project risks are considered to be negligible for avian receptor exposure to cobalt.
- Chromium
  - All calculated HQs for avian receptors were below target thresholds under the Application and Cumulative assessment cases. Risk to avian health are considered **negligible**.
- Selenium
  - Calculated HQs for terrestrial avian receptors (Common Raven and Whitetailed Ptarmigan) were unchanged for the Application and Cumulative case relative to the Base Case. Calculated HQs for terrestrial avian receptors are driven by baseline conditions a suggest a negligible risk associated with Project activities.
  - Calculated HQs for the Canada Goose are predicted to increase in the Application and Cumulative assessment cases relative to the Base Case.
  - Predicted HQs in exceedance of the target threshold for the Canada Goose are limited to CRLs which are located along Lower Grave Creek, and in direct proximity to the Project footprint or mine related infrastructure (CRL2, SRL3, and CRL4). These locations are not considered to be valued habitat which would support ecological receptors either now or in the future after Project development. HQs for areas of ecological habitat (i.e. not located within roadways) were below target thresholds for the Application and Cumulative assessment cases.
  - The overall Project risk associated with avian exposure to selenium (exclusive of water birds, which are assessed as part of the Aquatic Health Risk Assessment) are considered to **be low and likely negligible** under the Application and Cumulative assessment cases.
- Thallium
  - All calculated HQs for avian receptors were below target thresholds under the Application and Cumulative assessment cases. Risk to avian health are considered **negligible**.

5. Aquatic Health Risk Assessment

An assessment of potential health risks to aquatic biota (fish, benthic invertebrates) was conducted using the same fundamental principles used for wildlife. The approach assessed potential exposure and compared existing and predicted levels of COPCs to relevant toxicological reference values protective of the aquatic receptors. However, the approach differs from that for terrestrial wildlife receptors in that there is no multimedia foodchain model to predict the dose or intake rate of COPCs. Instead the health risk from exposure is assessed directly from exposure point concentrations (EPC) defined as the concentration in water or sediment and compared to reference concentrations (waterborne or sediment bound) considered to be protective of the specific ROCs. For the specific case of selenium and waterfowl, the exposure was benchmarked from a predicted waterborne exposure point concentration and converted by extrapolation factors (i.e., not a foodchain model) that predict critical tissue residues of selenium for comparison to a protective reference value.

5.1 Supplemental Problem Formulation

5.1.1 Receptors of Concern

This assessment focuses on aquatic wildlife species and groups that were selected as VCs for the Project, as documented in the approved Applications Information Requirements for the Project (EAO 2018).

Candidate VCs selected for the assessment and the rationale for their selection, receptors of concern (ROCs) and surrogate ROCs used to assess the VCs are provided in **Table 5-1**.

Table 5-1: Identified Valued Components and Surrogate Receptors of Concern used in the Aquatic Health Risk Assessment

Valued Component	Included in ERA? (Yes/No)	Rationale	Receptors of Concern	Surrogate ROC(s) (if applicable)
Aquatic Community	Yes	Aquatic life has been selected as a ROC via indirect fate & transport to surface water bodies supporting aquatic life. Benthic invertebrates are known to live in sediment or on the bottom of waterbodies within the LSA. Benthic invertebrates may be affected by changes in surface water quality and quantity, sediment quality, as well as groundwater (e.g., quality and quantity of groundwater flows).	Benthic Invertebrates Periphyton	Benthic Invertebrates
Amphibians	Yes	Several amphibian species have the potential to occur within the RSA, including western toad, Rocky Mountain tailed frog, and the Columbia spotted frog.	Western Toad	Amphibian
Fish	Yes	Fish species within the RSA may be impacted by changes in surface water quality and quantity as well as sediment quality. Western Cutthroat Trout and Bull Trout are blue-listed in BC and listed as Special Concern under SARA; Western Cutthroat Trout are also listed as Special Concern under COSEWIC. Bull Trout, Longnose Sucker, Mountain Whitefish, and Kokanee are important fish species for recreational fishing in the Elk Valley	West slope Cutthroat Trout Bull trout Burbot Longnose sucker Mountain Whitefish Kokanee	Fish Community

Valued Component	Included in ERA? (Yes/No)	Rationale	Receptors of Concern	Surrogate ROC(s) (if applicable)
Waterbirds	Yes	For selenium assessment only, all waterbirds that are suspected of breeding in lotic or lentic environments within the LSA will be considered. Bird health may be affected by concentrations of selenium in aquatic prey.	Red-winged Blackbird Spotted Sandpiper Mallard American Dipper Great Blue Heron	Waterbird Community

5.1.2 Secondary Pathway Analysis

The primary Project linkage potentially affecting aquatic health is the predicted change to surface water quality as a result of Project activities (Section 3.1.3). Surface water quality predictions based on a conceptual water balance and conservative mass balance model were developed to address all major facilities associated with the Project, accounting for flows and mass flux of substances of interest to the receiving environment (SRK, 2021).

Based on the conceptual model, all flows potentially impacted by surface water contact with waste rock are directed to the waste rock sedimentation pond, and subsequently discharged as effluent to Alexander Creek via West Alexander Creek.

Surface runoff from the Clean Coal Transfer Area is captured in a sediment pond with discharge from this pond reporting to node GC-7 upstream of the Grave Creek Reservoir. Surface runoff from the Rail Loadout area is captured and routed into the Rail Loop Sump, which is designed to be a non-discharge infiltration facility. Discharge from various mine related infrastructure along Grave Creek indicate very little impact to local stream quality (SRK, 2021) associated with proposed mine activities.

Based on the planned mine site hydrology, the principal pathway with a potential affect to aquatic health is effluent discharge to Alexander Creek. Grave creek does not receive seepage water from waste rock, which is the primary source of Project related contaminants to surface waters within the study area.

Changes to surface water quality may result in associated changes to sediment quality. Induced changes to sediment quality are identified as a secondary pathway for consideration in the present aquatic health risk assessment.

5.1.1 Identification of Exposure Pathways

As described in Section 5.2, the approach to the aquatic assessment differs from the Wildlife Health Risk Assessment in that receptors are assessed based on comparison of exposure point concentration to toxicity reference values. However, in order to develop the conceptual exposure model (**Figure 4-1**) an inventory of exposure pathways was documented (**Table 5-2**) for the aquatic receptors.

Table 5-2: Exposure pathway assessment for Aquatic receptors.

Receptor Group	Exposure Pathway	Included (Yes/No)	Rationale
Aquatic Community (*Benthic Invertebrates*)	Direct Contact (sediment)	**Yes**	Benthic invertebrates are in intimate contact with the sedimentary environment.
Amphibians	Water Ingestion	No	Amphibians do not drink water; rather, they absorb water through skin. As such, ingestion of water is not considered a viable pathway.
	Direct Contact (Surface Water or Ponded Seepage)	**Yes**	Potential changes to surface water may result in increased exposure to amphibian receptors. Sensitive early life stages may be present in standing bodies of water.
	Food Ingestion	No	While this route remains operable, there is a lack of empirical data on exposure and toxicity for amphibians.
	Incidental Soil Ingestion	No	While it is plausible, amphibians may ingest soil incidentally through feeding, scientific knowledge of this pathway is limited.
	Dermal Contact (Soil/Sediment)	No	While amphibian dermis is permeable and exposure is plausible, there is limited empirical data to support a credible analysis of transdermal exposure from soil contact.
Aquatic Life (Fish)	Water Ingestion	No	Fish do not drink water; rather, they absorb water through skin and gills. As such, ingestion of water is not considered a viable pathway.
	Direct Contact (Surface Water)	**Yes**	Potential changes to surface water may result in increased exposure to sensitive fish species. Waterborne exposure is considered the dominant and most sensitive exposure route and is supported by sufficient toxicological data to form the basis of the assessment.
	Food Ingestion	No	While this route remains operable, there is a lack of empirical data on exposure and toxicity for fish associated with dietary exposure.
	Incidental Sediment Ingestion	No	While it is plausible, fish may ingest sediment incidentally through feeding, scientific knowledge of this pathway is limited.

5.1.2 Contaminants of Potential Concern

Screening of contaminants of potential concern for the aquatic health risk assessment was based on comparison of predicted maximum monthly (30-day) rolling average concentrations of chemical constituents to water quality criteria. Modelled water quality was based on conservative upper bounds of source terms (95th percentile) assuming successful implementation of the layer cake deposition strategy. Water quality predictions were compared to the most stringent value from the following water quality objectives in order to identify to identify contaminants of potential concern:

- Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Freshwater Aquatic Life.
- British Columbia Water Quality Guidelines for the Protection of Freshwater Aquatic Life (BC WQG FAL).
- BC CSR Schedule 3.2 Generic Numerical Water Quality Standards for Protection of Freshwater Aquatic Life.
- Federal Environmental Quality Guidelines (EQGs).
  - EQGs are available for cobalt, copper, strontium, and vanadium.
- Other International Water Quality Standards where no provincial or federal guidelines exist.

Chemical constituents that were observed to exceed applicable environmental quality objectives and were predicted to increase by greater than 10% relative to the 95th percentile of baseline concentrations in upstream unimpacted surface water samples were retained as COPCs for the assessment of aquatic health risk. Details of the screening process are provided in **Appendix F**.

Water quality compliant with applicable water quality guidelines is considered to be sufficiently protective of the aquatic community, and as a secondary pathway changes to sediment quality as a result of changes to surface water quality will be assessed for those COPCs identified in the screening of surface water as described above.

The screening process identified cadmium, cobalt, and selenium as COPCs to be carried forward in the present aquatic health risk assessment.

The results of this screening process agree with the identification of “primary COPCs” for the Elk River Watershed and Lake Koocanusa Aquatic Environment Synthesis report (TECK, 2014) which forms a basis for the Elk Valley Water Quality Plan, approved by the British Columbia Minister of Environment November 18, 2014.

5.1.1 Assessment Endpoints and Measurement Indicators

The assessment endpoints applied to aquatic VCs are provided in (**Table 5-3**). The assessment endpoints support maintenance of self-sustaining and ecologically effective populations of the identified VCs. These endpoints consider growth, reproduction, and survival of the receptors of concern with the intention of maintaining ecological services (food production for fish species in the case of benthic invertebrates) and maintaining local populations of aquatic wildlife into the future with a low risk of extirpation.

Table 5-3. Assessment Endpoints and Measurement Indicators for Aquatic Valued Components.

Valued Components	Assessment Endpoint	Measurement Indicators
Aquatic Community *(Benthic Invertebrates as ROC)*	Maintenance of self-sustaining and ecologically effective populations.	Growth, survival, and reproduction of benthic invertebrates, assessed by comparison of predicted concentrations of water and sediment quality to screening values or benchmarks derived from literature-based toxicity information and that are protective of aquatic life
Amphibians	Maintenance of self-sustaining and ecologically effective populations	Growth, survival, and reproduction of benthic invertebrates, assessed by comparison of predicted concentrations of water and sediment quality to screening values or benchmarks derived from literature-based toxicity information and that are protective of aquatic life [a].
Fish	Maintenance of self-sustaining and ecologically effective populations	Growth, survival, and reproduction of fish, assessed by comparison of predicted concentrations of water and sediment quality to screening values or benchmarks derived from literature-based toxicity information and that are protective of populations of aquatic organisms.
Waterbirds *(Selenium Assessment Only)* [b]	Maintenance of self-sustaining and ecologically effective populations.	Growth, survival, and reproduction of waterbirds, assessed by comparison of predicted concentrations of selenium in water to screening values derived from literature-based toxicity information and that are protective of bird health.

Notes:

(a) Amphibian health may be affected by changes to surface water and/or sediment quality. Selenium mobilization is of particular concern with respect to coal mining activities in the Elk Valley. Selenium can lead to changes in reproductive health of egg-laying vertebrates. Available data suggest that amphibians are not more sensitive to selenium than fish and birds, and do not bioaccumulate more selenium than fish and birds. Therefore, a selenium benchmark based on the more sensitive of fish or birds is also expected to be conservatively predictive of potential effects on amphibians.

(b) Potential effects to avian receptors through exposure to contaminants of concern other than selenium are addressed in Section 4. Wildlife Health Assessment.

5.2 Exposure Assessment

Exposure assessment for the aquatic health risk assessment is conducted by comparing predicted concentrations of COPCs in environmental media to ecologically relevant toxicological benchmarks considered to be protective of the receptors being assessed in consideration of the assessment endpoints. The aquatic health risk assessment is based on predicted concentrations of COPCs in surface water (Section 5.2.2) and sediment (Section 5.2.3).

5.2.1 Spatial Boundaries

The present aquatic health risk assessment is based on predicted surface water quality at model prediction nodes included in the *Surface Water Quality Modelling Report (SRK, 2020)*. Details of the prediction nodes considered in the current HHERA are presented in **Table 5-4**.

Table 5-4: Surface water quality prediction nodes considered in the HHERA

Watershed	Node	Description	Assessment Case
Grave Creek	GC-1	Grave Creek upstream of confluence with Elk River	Cumulative
	GC-2	Grave Creek downstream of confluence with Harmer Creek	Cumulative
	GC-3	Grave Creek upstream of confluence with Harmer Creek	Project
	GC-4	Harmer Creek upstream of confluence with Grave Creek	Cumulative
	GC-5	Grave Creek downstream of GCR withdrawal location	Project
	GC-6	Grave Creek upstream of GCR withdrawal location	Project
	GC-7	Grave Creek downstream of Clean Coal Transfer Area	Project
	GC-8	Grave Creek downstream of CHPP	Project
Alexander Creek	AC-1	Alexander Creek Upstream of Highway 3	Project
	AC-2	Alexander Creek mid-reach (between highway 3 and West Alexander)	Project
	AC-3	Alexander Creek downstream of confluence with West Alexander	Project
	AC-4	Alexander Creek upstream of confluence with West Alexander	Project
	AC-5	West Alexander upstream of confluence with Alexander Creek	Project
	AC-6	West Alexander downstream of confluence with Alexander Creek	Project
Elk River Valley	EV_ER1	Elk River downstream of confluence with Michel Creek	Cumulative

Source: <Source>

5.2.1.1 Project Assessment Nodes

The upper reaches of Grave Creek (upstream of the confluence with Harmer Creek) and the Alexander Creek watershed are relatively undeveloped areas. Predicted changes to surface water quality at model prediction nodes in along these watercourses are attributable to proposed Project activities.

Water quality model prediction nodes associated with cumulative projects are identified in **Table 5-4**. Assessment of aquatic health risks at these prediction nodes are considered to be analogous to the Application assessment case, as described in Section 2.4.

5.2.1.2 Cumulative Assessment Nodes

Resource extraction activities have been ongoing in the Elk River valley since the early 1970's, and local watercourses with active pathways to current resource extraction projects show associated affects. There are three watercourses that will have potential cumulative effects from multiple mines in the Elk Valley:

- Harmer Creek (Harmer Creek flows into Grave Creek to the North of the Project downstream of the Grave Creek Reservoir, and is also impacted by Teck Coal's Elkview Operations).
- Michel Creek (West Alexander Creek to the south of the Project flows into Michel Creek, is also impacted by Teck Coal's Coal Mountain Operations).
- Elk River (Elk River receives runoff from all five current and past producing Teck Coal Operations, and several proposed coal projects).

The predictive water quality model incorporates geochemical source terms for all flows in all watersheds within the WQM LSA. As such, water quality model reporting nodes located along the watercourses indicated above are indicative of cumulative effects.

Water quality model prediction nodes associated with cumulative effects are identified in **Table 5-4**. Assessment of aquatic health risks at these prediction nodes are considered to be analogous to the Cumulative assessment case, as described in Section 2.4.

5.2.2 Surface Water

The assessment of potential aquatic health risks to aquatic VCs as a result of direct exposure to COPCs in surface water is conducted using predicted maximum 30-day average concentrations. Concentrations of COPCs in surface water were modelled using a conservative mass balance model, incorporating geochemical source terms for all modelled flows. Water quality predictions used in the present ERA are based on an upper bound of geochemical source terms (95th percentile), which is considered to be a conservative assessment. Calculated maximum 30-day average concentrations carried forward for the assessment of aquatic health risks are presented in **Appendix E**.

5.2.3 Sediments

Assessment of the aquatic community VCs additionally considers the potential effects to benthic invertebrates. Potential health risk to benthic invertebrates was assessed using predicted concentrations of COPCs in sediments. Concentrations of COPCs in sediments at water quality reporting nodes were calculated as a function of the annual mean of conservative predicted surface water concentrations and sediment-water partition coefficients (Kd). Details of the calculation of predicted sediment concentrations is provided in **Appendix A**.

5.3 Hazard Assessment

5.3.1 Toxicity Assessment

The assessment considered aquatic health (toxicity) benchmarks recently employed in EA projects within the Elk Valley in order to provide continuity between the present review process and those previously adjudicated. Prior to final selection of toxicity benchmark values the risk assessment team reviewed the relevant toxicological information to ensure adequacy and relevance to the present assessment. Toxicity benchmarks were derived from toxicological literature either presented in regulatory water quality derivation documents, or obtained from the US EPA ECOTOX knowledgebase (Accessed May 2021).

Toxicological benchmarks used to assess the identified aquatic VCs are presented in **Table 5-5** through **Table 5-9**.

Table 5-5: Toxicological benchmarks used for assessment of aquatic health risks to the Aquatic Community VC associated with aqueous exposures.

COPC	Benchmark (mg/L)	Endpoint	Critical Effect	Ref.
Cadmium	0.00055	LOEC	Survival	Suedel et al. (1997) in BC AWQG
Cobalt	0.0022	IC_{10}	Growth	Kimball, G. 1978
Selenium	0.005	MATC	Density	Swift (2002) as referenced in BC AWQG

Table 5-6: Toxicological benchmarks used for assessment of aquatic health risks to the Aquatic Community VC associated with sediment exposures.

COPC	Benchmark (mg/kg)	Ref.
Cadmium	0.6	CCME 1997
Cobalt	50	Ontario MPE 1993
Selenium	2	BC MoE 2014

Table 5-7: Toxicological benchmarks used for assessment of aquatic health risks to the Amphibian VC.

COPC	Benchmark (mg/L)	Endpoint	Critical Effect	Ref.
Cadmium	0.001	NOEC	Growth	Gross et al.. 2009
Cobalt	0.18	LOEC x UF[(a)]	Growth	WHO, 2006
Selenium	0.013	NOEC	Growth, Development	Vang 2008

Notes:

a) An uncertainty factor of 10 has been applied to convert LOEC to NOEC equivalent endpoint.

Table 5-8: Toxicological benchmarks used for assessment of aquatic health risks to fish.

COPC	Benchmark (mg/L)	Endpoint	Critical Effect	Ref.
Cadmium	0.00084	NOEC	Survival	Davies and Brinkman, 1994
Cobalt	0.348	EC10	Survival	Dave and Xiu (1991)
Selenium	0.019	EC10	Reproduction	Teck 2014

Table 5-9: Toxicological benchmarks used for assessment of aquatic health risks to waterbirds*.

COPC	Benchmark (mg/L)	Endpoint	Critical Effect	Ref.
Selenium	0.203	EC10	Growth	Teck 2014

**Waterbirds are assessed within the aquatic health risk assessment for potential impacts associated with selenium exposure only.*

5.3.2 Risk Estimation

Risk characterization for exposures of aquatic VCs entailed the calculation of HQs for each receptor and COPC. The HQs were calculated as:

$$HQ = \frac{EPC}{Toxicity\ Benchmark}$$

Where:
HQ = hazard quotient (unitless)
EPC = Exposure Point Concentration (mg/L in water or mg/kg sediment)

5.3.3 Screening Benchmark (mg/L in water of mg/kg sediment)Defining Negligible Wildlife Health Risk

Risk assessment hazard quotients are calculated using toxicity reference values that are intended to be protective of the receptors of concern and in consideration of the identified protection goals. As such, HQ values below one (1.0) indicate negligible potential for harm, whereas HQ values above one indicate that an adverse response is possible and that more precise or accurate evaluation of risks may be warranted to address uncertainty.

5.3.4 Criteria Used for Interpretation of Project Risk

To provide interpretive insight on the risk levels and conservative assumptions employed to offset various sources of uncertainty normally encountered in wildlife health risk assessment, the categories provided in **Table 4-6** were used to describe the risk magnitudes for wildlife exposure to COPCs.

Table 5-10: Categories of Magnitude of Effect in Wildlife Health Risk Assessment

Risk Estimate	Negligible	Low	Moderate	High
Hazard Quotient	No change, below applicable guidelines, or HQ<1	1.0 < HQ ≤ 5	5 < HQ ≤ 10	HQ > 10

5.4 Predicted Risk Estimates

Calculated hazard quotients for aquatic VCs exposed to COPCs through direct contact with surface water are presented in **Table 5-11**. For assessment of the Aquatic Community VC, and additional set of HQs based on direct contact with sediments is presented in **Table 5-12**

Table 5-11: Calculated HQs for aquatic VCs associated with exposure to COPCs in surface water.

		AC_1	AC_2	AC_3	AC_4	AC_5	_AC_6	ER1	GC_1	GC_2	GC_3	GC_4	GC_5	GC_6	GC_7	GC_8
Aquatic Community	**Cd**	0.1	0.1	0.1	0.0	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Co	0.8	0.9	**1.7**	0.0	**9.4**	**9.4**	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Se	0.4	0.5	0.6	0.3	**1.9**	**1.9**	**1.8**	**4.8**	**6.0**	0.3	**9.5**	0.3	0.3	0.3	0.3
Amphibians	**Cd**	0.0	0.0	0.1	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Co	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Se	0.2	0.2	0.2	0.1	0.7	0.7	0.7	**1.9**	**2.3**	0.1	**3.7**	0.1	0.1	0.1	0.1
Sensitive Fish Species	**Cd**	0.1	0.1	0.1	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Co	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Se	0.1	0.1	0.2	0.1	0.5	0.5	0.5	**1.3**	**1.6**	0.1	**2.5**	0.1	0.1	0.1	0.1
Waterbird	**Se**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.0	0.0	0.0	0.0

Table 5-12: Calculated HQs for the Aquatic Community VC exposed to COPCs through direct contact with sediments.

		AC_1	AC_2	AC_3	AC_4	AC_5	_AC_6	ER1	GC_1	GC_2	GC_3	GC_4	GC_5	GC_6	GC_7	GC_8
Aquatic Community (Benthic Invertebrates)	**Cd**	0.3	0.3	0.5	0.1	**2.7**	**2.7**	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
	Co	0.1	0.1	0.1	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Se	0.7	0.8	1.0	0.5	**3.2**	**3.1**	**2.9**	**7.9**	**9.8**	0.5	**15.5**	0.5	0.5	0.5	0.5

5.5 Risk Characterization and Uncertainty Analysis

5.5.1 Aquatic Community

The proposed Project and its activities are predicted to result in a low potential risk to aquatic health.

Project Assessment Nodes

Hazard quotients in exceedance of target thresholds were calculated for the following COPCs:

– *Cadmium:* Risk estimates in exceedance of target threshold are calculated for benthic invertebrates associated with direct sediment contact. Risk estimates in exceedance of target thresholds are limited to the lower reach of West Alexander Creek before the confluence of Alexander Creek. Maximum calculated HQ is 2.7 suggestive of a low magnitude of effect.

– *Cobalt:* HQs associated with surface water direct contact in exceedance of target thresholds were calculated for assessment nodes AC-3, AC-5 and AC-6. Maximum surface water HQs (HQ=9.4) were calculated for assessment nodes AC-5 and AC-6, located in West Alexander Creek, prior to the confluence with Alexander Creek. The calculated HQ is suggestive of a moderate potential magnitude of effect in the lower reach of West Alexander Creek.

– Calculated HQ in Alexander Creek at AC-3 immediately after the confluence with west alexander creek (HQ=1.7) is suggestive of a low potential magnitude of effect. Calculated HQs quickly decrease below target thresholds as one moves downstream.

– *Selenium:* Risk estimates in exceedance of target threshold are calculated for benthic invertebrates associated with direct sediment contact as well as aquatic invertebrates associated with direct contact with surface water. Risk estimates in exceedance of target thresholds are limited to the lower reach of West Alexander Creek before the confluence of Alexander Creek.

– Maximum calculated HQs are 1.9 and 3.2 for surface water and sediment exposure respectively. The calculated HQs are suggestive of a low potential magnitude of effect.

Cumulative Assessment Nodes

– *Cadmium:* Risk estimates in were calculated to be below target thresholds at all cumulative assessment nodes.

– *Cobalt:* Risk estimates in were calculated to be below target thresholds at all cumulative assessment nodes.

– *Selenium:* Risk estimates in exceedance of target threshold are calculated for benthic invertebrates associated with direct sediment contact as well as aquatic invertebrates associated with direct contact with surface water at all cumulative assessment nodes.

– Maximum calculated HQs are 9.5 and 15.5 for surface water and sediment exposure respectively. Maximum HQs are calculated at assessment node GC-4, located in Harmer Creek upstream of the confluence with Grave Creek.

– The calculated HQs are suggestive of a high potential magnitude of effect associated with historic and ongoing mining activities in the Harmer Creek watershed (i.e., Teck Coal's Elkview Operation).

5.5.2 Amphibians

Proposed Project activities are not predicted to result in a health risk to sensitive amphibian species. The overall potential health risk to amphibians as a result of the Project are considered to be negligible.

Project Assessment Nodes

Calculated hazard quotients associated with amphibian exposure to surface water were below the target threshold for all COPCs at all Project assessment nodes (**Table 5-11**).

Cumulative Assessment Nodes

Calculated HQs for cadmium and cobalt are below target thresholds at all cumulative assessment nodes (**Table 5-11**). Calculated hazard quotients for selenium exposure in cumulative assessment nodes in the Grave Creek watershed range from 1.9 to 3.7 suggestive of a low magnitude of potential risk (**Table 5-11**).

5.5.3 Fish

Proposed Project activities are not predicted to result in a health risk to sensitive fish species. The overall potential health risk to fish as a result of the Project are considered to be negligible.

Project Assessment Nodes

Calculated hazard quotients associated with surface water exposure to sensitive fish species were below the target threshold for all COPCs, at all water quality prediction nodes with the exception of those locations affected by surface water discharge from Harmer Creek (**Table 5-11**). Calculated hazard quotients for selenium exposure in Harmer Creek range from 1.2 to 2.5.

Cumulative Assessment Nodes

The secondary pathway analysis identified effluent release from the waste rock sedimentation pond to lower West Alexander Creek, and subsequently to Alexander Creek as the principal pathway affecting surface water quality. Calculated hazard quotients for water quality prediction nodes along the effluent flow pathway are below target thresholds for all COPCs. Calculated HQs range from <0.01 (Co @ ER1) to a maximum of 0.5 (Se and Cd @ AC6).

5.5.4 Waterbirds

Calculated hazard quotients for waterbird exposure to selenium in surface water are below target thresholds at all water quality prediction nodes (**Table 5-11**). Calculated hazard quotients range from 0.2 in Harmer Creek to 0.01 in Alexander Creek.

Proposed Project activities are not predicted to result in a health risk to waterbird as a result of selenium exposure in surface waters. The potential health risk to waterbirds as a result of the Project are considered to be negligible.

5.6 Conclusions of Aquatic Health Risk Assessment

Overall the proposed Project and associated activities are considered to present a low risk to aquatic health. Risk estimates in exceedance of target thresholds at Project assessment nodes were generally limited to the lower reaches of west alexander creek and immediately after the confluence with Alexander Creek for the aquatic community VC only. The limited geographic extent of the predicted risk estimates, the low to moderate potential magnitude of effect, and the conservative nature of the aquatic risk assessment suggest that overall risks are low despite predicted changes to surface water quality at Project assessment nodes.

Risk estimates at cumulative assessment nodes suggest a potentially high magnitude of effect associated with surface water quality and predicted sediment quality in the Grave Creek watershed below the confluence with Harmer Creek. It must be noted water quality within Harmer Creek is impacted by Teck Coal's existing Elkview Operation. According to the Water Quality Modelling Report the proposed Project activities do not appreciably add contaminant mass flux to the Grave Creek watershed, and the risk predictions associated with the cumulative assessment nodes are indicative of current baseline conditions.

6. Human Health Risk Assessment

6.1 Supplemental Problem Formulation

6.1.1 Receptors

The local study area is likely visited by a variety of human receptor groups, including recreational visitors, hunters, trappers, community residents, and Indigenous groups engaging in their traditional lifestyle.

Of the various groups of people who may visit the study area in the future, people engaged in traditional land uses are expected to have the greatest frequency of potential exposure based on duration of visit and the activities they engage in while in the study area.

The current HHRA therefore assesses potential risk to Indigenous people engaged in a traditional lifestyle for the duration of their lifespan. By developing risk estimates and risk-based management for the maximally exposed receptors (i.e. individuals engaged in a traditional subsistence based lifestyle) it is assumed that potential risks to other types of less intensive site use (e.g., sport fishing, recreational or transient use) would also be addressed.

6.1.2 Exposure Routes

Exposure pathway screening identifies potential routes by which people could be exposed to COPC. A COPC represents a potential health risk only if it can reach receptors through an exposure pathway at a concentration that could potentially lead to adverse effects. The following exposure pathways were considered relevant for human receptors in the present HHRA:

Ingestion

- Human receptors are exposed to contaminants in soil through incidental soil ingestion, typically associated with inadvertent hand to mouth behaviours, or as non-respirable dust. Incidental soil ingestion is retained as an operable route of exposure.
- People engaged in nearshore activities such as foraging are assumed to inadvertently ingest sediments. Sediment ingestion is included as an operable route of exposure.
- Contaminants in drinking water are absorbed by the body and result in an ingestion dose. Surface water ingestion is retained as an operable route of exposure.
- Contaminated produce/vegetation that is ingested will result in an ingestion dose.
- Important game species are assumed to forage and consume food items (as well as incidental ingestion of soils) and surface water from the local study area. Food items take up COPCs into their tissues through direct contact with contaminated soil, and wildlife that consume these food items may in turn incorporate COPCs into their edible tissues. Ingestion of wild food tissues is retained as an operable exposure pathway for the traditional land use receptor.

Inhalation

- Airborne contaminants (adsorbed to respirable particulates as PM10) at the receptor location may be inhaled and retained within the body resulting in an inhalation exposure.

Dermal Absorption

- Dermal contact with soil, sediment, and surface water will result in dermal absorption of COPCs to the exposed individual. Dermal contact with soil, sediment, and surface water is retained as an operable route of exposure.

6.1.3 Receptors Characteristics

The degree to which humans are exposed to chemical constituents in the environment in which they inhabit is dependent on the environmental conditions in the specific location of activity, the frequency and duration of exposure, and receptor-specific characteristics that dictate the intensity of exposure (i.e. ingestion rates, inhalation rate, etc.). These receptor characteristics form the basis for the conceptual model (qualitative) of exposure described in subsequent sections.

6.1.3.1 Locations

The HHRA considers receptor locations identified during discussions with the KNC to determine “critical receptor locations” (CRL) where Indigenous land users preferentially engage in a traditional lifestyle .

Discussions identified 15 critical receptor locations (CRL1-CRL15) (**Figure 6-1**), as well as the anticipated frequency and duration of occupation of these areas. A quantitative assessment of risk was completed at all critical receptor locations to provide the assessment with the breadth of likely exposure scenarios individuals may experience within the local study area. While human receptors may engage other areas of the local or regional study areas, the range of exposure estimates generated as part of the present assessment is anticipated to encapsulate any probable exposure scenario a human receptor is likely to encounter.

It should be noted that CRL2, 4, and 12 are in the Project footprint (e.g., essentially on planned haul road shoulders or within the planned water treatment pond) and are therefore unlikely to remain as active CRLs for traditional activities during the course of the mine life. For completeness these CRLs were assessed in the same manner as other CRLs, however the predicted exposure levels are highly influenced by conditions such as truck traffic safety and land use changes that will preclude traditional (and non-traditional) activities. Accordingly, exposure simulations are considered hypothetical scenarios.

6.1.3.2 Receptor Characteristics Controlling Frequency and Magnitude of Exposure

Exposure magnitude (i.e., expressed as dose rates) depends on both age-dependent physiological parameters and behavioural characteristics of the receptors. Frequency of exposure has been determined based on information provided by the KNC and incorporates traditional land use frequency and duration of exposure activity as described by KNC and dietary intake rates provided by the KNC.

It is recognized that people of all ages are part of traditional hunting and gathering parties and entire family units may participate in these associated activities which may lead to inadvertent exposure to environmental substances, either naturally occurring or Project-related COPCs. As a result, the HHRA included quantitative assessment for all representative age groups (Health Canada 2010a). Additionally, individuals are assumed to spend their entire lifespan engaged in a traditional lifestyle. As such, non-threshold carcinogenic risks have been assessed using a composite receptor (i.e., exposure weighted according to time-weighted stages of life) as described in Health Canada (2010b)

Details of human receptor exposure characteristics and the rationale for their derivation are presented in **Appendix H**.

6.1.4 Contaminants of Potential Concern

Screening of COPCs for inclusion in assessment of human health risk was accomplished by considering baseline chemistry data, and comparing predicted concentrations of chemical constituents in abiotic and biotic compartments as a result of Project activities.

For airborne constituents (as discussed in Section 3.1.1), the inhalation of fugitive dust is a primary pathway associated with Project activities which may affect air quality. Air quality objectives for chemical constituents associated with particulate material are generally lacking. To adequately capture COPCs associated with the particulate inhalation route of exposure, any modelled chemical constituents which have a published toxicological reference (HC) value specific for the inhalation pathway is included as a COPC for the assessment of human health risk.

All COPCs identified regardless of media are have been assessed for all exposure pathways in the human health risk assessment to yield (i.e., multi-media/multi pathway integrated exposure assessment). Details of the COPC screening are presented in **Appendix F**.

The screening process identified arsenic, benzo (a) pyrene[3], cadmium, chromium, cobalt, nickel, selenium, and thallium as COPCs to be carried forward for quantitative assessment:

In the case of thallium, there is significant uncertainty respecting the validity of this substance being a COPC due to the limited toxicological data that underpins the environmental quality standard. The toxicological data set relevant to human health is considered weak (US EPA 2012) and in light of the limited data, the Provisional Peer-Reviewed Toxicity Values and consequent environmental quality standards have been derived with significantly large uncertainty and adjustment factors to extrapolate from laboratory studies to human health. The risk assessment team examined additional reports including previous submissions that supported approvals from coal mine operations in Elk Valley and note a similar concern and subsequent decision to not assess thallium for these reasons. Accordingly, the present assessment has adopted the position to not assess thallium in relation to human health, but to note its presence and to monitor its presence in future monitoring programs.

6.1.5 Conceptual Exposure Model

A conceptual exposure model (CEM), which is qualitative in nature, provides both the diagrammatic and narrative context for the subsequent quantitative risk models. The CEM is presented below (**Figure 6-1)** and illustrates contaminant sources, release mechanisms, transport pathways, and routes of exposure for the human health assessment at the mine site.

[3] Benzo(a)pyrene is included as a COPC on the basis that Health Canada (2010b) provides an inhalation cancer slope factor. Human health risk associated with exposure to benzo(a)pyrene will be assessed for carcinogenic inhalation risk only.

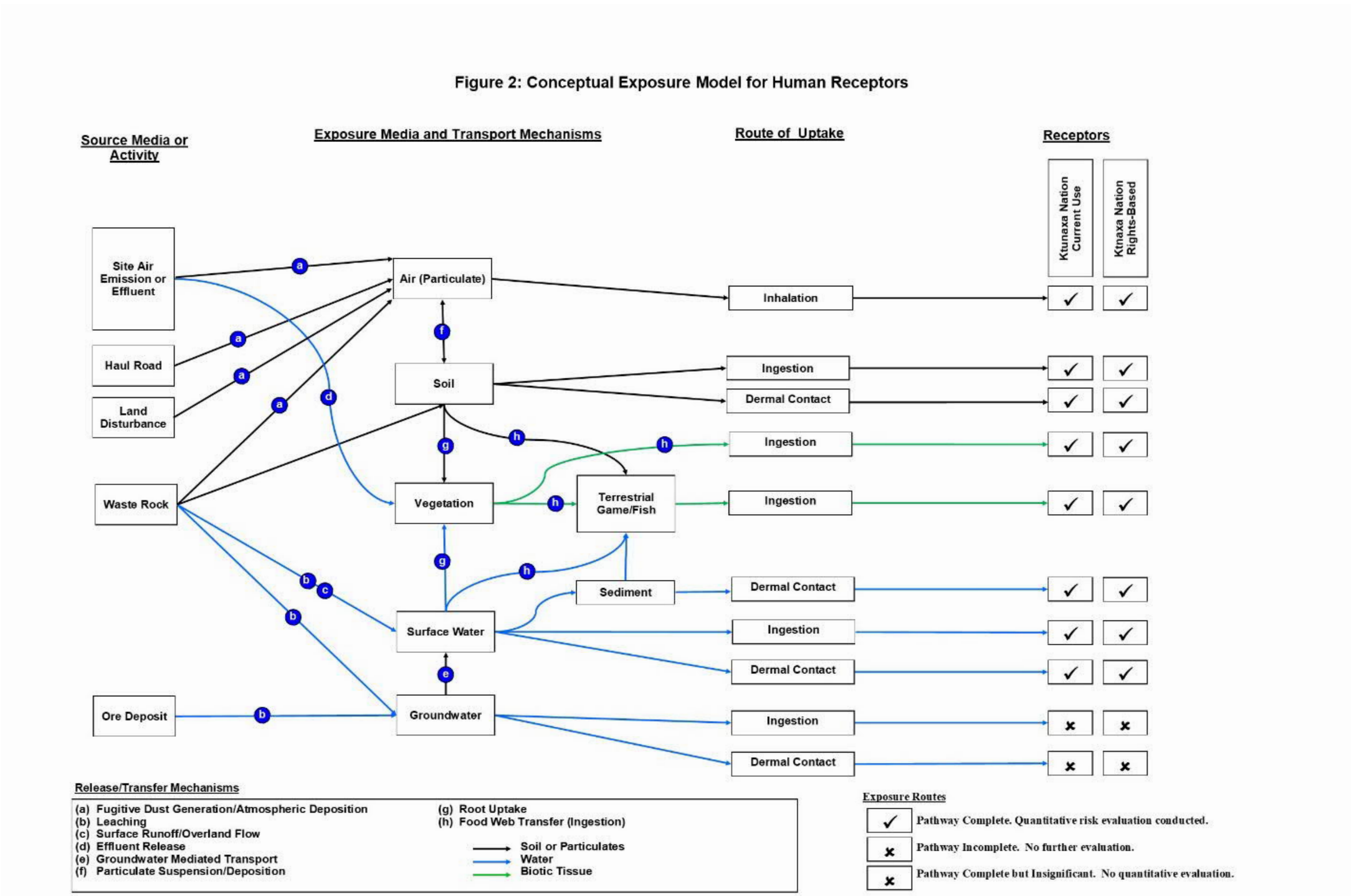

Figure 6-1: Conceptual exposure model for Crown Mountain Coal human health risk assessment

6.1.6 Exposure Assessment

An exposure assessment was conducted for each COPC identified in the problem formulation and for each of the human receptors assessed. Exposure estimates were conducted using foodweb and human exposure models developed in GoldSim, and reflect federal exposure and risk assessment principles (Health Canada 2010b).

Exposure of human receptors is calculated as a function of the concentration of COPCs in environmental media (soil, water, air, wild food tissues etc.), the frequency and duration of exposure, and the physiological characteristics of the receptors to be assessed. Receptor characteristics for current and rights based traditional land use receptors used in the quantitative exposure assessment are detailed in **Appendix H**.

Exposure assessment was conducted using a spatially explicit approach, whereby concentrations of COPCs in environmental media and edible tissues (vegetation, consumed wildlife, fish etc.) are determined for each of the identified critical receptor locations (CRID 1-15). A description of the methods for estimation of COPC concentration in wild food tissues and estimated concentrations carried forward for quantitative assessment are presented in **Appendix A**. This approach explicitly acknowledges that the probability of elevated exposure is directly related to the geographic location of KNC traditional activities and the proximity to projects related sources of contaminants.

Human exposure models in accordance with methods described by Health Canada (2010b) were developed for each of the current and rights-based receptors at each of the 15 identified critical receptor locations (10 receptors x 15 locations = 150 exposure estimates per COPC). Exposure estimates were calculated as the estimated daily dose (EDD), expressed as milligrams of a chemical absorbed per kilogram of bodyweight per day (mg/kg bw/day). To account for lifetime exposure and facilitate the assessment of carcinogenic risk estimates, lifetime amortized daily dose (LADD) was calculated for current and rights-based composite receptors spanning the entire lifespan in accordance with Health Canada (2010b) methods. Detailed methodology for human exposure models, graphical representation of the multimedia exposure model and the calculated dose estimates are presented in **Appendix A**.

6.2 Toxicity Assessment

The toxicity assessment identifies the types of potential adverse health effect elicited by each COPC including whether the chemical is considered a carcinogen. Specifically, the quantity of the COPC to which a receptor is exposed (i.e., dose) and the associated potential of an adverse effect is defined. In addition, chemicals are broadly classified in the toxicity assessment as having either carcinogenic or non-carcinogenic health effects. The purpose of the toxicity assessment in addition to describing the possible modes of toxicity associated with different routes and durations of exposure is to provide a quantitative basis to interpret hazard associated with exposure estimates. The numerical values used in this risk assessment describe the dose that provides and acceptable level of protection from non-carcinogenic effects, or increased probability of cancer; these numerical values are called the toxicological reference value (TRV).

6.2.1 Nature of Toxicity

The hazard assessment categorizes the potential types of adverse health effects a COPC may potentially cause. For the purposes of what is required in the present HHRA, COPCs are typically categorized with respect to the nature of their toxicity as being either chemicals that cause adverse health effects other than cancer (non-carcinogens) or chemicals that cause cancer (carcinogens).

6.2.1.1 Non-carcinogens

Most chemicals will elicit a non-carcinogenic health effect, however the dose required to cause the effect will vary depending on the specific chemical. Non-carcinogenic effects are often referred to as a threshold effects as there is typically a dose below which no adverse effect occurs, or conversely, above which an effect is commonly observed. Except for airborne exposures to gases and vapours, the TRVs for threshold effects are typically reported as equivalent units to the estimated dose (i.e. mg/kg/day).

TRVs are often associated with specific exposure durations and frequencies. Traditionally risk assessments have largely relied upon chronic TRVs, that is TRVs associated with exposure over extended periods of a person's life-time (i.e. years). The current risk assessment is based on a chronic exposure scenario and therefore TRVs developed for chronic exposures have been identified and carried forward.

Chemical compounds may exhibit different toxicological mechanisms of action depending on the route of exposure (i.e., ingestion, inhalation, dermal). Different TRVs are often provided for oral and inhalation exposure routes, depending on whether toxicity studies have been conducted and assessed for that route. In general, very few studies are available for dermal TRVs. For all compounds the oral TRV value was adopted to represent the combined oral and dermal routes of exposure.

6.2.1.2 Carcinogens

Carcinogens, often called non-threshold compounds, do not have a dose below which no adverse effect is predicted. Rather, genotoxic carcinogens are considered to represent risk factors at all concentrations since even one or a few DNA lesions may in principle result in mutations and, thus, increase cancer risk.

Since risk at low exposure levels cannot be measured directly either by animal experiments or by epidemiologic studies, mathematical models and procedures are used to extrapolate from high to low doses for the derivation of TRVs for carcinogenic substances. TRVs for assessment of carcinogenic risk are defined based on these models as the upper bound estimate (95% upper confidence limit) of the slope of the line between exposure and occurrence of effect (in this case cancer), known as the cancer slope factor. The cancer slope factor is the cancer risk (proportion affected) per unit of dose, which when multiplied by the exposure level (dose or concentration as appropriate), it provides an upper bound estimate of the probability of occurrence of cancer in a chronically exposed population.

Cancer slope factors are typically specific to the most sensitive target organ or system. For some chemicals separate cancer slope factors have been derived for oral versus inhalation exposures. In this case, cancer risk is estimated for each route of exposure separately[4].

6.2.2 Human Health TRV Hierarchy

Toxicological reference values associated with exposures to carcinogenic compounds were assembled based on the following hierarchy of preference/availability:

2. Health Canada Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors (Version 2.0);
3. United States Environmental Protection Agency, Integrated Risk Information System; and
4. World Health Organization, International Programme on Chemical Safety.

Toxicity reference values carried forward to the hazard assessment are provided in **Appendix I.**

6.3 Hazard Assessment

6.3.1 Assessment and Measurement Endpoints

For a human health risk assessment, the concept of assessment and measurement endpoint are underpinned on the basis that no significant health risk should arise from the Project. Thus, the assessment endpoint is that a Project should yield no significant (unacceptable) health effects to human receptors over duration of the Project life cycle, or a human lifetime. Accordingly, the measurement endpoint requires that TRVs used to judge estimated environmental exposure be reflective of no-effect levels over a lifetime of exposure.

[4] Cancer risk for the combined dermal and oral exposure routes are assessed relative to the oral cancer slope factor.

For substances presenting a risk other than cancer, a hazard quotient is the measurement endpoint and is calculated as the ratio of the estimated daily exposure to the applicable TRV (i.e., safe dose) for each contaminant as follows:

$$HQ = \frac{TDD}{RfD \; or \; TDI}$$

Where:
HQ = hazard quotient (unitless)
TDD = total daily dose from all exposure routes (mg/kg day-1)
TDI = tolerable daily intake (mg/kg day-1)

For threshold contaminants which impart a specific health risk to the respiratory system a separate hazard quotient is calculated as follows:

$$HQ = \frac{Air\ Concentration\ (mg/m^3)}{Tolerable\ Concentration\ (mg/m^3)}$$

For substances with no threshold dose response (i.e., carcinogens) the risk estimate is a calculation of the Incremental Lifetime Cancer Risk (ILCR). ILCR is the predicted risk of an individual in a population of a given size developing cancer over a lifetime. The ILCR is expressed as the one additional person per n people that would develop cancer, where the magnitude of n reflects the risks to that population. The generic equation for the calculation of an ILCR is as follows:

$$(ILCR) = Estimated\ Lifetime\ Amortized\ Daily\ Dose\ (mg/kg/day)\ x\ Cancer\ Slope\ Factor\ (mg/kg/day)^{-1}$$

For the present risk assessment, the ILCR was assessed for each of the human life stages (i.e., infant, toddler, child etc.) and then integrated these estimates to profile the risk of a “composite receptor” with exposure weightings reflective of the proportion of each life stage over an 80 year lifetime. The final ILCR estimate for the composite receptor accounts for lifetime exposure to COPCs from all sources previously described, and also accounts for the fact that air emissions from the mine are present for only 15 years of mine operations (i.e., air particulate inhalation exposure occurs for 15 years). The details of this assessment are provided in **Appendix A.**

6.3.2 Defining Negligible Human Health Risk

Negligible Hazard Quotient: Whereas a hazard quotient of unity infers the estimated exposure rate (dose) is equal to the toxicological reference value (tolerable daily intake (TDI)) and is considered protective of health, Health Canada guidance (Health Canada 2010b) generally scrutinizes HQ expressions of health risk against a value of 0.2 as a threshold of acceptable risk. The rationale is that site or Project incremental exposure (i.e., that caused by the site alone) does not account for other potential exposure sources, and benchmarking acceptable risk to a value of 0.2 (i.e., 20% of the protective threshold) allows “reserved protective space” for potential exposure from other sources (e.g., soil, air, food, water).

In risk assessments where a more comprehensive exposure analysis is considered, Health Canada supports interpretation of HQ values against a benchmark of unity (1.0) (Health Canada 2010b). In the present study, as described in subsequent sections, the HHRA evaluates exposure from a traditional food diet that is based on Aboriginal data, and also includes additional background contributions from sources that are not considered to be potentially affected by the Project (e.g., Elk meat). Accordingly, the benchmark for acceptable risk as expressed by the HQ metric is a value equal to or less than unity (1.0), in alignment with Health Canada policy respecting a comprehensive dietary exposure.

Negligible Incremental Lifetime Cancer Risk (ILCR): Health Canada defines a negligible incremental lifetime cancer risk as being a probability of less than 1 incremental cancer case in 100,000 individuals, or <1x10-5. For environmental health risk, the ILCR considers only those substances considered environmentally relevant, and excludes consideration of voluntary risk such as tobacco-related lung cancer.

6.3.3 Criteria Used for Interpretation of Project Risk

To provide interpretive insight on the risk levels and conservative assumptions employed to offset various sources of uncertainty normally encountered in health risk assessment, the following numerical categories (**Table 6-1**) were used to describe the risk magnitudes for non-carcinogenic and carcinogenic COPCs.

Table 6-1: Categories of Magnitude of Effect

Risk Estimate	Negligible	Low	Moderate	High
Hazard Quotient (Non-carcinogens)	No change, below applicable guidelines, or HQ<1	1.0 < HQ ≤ 5	5 < HQ ≤ 10	HQ > 10
ILCR (Carcinogens)	No change, below applicable guidelines, or ILCR < $1x10^{-5}$	$1x10^{-5}$ < ILCR ≤ $5x10^{-5}$	$5x10^{-5}$ < ILCR ≤ $1x10^{-4}$	ILCR > $1x10^{-4}$

In addition, risks are characterized to determine the potential for negative health effects or risks by considering the findings of the exposure and effects assessment, and also includes consideration of the significance of risk estimates and associated uncertainties. Risk characterization generally considers the following:

- Context – Are predicted risk estimates for the Application and Cumulative assessment cases appreciably different than those calculated for the Base Case?
- Pathways – What are the primary pathways of exposure, and what uncertainties exist in the exposure assessment?
- Conservatism and Uncertainty in Predictions – What uncertainties exists in the predicted concentrations of COPCs in environmental media to which receptors are exposed? What are the sources of conservatism inherent in these predictions and what effect are they likely to have on the predicted risk estimates?
- Conservatism and Uncertainty in Exposure Assumptions - What uncertainties exists exposure assumptions carried forward for quantitative exposure assessment? What are the sources of conservatism inherent in these predictions and what effect are they likely to have on the predicted risk estimates?
- Conservatism in TRVs – What conservatisms exists in the derived toxicity reference values, what impact might this have on the risk estimates?
- Overall Significance of the Calculated Quantitative Risk Estimate – Based on the above risk characterization exercise, what is the overall significance of the calculated risk estimates?

6.4 Predicted Risk Estimates

Detailed risk estimates are presented in **Appendix J**., including HQs for each receptor/location/COC combination as well as composite incremental lifetime cancer risks for current and rights-based traditional land use receptors for each critical receptor location.

6.4.1 Threshold Non-Carcinogenic Risk Estimates (HQs)

As described in Section 6.4.2, calculated HQs which are equal to or below unity (i.e. HQ≤1) are indicative of negligible human health risk as a result of threshold non-carcinogenic effects. Maximum calculated HQs for each COPC at each critical receptor location considering all potential human receptors (i.e. all age groups for current-use and rights-based exposure scenarios) have been initially screened to identify

COPCs for where a predicted HQ exceeds 1 (**Figure 6-2**). This screening process provides a coarse snapshot of the calculated risk estimates under the Base, Application, and Cumulative assessment cases. Maximum calculated HQ for each COPC at al critical receptor locations not within the exclusion zone (i.e. excluding CRID-15) are presented in **Table 6-2**.

As indicated in **Figure 6-2**, calculated HQs for arsenic and selenium do not exceed a value of 1 for any human receptor assessed (both current use and rights based receptors) at any of the critical receptor locations. Human health risk associated with exposure to arsenic and selenium are therefore considered to be negligible. No further qualitative assessment of the potential human health risks associated with arsenic and selenium exposure is required.

Calculated HQs for human receptors as a result of exposure to cadmium, cobalt, chromium, and nickel exceed a value of HQ=1. Risk estimates for cobalt, and chromium exceed a value of HQ=1 in the Base Case, Application Case, and Cumulative Case suggesting that risk estimates are driven primarily by the baseline assessment case. Calculated risk quotients for cadmium and nickel exceed a value of HQ=1 under in the Application and Cumulative assessment cases. These results suggest that Project activities and associated linkage to environmental conditions play a more significant role in the calculated HQs.

Further interpretation of threshold non-carcinogenic human health risk associated with exposure to cadmium, cobalt, chromium, and nickel is provided in Section 6.6 below.

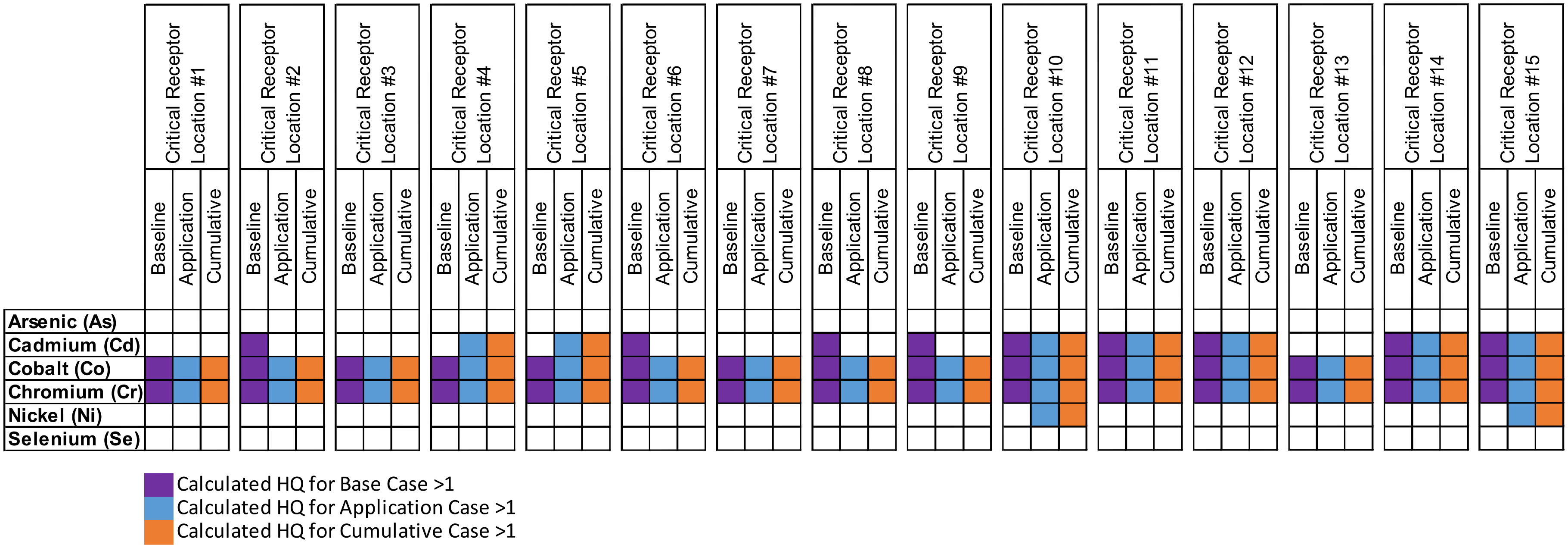

Figure 6-2: HQ Critical Receptor Screening

Table 6-2: Maximum calculated HQs for Base, Application, and Cumulative assessment cases.

	Base Case		Application Case		Cumulative Case	
	Min	Max*	Min	Max*	Min	Max*
Arsenic (As)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cadmium (Cd)	1.0	1.0	0.7	1.9	0.7	1.9
Cobalt (Co)	1.2	1.3	1.2	21.3	1.2	21.3
Chromium (Cr)	1.7	1.7	1.7	1.8	1.7	1.8
Nickel (Ni)	0.7	0.7	0.6	1.4	0.7	1.4
Selenium (Se)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

** Identified maximum values do not include calculated HQs from CRID-15 located within the Project Exclusion Zone.*

6.4.2 Non-Threshold Carcinogenic Risk Estimates (ILCRs)

As described in Section 6.4.2, calculated ILCRs which are below 1E-05 (i.e. 1:100,000) are indicative of an acceptable human health risk. Calculated ILCRs for each COPC at each critical receptor location were screened to identify COPCs for where a predicted ILCR exceeds the target threshold of 1E-05 (**Figure 6-3**). This screening process provides a coarse snapshot of the calculated incremental cancer risks under the Base, Application, and Cumulative assessment cases.

As indicated in **Figure 6-3**, calculated ILCRs for benzo(a)pyrene do not exceed the target threshold of 1E-05 for any of the for any of the assessment cases. Cancer risks associated with exposure to benzo(a)pyrene are therefore considered to be negligible.

- Calculated ILCRs for arsenic, cadmium, chromium, and nickel exceed the target threshold value of 1E-05.
- ILCRs for arsenic, and at some locations chromium, exceed the target threshold value in the Base Case, Application Case, and Cumulative Case suggesting that risk estimates are driven primarily by the baseline assessment case.
- Calculated ILCRs for cadmium, and nickel exceed the target threshold value under in the Application and Cumulative assessment cases at select critical receptor locations.

Further interpretation of non-threshold carcinogenic human health risk associated with exposure to arsenic, cadmium, , chromium, and nickel is provided in Section 6.6 below.

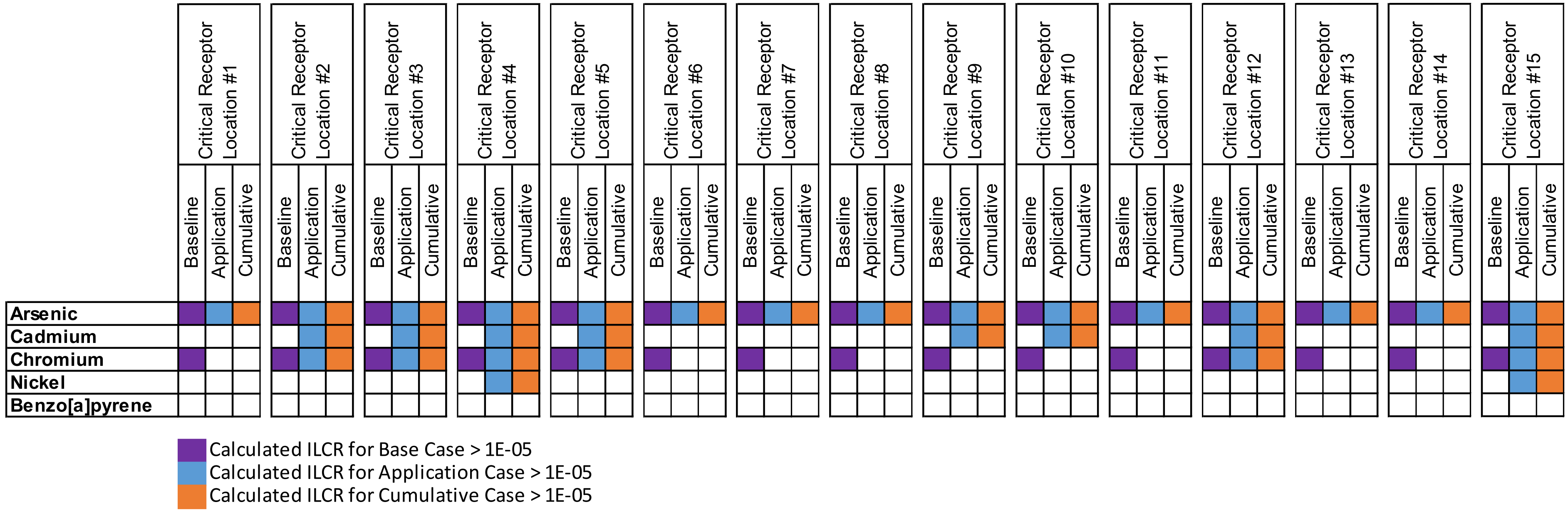

Figure 6-3: ILCR Critical Receptor Screening

6.5 Risk Characterization and Uncertainty Analysis

The following sections provide an assessment of the uncertainty and characterization of risks for COPCs assessed as part of the HHRA.

6.5.1 Arsenic

6.5.1.1 Threshold Non-Cancer Risks

Calculated HQs for exposure to arsenic to current and rights-based receptors were below target thresholds (HQ<1) for the Base, Application, and Current assessment cases. Threshold non-cancer human health risks associated with arsenic exposure are therefore considered to be negligible.

6.5.1.2 Non-threshold Cancer Risks

Magnitude

Calculated ILCRs for current and rights based human receptors exceed 1E-05 at all critical receptor locations for both the Application and Cumulative assessment cases. Calculated ILCRs have a range of 3.9E-04 to 4.8E-04 for the current use receptor and a range of 4.8E-04 to 9.7E-04 for the rights-based receptor.

Context

The calculated ILCRs for the current-use receptor scenario showed no change between the Base, Application and Cumulative assessment cases. Calculated ILCRs for the rights-based receptors were within 10% of the baseline risk estimates for the Application and Cumulative assessment cases.

Key Pathways

Calculated ILCRs are driven by the combined oral+dermal contact exposure pathways. Cancer risks associated with arsenic inhalation are a minor contributor to the total calculated ILCR (typically <2% of total ILCR).

For current and rights-based receptors the principal exposure route is ingestion of fish>fungi>berries, with variation depending on critical receptor location and receptor life stage.

Conservatism and Uncertainty in Predictions

Concentrations of arsenic in fish is calculated using site-specific water-to-fish concentration ratios and predicted surface water quality at modelled assessment nodes. Site-specific water-to-fish concentration ratios are based on a limited fish tissue dataset.

Concentration of arsenic in fungi are predicted as a factor of literature derived transfer factors (Slekovec & Irgolic, 1996) for edible mushroom species and predicted concentrations of arsenic in soils based on modelled particulate deposition and particulate species profiles. Deposition rates of COPCs adsorbed to particulate matter were modelled based on maximum Project emission rates for the duration of the Project lifecycle. It is considered likely that the conservative approach to modelled deposition results is an overestimate of the incremental change to soils with respect to arsenic concentration.

Predicted concentrations of arsenic in fungi incorporate multiple sources of uncertainty due to reliance on modelled particulate deposition, uncertainties in particulate chemistry, and literature derived uptake factors. Slekovec & Irgolic (1996) noted that for many fungi a statistically significant relationship between the concentration of arsenic in the fungi and the soil in which they grow cannot be identified. The predicted concentration of arsenic in fungi is considered to have a high degree of uncertainty.

Conservatism in Exposure Assumptions

Dietary ingestion rates were obtained through consultation with the Ktunaxa Nation. The calculated ingestion dose assumes that traditional foods are consumed daily year-round, and that the immediate vicinity of the critical receptor location can produce the annual dietary requirements for the assessed receptors. This assumption is considered conservative, as many foods, such as fungi and berries for instance, are only available seasonally. The assumption was retained however to be protective of those receptors that may treat and store traditional foods for consumption throughout the year.

Exposure assessment assumes full-time occupancy of critical receptor locations for the duration receptor lifetime. This is considered to be highly conservative, particularly at critical receptor locations in direct proximity to mine related infrastructure, such as rail load out and haul roads.

Conservatism in Toxicity Reverence Values

The oral slope factor used in the risk assessment was obtained from Health Canada (1.8 [mg/kg/day]-1; Health Canada 2010b). The slope factor was derived based on an epidemiological study in which humans were naturally exposed to arsenic in drinking water for up to 60 years. The use of a slope factor based on ingestion of drinking water would likely overestimate cancer risks associated with exposure from ingestion of country foods, because the arsenic in many foods (fish and fungi for instance) is predominantly in the less toxic organic forms (Byrne et al., 1995; Nearing et al., 2014).

Determination of Significance

For the current and rights-based human receptors, the calculated ILCRs exceeded the target threshold of 1E-05 at all critical receptor locations, resulting in a high magnitude of risk (i.e. ILCR >1E-04).

The elevated cancer risks are driven primarily by baseline soil condition and modelled concentration of arsenic in edible fish and mushroom species. Predicted concentration of arsenic in fungi are considered to have a high degree of uncertainty. Cancer slope factors do not consider arsenic species and relative toxicity of organic species versus inorganic arsenic.

Predicted ILCRs at all critical receptor locations are reported to have a small (<10%) increase relative to the Base Case for the high consuming rights-based receptor under the Application and Cumulative assessment cases.

Considering the above information, the overall Project related cancer risk associated with arsenic exposure is considered to be low and likely negligible for current and rights-based receptors for the Application and Cumulative assessment cases.

6.5.2 Cadmium

6.5.2.1 Threshold Non-Cancer Risks

Magnitude

Calculated HQs are predicted to exceed target thresholds (HQ>1) at six locations under the Application and Cumulative assessment cases outside the Project exclusion zone. For the Application and Cumulative assessment cases the calculated HQs ranged between 0.7 and 1.9. Calculated HQs are indicative of a potential for low magnitude of risk.

Context

The calculated HQs for the base case ranged between 0.7 and 1.0. Calculated HQs for the Application and Cumulative assessment cases are increased by a maximum of 171% relative to base case, with a maximum incremental HQ of 0.9 at CRID-12. Calculated HQ at CRID-10, located downstream of the confluence of West Alexander Creek and Alexander creek increase from a value of 1 in the Base Case to a value of 1.8 in the Application and Cumulative assessment cases.

Key Pathways

Calculated HQs at locations directly impacted by physical works are primarily driven by berry ingestion, followed by plant root ingestion and ingestion of fungi. For receptor locations along Alexander Creek located downstream of the proposed activities (CRID-10, -11, & -14), the maximally exposed individual is the rights-based adult receptor. The primary route of exposure for the rights-based adult receptor is fish ingestion, accounting for 61% of the total dose (**Figure 6-4**).

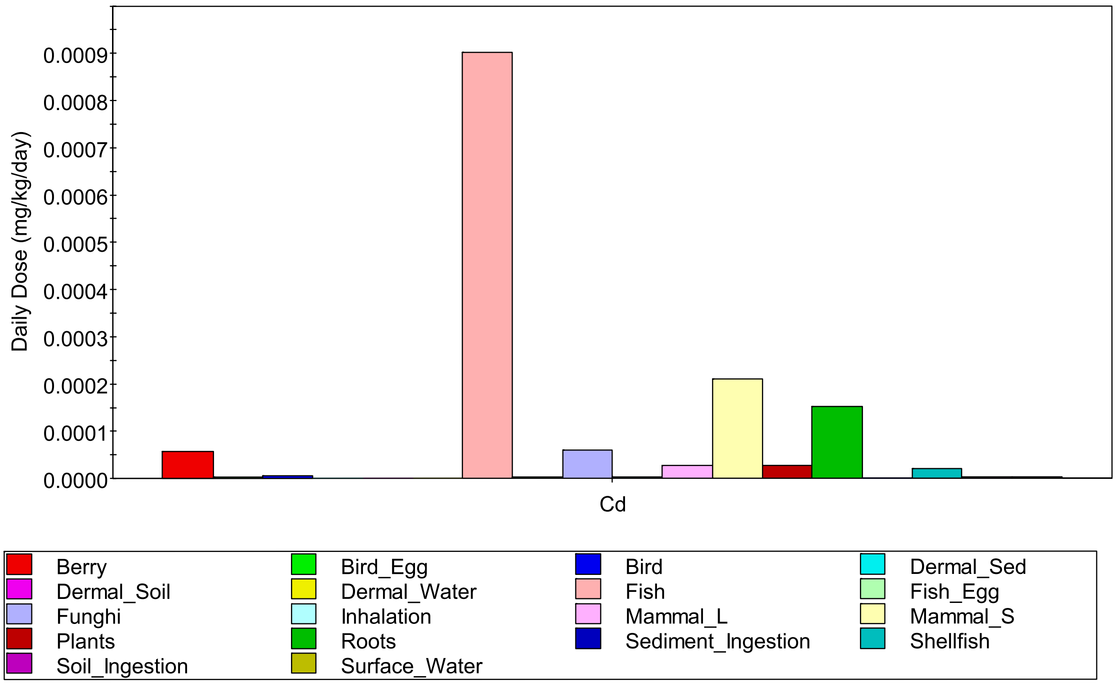

Figure 6-4: Calculated daily dose (mg/kg/day) of cadmium to the rights-based adult receptor at critical receptor location #12.

Conservatism and Uncertainty in Predictions

Concentrations of cadmium in berries is predicted based on site-specific soil-to-berry concentration ratios, predicted incremental soil concentration based on modelled particulate deposition, and generic particulate species profiles. Similarly, predicted concentration of cadmium in vegetable matter is calculated using site-specific concentration ratios. Concentration of cadmium in fungi are predicted using literature derived soil to edible fungi concentration ratios.

Deposition rates of COPCs adsorbed to particulate matter were modelled based on maximum Project emission rates for the duration of the Project lifecycle. It is considered likely that the conservative approach to modelled deposition results is an overestimate of the incremental change to soils with respect to cadmium concentration.

Predicted concentrations of cadmium in berries, roots, and fungi incorporate multiple sources of uncertainty due to reliance on modelled particulate deposition, uncertainties in particulate chemistry, and concentration ratios used.

Concentrations of cadmium were modelled using site specific water-to-fish concentration ratios, incorporating dissolved cadmium concentration measured in surface water within the WQM LSA and a limited dataset of collected fish tissue.

Concentrations of COPCs in surface water are modelled using a conservative mass balance model, incorporating geochemical source terms for all modelled flows. Water quality predictions used in the present ERA are based on an upper bound of geochemical source terms (95th %ile), which may result in an overestimate of mass flux and concentrations of COPCs in surface water at model prediction nodes. Additionally, the water quality model does not consider geochemical equilibrium reactions that may strip cobalt from the water column.

Concentration of COPCs in fish tissue is calculated based on maximum rolling 30-day average concentration from predicted surface water quality. This is considered to be a conservative approach, as the predicted concentration of COPCs in surface water is seen to fluctuate significantly throughout the year, and an instantons prediction of fish tissue based on the maximum 30-day average will tend to overestimate fish tissue concentration.

Conservatism in Exposure Assumptions

Dietary ingestion rates were obtained through consultation with the Ktunaxa Nation. The calculated ingestion dose assumes that traditional foods are consumed daily year-round, and that the immediate vicinity of the critical receptor location is capable of producing the annual dietary requirements for the assessed receptors. This assumption is considered conservative, as many foods, such as fungi and berries for instance, are only available seasonally. However, a key exposure pathway for cadmium exposure is fish ingestion. This assumption is reasonable as individuals may catch, treat, or preserve fish for future consumption.

Conservatism in Toxicity Reference Values

The provisional chronic oral tolerable daily intake (TDI) used in the risk assessment was obtained from Health Canada (0.001 [mg/kg/day; Health Canada 2010b). The Health Canada provisional TDI is based on chronic epidemiological occupational exposure, with renal dysfunction (proteinuria) as the critical health effect. This provisional TDI is the same as the more recently updated US EPA chronic reference dose (RfD) for food ingestion, which was developed using a toxicokinetic model with proteinuria as the critical health effect and an uncertainty factor of 10 applied to account for intra-human variability. The confidence in the TRV selected for the present risk assessment is high.

Determination of Significance

For the current and rights-based human receptors, the calculated HQs exceeded the target threshold at several critical receptor locations. The maximum calculated HQ is 1.9 for the rights-based toddler under the Cumulative assessment case, in areas directly influenced by physical mine works. Critical receptor locations along Alexander Creek, downstream of proposed activities have calculated HQs ranging from 1.3 to 1.8 for the Application and Cumulative assessment cases. This is suggestive of a low magnitude of risk (i.e. $1.0 < HQ \leq 5$).

HQs exceeding target thresholds are reported for critical receptor locations along Alexander Creek, with the primary source of exposure being fish ingestion. Dose associated with fish ingestion is calculated using conservative assumptions. These include the use of upper bound source terms for the water quality model, as well as using the maximum 30-day average predicted concentration to calculate fish tissue concentrations for the entire annual dietary intake.

Considering the above information, the overall Project related risk associated with cadmium exposure is considered to be low for current and rights-based receptors for the Application and Cumulative assessment cases.

6.5.2.2 Non-threshold Cancer Risks

Magnitude

Calculated ILCRs for current and rights based human receptors exceed 1E-05 at seven of 14 critical receptor locations outside the exclusion zone. ILCRs range from 7.6E-05 to 3.9E-04 at critical receptor locations within the Project footprint or in the immediate vicinity of Project infrastructure. Calculated ILCRs for critical receptor locations not in the immediate vicinity of Project infrastructure range from 1.7E-06 to 4.0E-05. Calculated ILCRs indicate a potentially high magnitude of effect.

Context

ILCRs for the Base Case are calculated to be 6.0E-06. Calculated ILCRs are critical receptor locations within the mine footprint, or within close proximity Project related infrastructure are seen to increase above target thresholds as a result of resuspension of respirable particulates.

Key Pathways

Cadmium is identified as a carcinogen for the inhalation route only. The key route of exposure is inhalation of respirable particulates.

Conservatism and Uncertainty in Predictions

Predicted fugitive respirable dust concentration is modelled based on maximum Project emission rates for the duration of the Project lifecycle. It is considered likely that the conservative approach to modelled respirable fugitive dust results in an overestimate of the inhalation exposure during the receptors lifespan. Chemistry of respirable dust is based on species profiles sourced from US EPA's SPECIATE 5.1[5] database and represent conservative estimates of maximum weight percent of COPCs in particulates originating from Project activities (Dillon, 2021).

Conservatism in Exposure Assumptions

The current exposure assessment assumes full time occupancy of critical receptor locations during the 15 year Project lifespan. This exposure scenario is considered to be implausible for critical receptor locations located in the immediate vicinity of Project infrastructure. This includes critical receptor locations located on or adjacent to the mine haul roads and rail load-out facility. The exposure assumptions for current and rights-based receptors are considered plausible for critical receptor locations not in the immediate vicinity of Project infrastructure.

Conservatism in Toxicity Reference Values

The inhalation slope factor used in the risk assessment was obtained from Health Canada (42 [mg/kg/day]-1; Health Canada 2010b). The slope factor was derived based on exposure of Wistar rats by inhalation to cadmium chloride aerosol for 18 months, with an additional 13-month observation period which resulted in a significant increase in incidence of lung tumors (Takenaka et al., 1983; as cited in Health Canada 2010b). The calculated tolerable concentration was adjusted for continuous exposure, standard lifetime, and differences in inhalation and body weight between rats and humans to derive the inhalation unit risk (9.8 per mg/m3) and cancer slope factor.

The US EPA (1987) derived inhalation unit risk and cancer slope factors based on respiratory tract cancer incidence associated with human occupational exposure. The US EPA inhalation cancer slope factor derived from human data is 6.1 $(me/kg/day)^{-1}$. While this estimate is lower than the estimate based on inhalation in laboratory rats, and thus less conservative, the US EPA determined that the use of available human data was more reliable because of species variations in response and the type of exposure (cadmium salt vs. cadmium fume and cadmium oxide). Based on the US EPA inhalation slope factor, US EPA (1987) calculates tolerable concentrations at the specified risk level of 1x10-5 (TC= 0.006 µg/m3). Concentrations of cadmium as respirable dust ($\mu g/m^3$) at critical receptors #9 and #10 do not exceed this tolerable air concentration. The inhalation cancer slope factor used in the present HHRA is considered to be conservative, and may overestimate cancer risks associated with particulate inhalation.

Determination of Significance

For the current and rights-based human receptors, the calculated ILCRs exceeded the target threshold of 1E-05 at 7 of 14 critical receptor locations outside the Project exclusion area, with a high magnitude of risk (i.e. ILCR >1E-04).

[5] Speciate 5.1 available at https://www.epa.gov/air-emissions-modeling/speciate

Critical receptor locations with unacceptable ILCRs are primarily confined to critical receptor locations located in the immediate vicinity of mine related infrastructure, such as the haul road and rail loadout. It is considered implausible that these locations would be used in a way that agrees with the exposure scenario assessed (i.e. full time, year-round occupancy for the duration of the Project lifecycle).

Predicted ILCRs are based on conservative cancer slope factors. Cancer estimates based on inhalation slope factors derived from human epidemiological data suggests that cancer risks may be overestimated.

Considering the above information, the overall Project related cancer risk associated with inhalation exposure to cadmium is considered to be low for current and rights-based receptors for the Application and Cumulative assessment cases.

6.5.3 Cobalt

6.5.3.1 Threshold Non-Cancer Risks

Magnitude

Calculated maximum HQs range between 1.2 and 5.7 for the Application and Cumulative assessment cases where critical receptor locations are not directly impacted by resource extraction activities. Calculated HQs indicate a low to moderate potential magnitude of effect.

The calculated maximum HQ at CRID-12 is 21.3 for the Application and Cumulative assessment cases. Calculated HQs indicate a high potential magnitude of effect.

Context

The HQs for current and rights-based human receptors were generally the same in the Application and Cumulative assessment cases as what was calculated for the Base Case. Incremental increase in calculated HQs is observed at critical receptor locations downstream of the confluence between West Alexander Creek (which carries mine effluent discharge) and Alexander Creek. Incremental HQs at these locations (CRID-10, -11, and -14) range between 1.7 and 4.4.

Key Pathways

For critical receptor locations outside of the exclusion zone and not directly impacted by Project activities the key pathway for exposure to cobalt is fish ingestion, accounting for 80% of the dose to the rights based toddler and 71% of the total dose to the rights-based adult receptor (**Figure 6-5**).

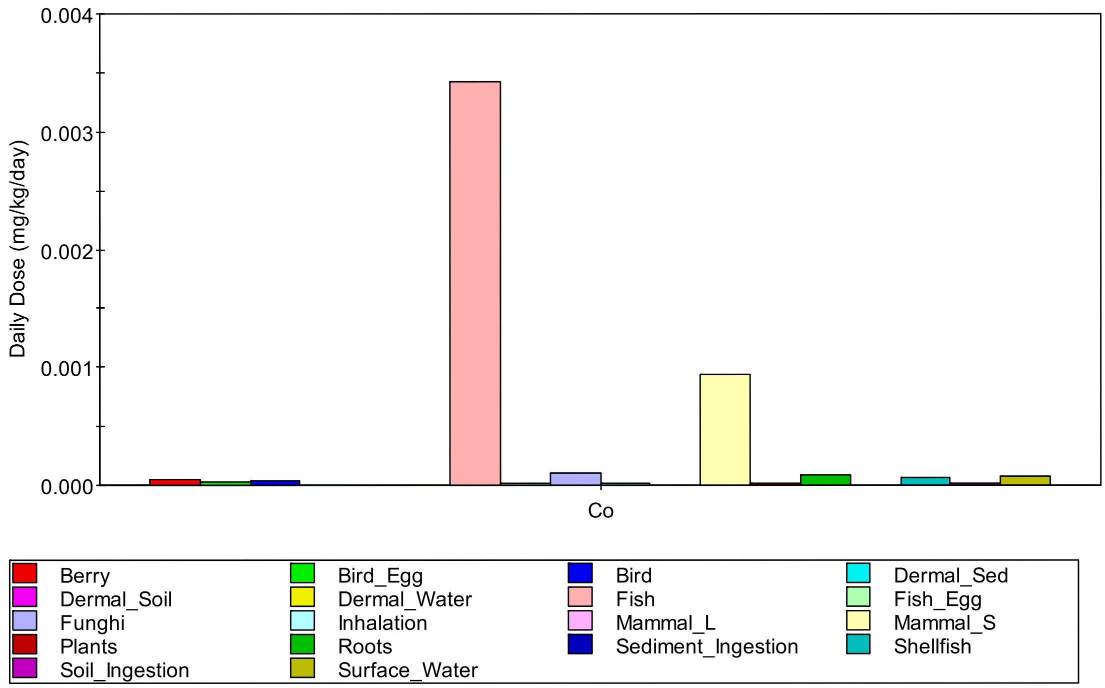

Figure 6-5: Calculated daily dose (mg/kg/day) of cobalt to the rights-based adult receptor at critical receptor location #10.

Conservatism and Uncertainty in Predictions

Concentration of COPCs in fish tissue is based on literature based water-to-fish concentration ratios. Water to fish tissue concentration ratios for cobalt show a high degree of variability, and the prediction of fish tissue concentrations represents an important source of uncertainty.

Concentrations of COPCs in surface water are modelled using a conservative mass balance model, incorporating geochemical source terms for all modelled flows. Water quality predictions used in the present ERA are based on an upper bound of geochemical source terms (95^{th} percentile), which may result in an overestimate of mass flux and concentrations of COPCs in surface water at model prediction nodes. Additionally, the water quality model does not consider geochemical equilibrium reactions that may strip cobalt from the water column.

Concentration of COPCs in fish tissue is calculated based on maximum rolling 30-day average concentration from predicted surface water quality. This is considered to be a conservative approach, as the predicted concentration of COPCs in surface water is seen to fluctuate significantly throughout the year, and an instantaneous prediction of fish tissue based on the maximum 30-day average will tend to overestimate fish tissue concentration.

Conservatism in Exposure Assumptions

Dietary ingestion rates were kindly provided by the Ktunaxa Nation. The calculated ingestion dose assumes that traditional foods are consumed daily year-round, and that the immediate vicinity of the critical receptor location is capable of producing the annual dietary requirements for the assessed receptors. Since the key exposure pathway for cobalt exposure is fish ingestion, this assumption is reasonable as individuals may catch, treat, or preserve fish for future consumption.

Conservatism in Toxicity Reference Values

A tolerable daily intake for cobalt has not been derived by Health Canada (2010b), and the US EPA has not derived an RfC or RfD for cobalt and compounds. The TDI used in the present HHERA (0.001 mg/kg/day) was sourced from the Ontario Ministry of the Environment (OMOE, 2011) and is a modification of information presented in the ATSDR (2004) toxicological profile for cobalt, although no information on the effect endpoint or process of modification is provided.

More recently Finley et al. (2012) derived a chronic oral reference dose for cobalt using standard US EPA risk assessment methodologies. This assessment was based on a ten-week multiple dose human study of thyroid effects, which identified decreased iodide uptake as the most sensitive endpoint. An uncertainty factor of 30 was applied to the identified point of departure (10x for human variability and 3x for database adequacy), yielding a chronic oral RfD of 0.03 mg/kg/day.

Based on the above, it is considered likely that threshold risks associated with oral intake of cobalt may be overestimated.

Determination of Significance

For the current and rights-based human receptors, the calculated HQs exceeded the target threshold at all locations for the Base, Application, and Cumulative assessment cases. Calculated HQs are essentially unchanged between Base and Application and Cumulative cases at all but 5 critical receptor locations.

Of critical receptor locations not immediately influenced by physical mine works, incremental change in calculated HQs is limited to locations immediately downstream of the confluence of West Alexander Creek and Alexander Creek. The maximum calculated HQ at these locations (i.e. excluding CRID-4 & -12) is 5.7 for the rights-based adult receptor under the Cumulative assessment case, a moderate magnitude of risk (i.e. $5 < HQ \leq 10$).

The HQs which indicate an incremental change in calculated HQ and which are exceeding target thresholds are limited to locations directly influenced by physical works (CRID-4 and CRID12) and three critical receptor locations (CRID-10, -11 & -14) which are downstream but in close proximity to the confluence between West Alexander Creek and Alexander Creek. Uncertainty and conservative assumptions in the modelled surface water quality, as well as conservatism in the TRV used in the present assessment likely overestimate threshold non-cancer health risks associated with oral exposure to cobalt.

Considering the above information, the overall Project related threshold risk associated with cobalt exposure is considered to be low and likely negligible for current and rights-based receptors for the Application and Cumulative assessment cases.

6.5.4 Chromium

6.5.4.1 Threshold Non-Cancer Risks

Magnitude

Maximum calculated HQs for Application and Cumulative assessment cases range from 1.7 to 1.8. Low potential magnitude of effect.

Context

Calculated HQs exceed target threshold ($HQ \leq 1$) at all critical receptor locations for the Base, Application, and Cumulative assessment cases. Maximum incremental HQ for the Application and Cumulative application cases is 0.1.

Key Pathways

Key pathways of chromium exposure are bird (+bird egg) and fish ingestion for adult receptors. Key exposure pathways for the toddler receptors are fish ingestion, berry ingestion, and incidental soil ingestion.

Conservatism and Uncertainty in Predictions

Concentration of COPCs in fish tissue is based on literature derived water-to-fish concentration ratios. Water to fish tissue concentration ratios show a high degree of variability, and the prediction of fish tissue concentrations represents an important source of uncertainty.

Concentrations of COPCs in surface water are modelled using a conservative mass balance model, incorporating geochemical source terms for all modelled flows. Water quality predictions used in the present ERA are based on an upper bound of geochemical source terms (95th percentile), which may result in an overestimate of mass flux and concentrations of COPCs in surface water at model prediction nodes.

Concentration of COPCs in fish tissue is calculated based on maximum rolling 30-day average concentration from predicted surface water quality. This is considered to be a conservative approach, as the predicted concentration of COPCs in surface water is seen to fluctuate significantly throughout the year, and an instantaneous prediction of fish tissue based on the maximum 30-day average will tend to overestimate fish tissue concentration.

Conservatism in Exposure Assumptions

Dietary ingestion rates were kindly provided by the Ktunaxa Nation. The calculated ingestion dose assumes that traditional foods are consumed daily year-round, and that the immediate vicinity of the critical receptor location is capable of producing the annual dietary requirements for the assessed receptors. Since the key exposure pathway for cobalt exposure is fish ingestion, this assumption is reasonable as individuals may catch, treat, or preserve fish for future consumption.

Conservatism in Toxicity Reference Values

The chronic oral tolerable daily intake (TDI) used in the risk assessment was obtained from Health Canada (0.001 [mg/kg/day; Health Canada 2010b), for total chromium. The Health Canada provisional TDI is based on a maximum acceptable concentration (MAC) for hexavalent chromium in drinking water, but is not well suited to assessment of dietary exposure and is likely to overestimate health risks.

At human dietary exposure levels chromium absorption is relatively low (< 10 % of the ingested dose) and depends on its valence state and ligands. Most of the ingested Cr(VI) is considered to be reduced in the stomach to Cr(III), which is poorly bioavailable and presents low ability to enter cells. In contrast to Cr(III), Cr(VI) is able to cross cellular membranes. The interconversion of Cr(VI) to Cr(III) is of relevance for risk assessment since, in general, Cr(VI) compounds are much more toxic than Cr(III) compounds (EFSA, 2014).

EFSA (2014) have derived a TDI of 0.3 mg/kg/day for oral intake of trivalent chromium. It should be noted that there is a lack of data on chromium speciation in food, but the EFSA Panel decide to consider all the reported analytical results in food as Cr(III). This assumption was based on the outcome of recent speciation work, the fact that food is by-and large a reducing medium, and that oxidation of Cr(III) to Cr(VI) would not be favoured in such a medium.

Determination of Significance

For the current and rights-based human receptors, the calculated HQs exceeded the target threshold at all locations for the Base, Application, and Cumulative assessment cases. Calculated HQs are essentially unchanged between Base and Application and Cumulative cases. Maximum incremental HQ for the Application and Cumulative application cases is 0.1.

Uncertainty and conservative assumptions in the modelled surface water quality, as well as conservatism in the TRV used in the present assessment likely overestimate threshold non-cancer health risks associated with oral exposure to cobalt.

Considering the above information, the overall Project related threshold risk associated with chromium exposure is considered to be low and likely negligible for current and rights-based receptors for the Application and Cumulative assessment cases.

6.5.4.2 Non-threshold Cancer Risks

Magnitude

Calculated ILCRs for current and rights based human receptors exceed 1E-05 at 5 of 14 critical receptor locations outside the exclusion zone. ILCRs range from 5.7E-05 to 2.7E-04 at critical receptor locations within the Project footprint or in the immediate vicinity of Project infrastructure. Calculated ILCRs for critical receptor locations not in the immediate vicinity of Project infrastructure range from 6.5E-06 to 9.6E-06. Calculated ILCRs indicate a potentially high magnitude of effect in areas directly affected by mine works.

Context

ILCRs for the Base Case are calculated to be 3.4 E-05. Calculated ILCRs are critical receptor locations within the mine footprint, or within close proximity Project related infrastructure are seen to increase above target thresholds as a result of resuspension of respirable particulates.

Key Pathways

Chromium is identified as a carcinogen for the inhalation route only. The key route of exposure is inhalation of respirable particulates.

Conservatism and Uncertainty in Predictions

Predicted fugitive respirable dust concentration is modelled based on maximum Project emission rates for the duration of the Project lifecycle. It is considered likely that the conservative approach to modelled respirable fugitive dust results in an overestimate of the inhalation exposure during the receptors lifespan. Chemistry of respirable dust is based on species profiles sourced from US EPA's SPECIATE 5.1 database and represent conservative estimates of maximum weight percent of COPCs in particulates originating from Project activities.

Conservatism in Exposure Assumptions

The current exposure assessment assumes full time occupancy of critical receptor locations during the 15-year Project lifespan. This exposure scenario is considered to be implausible for critical receptor locations located in the immediate vicinity of Project infrastructure. This includes critical receptor locations located on or adjacent to the mine haul roads and rail load-out facility. The exposure assumptions for current and rights-based receptors are considered plausible for critical receptor locations not in the immediate vicinity of Project infrastructure.

Conservatism in Toxicity Reference Values

The inhalation slope factor used in the risk assessment was obtained from Health Canada (42 [mg/kg/day]-1; Health Canada 2010b). The slope factor was derived from epidemiological occupational exposure and considered adequate for the current HHRA.

Determination of Significance

For the current and rights-based human receptors, the calculated ILCRs exceeded the target threshold of 1E-05 at 5 of 14 critical receptor locations outside the Project exclusion area, with a high magnitude of risk (i.e. ILCR >1E-04).

Critical receptor locations with unacceptable ILCRs are limited to locations in the immediate vicinity of mine infrastructure, such as the haul road and rail loadout. It is considered implausible that these locations would be used in a way that agrees with the exposure scenario assessed (i.e. full time, year round occupancy for the duration of the Project lifecycle).

Considering the above information, the overall Project related cancer risk associated with inhalation exposure to chromium is considered to be low for current and rights based receptors for the Application and Cumulative assessment cases.

6.5.5 Nickel

6.5.5.1 Threshold Non-Cancer Risks

Magnitude

Calculated maximum HQs range between 0.6 and 1.4 for the Application and Cumulative assessment cases. Calculated HQs indicate a low potential magnitude of effect.

Context

The HQs for current and rights-based human receptors were generally the same in the Application and Cumulative assessment cases as what was calculated for the Base Case.

Incremental increase in calculated HQs is observed at critical receptor locations downstream of the to the confluence between West Alexander Creek (which carried mine effluent discharge) and Alexander Creek. Incremental HQs at these locations (CRID-10, -11, and -14) range between 0.3 and 0.7.

Key Pathways

The key pathway for exposure to nickel is fish ingestion, accounting for 63% of the dose to the rights based adult receptor (**Figure 6-6**) and 52% of the total dose to the rights-based toddler receptor.

Conservatism and Uncertainty in Predictions

Concentration of COPCs in fish tissue is based on literature derived water-to-fish concentration ratios. Water to fish tissue concentration ratios show a high degree of variability, and the prediction of fish tissue concentrations represents an important source of uncertainty.

Concentrations of COPCs in surface water are modelled using a conservative mass balance model, incorporating geochemical source terms for all modelled flows. Water quality predictions used in the present ERA are based on an upper bound of geochemical source terms (95^{th} %ile), which may result in an overestimate of mass flux and concentrations of COPCs in surface water at model prediction nodes.

Concentration of COPCs in fish tissue is calculated based on maximum rolling 30-day average concentration from predicted surface water quality. This is considered to be a conservative approach, as the predicted concentration of COPCs in surface water is seen to fluctuate significantly throughout the year, and an instantaneous prediction of fish tissue base don the maximum 30-day average will tend to overestimate fish tissue concentration.

Conservatism in Exposure Assumptions

Dietary ingestion rates were kindly provided by the Ktunaxa Nation. The calculated ingestion dose assumes that traditional foods are consumed daily year-round, and that the immediate vicinity of the critical receptor location is capable of producing the annual dietary requirements for the assessed receptors. Since the key exposure pathway for cobalt exposure is fish ingestion, this assumption is reasonable as individuals may catch, treat, or preserve fish for future consumption.

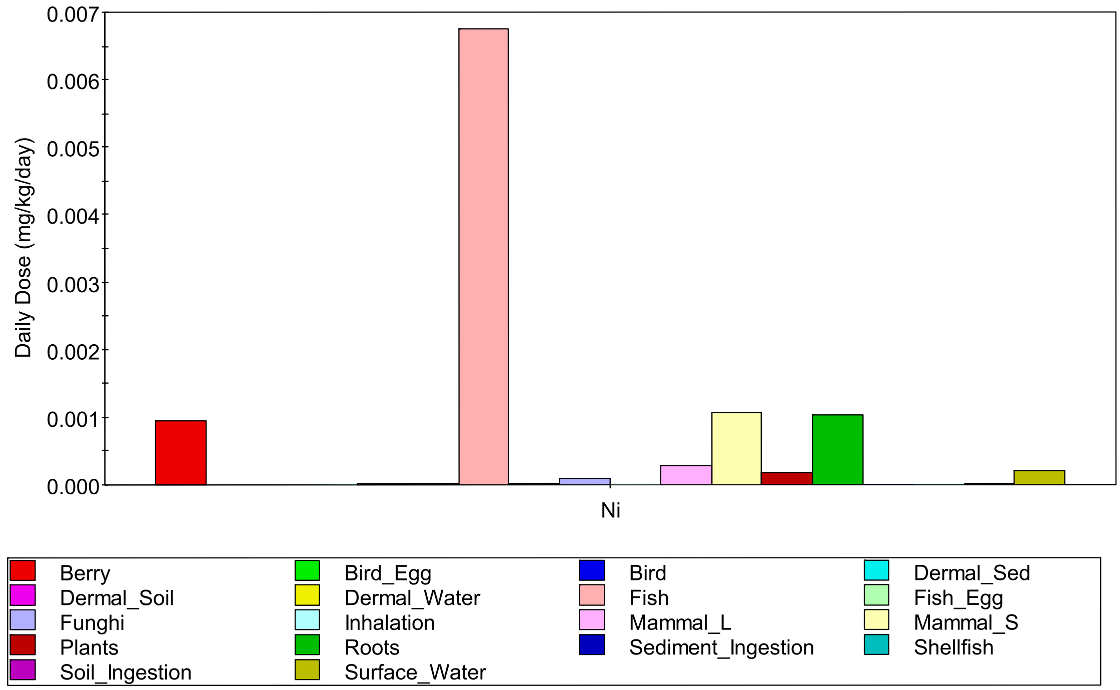

Figure 6-6: Calculated daily dose (mg/kg/day) of nickel to the rights-based adult receptor at critical receptor location #10.

Conservatism in Toxicity Reference Values

The chronic oral tolerable daily intake (TDI) used in the risk assessment was obtained from Health Canada (0.011 [mg/kg/day; Health Canada 2010b), for soluble nickel (nickel chloride and nickel sulphate). The TDI is based on reproductive toxicity measured in laboratory rats following administration of soluble nickel in drinking water. The TDI was derived as the NOAEL with the application of an uncertainty factor of 100 (10x each for intra- and interspecies variability).

The US EPA (1991) have derived a chronic RfD based on a 2-year feeding study using laboratory rats, with reduced body weight and organ weights identified as the critical effect. A NOAEL of 5 mg/kg/day was used to derive the RfD by application of an uncertainty factor of 300 (10x for interspecies extrapolation, 10x for protection of sensitive populations and 3x for dataset adequacy). The Ni dietary study by Ambrose et al. (1976; referenced in US EPA 1991) identifying a NOAEL of 100 ppm (RfD = 5 mg/kg/day) is supported by the subchronic gavage study in water (ABC, 1986; referenced in US EPA 1991), which indicated the same NOAEL.

Based on the above, it is considered possible that threshold risks associated with oral intake of nickel may be overestimated.

Determination of Significance

For the current and rights-based human receptors, the calculated HQs exceeded the target threshold three critical receptor locations within Alexander Creek for the Base, Application, and Cumulative assessment cases.

Of critical receptor locations not immediately influenced by physical mine works, incremental change in calculated HQs is limited to locations immediately downstream of the confluence of West Alexander Creek and Alexander Creek. The maximum HQ calculated at these locations (i.e. excluding CRID-15) is 1. 4 for the rights-based child receptor under the Cumulative assessment case, a low magnitude of risk (i.e. 1.0 < HQ ≤ 5).

The HQs exceeding target thresholds are limited to three critical receptor locations (excluding CRID-15) which are downstream but in close proximity to the confluence between West Alexander Creek and Alexander Creek. Uncertainty and conservative assumptions in the modelled surface water quality, as well as conservatism in the TRV used in the present assessment likely overestimate threshold non-cancer health risks associated with oral exposure to nickel.

Considering the above information, the overall Project related threshold risk associated with cobalt exposure is considered to be low and likely negligible for current and rights-based receptors for the Application and Cumulative assessment cases.

6.5.5.2 Non-threshold Cancer Risks

Magnitude

Calculated ILCRs are below target thresholds (1E-05) for all receptors at all critical receptor locations under the Application and Cumulative assessment cases, with the exception of CRID-4. Calculated ILCR for the Application and Cumulative assessment cases at CRID-4 is 1.1E-05 for current and rights-based receptors. Calculated ILCRs indicate potential low magnitude of effect.

Context

Calculated ILCRs marginally exceed the targe thresholds at a single critical receptor location (CRID-4). This location is in the direct vicinity of the rail loadout and is unique in it's future land use.

Key Pathways

Nickel does not pose a cancer risk through oral exposures. The key pathway for assessment of cancer risks is particulate inhalation.

Conservatism and Uncertainty in Predictions

Predicted fugitive respirable dust concentration is modelled based on maximum Project emission rates for the duration of the Project lifecycle. It is considered likely that the conservative approach to modelled respirable fugitive dust results in an overestimate of the inhalation exposure during the receptors lifespan. Chemistry of respirable dust is based on species profiles sourced from US EPA's SPECIATE 5.1 database and represent conservative estimates of maximum weight percent of COPCs in particulates originating from Project activities.

Conservatism in Exposure Assumptions

The current exposure assessment assumes full time occupancy of critical receptor locations during the 15-year Project lifespan. This exposure scenario is considered to be implausible for CRID-4 located in the immediate vicinity of Project infrastructure.

Determination of Significance

For the current and rights-based human receptors, the calculated ILCRs exceeded the target threshold of 1E-05 at a single location (CRID-4) located at the rail load-out, with a low magnitude of risk ($1\times10^{-5} < ILCR \leq 5\times10^{-5}$).

It is considered implausible that CRID-4 would be used in a way that agrees with the exposure scenario assessed (i.e. full time, year-round occupancy for the duration of the Project lifecycle).

Considering the above information, the overall Project related cancer risk associated with inhalation exposure to cadmium is considered to be low and likely negligible for current and rights-based receptors for the Application and Cumulative assessment cases.

6.5.6 Selenium

6.5.6.1 Threshold Non-Cancer Risks

Calculated hazard quotients for exposure to selenium to current and rights-based receptors were below target thresholds (HQ<1) for the Base, Application, and Current assessment cases. Threshold non-cancer human health risks associated with selenium exposure are therefore considered to be negligible.

6.5.7 Benzo(a)pyrene

Benzo(a)pyrene was assessed as a non-threshold inhalation carcinogen only. Calculated ILCRs for exposure to benzo(a)pyrene to current and rights-based receptors were below target thresholds (ILCR < 1E-05) for the Base, Application, and Current assessment cases. Non-threshold cancer human health risks associated with benzo(a)pyrene inhalation exposures are therefore considered to be negligible.

6.6 Conclusions of Human Health Risk Assessment

Overall conclusions to the HHRA are drawn in consideration of the key question identified in Section 2.1 Study Objectives - ***What will be the collective effect of changes to water, air, soil, and food to human health risks?***

The present quantitative human health risk assessment was conducted in consideration of current and rights-based Indigenous traditional lifestyle scenarios. Indigenous communities represent the maximally exposed receptor, and as such risk estimates calculated for Indigenous receptors are sufficiently conservative to infer maximal potential risk to non-Indigenous peoples also frequenting the study area.

The overall conclusions of the Human Health Risk Assessment are as follows for COPC:

For Arsenic:

- Calculated hazard quotients for exposure to arsenic to current and rights-based receptors were below target thresholds (HQ<1) for the Base, Application, and Current assessment cases. Threshold non-cancer human health risks associated with arsenic exposure are therefore considered to be **negligible**.
- ILCRs for the current and rights-based human receptors exceeded the target threshold of 1E-05 at all critical receptor locations, resulting in a high magnitude of risk (i.e. ILCR >1E-04). The elevated cancer risks are driven primarily by baseline soil condition and modelled concentration of arsenic in edible fish and mushroom species. Predicted concentration of arsenic in fungi are considered to have a high degree of uncertainty. Cancer slope factors do not consider arsenic species and relative toxicity of organic species versus inorganic arsenic.
  Predicted ILCRs at all critical receptor locations are reported to have a small (<10%) increase relative to the Base Case for the high consuming rights-based receptor under the Application and Cumulative assessment cases.
- Considering the above information, the overall Project related cancer risk associated with arsenic exposure is considered to **be low and likely negligible** for current and rights-based receptors for the Application and Cumulative assessment cases.

For Cadmium:

- For threshold effects, calculated HQs for the current and rights-based human receptors exceeded the target threshold at seven single critical receptor locations. The maximum calculated HQ is 1.9 for the rights-based toddler under the Cumulative assessment case, a low magnitude of risk (i.e. 1.0 < HQ ≤ 5). Critical receptor locations along Alexander Creek, downstream of proposed activities have calculated HQs ranging from 1.3 to 1.8 for the Application and Cumulative assessment cases. Project related risk from threshold effects associated with cadmium exposure is considered to be **low** for current and rights-based receptors for the Application and Cumulative assessment cases.

- Calculated ILCRs for the current and rights-based human receptors exceeded the target threshold of 1E-05 at 7 of 14 critical receptor locations outside the Project exclusion area, with a high magnitude of risk (i.e. ILCR >1E-04). Critical receptor locations with unacceptable ILCRs are primarily confined to critical receptor locations located in the immediate vicinity of mine related infrastructure, such as the haul road and rail loadout. It is considered implausible that these locations would be used in a way that reflects with the exposure scenario assessed (i.e. full time, year-round occupancy for the duration of the Project lifecycle). Predicted ILCRs are based on conservative cancer slope factors. Cancer estimates based on inhalation slope factors derived from human epidemiological data suggests that cancer risks may be overestimated. Considering the above information, the overall Project related cancer risk associated with inhalation exposure to cadmium is considered to be **low and likely negligible** for current and rights-based receptors for the Application and Cumulative assessment cases.

For Chromium:

- For threshold effects, calculated HQs for the current and rights-based human receptors exceeded the target threshold at all locations for the Base, Application, and Cumulative assessment cases. Calculated HQs are essentially unchanged between Base and Application and Cumulative cases at several critical receptor locations. Maximum incremental HQ for the Application and Cumulative application cases is 0.1. The maximum calculated HQ is 1.8 for the rights-based adult receptor under the Cumulative assessment case, a low magnitude of risk (i.e. 1.0 < HQ ≤ 5). Uncertainty and conservative assumptions in the modelled surface water quality, as well as conservatism in the TRV used in the present assessment likely overestimate threshold non-cancer health risks associated with oral exposure. Considering the above information, the overall Project related threshold risk associated with chromium exposure is considered to be **low and likely negligible** for current and rights-based receptors for the Application and Cumulative assessment cases.
- Calculated ILCRs for the current and rights-based human receptors exceeded the target threshold of 1E-05 at 5 of 14 critical receptor locations outside the Project exclusion area, with a high magnitude of risk (i.e. ILCR >1E-04).Critical receptor locations with unacceptable ILCRs are limited to locations in the immediate vicinity of mine infrastructure, such as the haul road and rail loadout. It is considered implausible that these locations would be used in a way that reflects with the exposure scenario assessed (i.e. full time, year-round occupancy for the duration of the Project lifecycle).Considering the above information, the overall Project related cancer risk associated with inhalation exposure to chromium is considered to be **low** for current and rights-based receptors for the Application and Cumulative assessment cases.

For Cobalt:

- For threshold effects, calculated HQs for the current and rights-based human receptors exceeded the target threshold at all locations for the Base, Application, and Cumulative assessment cases. Calculated HQs are essentially unchanged between Base and Application and Cumulative cases at all but 5 critical receptor locations.
- Of critical receptor locations not immediately influenced by physical mine works, incremental change in calculated HQs is limited to locations immediately downstream of the confluence of West Alexander Creek and Alexander Creek. The maximum calculated at these locations (i.e. excluding CRID-12) is HQ is 5.7 for the rights-based adult receptor under the Cumulative assessment case, a moderate magnitude of risk (i.e. 5.0 < HQ ≤ 10).
- The HQs which indicate an incremental change in calculated HQ and which are exceeding target thresholds are limited to locations directly influenced by physical works (CRID-4 and CRID12) and three critical receptor locations (CRID-10, -11 & -14) which are downstream but in close proximity to the confluence between West Alexander Creek and Alexander Creek. Uncertainty and conservative assumptions in the modelled surface water quality, as well as conservatism in the TRV used in the present assessment likely overestimate threshold non-cancer health risks associated with oral exposure to cobalt.

- Considering the above information, the overall Project related threshold risk associated with cobalt exposure is considered to be **low** for current and rights-based receptors for the Application and Cumulative assessment cases.

For Nickel:

- For threshold effects, calculated HQs for the current and rights-based human receptors exceeded the target threshold at one location within Alexander Creek for the Application, and Cumulative assessment cases. Of critical receptor locations not immediately influenced by physical mine works, incremental change in calculated HQs is limited to locations immediately downstream of the confluence of West Alexander Creek and Alexander Creek. The maximum calculated at these locations (i.e. excluding CRID-15) is 1.4 for the rights-based toddler receptor under the Cumulative assessment case, a low magnitude of risk (i.e. 1.0 < HQ ≤ 5). Uncertainty and conservative assumptions in the modelled surface water quality, as well as conservatism in the TRV used in the present assessment likely overestimate threshold non-cancer health risks associated with oral exposure to nickel. Considering the above information, the overall Project related threshold risk associated with cobalt exposure is considered to be **low and likely negligible** for current and rights-based receptors for the Application and Cumulative assessment cases.
- Calculated ILCRs for the current and rights-based human receptors exceeded the target threshold of 1E-05 at a single location (CRID-4) located at the rail load-out, with a low magnitude of risk (1x10-5 < ILCR ≤ 5x10-5).It is considered implausible that CRID-4 would be used in a way that reflects with the exposure scenario assessed (i.e. full time, year round occupancy for the duration of the Project lifecycle).Considering the above information, the overall Project related cancer risk associated with inhalation exposure to nickel is considered to be **low and likely negligible** for current and rights-based receptors for the Application and Cumulative assessment cases.

For Selenium:

- Calculated hazard quotients for exposure to selenium to current and rights-based receptors were below target thresholds (HQ<1) for the Base, Application, and Current assessment cases. Threshold non-cancer human health risks associated with selenium exposure are therefore considered to be **negligible**.

For Benz(a)pyrene:

- Benzo(a)pyrene was assessed as a non-threshold inhalation carcinogen only. Calculated ILCRs for exposure to benzo(a)pyrene to current and rights-based receptors were below target thresholds (ILCR < 1E-05) for the Base, Application, and Current assessment cases. Non-threshold cancer human health risks associated with benzo(a)pyrene inhalation exposures are therefore considered to be **negligible**.

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Appendix A Multimedia Food-web and Exposure Model

The current appendix provides the complete multimedia food-web and exposure model for the ecological and human health risk assessment as a digital GoldSim Player model file, which can be opened using the GoldSim Player utility. The GoldSim Player is a special version of GoldSim that allows you to "play" or “read” an existing GoldSim model without having to license the GoldSim software. In general, the user interface for the GoldSim Player is identical to that of the full GoldSim version, with menu options and controls for editing the model removed or disabled. The player file allows the user to directly view the underlying details of GoldSim model, and view model results. You cannot, however, modify the model in any way. the GoldSim Player is available as a free download at the GoldSim website (http://www.goldsim.com).

The GoldSim simulation environment is highly-graphical and completely object oriented. That is, models are created, documented, and presented by creating and manipulating graphical objects representing data and relationships between the data. In a sense, GoldSim is like a "visual spreadsheet" allowing you to visually create and manipulate data and equations.

The multimedia food web and exposure model for the current HHERA is expansive, consisting of thousands of model elements, and millions of outputs. Transcribing the model to a series of tables would result in hundreds of pages of tables, while eliminating the ability to see and trace the relationships between model input, elements, and results. On the other hand, the digital player file provides a graphical representation of the links between abiotic and biotic media and allows for a complete and transparent inspection of the model elements, data inputs, calculations within the model, and all model outputs.

The GoldSim player file (filename: App A_MOD_Crown Mountain HHERA_60590462.gsp) can be made available upon request by NWP Coal Canada Ltd. or AECOM Canada Ltd.

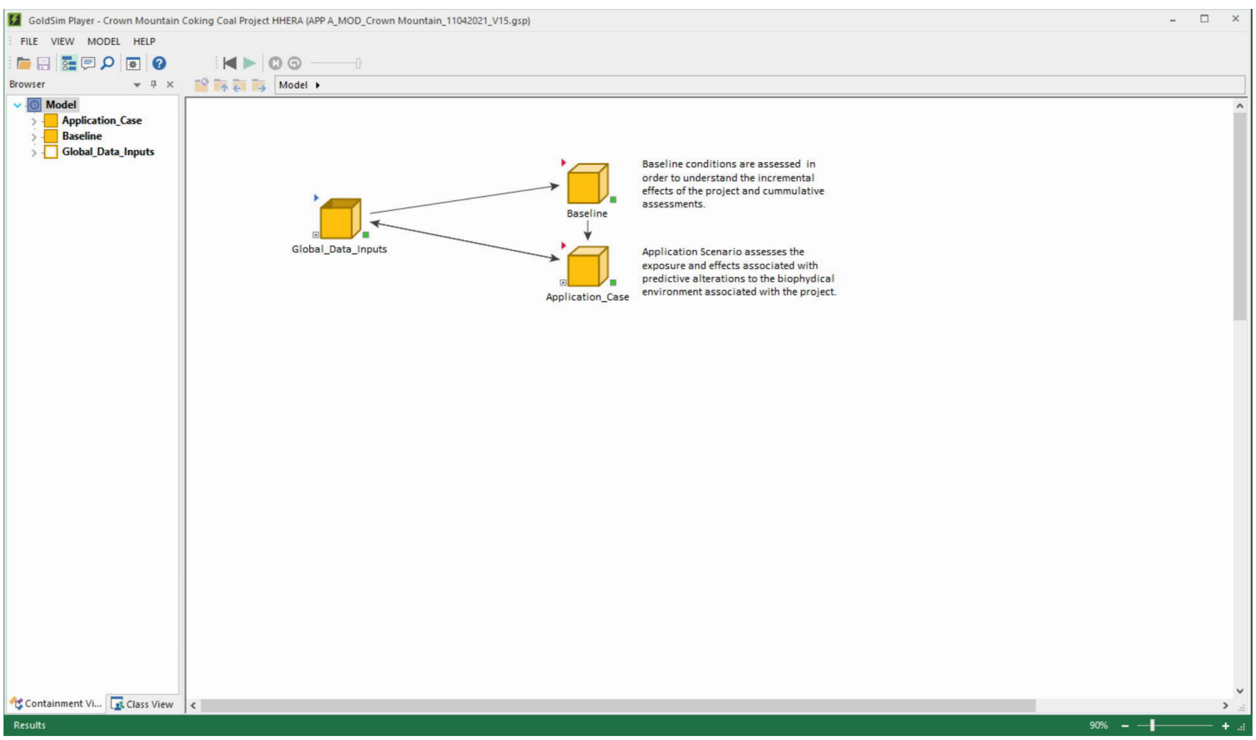

Figure 1: Screen capture of model player file upon opening.

Appendix B Incremental Soil Concentration

Introduction

The following technical appendix provides details on the calculation of incremental change in soil concentration as a result of total particulate deposition. Particulate deposition was reported as part of the air quality modelling discipline, and provided to the HHERA as a data input. Details on the modelled particulate deposition rates is presented in the Dillon (2021) air quality modelling report.

It is expected that particulate emissions will be associated with land disturbance, coal handling, hauling, and combustion emissions associated with vehicle traffic and other emission sources associated with the Project. Chemical constituents associated with Project derived particulate emissions have the potential to accumulate in soils within the local study area as a result of particulate deposition and mixing with surficial soil horizons.

The incremental change in soil concentration (ISC) was calculated at critical receptor locations within the HHERA LSA for the purpose of deriving a representative conservative concentration of COPCs to be carried forward in the perspective quantitative exposure assessment for human and terrestrial wildlife receptors. Incremental soil concentrations at critical receptor locations for the Application Case and Cumulative Case were derived based on a conservative upper bound of the baseline soil concentration data, in this case the 95^{th} percentile, and the predicted annual total deposition (wet and dry deposition) associated with project related emissions associated with fugitive coal dust and combustion emissions.

Annual wet and dry deposition were calculated as an integral of the wet and dry deposition predicted from the air quality modelling report for a 365-day period. The calculated annual wet and dry deposition rates obtained from the air quality model are based on the planned year of highest production and are assumed to represent a worst-case scenario. These deposition rates are conservatively applied to the entire 15-year active mine life. This is a conservative approach that likely overestimates

The ISC was calculated for each critical receptor location for each of the emissions sources (coal dust and combustions sources) based on the US EPA (1999, 2005) incremental soil concentration model, as follows:

$$ISC = \frac{(Dyd + Dyw) \times tD}{Zs \times BD}$$

Where:
ISC = Incremental change in soil concentration (mg/kg dry weight)
Dyd = Dry deposition rate (g/m2/year)
Dyw = Wet deposition rate (g/m2/year)
tD = Deposition time (15 year)
Zs = Soil mixing depth (0.2 m)
BD = Bulk density (1,500 kg/m3)

The incremental soil equation represents a simple soil compartment model that assumes that deposition represents a mass input of constituent per unit volume of soil. All constituents deposited onto soil were assumed to mix within the top 0.2 m, as recommended for tilled soils since the root depth is assumed to equal the tilling depth (US EPA 2005). The current assessment assumes no loss through degradation processes, and functions as a conservative mass flux model (i.e. all mass of COPCs remains in perpetuity). This is a conservative approach which may overestimate the incremental soil concentration.

Application Case

Concentration of COPCs in soil at each critical receptor locations for the application assessment case were calculated as follows:

$$Csoil = Baseline + ISCcoal + ISCcombustion$$

Where:
C_{soil} = Concentration of COPC in soil at critical receptor location (mg/kg dry weight)
Baseline = 95^{th} %ile of baseline soil quality dataset (mg/kg dry weight)
ISC_{coal} = Incremental change in soil concentration associated with coal dust deposition (mg/kg dry weight)
ISC_{com} = Incremental change in soil concentration associated with combustion emissions (mg/kg dry weight)

Baseline concentrations of COPCs are presented in Table 1.

Predicted concentrations of COPCs in soil for the application case are provided in Table 2.

Cumulative Case

The Cumulative Case assesses the potential effects associated with the proposed Project in addition to incremental changes associated with ongoing or reasonably foreseeable future development. The Cumulative Case is based on reasonably foreseeable projects included in the assessments conducted by the air quality discipline, as predictions from the air quality model forms the basis for calculation of the ISC.

Predicted ISC changes to soil and subsequent changes to vegetation and wildlife tissue associated with 15 years of additional particulate deposition assuming baseline dust fall data represents predicted ongoing cumulative dust fall from sources aside from the proposed Project.

Concentration of COPCs in soil at each critical receptor locations for the cumulative assessment case are therefore calculated as follows:

$$Csoil_{cum} = Csoil_{app} + ISCongoing$$

Where:
$Csoil_{cum}$ = Concentration of COPC in soil at critical receptor location (mg/kg dry weight) for cumulative case
$Csoil_{app}$ = Concentration of COPC in soil at critical receptor location (mg/kg dry weight) for application case
$ISC_{ongoing}$ = Incremental change in soil concentration associated other ongoing sources within the LSA (mg/kg dry weight).

Predicted concentrations of all substances of interest in soil for the cumulative case are provided in Table 3

Table 1: Statistically derived upper bound (95th percentile) of the concentration of COPCs in baseline soils.

COPC	Concentration (mg/kg dw)
As	9.404
Cd	1.952
Co	10.03
Cr	25.97
Ni	33.61
Se	3.042
Tl	0.454
Benzo(a)pyrene	5.00E-03

Table 2: Calculated concentration of COPCs in soil at critical receptor locations for the application case.

CRID	As	Cd	Co	Cr	Ni	Se	Tl	Benzo(a)pyrene
1	9.404	1.953	10.07	25.97	33.61	3.042	0.454	5.24E-08
2	9.404	1.961	10.54	25.97	33.61	3.043	0.454	1.52E-05
3	9.404	1.961	10.54	25.97	33.61	3.042	0.454	9.30E-06
4	9.404	2.247	26.45	26.04	33.61	3.044	0.454	6.08E-05
5	9.404	1.96	10.49	25.97	33.61	3.042	0.454	4.41E-06
6	9.404	1.957	10.33	25.97	33.61	3.042	0.454	4.18E-07
7	9.404	1.96	10.49	25.97	33.61	3.042	0.454	6.04E-07

CRID	As	Cd	Co	Cr	Ni	Se	Tl	Benzo(a)pyrene
8	9.404	1.96	10.46	25.97	33.61	3.042	0.454	5.01E-07
9	9.404	1.982	11.68	25.98	33.61	3.042	0.454	2.08E-06
10	9.404	1.975	11.33	25.98	33.61	3.042	0.454	1.72E-06
11	9.404	1.952	10.05	25.97	33.61	3.042	0.454	2.56E-08
12	9.404	5.141	187.3	26.72	33.61	3.042	0.454	7.51E-06
13	9.404	1.953	10.07	25.97	33.61	3.042	0.454	5.00E-08
14	9.404	1.954	10.15	25.97	33.61	3.042	0.454	1.34E-07

Table 3: Calculated concentration of COPCs in soil at critical receptor locations for the cumulative case.

CRID	As	Cd	Co	Cr	Ni	Se	Tl	Benzo(a)pyrene
1	9.419	1.955	10.08	25.98	33.63	3.071	0.4569	5.24E-08
2	9.442	1.965	10.56	26	33.68	3.078	0.4576	1.52E-05
3	9.434	1.968	10.54	25.99	33.65	3.074	0.4571	9.30E-06
4	9.412	2.257	26.46	26.07	33.64	3.085	0.4581	6.08E-05
5	9.434	1.967	10.5	25.99	33.65	3.073	0.4571	4.41E-06
6	9.433	1.96	10.33	25.99	33.64	3.084	0.4582	4.18E-07
7	9.442	1.964	10.5	26	33.68	3.078	0.4576	6.04E-07
8	9.437	1.963	10.47	26	33.65	3.095	0.4593	5.01E-07
9	9.435	1.986	11.69	26.01	33.66	3.098	0.4596	2.08E-06
10	9.435	1.98	11.34	26	33.66	3.098	0.4596	1.72E-06
11	9.431	1.955	10.06	25.99	33.63	3.078	0.4576	2.56E-08
12	9.433	5.143	187.3	26.74	33.64	3.084	0.4582	7.51E-06
13	9.419	1.955	10.08	25.98	33.63	3.071	0.4569	5.00E-08
14	9.431	1.957	10.16	25.99	33.63	3.078	0.4576	1.34E-07

Table 4: Species profile for particulate emissions from fugitive coal dust and combustion emissions.

Substances of Interest	Coal Dust [(a)]	Combustion [(b)]
Ag	0	0.009
Al	6.462	5.5896
As	0	0.015
B	0	0.13
Ba	0.023	0.478
Be	0	0
Bi	0	0
Ca	3.422	2.8493
Cd	0.017	0
Cl	0	0

Substances of Interest	Coal Dust [(a)]	Combustion [(b)]
Co	0.945	0
Cr	0.004	0.152
Cu	0.006	0.059
F	0	0
Fe	0.418	2.6446
Hg	0	0.053
K	0.63	0.6199
Li	0	0
Mg	0	0.9
Mn	0.004	0.112
Mo	0	0
Na	0	0.8
NH4	0	1.0621
Ni	0	0.03
NO2	0	0
NO3	0	2.129
P	0.117	0.467
Pb	0.034	1.3
Phenanthrene	0	0.004
S	0.461	2.7
Sb	0.018	0
Se	0	0.066
Si	14.617	8.7487
Sn	0.008	0
SO4	0	4.9
Sr	0.015	0.2078
Ti	0.197	0.4797
Tl	0	0
U	0	0
V	0	0.06
Zn	0.01	0.16
Zr	0	0.0403
Acridine	0	0.004
Benzo(e)pyrene	0	0.002
Benzo[a]pyrene	0	0.003
Chrysene	0	0.004
Fluoranthene	0	0.009
Pyrene	0	0.015

Notes:
Profile data obtain from US EPA's SPECIATE 5.1.
(a) Two profiles were available for coal dust PM10, to be conservative the maximum weight percent of each species was used.
(b) Combustion profiles for boilers, heavy duty vehicles and diesel engines were used, to be conservative, the maximum weight percent of each species was used.

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Appendix C Bioaccumulation Factors and Concentration Ratios

1 Introduction

This appendix summarized the methods used to estimate the concentrations of contaminants of potential concern (COPCs) in dietary items and tissues for the human health and wildlife health risk assessments.

In the absence of measured tissue concentrations (or measurable in the case of prospective risk assessment) the concentrations of COPCs in tissues (plants, animals, etc.) are calculated using measured of predicted concentrations of COPCs in environmental media (soil or water) in combination with element specific media-to-whole organisms concentration ratios.

Concentration ratios assume equilibrium between the organism and the environmental media in which it resides. The concentration ratio approach is the preferred approach in the present HHERA because of:

i. it's simplicity and user-friendliness;
ii. the relatively large amount of relevant information available for organisms, elements and ecosystems compared to other methods of quantifying transfer; and
iii. the common use of this parameter in existing environmental exposure assessment models.

Wildlife transfer parameters are primarily obtained from the Wildlife Transfer Parameter Database (version 1,3) available at https://www.wildlifetransferdatabase.org/.

1.1 Soil-to-Whole-Organism Concentration Ratios

The concentration of COPCs in wildlife tissues whose home range significantly overlaps the LSA were determined using concentration ratios between the organism and its associated environmental media. Unless otherwise noted, concentrations of COPCs in terrestrial wildlife and plant tissues were calculated based on soil-to-whole organisms concentration ratios (Table 1) sourced from the Wildlife Transfer Parameter Database (v 1.3).

Table 1: Soil-to-whole organism concentration ratios used in the quantitative assessment.

Tissue Type	COPC						
	As	Cd	Co	Cr	Ni	Se	Tl
Annelid	3.09E-1	4.24E+0	2.12E-2	2.77E-2	7.19E-2	3.12E+0	3.69E-2
Arthropod	2.19E-2	3.32E+0	7.07E-3	3.14E-3	1.17E-2	1.40E-1	2.67E-2
Mammal	3.04E-4	3.60E-1	2.80E-1	1.70E-3	1.08E-1	1.70E-1	NA
Rangifer	NA	1.44E-1	7.79E-3	4.71E-5	NA	6.98E-1	NA
Bird	NA	9.77E-3	1.30E-2	9.20E-2	NA	3.52E-1	NA
Lichen/Bryophyte	4.09E-1	1.44E-1	8.42E-2	5.59E-2	2.40E-1	1.38E-1	6.78E-2
Berry[(b)]	4.39E-3	4.20E-2	5.68E-3	3.33E-3	4.08E-2	2.50E-1	1.13E-2
Fungi	2.80E-1[(a)]	8.40E-1[(a)]	2.40E-1[(a)]	4.00E-2[(a)]	7.50E-2[(a)]	1.38E-1[(d)]	6.78E-2[(d)]
Plant Tissue[(c)]	7.56E-3	1.14E-1	1.10E-2	7.91E-3	4.54E-2	2.50E-1	1.50E-2

Notes:
a) Heavy metals transfer factors from soil to edible mushrooms derived as median value of Sithole et al (2017) for white button mushrooms from trace metal polluted soils.
b) Site specific concentration ratio calculated based on dry weight concentrations of COPCs in soil and collocated berry samples.
c)Site specific concentration ratio base on dry weight concentrations in soil and collocated vegetation samples.

d) Based on Wildlife Transfer Parameter Database values for lichen and bryophytes.

NA – Concentration ratio not available. Tissue ingestion by wildlife receptors assumed to be a negligible contributor to overall dose.

1.1.1 Predicted Large Mammal Tissue Concentrations for Human Consumption

Concentrations of COPCs in large mammals was calculated based on calculated intake, and feed-to-beef transfer factors (RAIS, 2015). For the purposes of this assessment, these transfer factors were assumed to

Represent all large mammals consumed by humans. Transfer factors used in the quantitative assessment are presented in Table 2.

Table 2: Feed-to-beef transfer factors used for prediction of large mammal tissue quality.

COPC	Feed-to-Beef Transfer Factor (d/kg)
As	2e-3 d/kg
Cd	5.8e-3 d/kg
Co	4.3e-4 d/kg
Cr	5.5e-3 d/kg
Ni	6e-3 d/kg
Se	0.015 d/kg
Tl	0.04 d/kg

1.2 Freshwater-to-Whole-Organism Concentration Ratios

1.2.1 Fish

Concentration of COPCs in fish tissue was calculated based on site specific surface water-to-whole organism concentration ratios. Concentration ratios were calculated based on measured concentration of total COPC concentration in water, to measured concentration in collected fish tissues. Concentration ratios were calculated for each of Alexander Creek and Grave Creek, with the arithmetic mean of the two used as the final concentration ratio for the quantitative assessment.

In consideration of the limited data and uncertainties associated with calculating water-to-whole organism tissue concentrations, the calculated site-specific concentration ratios were validated by comparing the calculated value to a reasonable upper bound (defined as the mean + 2 standard deviations) of the literature derived value. Site specific concentration ratios that fell outside this value were considered to be unreliable, and the arithmetic mean of the concentration ratios presented in the wildlife transfer database was used. Freshwater-to-whole organisms concentration ratios used to predict the concentration of COPCs in fish tissues are presented in Table 3.

Table 3:Water-to-Fish Tissue Concentration Ratios.

COPC	Water-to-Whole Organism Concentration Ratio ((mg/kg)/(mg/L))	Source
As	364.7	Site Specific Value
Cd	3207	Site Specific Value
Co	264.1	WTD Version 1.3

Cr	195.6	WTD Version 1.3
Ni	200	WTD Version 1.3
Se	1071	Site Specific Value
Tl	7134	Site Specific Value

1.2.1.1 Fish Eggs

Concentrations of COPCs in fish eggs, with the exception of selenium, are assumed to be equivalent to the predicted concentration in fish tissue. For selenium, concentration predicted in fish eggs is based on the two-step selenium bioaccumulation model (TECK, 2014[1])

1.2.1.2 Bird Eggs

Concentrations of COPCs in fish eggs, with the exception of selenium, are assumed to be equivalent to the predicted concentration in fish tissue. For selenium, concentration predicted in fish eggs is based on the two-step selenium bioaccumulation model (TECK, 2014[1])

1.2.1.3 Other Aquatic Tissues

Other aquatic tissues included in the multimedia food web include freshwater insects, aquatic plants, and shellfish. Tissue concentrations of these potential prey items are calculated using fresh water-to-whole organism concentration ratios Table 4.

Table 4: Water-to-Aquatic Tissue Concentration Ratios

COPC	Water-to-Whole Organism Concentration Ratio ((mg/kg)/(mg/L))		
	Aquatic Plants	Aquatic Insects	Freshwater Crustaceans
As	23.32	NA	375.5
Cd	3586	169653	27744
Co	928.1	1851	1851
Cr	365	1318	NA
Ni	518.4	1851	NA
Se	223	3193	440.7
Tl	14914	2500	1028

[1] Elk Valley Water Quality Plan (TECK, 2014) is available at https://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/mining-smelt-energy/area-based-man-plan/evwq_full_plan.pdf

Appendix D Ecological Receptor Characteristics

1 Introduction

The following appendix summarizes wildlife receptor parameters used as inputs to the multimedia food chain model and wildlife exposure assessment.

1.1 Foraging Range

Receptor foraging range considered in the present assessment is presented in Table 1. No exposure adjustment was made based on foraging range for receptors with a foraging range less than 1,000 hectares. Receptors with extremely large foraging ranges were subject to an adjustment based on the ratio of the receptor foraging range and an assumed 1,000 hectare exposure are centered on each critical receptor location.

Table 1: Foraging Range of Wildlife Receptors

Wildlife Receptor	Home Range (ha)	Source
American Badger	3500	Hatler et al. 2008
American Marten	230	Reid and Helgen 2008
Bighorn Sheep	541	Demarchi 2004
Canada Goose	983	US EPA 1993
Canada Lynx	39,550	Hatler et al. 2008
Common Merganser	697	Environment Canada 2012
Common Raven	103.5	Roth et al. 2004
Deer Mouse	0.25	Environment Canada 2012
Elk	4506	Edge et al. 1985
Grizzly Bear	40,000	Minister of the Environment 1991
Least Chipmunk	0.66	Verts and Carraway 2001
Little Brown Myotis	65	n/a
Masked Shrew	0.04	Nocera and Dawe 2008
Moose	13,330	Environment Canada 2012
Northern Goshawk	273	Squires and Reynolds 1997
Northern River Otter	12,000	Environment Canada 2012
Snowshoe Hare	5.9	Environment Canada 2012
White-tailed Ptarmigan	44	Giesen and Braun 1992
Mallard	434	US EPA 1993
American Dipper	1.74	Wilson and Kingery 2011

1.1.1 Body Weight

Bodyweights of identified receptors are presented in Table 2.

Table 2: Body Weight of Wildlife Receptors

Wildlife Receptor	Body Weight (kg)	Source
American Badger	8	Eder and Pattie 2001
American Marten	0.85	Eder and Pattie 2001
Bighorn Sheep	105	Eder and Pattie 2001
Canada Goose	4.39	Dunning 1984(a)

Wildlife Receptor	Body Weight (kg)	Source
Canada Lynx	12.5	Eder and Pattie 2001
Common Merganser	1.47	Dunning 1984
Common Raven	1.2	Dunning 1984
Deer Mouse	0.03	Eder and Pattie 2001
Elk	340	Eder and Pattie 2001
Grizzly Bear	320	Eder and Pattie 2001
Least Chipmunk	0.05	Eder and Pattie 2001
Little Brown Myotis	0.075	Sample and Suter 1994
Masked Shrew	0.005	Eder and Pattie 2001
Moose	385	Eder and Pattie 2001
Northern Goshawk	1.02	Dunning 1984
Northern River Otter	7.5	Environment Canada 2012
Snowshoe Hare	1.25	Eder and Pattie 2001
White-tailed Ptarmigan	0.35	Dunning 1984
Mallard	1.08	Dunning 1984
American Dipper	0.06	Dunning 1984

(a) Mean of reported values for Canada goose.

1.1.2 Diet

Dietary preferences were based on the feeding behaviour of the individual species selected as receptors for this study.

Table 3: Dietary Preferences of Receptors Used in Food Chain Model

Item	Diet	Source
American Badger	95% small mammal, 5% terrestrial invertebrates	Eder and Pattie 2001
American Marten	40% small mammal, 40% medium mammal, 10% terrestrial invertebrates, 10% berries	Eder and Pattie 2001
Bighorn Sheep	50% grasses herbs; 50% leaves	Todd 1975
Canada Goose	50% aquatic plants; 50% grasses herbs	Mowbray et al. 2002
Canada Lynx	90% small mammal, 10% medium mammals	Eder and Pattie 2001
Common Merganser	100% fish	Mallory and Metz 1999
Common Raven	15% grasses herbs; 20% berries; 25% terrestrial invertebrates; 20% small mammal, 20% medium mammals	Boarman and Heinrich 1999
Deer Mouse	50% terrestrial invertebrates, 50% grasses herbs	Eder and Pattie 2001
Elk	50% grasses herbs, 50% Leaves	Stevens 1966
Grizzly Bear	20% berries, 20% leaves; 35% grasses herbs; 10% fish; 10% large mammals; 5% terrestrial invertebrates	Eder and Pattie 2001
Least Chipmunk	10% terrestrial invertebrates; 20% leaves; 20% grasses herbs, 50% berries	Eder and Pattie 2001; Verts and Carraway 2001

Item	Diet	Source
Little Brown Myotis	100% terrestrial invertebrates	British Columbia Conservation Data Centre 2015
Masked Shrew	100% terrestrial invertebrates	Nagorsen, 1996; Eder and Pattie 2001
Moose	60% leaves; 20% grasses herbs; 20% aquatic plants	Eder and Pattie 2001
Northern Goshawk	50% small mammals; 50% medium mammals	Squires and Reynolds 1997
Northern River Otter	80% fish; 15% aquatic invertebrates; 5% small mammals	*Federal Contaminated Sites Action Plan* (FCSAP) 2012; United States Environmental Protection Agency (US EPA) 1993; Eder and Pattie 2001
Snowshoe Hare	40% grasses herbs; 50% leaves; 10% berries	Eder and Pattie 2001
White-tailed Ptarmigan	50% leaves; 20% berries, 20% grasses herbs; 10% terrestrial invertebrates	Braun et al. 1993
Mallard	40% aquatic plants; 40% grasses herbs; 20% aquatic invertebrates	Drilling et al. 2002
American Dipper	100% aquatic invertebrates	Wilson and Kingery 2011

1.1.3 Ingestion Rates

The ingestion rates used for each receptor are presented in Table 4. Ingestion rates are presented in wet weight and dry weight basis. Ingestion rates were converted from wet weight to dry weight based on the total % moisture in the receptors diet, presented in Table 5.

Table 4: Ingestion Rates

Wildlife Receptor	Food Ingestion (kg/day ww)	Source	Soil Ingestion (%)	Source	Soil Ingestion (kg/day dw)[4]	Sediment Ingestion (%)[3]	Source	Sediment Ingestion (kg/day dw)[4]	Water Ingestion Rate (L/day)	Source
American Badger	1.22	US EPA 1993(b)	2	Assumed based on dietary preferences	0.0244	0		0	0.64	US EPA 1993(d)
American Marten	0.35	US EPA 1993(b)	2	Assumed based on dietary preferences	0.007	0		0	0.09	US EPA 1993(d)
Bighorn Sheep	7.77	US EPA 1993(b)	2	assumed to be the same as elk	0.1554	0		0	6.53	US EPA 1993(d)
Canada Goose	0.48	US EPA 1993(a)	4.1	Beyer et al. 1994	0.019657	4.1		0.019657	0.16	US EPA 1993(c)
Canada Lynx	1.71	US EPA 1993(b)	0	Assumed based on dietary preferences	0	0		0	0.96	US EPA 1993(d)
Common Merganser	0.31	US EPA 1993(a)	0	Assumed based on dietary preferences	0	0		0	0.08	US EPA 1993(c)
Common Raven	0.21	US EPA 1993(a)	2.6	Sample and Suter 1994; applied robin value and adjusted to eating 25% earthworms (assume	0.00546	0		0	0.07	US EPA 1993(c)

Wildlife Receptor	Food Ingestion (kg/day ww)	Source	Soil Ingestion (%)	Source	Soil Ingestion (kg/day dw)[4]	Sediment Ingestion (%)[3]	Source	Sediment Ingestion (kg/day dw)[4]	Water Ingestion Rate (L/day)	Source
				primary source of soil is from eating worms)						
Deer Mouse	0.01	US EPA 1993(b)	2	Sample and Suter 1994; white-footed mouse	0.0002	0		0	0.004	US EPA 1993(d)
Elk	20.41	US EPA 1993(b)	2	Beyer et al 1994	0.405734	0		0	18.79	US EPA 1993(d)
Grizzly Bear	22.96	US EPA 1993(b)	1	Mattson 1999	0.2296	0		0	17.79	US EPA 1993(d)
Least Chipmunk	0.02	US EPA 1993(b)	2.4	Sample and Suter 1994; assumed similar to meadow vole based on dietary preferences	0.000476	0		0	0.007	US EPA 1993(d)
Little Brown Myotis	0.0056	US EPA 1993(b)	0	Assumed based on dietary preferences	0	0		0	0.0012	US EPA 1993(d)
Masked Shrew	0.01	US EPA 1993(b)	13	Sample and Suter 1994; short-tailed shrew	0.0013	0		0	0.001	US EPA 1993(d)

Wildlife Receptor	Food Ingestion (kg/day ww)	Source	Soil Ingestion (%)	Source	Soil Ingestion (kg/day dw)[4]	Sediment Ingestion (%)[3]	Source	Sediment Ingestion (kg/day dw)[4]	Water Ingestion Rate (L/day)	Source
Moose	35.56	US EPA 1993(b)	2	Beyer et al 1994	0.7112	0		0	21.02	US EPA 1993(d)
Northern Goshawk	0.18	US EPA 1993(a)	0	Sample and Suter 1994; red-tailed hawk	0	0		0	0.06	US EPA 1993(c)
Northern River Otter	1.5	US EPA 1993(b)	0	Assumed based on dietary preferences	0	0		0	0.61	US EPA 1993(d)
Snowshoe Hare	0.22	US EPA 1993(b)	6.3	Sample and Suter 1994; eastern cottontail	0.01386	0		0	0.12	US EPA 1993(d)
White-tailed Ptarmigan	0.1	US EPA 1993(a)	2	Assumed based on dietary preferences	0.002	0		0	0.03	US EPA 1993(c)
Mallard	0.2	US EPA 1993(a)	1.65	Beyer et al. 1994	0.0033	1.65		0.0033	0.06	US EPA 1993(c)
American Dipper	0.042	US EPA 1993(a)	0	Assumed based on dietary preferences	0	2		0.00084	0.009	US EPA 1993(c)

Notes:

Soil ingestion of 0 indicates a negligible amount of soil ingestion by receptor.

Soil/Sediment ingestion % based assumed based on dietary preferences or from Saple and Suter 1994, Mattson 1999, or Beyer et al. 1994

Table 5: Percent moisture of dietary items used in food chain model

Food Item	% Moisture	Source
Small Mammals	68	US EPA 1993
Medium Mammals	68	US EPA 1993
Large Mammals	68	US EPA 1993
Terrestrial Invertebrates	84	US EPA 1993
Aquatic Invertebrates	78	US EPA 1993
Grasses Herbs	51.7	Golder, 2015
Aquatic Plants	87	US EPA 1993
Leaves	61.3	Golder, 2015
Berries	76.4	Golder, 2015
Fish	75.5	Golder, 2015
Seeds	9.7	Roberts, E.H. (ed.) (1972) Seed Viability. Chapman and Hall, London.

Notes:

1 IRdw = IRww x [(100 -%MC)/100]

2 Soil ingestion of 0 indicates a negligible amount of soil ingestion by receptor.

3 Soil/Sediment ingestion % based assumed based on dietary preferences or from Saple and Suter 1994, Mattson 1999, or Beyer et al. 1994

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Appendix E Exposure Point Concentrations for Baseline, Application, and Cumulative Assessment Cases

The current appendix provides the exposure point concentrations for all abiotic and biotic media in the multimedia food-web and exposure model. As described in Appendix A, the multimedia and exposure model GoldSim player file provides a graphical representation of the links between abiotic and biotic media and allows for a complete and transparent inspection of the model elements, data inputs, calculations within the model, and all model outputs.

The reader is directed to Appendix A and the GoldSim player file (filename: App A_MOD_Crown Mountain HHERA_60590462.gsp) for a complete database of exposure point concentrations used in the present HHERA.

The GoldSim player file (filename: App A_MOD_Crown Mountain HHERA_60590462.gsp) can be made available upon request by NWP Coal Canada Ltd. or AECOM Canada Ltd.

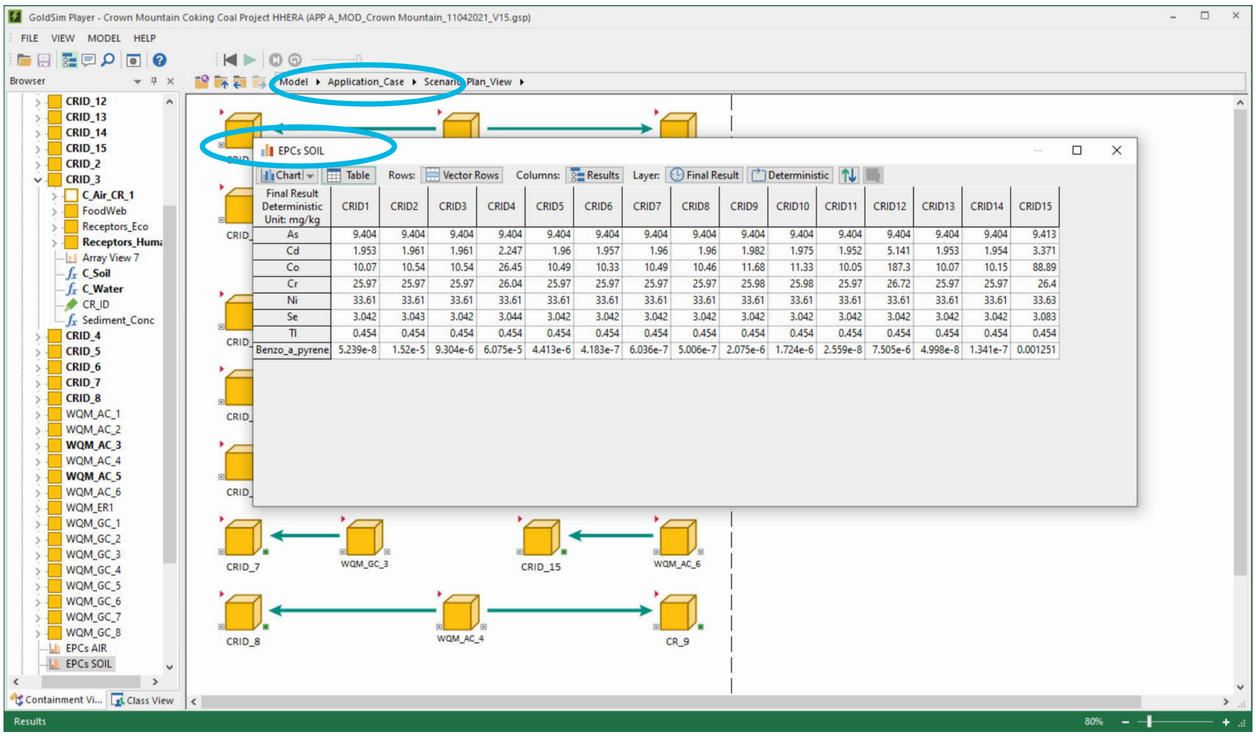

Figure 1: Screen capture of GoldSim Player result element showing exposure point concentrations (mg/kg) for soil at all critical receptor locations under the application case.

Appendix F Multimedia Contaminant Screening

Introduction

The current appendix provides the objectives and outcome of a quantitative screening of Contaminants of Potential Concern (COPCs) that may be nominated for further study and input into the Human Health and Ecological Risk Assessment. The specific objective of the screening is to create a broad and inclusive framework for the identification of substances of interest (SOI), defined as substances with the potential to be present in any compartment of the mine process or lifecycle that may have the ability to alter the current baseline conditions of environmental media by a significant degree.

Screening Framework

A broad screening framework (depicted in Figure 1 below) was used to identify substances of interest. The screening framework consists of three broad tracks as follows:

1. Substances whose maximum measured concentration in site media exceed applicable guidelines will be retained as substances of interest. Substances which are in compliance with the aforementioned EQGs will not be retained as substances of interest.
2. A lack of federal or provincial EQGs does not preclude risks to human health. As such, substances for which there are no EQGs will be screened based on site specific background concentrations. Substances whose maximum measured concentration in site media exceed site specific background concentrations will be retained as substances of interest. Substances which are in compliance with site specific background concentrations will not be retained as substances of interest.
3. If no suitable EQG or background data is available, further qualitative assessment based on professional judgement and the precautionary principle is required. Substances may be retained as a SOI if appropriate regulatory bodies (such as Health Canada, US EPA, World Health Organization or others) indicate toxicity, and suitable toxicological data exists upon which to base an assessment.

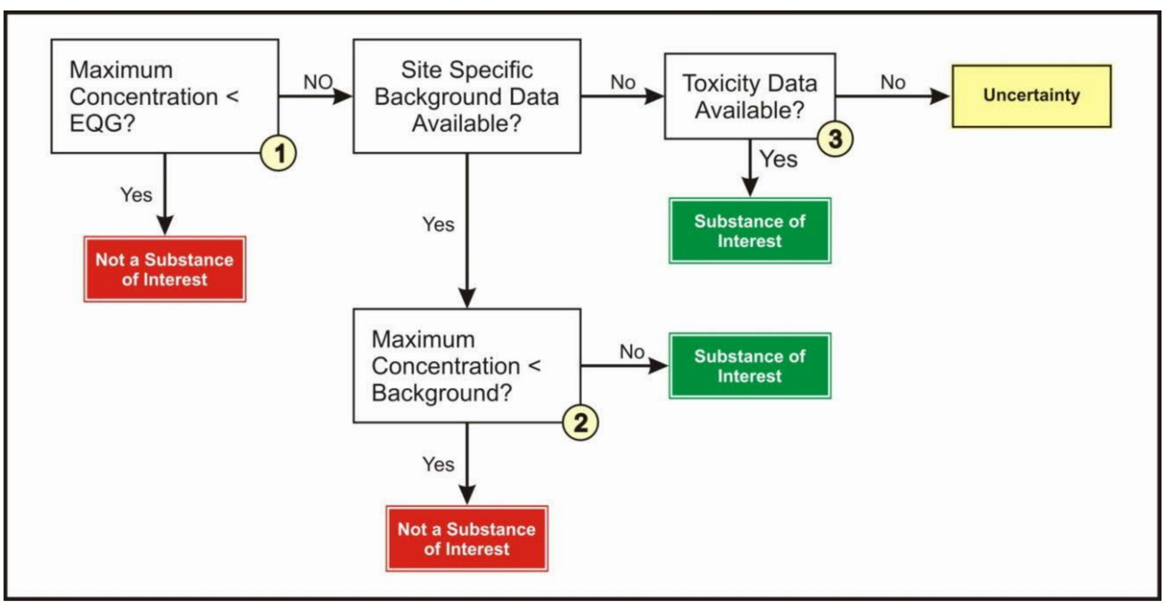

Figure 1: General Framework for Identification of Substances of Interest

Screening and COPCs Identified by Media

Soil

Particulate emissions associated with project activities have the potential to accumulate in soils within the local study area as a result of particulate deposition and mixing with surficial soil horizons. This pathway represents a defined uncontrolled release from the Project.

Predicted concentrations of all substances of interest (defined as those substances modeled in the air quality and deposition model) were screened relative to soil quality guidelines protective of human and ecological health (Table 1).

Soil screening identified selenium cadmium and cobalt as potential COPCs in soil.

Surface Water

Residual effects to surface water quality, specifically within Alexander Creek which will be a receiver of treatment pond effluent, are predicted as a result of Project activities (SRK, 2021). Effluent discharge from the Project site is predicted to have a measurable effect on surface water quality and as such this pathway is considered to be of primary importance to the overall quantitative environmental risk assessment.

Predicted concentrations of substances of interests, defined as all elements or compounds included in the SRK (2021) Surface Water Quality Model Report, were screened relative to water quality guidelines protective of freshwater aquatic life (Table 2), and use as a drinking water source (Table 3).

Surface water screening identified cadmium, cobalt, and selenium as contaminants of potential concern.

Sediment

Changes to surface water quality can potentially influence sediment chemistry in receiving waterbodies. Changes to sediment quality is a function of predicted changes to surface water quality, and as such is considered as a secondary pathway. Surface runoff from the Clean Coal Transfer Area is captured in a sediment pond with discharge from this pond reporting to node GC-7 upstream of the Grave Creek Reservoir. Surface runoff from the Rail Loadout area is captured and routed into the Rail Loop Sump, which is designed to be a non-discharge infiltration facility. Discharge from various mine related infrastructure along Grave Creek indicate very little impact to local stream quality (SRK, 2021) associated with proposed mine activities.

Predicted changes to sediment quality are considered to have a significant degree of uncertainty, asn is a secondary pathway which is entirely dependent on the modelled surface water quality results. As such screening of sediment quality was limited to those receptors where a connection between site effluent and the receiving environment can be demonstrated.

Screening for contaminants of concern based on predicted changes to sediment quality identified arsenic, cadmuium, nickel and selenium as COPCs.

Table 1: Predicted soil quality screening for protection of human and environmental health.

SOI	BC CSR 3.1 Part 1 HH Intake	BC CSR 3.1 Part 1 GW>DW	BC CSR 3.1 Part 1 P+Inv.	BC CSR 3.1 Part 1 GW>FAL	BC CSR 3.1 Part 2 HH	CCME Soil Quality Guidelines SQG_E	CCME Soil Quality Guidelines SQG_{HH}	Baseline Concentration	Maximum Predicted Soil Concentration
Ag					400	20	20	4.9E-1	4.9E-1
Al					40000			2.7E+4	2.8E+4
As	40	10	15	10		17	12	9.4E+0	9.4E+0
B					15000			2.1E+1	2.1E+1
Ba	15000	350	350	3500			500	4.6E+2	4.6E+2
Be*	150	4	75	4			4	1.3E+0	1.3E+0
Bi								3.5E-1	3.5E-1
Ca								5.3E+4	5.4E+4
Cd	40	1	15	1			10	**2.0E+0**	**5.1E+0**
Co	25	25	25	25			50	1.0E+1	**1.9E+2**
Cr	250	60	100	60			64	2.6E+1	2.7E+1
Cu*	7500	10000	85	700			63	3.1E+1	3.2E+1
Fe					35000			2.8E+4	2.8E+4
Hg	25		25				6.6	8.5E-2	8.7E-2
K								3.3E+3	3.4E+3
Li					65			3.1E+1	3.1E+1
Mg								7.8E+3	7.8E+3
Mn	10000	2000	2000					1.2E+3	1.2E+3
Mo	400	15	60	650			10	3.5E+0	3.5E+0
Na	1000000	15000	150					1.5E+2	1.5E+2
Ni*	900	70	100	200			45	3.4E+1	3.4E+1
Pb	120	800	400	8500			140	2.0E+1	2.7E+1
Phenanthrene					3500	5		5.3E-2	5.3E-2
S								2.8E+3	2.9E+3
Sb					500	20		1.4E+0	4.8E+0
Se	400	1	1.5	1			1	**3.0E+0**	**3.0E+0**
Sn					50000	50	5.00E+01	2.0E+0	3.5E+0
Sr					20000			2.0E+2	2.0E+2
Ti								3.9E+2	4.3E+2
Tl						9	1.00E+00	4.5E-1	4.5E-1
U	250	30	300	150			23	2.4E+0	2.4E+0
V	400	100	100				1.30E+02	5.1E+1	5.1E+1
Zn*	25000	450	300	250			250	1.6E+2	1.6E+2
Zr								6.4E+0	6.4E+0
Acridine								NV	1.2E-4
Benzo(e)pyrene	1.00E+01		1.50E+01					NV	6.1E-5
Benzo[a]pyrene						5.30E+00	20	5.0E-3	5.1E-3
Chrysene							6.2	1.0E-2	1.0E-2
Fluoranthene	1.50E+03		2.00E+02				50	5.0E-3	5.3E-3
Pyrene							0.1	5.0E-3	5.5E-3

Notes:

Shaded cells indicated inclusions as a COPC

Table 2: Surface water quality screening protective of freshwater aquatic life.

SOI	BC WQG Chrionic[a,b]	BC WQG Acute[a,b]	BC CSR Schedule 3.2 (FW)	CCME) Long Term[c]	CCME Short Term[c]	Federal EQG[d]	Min. Applicable Guideline	AC_1	AC_2	AC_3	AC_4	AC_5	AC_6	ER1	AC Bkg.	GC_1	GC_2	GC_3	GC_4	GC_5	GC_6	GC_7	GC_8	GC Bkg.
Ag	1.5E-03	3.0E-03		2.5E-04			6.7E-6	6.9E-6	8.6E-6	5.0E-6	2.5E-5	2.5E-5	1.1E-6	5.0E-6	7.5E-6	8.1E-6	5.0E-6	1.0E-5	5.0E-6	5.0E-6	5.1E-6	5.0E-6	5.0E-6	6.7E-6
Al	5.0E-02	1.0E-01		Variable			7.1E-3	7.2E-3	7.5E-3	6.8E-3	1.1E-2	1.1E-2	1.2E-3	7.3E-3	7.1E-3	7.1E-3	6.8E-3	7.4E-3	6.8E-3	6.8E-3	6.9E-3	6.8E-3	1.6E-2	7.1E-3
As	5.0E-03			5.0E-03			1.7E-4	1.8E-4	2.2E-4	1.2E-4	6.8E-4	6.7E-4	2.5E-5	1.4E-4	1.6E-4	1.7E-4	1.3E-4	1.9E-4	1.3E-4	1.2E-4	1.3E-4	1.2E-4	1.8E-4	1.7E-4
B	1.2E+00			1.5E+00	2.9E+01		5.1E-2	5.1E-2	5.2E-2	5.0E-2	5.9E-2	5.6E-2	7.3E-3	5.0E-2	3.0E-2	2.5E-2	5.0E-2	1.0E-2	5.0E-2	5.0E-2	5.1E-2	5.0E-2	5.0E-2	5.1E-2
Ba			1.0E+01				4.2E-2	4.3E-2	4.9E-2	3.6E-2	1.1E-1	1.1E-1	7.4E-3	4.1E-2	5.3E-2	5.8E-2	3.6E-2	7.1E-2	3.6E-2	3.6E-2	3.7E-2	3.6E-2	7.9E-2	4.2E-2
Be	1.3E-04						1.6E-5	1.7E-5	2.2E-5	1.0E-5	7.9E-5	7.8E-5	4.6E-6	1.0E-5	5.4E-5	6.6E-5	1.0E-5	1.0E-4	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.6E-5
Cd	2.6E-04	8.0E-04		2.0E-04	2.8E-03		4.4E-5	4.9E-5	8.1E-5	1.2E-5	**4.0E-4**	**4.0E-4**	4.3E-6	1.1E-5	1.8E-5	2.0E-5	1.2E-5	2.5E-5	1.2E-5	1.2E-5	1.2E-5	1.2E-5	1.3E-5	4.4E-5
Cl	1.5E+02	6.0E+02		1.2E+02	6.4E+02		7.9E-1	7.9E-1	7.9E-1	7.9E-1	7.6E-1	6.8E-1	1.7E-1	8.9E-1	1.4E+0	1.6E+0	8.0E-1	2.1E+0	8.0E-1	7.9E-1	8.1E-1	7.9E-1	1.4E+0	7.9E-1
Co	4.0E-03	1.1E-01				1.2E-03	**1.8E-3**	**2.0E-3**	**3.7E-3**	1.6E-5	**2.1E-2**	**2.1E-2**	1.4E-4	1.6E-5	5.7E-5	6.8E-5	1.6E-5	1.0E-4	1.6E-5	1.6E-5	1.7E-5	1.6E-5	3.0E-5	1.8E-3
Cr	1.0E-03					5.0E-03	3.9E-4	3.9E-4	4.0E-4	3.7E-4	5.3E-4	5.1E-4	5.8E-5	3.6E-4	2.9E-4	2.7E-4	3.7E-4	2.0E-4	3.7E-4	3.7E-4	3.8E-4	3.7E-4	2.3E-4	3.9E-4
Cu	5.4E-03	1.5E-02		3.1E-03			6.4E-4	6.6E-4	7.3E-4	5.7E-4	1.5E-3	1.5E-3	9.7E-5	5.7E-4	5.3E-4	5.3E-4	5.7E-4	5.0E-4	5.7E-4	5.7E-4	5.8E-4	5.7E-4	6.7E-4	6.4E-4
F	1.5E+00			1.5E+00			1.8E-1	1.8E-1	1.8E-1	1.8E-1	1.7E-1	1.5E-1	2.5E-2	3.0E-1	9.2E-2	6.9E-2	1.8E-1	0.0E+0	1.8E-1	1.8E-1	1.8E-1	1.8E-1	2.4E-1	1.8E-1
Fe	3.5E-01			3.0E-01			6.5E-3	6.5E-3	7.0E-3	6.0E-3	1.1E-2	1.1E-2	1.2E-3	6.1E-3	8.0E-3	8.5E-3	6.0E-3	1.0E-2	6.1E-3	6.0E-3	6.2E-3	6.0E-3	2.2E-2	6.5E-3
Hg	2.0E-05			2.6E-05			1.0E-5	1.0E-5	9.9E-6	1.0E-5	9.5E-6	8.5E-6	1.7E-6	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5
Mn	1.2E+00	2.0E+00		Variable	Equation		3.5E-3	4.0E-3	7.2E-3	2.0E-4	3.9E-2	3.9E-2	3.9E-4	2.6E-4	2.8E-3	3.5E-3	2.0E-4	5.5E-3	2.0E-4	2.0E-4	2.0E-4	2.0E-4	1.5E-3	3.5E-3
Mo	Variable	2.0E+00		7.3E-02			2.7E-3	2.9E-3	4.6E-3	8.9E-4	2.2E-2	2.2E-2	2.5E-4	9.1E-4	9.4E-4	9.5E-4	9.0E-4	9.9E-4	9.0E-4	8.9E-4	9.2E-4	8.9E-4	1.7E-3	2.7E-3
NH4			1.3E+00				2.6E-2	2.6E-2	2.6E-2	2.6E-2	2.5E-2	2.2E-2	3.6E-3	3.8E-2	1.3E-2	1.0E-2	2.6E-2	0.0E+0	2.6E-2	2.6E-2	2.7E-2	2.6E-2	4.6E-2	2.6E-2
Ni	Variable	N/A		1.5E-01			4.7E-3	5.4E-3	9.7E-3	2.4E-4	5.3E-2	5.3E-2	4.0E-4	3.1E-4	6.0E-4	6.9E-4	2.4E-4	9.7E-4	2.4E-4	2.4E-4	2.4E-4	2.4E-4	5.0E-4	4.7E-3
NO2	2.0E-02	6.0E-02					5.0E-3	5.0E-3	5.0E-3	5.0E-3	4.8E-3	4.5E-3	8.4E-4	5.0E-3	5.0E-3	5.0E-3	5.0E-3	5.0E-3	5.0E-3	5.0E-3	5.1E-3	5.0E-3	8.5E-3	5.0E-3
NO3	3.0E+00	3.3E+01		1.3E+01	5.5E+02		1.0E-1	1.1E-1	1.1E-1	1.0E-1	1.6E-1	1.5E-1	1.2E+0	1.2E-1	6.6E-1	8.1E-1	1.0E-1	1.3E+0	1.0E-1	1.0E-1	1.0E-1	1.0E-1	1.4E-1	1.0E-1
P	5.0E-03						1.4E-5	1.6E-5	3.0E-5	0.0E+0	1.7E-4	1.7E-4	4.4E-4	2.3E-2	7.2E-3	9.1E-3	0.0E+0	1.5E-2	0.0E+0	0.0E+0	0.0E+0	0.0E+0	1.6E-1	1.4E-5
Pb	8.0E-03	1.2E-01		Equation			4.4E-5	4.6E-5	6.1E-5	2.9E-5	2.1E-4	2.1E-4	6.1E-6	3.4E-5	3.9E-5	4.2E-5	2.9E-5	5.0E-5	2.9E-5	2.9E-5	2.9E-5	2.9E-5	3.2E-5	4.4E-5
Phenanthrene			3.0E-03				2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	NP	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	NP	2.0E-5
Sb	9.0E-03						2.1E-4	2.4E-4	4.2E-4	3.1E-5	2.2E-3	2.2E-3	1.9E-5	3.1E-5	6.5E-5	7.4E-5	3.1E-5	1.0E-4	3.1E-5	3.1E-5	3.2E-5	3.1E-5	4.9E-5	2.1E-4
Se	2.0E-03			1.0E-03			**2.2E-3**	**2.3E-3**	**3.0E-3**	**1.5E-3**	**9.7E-3**	**9.6E-3**	**8.8E-3**	**1.4E-3**	**2.4E-2**	**3.0E-2**	**1.5E-3**	**4.8E-2**	**1.5E-3**	**1.5E-3**	**1.6E-3**	**1.5E-3**	**2.3E-3**	**2.2E-3**
Sn								2.0E-4	2.0E-4	2.0E-4	1.9E-4	1.8E-4	3.1E-5	2.0E-4	1.5E-4	1.4E-4	2.0E-4	1.0E-4	2.0E-4	2.0E-4	2.1E-4	2.0E-4	2.0E-4	2.0E-4
SO4	3.1E+02						3.5E+1	3.6E+1	4.2E+1	2.9E+1	1.0E+2	1.0E+2	1.7E+2	3.1E+1	1.3E+2	1.5E+2	2.9E+1	2.3E+2	2.9E+1	2.9E+1	2.9E+1	2.9E+1	2.9E+1	3.5E+1
Sr						2.5E+00	3.8E-2	3.8E-2	3.8E-2	3.8E-2	3.7E-2	3.3E-2	9.7E-3	1.1E-1	9.0E-2	1.0E-1	3.8E-2	1.4E-1	3.8E-2	3.8E-2	3.9E-2	3.8E-2	1.9E-1	3.8E-2
Ti			1.0E+00				5.0E-4	5.0E-4	5.0E-4	5.0E-4	4.8E-4	4.5E-4	4.0E-4	5.0E-4	5.7E-3	7.0E-3	5.0E-4	1.1E-2	5.0E-4	5.0E-4	5.1E-4	5.0E-4	5.0E-4	5.0E-4
Tl				8.0E-04			4.0E-6	4.1E-6	4.9E-6	3.2E-6	1.3E-5	1.3E-5	7.8E-7	5.0E-6	6.5E-6	7.4E-6	3.2E-6	1.0E-5	3.2E-6	3.2E-6	3.3E-6	3.2E-6	6.0E-6	4.0E-6
U	8.5E-03			1.5E-02	3.3E-02	1.2E-01	8.9E-4	9.1E-4	1.0E-3	7.6E-4	2.2E-3	2.2E-3	2.0E-4	8.4E-4	1.9E-3	2.1E-3	7.6E-4	3.0E-3	7.6E-4	7.6E-4	7.8E-4	7.6E-4	1.3E-3	8.9E-4
V								2.8E-4	2.9E-4	2.7E-4	4.2E-4	4.0E-4	6.8E-5	2.5E-4	6.3E-4	7.2E-4	2.7E-4	1.0E-3	2.7E-4	2.7E-4	2.7E-4	2.7E-4	2.0E-4	2.8E-4
Zn	4.1E-02	6.7E-02		Equation	Equation		2.6E-3	2.7E-3	3.1E-3	2.1E-3	7.7E-3	7.6E-3	4.1E-4	2.1E-3	2.6E-3	2.7E-3	2.1E-3	3.0E-3	2.1E-3	2.1E-3	2.2E-3	2.1E-3	1.3E-3	2.6E-3
Zr	1.0E+34	1.0E+34		1.0E+34	1.0E+34		1.0E-4	1.0E-4	9.9E-5	1.0E-4	9.7E-5	9.0E-5	1.4E-5	1.0E-4	5.1E-5	3.8E-5	1.0E-4	0.0E+0	1.0E-4	1.0E-4	1.0E-4	1.0E-4	1.1E-4	1.0E-4

Notes:

Shaded cells indicated inclusions as a COPC

a) *British Columbia Ministry of Environment and Climate Change Strategy. 2021. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture - Guideline Summary. Water Quality Guideline Series, WQG-20. Prov. B.C., Victoria B.C.*

b) *B.C. Ministry of Environment and Climate Change Strategy 2021. Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture. Water Quality Guideline Series, WQG-08. Prov. B.C., Victoria B.C*

c) *CCME Water Quality Guidelines for the Protection of Freshwater Aquatic Life, Available online at: Canadian Council of Ministers of the Environment | Le Conseil canadien des ministres de l'environment (ccme.ca)*

d) *Federal Environmental Quality Guidelines, available online at https://www.canada.ca/en/health-canada/services/chemical-substances/fact-sheets/federal-environmental-quality-guidelines.html*

Table 3: Surface water screening protective of drinking water use.

Substance of Interest	Health Canada Drinking Water Quality Guidelines [a]	BC CSR Schedule 3.2 Drinking Water Quality	AC_1	AC_2	AC_3	AC_4	AC_5	AC_6	ER1	AC Bkg.	GC_1	GC_2	GC_3	GC_4	GC_5	GC_6	GC_7	GC_8	GC Bkg.
Ag	none	0.02	6.7E-6	6.9E-6	8.6E-6	5.0E-6	2.5E-5	2.5E-5	1.1E-6	5.0E-6	7.5E-6	8.1E-6	5.0E-6	1.0E-5	5.0E-6	5.0E-6	5.1E-6	5.0E-6	5.0E-6
Al	0.1	9.5	7.1E-3	7.2E-3	7.5E-3	6.8E-3	1.1E-2	1.1E-2	1.2E-3	7.3E-3	7.1E-3	7.1E-3	6.8E-3	7.4E-3	6.8E-3	6.8E-3	6.9E-3	6.8E-3	1.6E-2
As	0.01	0.01	1.7E-4	1.8E-4	2.2E-4	1.2E-4	6.8E-4	6.7E-4	2.5E-5	1.4E-4	1.6E-4	1.7E-4	1.3E-4	1.9E-4	1.3E-4	1.2E-4	1.3E-4	1.2E-4	1.8E-4
B	5	5	5.1E-2	5.1E-2	5.2E-2	5.0E-2	5.9E-2	5.6E-2	7.3E-3	5.0E-2	3.0E-2	2.5E-2	5.0E-2	1.0E-2	5.0E-2	5.0E-2	5.1E-2	5.0E-2	5.0E-2
Ba	2	1	4.2E-2	4.3E-2	4.9E-2	3.6E-2	1.1E-1	1.1E-1	7.4E-3	4.1E-2	5.3E-2	5.8E-2	3.6E-2	7.1E-2	3.6E-2	3.6E-2	3.7E-2	3.6E-2	7.9E-2
Be	NA	0.008	1.6E-5	1.7E-5	2.2E-5	1.0E-5	7.9E-5	7.8E-5	4.6E-6	1.0E-5	5.4E-5	6.6E-5	1.0E-5	1.0E-4	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5
Bi	NA	NA	5.0E-6	5.0E-6	5.0E-6	5.0E-6	5.0E-6	4.6E-6	1.6E-5	5.0E-6	2.5E-4	3.1E-4	5.0E-6	5.0E-4	5.1E-6	5.0E-6	5.2E-6	5.0E-6	5.0E-6
Cd	0.007	0.005	4.4E-5	4.9E-5	8.1E-5	1.2E-5	4.0E-4	4.0E-4	4.3E-6	1.1E-5	1.8E-5	2.0E-5	1.2E-5	2.5E-5	1.2E-5	1.2E-5	1.2E-5	1.2E-5	1.3E-5
Cl	none	250	7.9E-1	7.9E-1	7.9E-1	7.9E-1	7.6E-1	6.8E-1	1.7E-1	8.9E-1	1.4E+0	1.6E+0	8.0E-1	2.1E+0	8.0E-1	7.9E-1	8.1E-1	7.9E-1	1.4E+0
Co		0.001	**1.8E-3**	**2.0E-3**	**3.7E-3**	1.6E-5	**2.1E-2**	**2.1E-2**	1.4E-4	1.6E-5	5.7E-5	6.8E-5	1.6E-5	1.0E-4	1.6E-5	1.6E-5	1.7E-5	1.6E-5	3.0E-5
Cr (VI)	0.05	0.05	3.9E-4	3.9E-4	4.0E-4	3.7E-4	5.3E-4	5.1E-4	5.8E-5	3.6E-4	2.9E-4	2.7E-4	3.7E-4	2.0E-4	3.7E-4	3.7E-4	3.8E-4	3.7E-4	2.3E-4
Cu	2	1.5	6.4E-4	6.6E-4	7.3E-4	5.7E-4	1.5E-3	1.5E-3	9.7E-5	5.7E-4	5.3E-4	5.3E-4	5.7E-4	5.0E-4	5.7E-4	5.7E-4	5.8E-4	5.7E-4	6.7E-4
F	1.5	1.5	1.8E-1	1.8E-1	1.8E-1	1.8E-1	1.7E-1	1.5E-1	2.5E-2	3.0E-1	9.2E-2	6.9E-2	1.8E-1	0.0E+0	1.8E-1	1.8E-1	1.8E-1	1.8E-1	2.4E-1
Fe	none	6.5	6.5E-3	6.5E-3	7.0E-3	6.0E-3	1.1E-2	1.1E-2	1.2E-3	6.1E-3	8.0E-3	8.5E-3	6.0E-3	1.0E-2	6.1E-3	6.0E-3	6.2E-3	6.0E-3	2.2E-2
Hg	0.001	0.001	1.0E-5	1.0E-5	9.9E-6	1.0E-5	9.5E-6	8.5E-6	1.7E-6	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5	1.0E-5
Mn	0.12	1.5	3.5E-3	4.0E-3	7.2E-3	2.0E-4	3.9E-2	3.9E-2	3.9E-4	2.6E-4	2.8E-3	3.5E-3	2.0E-4	5.5E-3	2.0E-4	2.0E-4	2.0E-4	2.0E-4	1.5E-3
Mo		0.25	2.7E-3	2.9E-3	4.6E-3	8.9E-4	2.2E-2	2.2E-2	2.5E-4	9.1E-4	9.4E-4	9.5E-4	9.0E-4	9.9E-4	9.0E-4	8.9E-4	9.2E-4	8.9E-4	1.7E-3
NH4		NA	2.6E-2	2.6E-2	2.6E-2	2.6E-2	2.5E-2	2.2E-2	3.6E-3	3.8E-2	1.3E-2	1.0E-2	2.6E-2	0.0E+0	2.6E-2	2.6E-2	2.7E-2	2.6E-2	4.6E-2
Ni		0.08	4.7E-3	5.4E-3	9.7E-3	2.4E-4	5.3E-2	5.3E-2	4.0E-4	3.1E-4	6.0E-4	6.9E-4	2.4E-4	9.7E-4	2.4E-4	2.4E-4	2.4E-4	2.4E-4	5.0E-4
NO2	3	1	5.0E-3	5.0E-3	5.0E-3	5.0E-3	4.8E-3	4.5E-3	8.4E-4	5.0E-3	5.0E-3	5.0E-3	5.0E-3	5.0E-3	5.0E-3	5.0E-3	5.1E-3	5.0E-3	8.5E-3
NO3	45	10	1.0E-1	1.1E-1	1.1E-1	1.0E-1	1.6E-1	1.5E-1	1.2E+0	1.2E-1	6.6E-1	8.1E-1	1.0E-1	1.3E+0	1.0E-1	1.0E-1	1.0E-1	1.0E-1	1.4E-1
P		NA	1.4E-5	1.6E-5	3.0E-5	0.0E+0	1.7E-4	1.7E-4	4.4E-4	2.3E-2	7.2E-3	9.1E-3	0.0E+0	1.5E-2	0.0E+0	0.0E+0	0.0E+0	0.0E+0	1.6E-1
Pb	0.005	0.01	4.4E-5	4.6E-5	6.1E-5	2.9E-5	2.1E-4	2.1E-4	6.1E-6	3.4E-5	3.9E-5	4.2E-5	2.9E-5	5.0E-5	2.9E-5	2.9E-5	2.9E-5	2.9E-5	3.2E-5
Phenanthrene		NA	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	NP	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	2.0E-5	NP
Sb	0.006	6	2.1E-4	2.4E-4	4.2E-4	3.1E-5	2.2E-3	2.2E-3	1.9E-5	3.1E-5	6.5E-5	7.4E-5	3.1E-5	1.0E-4	3.1E-5	3.1E-5	3.2E-5	3.1E-5	4.9E-5
Se	0.05	0.01	2.2E-3	2.3E-3	3.0E-3	1.5E-3	9.7E-3	9.6E-3	8.8E-3	1.4E-3	**2.4E-2**	**3.0E-2**	1.5E-3	**4.8E-2**	1.5E-3	1.5E-3	1.6E-3	1.5E-3	2.3E-3
Sn		2.5	2.0E-4	2.0E-4	2.0E-4	2.0E-4	1.9E-4	1.8E-4	3.1E-5	2.0E-4	1.5E-4	1.4E-4	2.0E-4	1.0E-4	2.0E-4	2.0E-4	2.1E-4	2.0E-4	2.0E-4
SO4	none	500	3.5E+1	3.6E+1	4.2E+1	2.9E+1	1.0E+2	1.0E+2	1.7E+2	3.1E+1	1.3E+2	1.5E+2	2.9E+1	2.3E+2	2.9E+1	2.9E+1	2.9E+1	2.9E+1	2.9E+1
Sr	7	2.5	3.8E-2	3.8E-2	3.8E-2	3.8E-2	3.7E-2	3.3E-2	9.7E-3	1.1E-1	9.0E-2	1.0E-1	3.8E-2	1.4E-1	3.8E-2	3.8E-2	3.9E-2	3.8E-2	1.9E-1
Ti		NA	5.0E-4	5.0E-4	5.0E-4	5.0E-4	4.8E-4	4.5E-4	4.0E-4	5.0E-4	5.7E-3	7.0E-3	5.0E-4	1.1E-2	5.0E-4	5.0E-4	5.1E-4	5.0E-4	5.0E-4
Tl		NA	4.0E-6	4.1E-6	4.9E-6	3.2E-6	1.3E-5	1.3E-5	7.8E-7	5.0E-6	6.5E-6	7.4E-6	3.2E-6	1.0E-5	3.2E-6	3.2E-6	3.3E-6	3.2E-6	6.0E-6
U	0.02	0.02	8.9E-4	9.1E-4	1.0E-3	7.6E-4	2.2E-3	2.2E-3	2.0E-4	8.4E-4	1.9E-3	2.1E-3	7.6E-4	3.0E-3	7.6E-4	7.6E-4	7.8E-4	7.6E-4	1.3E-3
V		0.02	2.8E-4	2.8E-4	2.9E-4	2.7E-4	4.2E-4	4.0E-4	6.8E-5	2.5E-4	6.3E-4	7.2E-4	2.7E-4	1.0E-3	2.7E-4	2.7E-4	2.7E-4	2.7E-4	2.0E-4
Zn	5 (AO)	3	2.6E-3	2.7E-3	3.1E-3	2.1E-3	7.7E-3	7.6E-3	4.1E-4	2.1E-3	2.6E-3	2.7E-3	2.1E-3	3.0E-3	2.1E-3	2.1E-3	2.2E-3	2.1E-3	1.3E-3
Zr			1.0E-4	1.0E-4	9.9E-5	1.0E-4	9.7E-5	9.0E-5	1.4E-5	1.0E-4	5.1E-5	3.8E-5	1.0E-4	0.0E+0	1.0E-4	1.0E-4	1.0E-4	1.0E-4	1.1E-4
Acridine		NA	NP	NP	NP	NP	NP	NP	NP	NV	NP	NP	NP	NP	NP	NP	NP	NP	NV
Benzo(e)pyrene		NA	NP	NP	NP	NP	NP	NP	NP	NV	NP	NP	NP	NP	NP	NP	NP	NP	NV
Benzo[a]pyrene	0.00004	0.00001	NP	NP	NP	NP	NP	NP	NP	NV	NP	NP	NP	NP	NP	NP	NP	NP	NV
Chrysene		0.007	NP	NP	NP	NP	NP	NP	NP	NV	NP	NP	NP	NP	NP	NP	NP	NP	NV
Fluoranthene		0.15	NP	NP	NP	NP	NP	NP	NP	NV	NP	NP	NP	NP	NP	NP	NP	NP	NV
Pyrene		0.1	NP	NP	NP	NP	NP	NP	NP	NV	NP	NP	NP	NP	NP	NP	NP	NP	NV

Notes:

Shaded cells indicated inclusions as a COPC

a) *Health Canada (2020). Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.*

Table 4: Sediment Quality Screening

Substance of Interest	**BC Lower WSQG**	**BC Upper WSQG**	**CRID 1 Elk River**	**CRID 13 Elk River, West Side Downstream of Sparwood, BC**	**CRID 10 Alexander Creek at Confluence with West Alexander Creek**	**CRID 14 Alexander Creek Midway between CRID 10 and CRID 11**	**CRID 11 Bottom of Alexander Creek**
Ag	0.5		1.99E-02	1.99E-02	1.01E-01	8.18E-02	7.89E-02
As	5.9	17	1.465	1.465	**9.065**	**7.235**	**6.956**
Cd	0.6	3.5	0.3781	0.3781	**3.8**	**2.308**	**2.08**
Cr	37.3	90	4.99	4.99	15.03	14.56	14.48
Cu	35.7	197	3.952	3.952	11.31	10.14	9.959
Fe	21200	43800	0	0	0	0	0
Hg	0.17	0.486	0.01546	0.01546	0.06441	0.06504	0.06514
Mn	460	1100	0	0	0	0	0
Ni	16	75	**35.73**	**35.73**	**578.4**	**319.2**	**279.6**
Pb	35	91.3	5.697	5.697	9.263	7.001	6.655
Se	2		**7.294**	**7.294**	1.904	1.484	1.42
Zn	123	315	61.8	61.8	119.1	101.8	99.17

Notes:

Shaded cells indicated inclusions as a COPC

a) Predicted sediment concentrations screened relative to sediment quality guidelines presented in B.C. Ministry of Environment and Climate Change Strategy 2021. Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture. Water Quality Guideline Series, WQG-08. Prov. B.C., Victoria B.C

Lower WSQG – a concentration that will protect aquatic life from the adverse effects of a toxic substance in most situations (equivalent to CCME's Threshold Effect Level or Interim Sediment Quality Guidelines (TEL or ISQGs; CCME 2001)); and

Upper WSQGs – a concentration that if exceeded will likely cause severe effects on aquatic life (equivalent to CCME's Probable Effect Level (PEL; CCME (2001)).

Appendix G Calculated Dose and Risk Estimates to Ecological Receptors

The current appendix provides the calculated dose and risk estimates for all ecological receptors at each critical receptor location. As described in Appendix A, the multimedia and exposure model GoldSim player file provides a graphical representation of the links between abiotic and biotic media and allows for a complete and transparent inspection of the model elements, data inputs, calculations within the model, and all model outputs.

The reader is directed to Appendix A and the GoldSim player file (filename: App A_MOD_Crown Mountain HHERA_60590462.gsp) for a complete output of calculated dose and risk estimates for ecological receptors considered as part of the HHERA.

The GoldSim player file (filename: App A_MOD_Crown Mountain HHERA_60590462.gsp) can be made available upon request by NWP Coal Canada Ltd. or AECOM Canada Ltd.

Appendix H Human Receptor Exposure Characteristics

Introduction

This appendix documents proposed receptor characteristics and exposure parameters for use in the quantitative exposure assessment of Ktunaxa ʔaqⱡsmaknik Receptors for the Crown Mountain Coking Coal Project Human Health Risk Assessment.

Receptor Characteristics

It is recognized that people of all ages are part of traditional hunting and gathering parties and entire family units may participate in these associated activities which may lead to inadvertent exposure to environmental substances, either naturally occurring or project-related. In exposure assessment, the resultant dose depends on age-dependent metabolic and behavioural characteristics of the receptors. As such, all age groups for which Health Canada (2010) provides receptor characteristics have been considered, in addition to preferred rates proposed by the Ktunaxa ʔaqⱡsmaknik Nation Council (KNC, August 24, 2020).

Physiological Characteristics

Human receptor physiological characteristics (body weight, skin surface area, soil loading factors, water ingestion rate etc.) are adopted from Health Canada (2010) without modification (Table 1 and 2).

Soil Ingestion Rate

It is recognized that indigenous people engaged in a traditional lifestyle are likely to have a higher incidental soil ingestion rate than the average Canadian. Quantification of soil ingestion rates reported in scientific literature have typically used either a mechanistic model (i.e. hand to mouth transfer estimates) or mass balance chemical tracer studies, each with their associated uncertainties and variability.

Based on supportive feedback by KNC noting a study by Irvine et al (2014), AECOM has assumed a soil ingestion rate equal to the geometric mean of the average values presented in two pilot mass balance tracer studies of Canadian indigenous peoples engaged in a traditional lifestyle as follows:

- Doyle et al. (2012) conducted a mass balance tracer study using a group of seven volunteers engaged in a traditional lifestyle for a period of three weeks in the Chilko River watershed in the Cariboo Forest Region of British Columbia and within the traditional lands of the Xeni Gwet'in First Nation approximately 230 km west of Williams Lake. Four subjects were community members of the Xeni Gwet'in and 3 were not. The mean calculated soil ingestion rate was reported to be 75 mg/day, with a median of 50 mg/day and a 90th percentile of 211 mg/day.

- Irvine et al. (2014) conducted a mass balance tracer study of 9 subjects from the Cold Lake First Nations in northern Alberta practicing traditional activities over a 13-day study period. Mean calculated soil ingestion rate was reported to be 32 mg/day, with a median of 18 and a 90th percentile of 152 mg/day.

The geometric mean of the reported average soil ingestion rate for the two referenced studies is 49 mg/day. The geometric mean was considered as an appropriate estimate as the studies from which the estimates were drawn contain significant variability. Additionally, neither of these studies included the recommended 225 subject days necessary to detect a difference of 20 mg/day of soil ingestion, as estimated by Doyle et al. (2010), and should be considered as pilot studies.

The mass balance tracer studies referenced herein were conducted using adult volunteers. To apply the estimated soil ingestion rate to other age groups within the quantitative risk assessment AECOM has scaled the geometric mean adult soil ingestion rates noted above based on the inter-receptor ratios reported in Health Canada (2010). For example, Health Canada (2010) reported toddler daily soil intake rate 4-fold greater than adults, so this ratio was applied to the geometric mean of the Doyle (2012) and Irvine (2014) studies to derive the a KNC toddler soil intake rate (see Table 1).

Ancillary Receptor Assessments

In addition to the representative human receptors defined above, AECOM will conduct two additional ancillary assessments as part of the sensitivity analysis for the HHRA:

1. Assess human exposures based on the geometric mean of the 90th %ile values reported by Doyle et al. (2012) and Irvine et al. (2014).

2. Assess human exposure based on the standard Health Canada (2010) soil ingestion rates. These ingestion rates are to be assessed to provide consistent application of risk assessment principals to those projects which have recently been submitted and reviewed by regulatory agencies.

Sediment Ingestion Rate

Sediment ingestion will be assessed following Health Canada (2017) recommended sediment ingestion rate for near shore activities, such as wading or harvesting. Sediment ingestion will be assessed assuming a 2- hour exposure duration for 138 days per year.

Land-use Characteristics

Based on feedback regarding Critical Receptor Locations and Assumed Duration provided by KNC, AECOM has assumed 365 day per year land occupancy by current and rights-based Ktunaxa ʔaqłsmaknik receptors.

Traditional Food Ingestion Rates

Ingestion rates of traditional foods for the Current and Rights-based Ktunaxa ʔaqłsmaknik receptors are presented in Tables 1 and 2 respectively.

- **Current Ktunaxa ʔaqłsmaknik Receptors** - Ingestion rates are drawn from the 2015 Ktunaxa First Nation Diet Study (Firelight, 2015) using the 95th percentile of traditional food ingestion rate (grams per person per day) for identified *consumers* only. This is a conservative approach as the Firelight (2015) report recommends using the 95th percentile ingestion rate from the entire dataset for risk characterization. AECOM has elected to use the *consumer* only data, as this is more protective of those individuals or family groups that rely more heavily on traditional foods.

- **Rights-based Ktunaxa ʔaqłsmaknik Receptors** - Ingestion rates are based on the Ktunaxa Preferred Rates for Human Health Risk Assessments for Coal Mining Environmental Assessments within Qukin ʔamakʔis provided to AECOM in a KNC memorandum dated August 24, 2020. The “Preferred Rates” provided to AECOM were determined based on the results of the 2019 Ktunaxa First Nation Diet Study (currently in review stages) and engagement with Ktunaxa communities through 10 focus groups held during the fall of 2019. The preferred rates are amounts of Ktunaxa foods determined to support the needs of a Ktunaxa person including but not limited to the nutrition needs.

Country Food Ingestion Frequency

Ingestion of traditional food is assumed to occur daily, 365 days per year for the Current and Rights-based Ktunaxa ʔaqłsmaknik receptors.

Dermal Contact with Surface Water (swimming/Bathing)

Assumes 1 event per week with a duration of 1 hour, 52 weeks per year for all receptors. This is in agreement with previous assessments conducted in the Elk Valley (Baldy Ridge for example).

Table 1 - Human receptor characteristics for Current Ktunaxa ʔaqłsmaknik Receptors.

		Infant	Toddler	Child	Teen	Adult
Age		0-6 mo.	7 mo. – 4 yr.	5 – 11 yr.	12 – 19 yr.	≥ 20 yr.
Bodyweight (kg)		8.2	16.5	32.9	59.7	70.7
Soil Ingestion Rate (kg/day)		0.000049	0.000196	0.000049	0.000049	0.000049
Sediment Ingestion Rate (kg/day)		0	144	114	36	40
Sediment Exposure Term (days/year)		0	138	138	138	138
Inhalation Rate (m^3/day)		2.2	8.3	14.5	15.6	16.6
Water Ingestion Rate (L/day)		0.3	0.6	0.8	1	1.5
Time Spend Outdoors (hrs / day)		24	24	24	24	24
Skin Surface Area (cm^2)	*Hands*	320	430	590	800	890
	Arms	550	890	1480	2230	2500
	Legs	910	1690	3070	4970	5720
	Total Body	3620	6130	10140	15470	17640
Soil Loading to Exposed Skin (kg/cm^2/event)	*Hands*	1×10^{-7}	1×10^{-7}	1×10^{-7}	1×10^{-7}	1×10^{-7}
	Other	1×10^{-8}	1×10^{-8}	1×10^{-8}	1×10^{-8}	1×10^{-8}
Time on Site (days/year)		365	365	365	365	365
Country Food Ingestion	*Days per Year Consumed*	365	365	365	365	365
Country Food Ingestion Rates (g/day)	*Fish*	0.0	12.0	28.7	38.7	44.0
	Fish Eggs	0.0	0.2	0.5	0.6	0.7
	Shellfish	0.0	0.2	0.4	0.5	0.6
	Large Mammals	0.0	13.3	55.3	172.8	384.0
	Small Mammals	0.0	0.1	0.6	1.8	4.0
	Birds	0.0	0.8	3.5	10.8	24.0
	Bird Eggs	0.0	0.6	2.4	7.7	17.0
	Berries	127.9	228.4	237.9	216.3	206.0
	Plan Roots	13.6	26.1	53.2	73.9	84.0
	Other Plants	2.6	5.0	10.1	14.1	16.0
	Lichen + Mushroom	2.9	5.6	11.4	15.8	18.0

Note: Ingestion rates for age groups other than adults were determined by adjusting the consumption rates provided for adults based on the relative ingestion rates for similar food items as provided in Richardson (1997).

Table 2 - Human receptor characteristics for Rights-based Ktunaxa ʔaqłsmaknik receptors.

		Infant	Toddler	Child	Teen	Adult
Age		0-6 mo.	7 mo. – 4 yr.	5 – 11 yr.	12 – 19 yr.	≥ 20 yr.
Bodyweight (kg)		8.2	16.5	32.9	59.7	70.7
Soil Ingestion Rate (kg/day)		0.000049	0.000196	0.000049	0.000049	0.000049
Sediment Ingestion Rate (kg/day)		0	144	114	36	40
Sediment Exposure Term (days/year)		0	138	138	138	138
Inhalation Rate (m^3/day)		2.2	8.3	14.5	15.6	16.6
Water Ingestion Rate (L/day)		0.3	0.6	0.8	1	1.5
Time Spend Outdoors (hrs / day)		24	24	24	24	24
Skin Surface Area (cm^2)	*Hands*	320	430	590	800	890
	Arms	550	890	1480	2230	2500
	Legs	910	1690	3070	4970	5720
	Total Body	3620	6130	10140	15470	17640
Soil Loading to Exposed Skin (kg/cm^2/event)	*Hands*	1×10^{-7}	1×10^{-7}	1×10^{-7}	1×10^{-7}	1×10^{-7}
	Other	1×10^{-8}	1×10^{-8}	1×10^{-8}	1×10^{-8}	1×10^{-8}
Time on Site (days/year)		365	365	365	365	365
Country Food Ingestion	*Days per Year Consumed*	365	365	365	365	365
Country Food Ingestion Rates (g/day)	*Fish*	0.0	67.0	159.5	215.6	245.0
	Fish Eggs	0.0	0.2	0.5	0.6	0.7
	Shellfish	0.0	0.2	0.4	0.5	0.6
	Large Mammals	0.0	21.7	90.4	282.6	628.0
	Small Mammals	0.0	0.7	3.0	9.5	21.0
	Birds	0.0	0.6	2.3	7.2	16.0
	Bird Eggs	0.0	0.4	1.7	5.4	12.0
	Berries	129.2	230.6	240.2	218.4	208.0
	Plan Roots	23.2	44.7	91.2	126.7	144.0
	Other Plants	4.0	7.8	15.8	22.0	25.0
	Lichen + Mushroom	2.7	5.3	10.8	15.0	17.0

Note: Ingestion rates for age groups other than adults were determined by adjusting the consumption rates provided for adults based on the relative ingestion rates for similar food items as provided in Richardson (1997).

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Health Canada. 2010. Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0.

Health Canada. 2017. Federal Contaminated Site Risk Assessment in Canada, Supplemental Guidance on Human Health Risk Assessment of Contaminated Sediments: Direct Contact Pathway

Appendix I Human Health Toxicological Profiles

The current appendix provides the toxicity reference values used in the present HHRA.

Toxicity is an inherent property of a substance, which is brought about by the physical-chemical properties of the substance and its chemical reactivity within living organisms. Toxicity assessment in this context involves identification of the potential toxic effects of chemicals, and determination of the rate of intake of a chemical that can be tolerated over a lifetime without experiencing adverse health effects. Toxicity assessment also considers the following concepts:

- Non-carcinogens (chemicals that do not cause cancer)
- Carcinogens (chemicals that have the potential to cause cancer)
- Bioavailability (the proportion of chemical in a medium that is considered to be available for uptake by a human after the human contacts the medium)

Toxicity reference values and critical effects for threshold contaminants are presented in Table 1. Cancer slope factors for oral and inhalation exposures are also presented in Table 1. Relative Absorption Factors for Oral and Dermal exposure are presented in Table 2.

Table 1: Toxicity reference values (TRVs) used in the assessment of human health risk.

COPC	TDI (mg/kg bw/day)	Chronic Effects Endpoint	Tolerable Concentration in Air (mg/m3)	Oral Cancer Slope Factor $(mg/kg\ bw/day)^{-1}$	Inhalation Cancer Slope Factor $(mg/kg\ bw/day)^{-1}$
Arsenic	0.3[c]	hyperkeratosis, hyperpigmentation and possible vascular complications		1.8a	27a
Cadmium	0.001[a]	renal tubular dysfunction (proximal tubule epithelial cell damage), manifested by low molecular weight proteinuria		-	42a
Chromium	0.001[a]	hepatotoxicity, irritation, or corrosion of the gastrointestinal mucosa, encephalitis		-	46
Cobalt	0.001[d]	Polycythemia. TRV based on an intermediate oral exposure with a safety factor of 10 applied to account for intermediate-to-chronic duration.			-
Nickel	0.011[a]	implantation loss/perinatal lethality and perinatal mortality; respiratory track effects: alveolar macrophages, hyperplasia	0.000018[a]	-	5.3[a]
Selenium[ab]	0-0.5 years = 5.5 0.6-4 years = 6.2 5-11 years = 6.3 12-19 years = 6.2 20+ years = 5.7	biochemical alterations associated with clinical selenosis	-	-	-
Thallium	0.00001[e]	for hair follicle atrophy	-	-	-
Benzo(a)pyrene	0.0003[c]	Developmental toxicity (including developmental neurotoxicity); Decreased embryo/fetal survival (inhalation)	0.000002[c]	1[c]	0.13[a]

Sources/Notes

a) TRV sourced from Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical Specific Factors, Version 2.0 (Health Canada, 2010)

b) Tolerable daily intake for essential trace elements are defined based on an age -group specific basis.

c) TRV sourced from US EPA (2017) Integrated Risk Information System, Toxicological Review of Benzo(a)pyrene. EPA/635/R-17/003fc

d) TRV sourced from Rationale for the Development of Soil and Groundwater Standards for Use at Contaminated Sites in Ontario (OMOE, 2011).

Table 2: Chemical-specific factors used in the human health risk assessment.

COPC	Oral RAF for Soil Ingestion[a] (unitless)	Dermal RAF for Soil Contact (unitless)	Dermal Permeability Coefficient of Compound in Water (cm/hr)[d]
Arsenic	1	0.03[b]	1.00E-03
Cadmium	1	0.01[b]	1.00E-3
Cobalt	1	0.01[c]	1.00E-3
Chromium	1	0.1[b]	2.00E-03[e]
Nickel	1	0.091[b]	2.00E-04
Selenium	1	0.01[b]	1.00E-03
Thallium	1	0.01[c]	1.00E-03
Benzo[a]pyrene	1	0.13[d]	0.713

Sources/Notes:

a) Soil ingestion default oral RAF value as recommended by Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical Specific Factors, Version 2.0 (Health Canada, 2010)

b) Dermal RAFs sources from Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical Specific Factors, Version 2.0 (Health Canada, 2010)

c) Value sources from Rationale for the Development of Soil and Groundwater Standards for Use at Contaminated Sites in Ontario (OMOE, 2011)

d) Dermal permeability Coefficients sourced from US EPA (2004) Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). EPA/540/R/99/005

e) Value conservatively selected for hexavalent chromium.

Appendix J Calculated Dose and Risk Estimates for Human Receptors

The current appendix provides the calculated dose and risk estimates for all human receptors at each critical receptor location. As described in Appendix A, the multimedia and exposure model GoldSim player file provides a graphical representation of the links between abiotic and biotic media and allows for a complete and transparent inspection of the model elements, data inputs, calculations within the model, and all model outputs.

The reader is directed to Appendix A and the GoldSim player file (filename: App A_MOD_Crown Mountain HHERA_60590462.gsp) for a complete output of calculated dose and risk estimates for human receptors considered as part of the HHERA.

The GoldSim player file (filename: App A_MOD_Crown Mountain HHERA_60590462.gsp) can be made available upon request by NWP Coal Canada Ltd. or AECOM Canada Ltd.

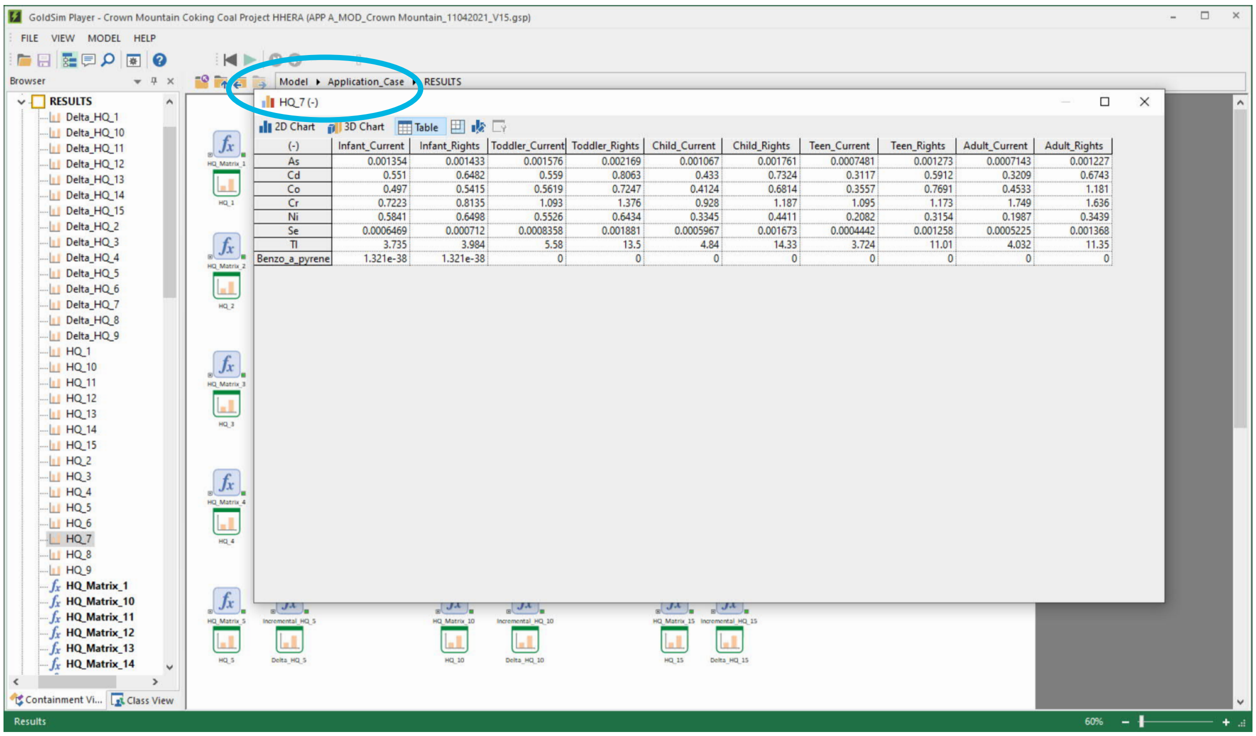

Figure 1: Screen capture from GoldSim player file showing calculated hazard quotients for the application assessment case at CRID_7.

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