RED MOUNTAIN UNDERGROUND GOLD PROJECT
VOLUME 3 | CHAPTER 22
HEALTH EFFECTS ASSESSMENT

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22 HEALTH EFFECTS ASSESSMENT

22.1 Introduction

The Red Mountain Underground Gold Project (the Project) is a proposed underground gold mine in the Bitter Creek valley, located approximately 15 kilometres (km) from Stewart in northwest British Columbia (BC). The Project is being developed by IDM Mining Ltd., (IDM, the proponent).

The Project comprises two main areas of activity with interconnecting Access and Haul Roads: the Mine Site with an underground mine and dual portal access at the upper elevations of Red Mountain (1950 metres above sea level (masl)); and Bromley Humps, situated in the Bitter Creek valley (500 masl), with a Process Plant and Tailings Management Facility (TMF).

Human Health has been selected as a valued component (VC) and is included in this Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS) because of its fundamental importance to people who live and work in the region where the Project will be developed. The purpose of this health effects assessment (HEA) is to assess the potential exposure of human receptors to chemicals and the potential effects of the proposed Project on Human Health through the incidental ingestion and dermal contact with soil, consumption and dermal contact with surface water and groundwater, inhalation of air, consumption of country foods, and exposure to noise, electromagnetic fields (EMFs), and light. This HEA was completed to assess potential physical health effects to both Aboriginal and non-Aboriginal Groups; however, special focus was given to Aboriginal Groups when considering the types of receptors and land use.

Figure 22.1-1, Figure 22.1-2, and Figure 22.1-3 illustrate the established disturbance limits for the entire Project, the established disturbance limits for Bromley Humps, and the established disturbance limits for the Mine Site, respectively.

“Health” is recognized as comprising more than just physical health. The World Health Organization (WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO 1948). Additional determinants of a person’s overall health and feeling of well-being include social, nutritional, and economic factors, education, social status, access to healthcare, as well as customs and cultural practices. These other important determinants of Human Health are assessed separately in Volume 3, Chapters 19 (Economics Effects Assessment) and 20 (Social Effects Assessment) and are therefore not included here. An assessment of the Project’s potential effects on Aboriginal individuals is included in Volume 4, Chapters 25 (Tsetsaut Skii km Lax Ha (TSKLH)), 26 (Métis Nation BC (MNBC)), and 27 (Nisga’a Nation).

Neither TSKLH nor MNBC have a specific community within the Human Health LSA (presented in Section 22.3.4 below), and it is IDM's understanding that TSKLH members and MNBC citizens reside in other communities in northwest BC, such as Terrace, Smithers, and Hazelton. As such, IDM has not provided human health information specific to these Aboriginal Groups. The human health information provided for the communities in northwest BC are assumed to be generally inclusive of TSKLH members and MNBC citizens. Baseline health information for Nisga'a citizens is provided in Volume 4, Chapter 27.

It should be noted that the assessment of human health risk associated with physical hazards focuses on non-occupational exposures with the exception of non-Mine related occupational activities in the region. Occupational exposures associated with the Project will be addressed in the Project's health and safety program and will comply with the BC Occupational Health and Safety Regulation (BC Reg. 296/97) and associated policies and guidelines administered by WorkSafeBC and the Health, Safety and Reclamation Code for Mines in British Columbia (BC MEMPR 2008).

The principal study completed to inform the HEA, with respect to baseline and predicted future chemical exposures and their potential to cause adverse health effects, was the Human Health Risk Assessment (HHRA), which is presented in Volume 8, Appendix 22-A. It should be noted that the HHRA does not address noise, EMFs, and lighting, which are discussed further below.

All chemicals and other physical stressors have the potential to cause adverse effects, but three components are necessary for a health risk to exist, and, therefore, to warrant an HEA:

- The chemical or stressor released must be at a high enough concentration or level to cause harm to human health;
- A pathway must exist from the point of release of the chemical or stressor to the human receptor, and the human receptor must be exposed to the chemical or stressor; and
- A human receptor must be present.

This HEA evaluates the pathway effects of surface water, groundwater, and air quality to Human Health. Direct Project effects on air quality, groundwater, and surface water are assessed separately in Volume 3, Chapters 7, 11, and 13, respectively. Baseline surface water and groundwater quality is also described in Volume 8, Appendix 14-A; however, because water quality was assessed using only aquatic life guidelines and does not consider surface water for drinking water purposes, this HEA assesses the drinking water quality aspects of surface water. Baseline air quality is described in Volume 8, Appendix 7-A; however, the Air Quality Effects Assessment does not explicitly consider metals in air particulate or the potential for non-threshold effects associated with exposure to NO_2 and $PM_{2.5}$; accordingly, these effects are considered in this HEA.

The evaluation of the noise effects of the project to human health is documented in the Noise Effects Assessment (Volume 3, Chapter 8). Although not reevaluated in this chapter a summary of the noise effects assessment chapter is presented. The evaluation of visual effects to the social effects to human health is documented in the Social Effects Assessment Chapter 20 and is not presented in this chapter.

This HEA follows the effects assessment methodology described in Volume 3, Chapter 6 of the Application/EIS.

Figure 22.1-1: Project Overview

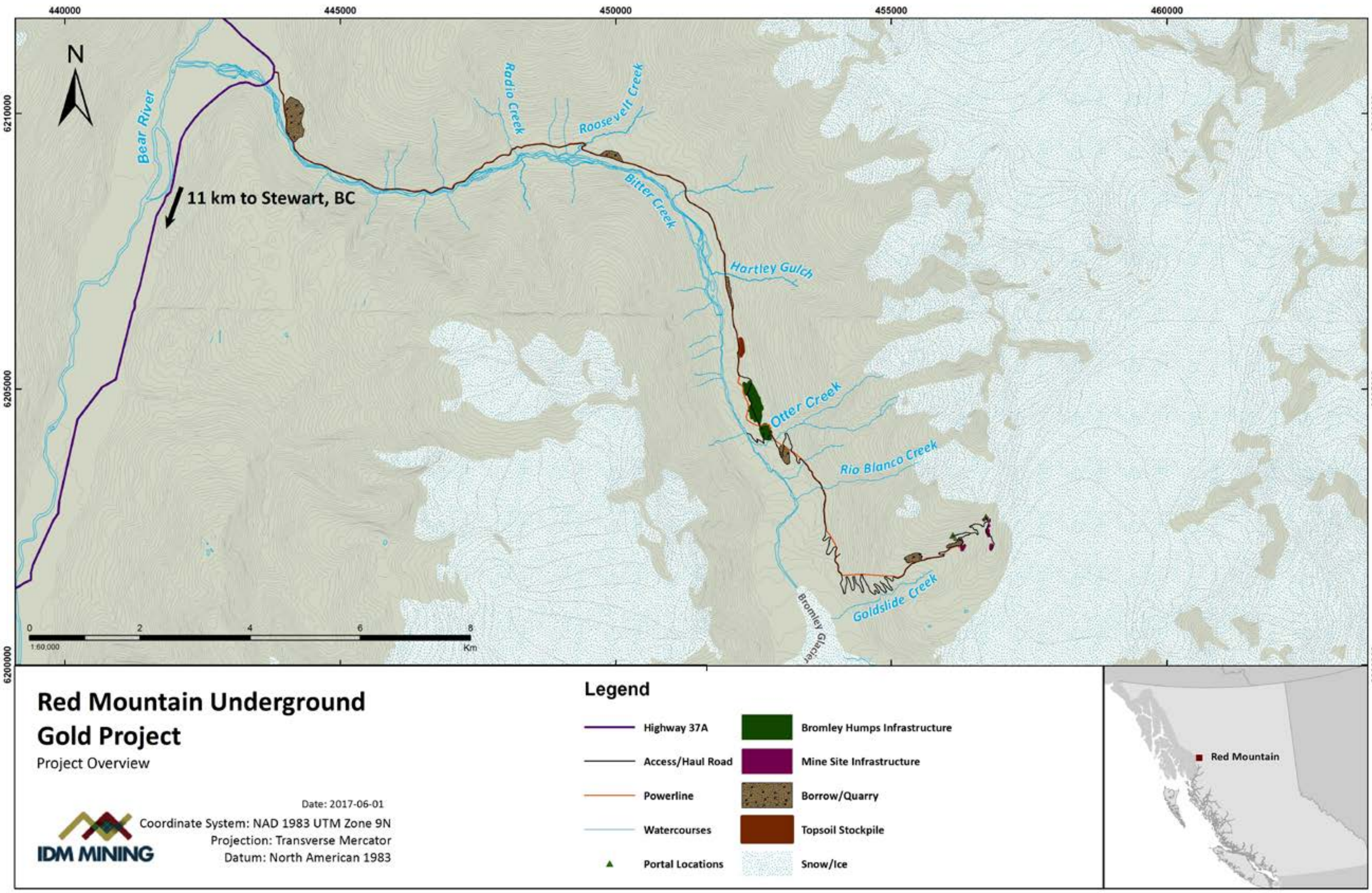


Figure 22.1-2: Project Footprint – Bromley Humps

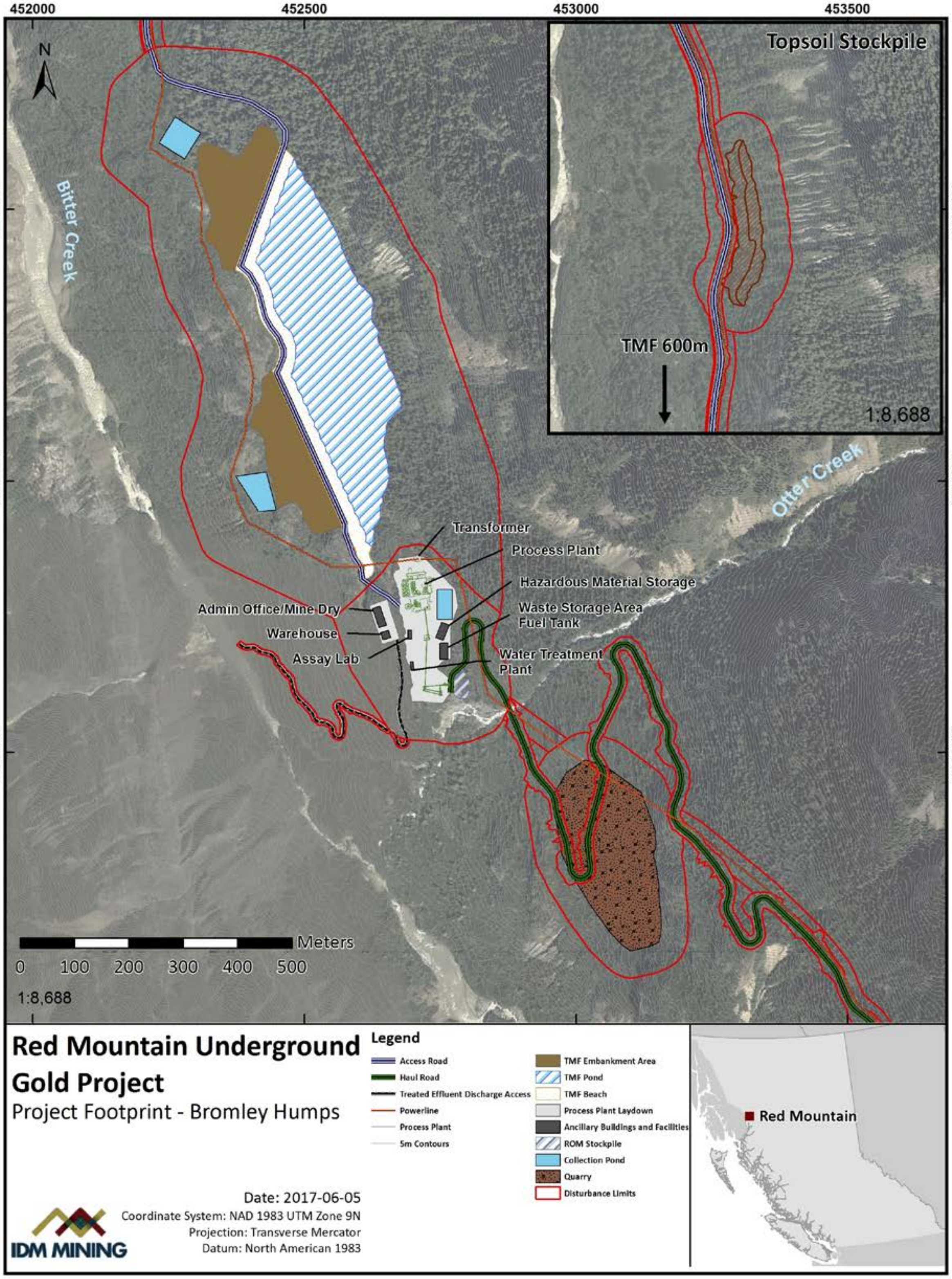
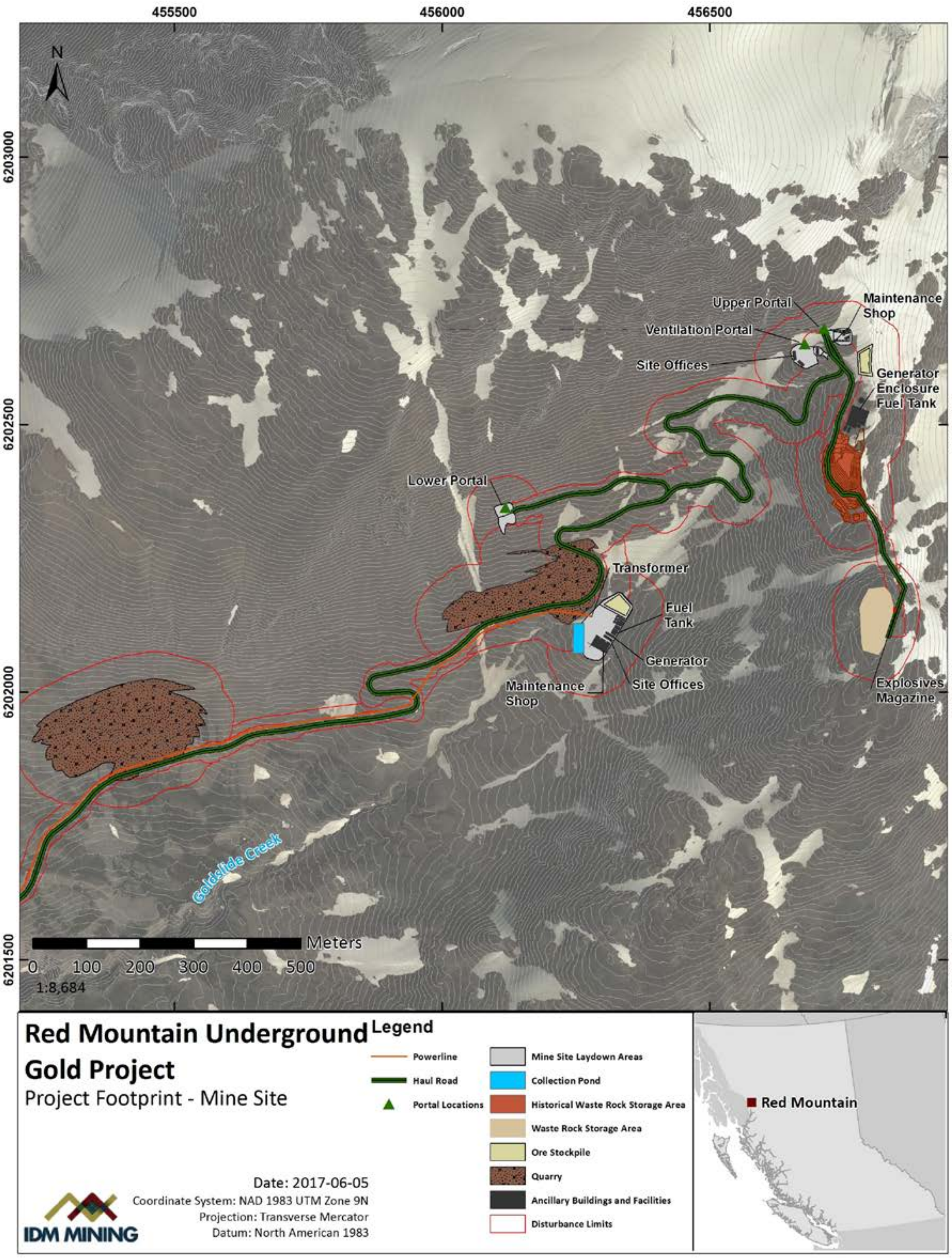


Figure 22.1-3: Project Footprint – Mine Site



22.2 Regulatory, Policy Setting, and Linkages to Other Disciplines

The Application Information Requirements (AIR) for the Project, issued by the BC Environmental Assessment Office (EAO) in March 2017 and the Guidelines for the Preparation of an Environmental Impact Statement pursuant to the *Canadian Environmental Assessment Act, 2012*, (the EIS Guidelines) issued by the Canadian Environmental Assessment Agency (the Agency) outline the scope of the HEA and the requirements to meet both the provincial and federal environmental assessment requirements under the *BC Environmental Assessment Act* (2002) and the *Canadian Environmental Assessment Act* (2012), respectively.

Public health in BC is a responsibility of the BC Minister of Health, in accordance with the *Public Health Act* (2008). Federally, Health Canada's mandate also includes the protection of human health.

A number of VCs and intermediate components (ICs) inform the HEA. These are discussed below and further summarized in Section 22.3.1.

22.2.1 Guidance to Address Noise Related Health Effects

Noise is a pathway that may affect Human Health. The assessment of health effects associated with potential exposure to Noise is based on information reported in the Environmental Code of Practice for Metal Mines (Environment Canada 2009), which stipulates that the equilibrium sound pressure (L_{eq}) from mining activities should not exceed 55 A-weighted decibels (dBA) during the day (L_d) and 45 dBA at night (L_n) in residential areas adjacent to mining activities. These levels are conservatively applied here because the nearest residence is in Stewart, BC, approximately 15 km away. During blasting, ground vibrations should also not exceed 12.5 millimetres per second (mm/sec) peak particle velocity, measured below grade or less than 1 metre above the ground. Blasting will occur above ground during the Construction Phase and will continue to occur underground during the Operation Phase.

22.2.2 Guidance to Address Air Quality Related Health Effects

Air Quality is a pathway that may affect Human Health. The air quality criteria (Table 22.2-1) considered in the Air Quality Effects Assessment and relevant to health were the BC Ambient Air Quality Objectives (AAQOs), which are a suite of ambient air quality criteria, including Provincial Air Quality Objectives (AQOs), National Ambient Air Quality Objectives (NAAQOs), and Canadian Ambient Air Quality Standards (CAAQS), with the most stringent selected. Chemical exposure in ambient air was evaluated as part of the chemically related health effects.

Table 22.2-1: Relevant BC Ambient Air Quality Objectives

Contaminant	Averaging Period	Air Quality Objective ($\mu g/m^3$)	Source
Nitrogen Dioxide (NO_2)	1-hour	188	Interim Provincial Air Quality Objective (AQO)
	Annual	60	
Sulphur Dioxide (SO2)	1-hour	196	Interim Provincial Air Quality Objective (AQO)
	1-hour	183	CAAQS
	Annual	13	CAAQS
Particulate Matter < 2.5 microns ($PM_{2.5}$)	24-hour	25	BC AAQO
	24-hour	28	CAAQS
	Annual	8	BC AAQO
	Annual	10	CAAQS
Particulate Matter < 10 microns (PM_{10})	24-hour	50	BC AAQO
Total Suspended Particulate (TSP)	24-hour	120	National Ambient Air Quality Objective (NAAQO)
	Annual	60	NAAQO

For metals, the Texas Commission on Environmental Quality Effects Screening Levels (1-hour and annual averaging period PM_{10}s; Texas CEQ 2014) and the Ontario Ministry of the Environment Ambient Air Quality Criteria (24-hour averaging period; Ontario MOE 2012) were used. The lowest screening level was used when more than one screening value was available for a given averaging period. The 1-hour averaging period screening values were presented for general comparison purposes. The 24-hour averaging period screening values were compared the 24-hour modelled air concentrations. The annual averaging period screening values were compared to the annual modelled air concentrations. Air screening levels are outlined in Volume 8, Appendix 22-A (Attachment A, Tables A1 and A2).

22.2.3 Guidance to Address Light Related Health Effects

Light is a pathway that may affect Human Health. Because the Human Health LSA is sufficiently insulated from off-Project sources of light, a baseline monitoring program to quantify existing light levels was not conducted. Furthermore, as no worker residences will be present at the mine, no adverse effects to non-worker human health are anticipated as a result of light. Therefore, no light assessment was completed for the Project, and light is not discussed further in this report.

22.2.4 Guidance to Address Electromagnetic Field Related Health Effects

EMFs are a pathway that may affect Human Health. The assessment of health effects associated with potential exposure to EMF was based on information reported by Health Canada (2017), the World Health Organization (2007, 2017), and WorkSafeBC (2017). It is reported that EMF exposure levels are unlikely to pose health concerns except potentially at extremely high levels when electric current or fields may be generated in the body that are capable of interfering with the brain, nerves, and heart (Health Canada 2017, WHO 2007). Electromagnetic fields have been classified by the International Agency for Research on Cancer (IARC) as possibly carcinogenic to humans; however, this is based on animal studies and no correlation has been established linking exposure to EMF with increased cancer risk in humans (Health Canada 2017, IARC 2002, WHO 2017).

The EMF criteria (Table 22.2-2) considered in the evaluation of exposure to EMFs were the International Commission on Non-Ionizing Radiation Protection (ICNIRP) short-term exposure limits.

Table 22.2-2: Exposure Limits for EMF

Parameter	Residential	Occupational
Magnetic Field (mG)	2000	10000
Electric Field (kV/m)$_b$	30	

Source: BC Hydro 2017

22.2.5 Guidance to Address Soil Related Health Effects

Soil Quality is an aspect of the environment that may be altered by the Project and is a pathway that may have an effect on Human Health. The primary measurement indicator for Soil Quality is changes in concentrations of soil quality parameters compared to baseline and federal guidelines and provincial standards for direct contact with soil. When federal and provincial guidelines/standards were not available, guidelines from other jurisdictions were considered. Soil screening levels are outlined in Volume 8, Appendix 22-A (Attachment A, Table A4).

22.2.6 Guidance to Address Surface Water Related Health Effects

Surface Water Quality is an aspect of the environment that may be altered by the Project and is a pathway that may affect Human Health. The primary measurement indicator for Surface Water Quality is changes in concentrations of water quality parameters compared to baseline and provincial guidelines and provincial standards for drinking water. When federal and provincial guidelines were not available. Guidelines from other jurisdictions were considered. Water screening levels used for drinking water are outlined in Volume 8, Appendix 22-A (Attachment A, Table A6).

22.2.7 Guidance to Address Groundwater Related Health Effects

Groundwater is an aspect of the environment that may be altered by the Project and is a pathway that may affect Human Health. The primary measurement indicator for Groundwater Quality is changes in concentrations of water quality parameters compared to baseline and provincial guidelines and provincial standards for drinking water. When federal and provincial guidelines were not available, guidelines from other jurisdictions were considered. Surface water screening levels used for drinking water are outlined in Volume 8, Appendix 22-A (Attachment A, Table A6).

22.2.8 Guidance to Address Sediment Related Health Effects

Sediment Quality is an aspect of the environment that may be altered by the Project and is a pathway that may affect Human Health. The primary measurement indicator for Sediment Quality is changes in concentrations of sediment quality parameters compared to baseline and federal guidelines and provincial standards for direct contact with sediment. When federal and provincial guidelines/standards were not available, guidelines from other jurisdictions were considered. As there are no sediment screening levels for direct contact with humans, soil screening levels were used as surrogates for sediment screening levels. These levels are outlined in Volume 8, Appendix 22-A (Attachment A, Table A4).

22.2.9 Guidance to Address Wildlife Related Health Effects

The Wildlife Effects Assessment informed the HEA by providing information regarding the types of species present in the Bitter Creek valley. Wildlife may be affected by the Project and is a pathway that may affect Human Health.

Individual wildlife species were selected VCs for the Project because of their potential for interactions with the Project. Project interactions considered spatial or temporal overlap with Project activities, legislative or regulatory requirements (e.g., species at risk), and consultation with the public, Aboriginal Groups, government agencies, and stakeholders. Selected Wildlife VCs included Mountain Goat, Grizzly Bear, Moose, Furbearers, Hoary Marmot, Bats, Migratory Breeding Birds, Migratory Bird Species at Risk, Raptors, Non-Migratory Game Birds, and Amphibians.

Human Health may be affected by chemical concentrations in wildlife that is consumed as game or “country food.” Country foods screening levels were applied using an approach developed for deriving action levels for fish advisories (OHA 2016; Volume 8, Appendix 22-A, Section 6.3.6.3). The country foods screening levels are presented in Volume 8, Appendix 22-A (Attachment A, Table A11).

22.2.10 Guidance to Address Vegetation and Ecosystem Related Health Effects

Vegetation and Ecosystems are aspects of the environment that may be altered by the proposed Project and are a pathway that may affect Human Health. The Ecosystems and Vegetation VCs included in the assessment are:

- Ecologically valuable soil;
- Alpine and parkland ecosystems;
- Old growth and mature forested ecosystems;
- Floodplain and wetland ecosystems;
- BC Conservation Data Centre (CDC)-listed ecosystems; and
- Rare plants, lichens, and associated habitat.

Measurement indicators in the Vegetation and Ecosystems Effects Assessment (Volume 3, Chapter 15) were soil chemistry soil and tissue residue concentration in plants. To assess whether chemicals in soil had the potential to harm human health, their concentration was compared to federal soil guidelines for the protection of human health (CCME 2017) and to provincial soil standards for the protection of human health (BC CSR 1997 and its addenda; Volume 8, Appendix 22-A, Section 6.3.2). Chemical concentrations in plants were compared to risk-based screening levels developed for country foods (Volume 8, Appendix 22-A, Section 6.3.4, and Attachment A, Table A11).

22.2.11 Guidance to Address Fish Related Health Effects

Fish is an aspect of the environment that may be altered by the Project and is a pathway that may affect Human Health.

Rationale for selection of this VC includes the importance of fish to Aboriginal Groups, the role of fish in the aquatic food-web, their potential as a food sources for humans and wildlife, and federal and provincial requirements. The Fish and Fish Habitat VC is represented by the following species found within the Project area: Dolly Varden (*Salvelinus malma*), Bull Trout (*Salvelinus malma*), Eulachon (*Thaleichthys pacificus*), and Salmonid Species (*Oncorhynchus* spp.).

The primary measurement indicators for Fish are habitat loss and alteration, fish species presence or absence, fish population metrics, growth, survival, and reproduction of fish, and water quality. The primary measurement indicators for Fish Habitat are water quality, flows and flow timing, sediment quality, periphyton and benthic invertebrate community metrics, and channel morphology.

Increase in the concentration of constituents of potential concern (COPCs) in surface water may result in an increase concentration of these COPCs in fish tissue. Risk-based tissue residue screening concentrations were developed following the United States Environmental Protection Agency (USEPA) guidance (2005) based on a hazard of 0.2 for non-carcinogens and a cancer risk or $1x10^{-5}$ for carcinogens.

The country foods screening levels are presented in Volume 8, Appendix 22-A (Attachment A, Table A11).

22.2.12 Guidance to Address Chemical-related Health Effects

Guidance on the assessment of health effects associated with potential exposure to chemicals in air, soil, groundwater, sediment, surface water, groundwater, and country foods was based on information reported by the following references below:

- Health Canada. 2012a. Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0;
- Health Canada. 2010a. Part II: Health Canada Toxicological Reference Values;
- Health Canada. 2012b. Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRA);
- Health Canada. 2010b. Supplemental Guidance on Human Health Risk Assessment for Country Foods;
- BCMOE. 2015. Technical Guidance on Contaminated Sites 7 - Supplemental Guidance for Risk Assessments;
- Northern Health. 2015. Guidance on Human Health Risk Assessment; and
- United States Environmental Protection Agency (USEPA). 1989. Risk Assessment Guidance for Superfund, Part A.

Other regulatory guidance considered specifically to support sub-components of the HHRA (e.g., selection of COPCs), are presented in Appendix 22-A and in the relevant supporting effects assessment chapters (or associated appendices) noted in Section 22.3.1.

The chemical health effects assessment criteria utilized in the evaluation of exposure to chemicals were the British Columbia Contaminated Sited Regulation (BC CSR 1997) and Health Canada hazard and incremental lifetime cancer risk thresholds (Table 22.2-3).

Table 22.2-3: Health Risk Thresholds

Type	Regulatory Threshold	Source
Non-Cancer Effects	HI: 1 (unitless)	Provincial: BC Contaminated Sites Regulation
Non-Cancer Effects	HQ: 0.2 (unitless)	Federal: Health Canada
Cancer	ILCR: $1x10^{-5}$ (unitless)	Provincial: BC Contaminated Sites Regulation Federal: Health Canada

22.3 Scope of the Assessment

22.3.1 Information Sources

The evaluation of health effects is informed by the findings of the HHRA (Appendix 22-A), along with information, analytical results, and predictive modelling results associated with the effects assessments completed for a number of the other ICs and VCs, including:

- Air Quality Effects Assessment (Volume 3, Chapter 7);
- Noise Effects Assessment (Volume 3, Chapter 8);
- Hydrogeology Effects Assessment (Volume 3, Chapter 10);
- Groundwater Quality Effects Assessment (Volume 3, Chapter 11);
- Surface Water Quality Effects Assessment (Volume 3, Chapter 13);
- Sediment Quality Effects Assessment (Volume 3, Chapter 14);
- Vegetation and Ecosystems Effects Assessment (Volume 3, Chapter 15);
- Wildlife and Wildlife Habitat Effects Assessment (Volume 3, Chapter 16); and
- Fish and Fish Habitat Effects Assessment (Volume 3, Chapter 18).

As outlined in Chapter 6 (Effects Assessment Methodology), IDM has not conducted primary traditional use or traditional ecological knowledge (TEK) surveys in support of the Project due to the preferences of Nisga'a Nation, as represented by the Nisga'a Lisims Government (NLG), and EAO's and the Agency's direction for comparatively low levels of engagement with the other Aboriginal Groups potentially affected by the Project. IDM has committed to using TEK where that information is publicly available. As no TEK relevant to this effects assessment was publicly available at the time of writing, no TEK has been incorporated.

22.3.1.1 Summary of Air Quality Effects Assessment

Air Quality is considered an IC. Effects on Air Quality caused by Project-related components and activities have the potential to affect VCs, including Surface Water Quality, Vegetation and Ecosystems, Wildlife and Wildlife Habitat, Aquatic Resources, Fish and Fish Habitat, Social VCs, and Human Health.

Spatial boundaries established for the Air Quality effects assessment are presented in Figure 22.3-2 below (Section 22.3.4 Assessment Boundaries). Air Quality effects were assessed for a local study area (LSA) that included consideration of topographical features that are expected to limit dispersion of air emissions by the Project. The LSA also included the nearest community, Stewart, located approximately 15 km southwest of the Project. A regional study area (RSA) was not established as the LSA was considered sufficiently large to include pollutant isopleths representing 10% of the BC Ambient Air Quality Objectives, as recommended in the Guidelines for Air Quality Dispersion Modelling in British Columbia (MOE 2015).

The Project is located in an area of complex terrain with steep valleys dominated by forest cover at lower elevations and rock, snow, and ice at higher elevations. The area is remote and there are no specific anthropogenic sources of air emissions, except for occasional recreational and commercial activities along the Access Road. Baseline air quality is likely to be influenced by natural sources or long-range pollutant transport by regional or continental airflow.

22.3.1.1.1 Assessment

The temporal boundaries for the Air Quality Effects Assessment considered those periods when the highest levels of air emissions are expected: the 18-month Construction Phase and the 6-year Operation Phase. During the Construction Phase, Year -1 was selected as it will include site development and construction of the TMF. During the Operation Phase, Year +3 was selected as it will have the highest throughput levels and is considered to be the 'worst-case' scenario for air emissions.

Project activities will generate fugitive dust, exhaust emissions from mine equipment, and air emissions from the Process Plant. The primary measurement indicators for Air Quality are dustfall rates and concentrations of criteria air contaminants, such as particulate matter, SO_2, and NO_2.

Baseline air quality was modelled using data from air quality monitoring stations that are representative of remote areas typical of mine locations in northwest BC, that are in the same Biogeoclimatic zone, and that are subject to similar seasonal climatic regimes. Dustfall rates have been modelled to support other VC assessments. Baseline dustfall data have been collected at five mine projects within an approximate 180 km radius of the Project.

The Air Quality Effects Assessment used predictive methods to quantify the air pollutant concentrations at receptor sites within the LSA. Potential effects were quantified based on the following:

- A review of Project data to identify potential air emission sources;
- Collection and identification of potential sensitive receptors or receptors of interest identified for other VC assessments;
- Dispersion modelling used to predict potential pollutant concentrations levels from mining activities; and
- Comparison of predicted pollutant concentration levels with provincial ambient air quality.

Measures to mitigate the effects on Air Quality are focused on reducing emissions from point or equipment sources and controlling fugitive dust from mining-related activities. Most of the mitigation measures are relevant for the Construction, Operation, and Closure and Reclamation Phases of the Project and rely on mitigation by design, best available technologies, and best management practices (BMPs). The measures include the following:

- Reducing the number of Project-related vehicles on roads, the amount of time vehicles operate, and distance travelled;
- Ensuring all equipment is properly maintained and turned off when not in use;

- Using vapour-recovery units at fuel and chemical storage tanks;
- Ensuring roads are maintained and kept in good repair;
- Designing the underground ventilation systems to dilute and remove dust, diesel emissions, and blasting fumes;
- Designing the TMF to reduce dust sources, generation, and dispersal; and
- Training all on-site equipment operators in ways to reduce generation of dust and emissions and to optimize dust and emission controls.

Residual effects on Air Quality include increased criteria air contaminants and fugitive dust that will affect a local geographical extent within the LSA. The magnitude of these effects is expected to be low and the effects are reversible; levels are expected to return to baseline levels after mine closure.

There are three proposed or currently operating projects within the LSA that have the potential to cumulatively affect Air Quality: Stewart Bulk Terminal, Stewart World Port, and the proposed Bitter Creek Hydro Project. Cumulative effects are predicted to be of low magnitude (i.e., below provincial ambient air quality objectives), reversible, and affect a local geographical extent within the LSA.

22.3.1.2 Summary of Noise Quality Effects Assessment

Noise is an IC that may have an effect on identified VCs, such as Wildlife and Wildlife Habitat, Cultural and Heritage Resources, Human Health, and Social VCs, including Recreational Values and Current Use of Lands and Resources for Traditional Purposes.

The LSA for the Noise Effects Assessment was selected to include the extent of changes in background noise levels and includes a 3 km buffer around the proposed Project footprint. This distance is twice that required to limit the effects of noise from industrial development, as recommended in BC Oil and Gas Commission guidelines (OGC 2009).

As noise effects dissipate relatively quickly and are not predicted to occur beyond the area identified in the LSA.

22.3.1.2.1 Assessment

The primary measurement indicators for noise were A-weighted sound pressure level (in dBA) at potentially affected wildlife and human receptors and peak noise levels and vibration from blasting events.

Project-specific baseline noise studies were not conducted. Baseline noise levels were characterized based on existing data, methods, and assumptions used to define baseline conditions for oil and gas activities in similar remote locations. Existing data from previous mine environmental assessments in the region were also used; these relied on recommended baseline ambient sound levels referenced in the Alberta Energy and Utilities Board Noise Control Directive 38 (EUB 2007) and the BC Oil and Gas Commission Noise Control Best Practices Guideline (OGC 2009).

The Noise Effects Assessment used the following sources to identify and quantify potential noise and blasting-related effects of the Project:

- A review of Project data and information to identify potential noise sources and blasting locations;
- Collection and identification of potential sensitive receptors or receptors of interest related to other VC assessments;
- Noise model runs to calculate potential noise levels from construction and mining activities and to account for potential effects from blasting; and
- A comparison of predicted noise and blast effect levels to applicable Project thresholds at specific receptors.

Surface blasting will only take place during the Construction Phase, so blasting effects are limited to this phase.

Vibration levels from blasting were predicted to be below noise criteria thresholds identified for effects at fish habitat and spawning areas, which were considered as possible receptors. Therefore, further assessment of vibration effects was not undertaken.

Noise effects will occur throughout the Construction, Operation, and Closure and Reclamation Phases. Key noise mitigation measures rely on design mitigation and BMPs and are primarily focused on controlling noise at the source and controlling the noise pathway. The measures include:

- Limiting impulse events, such as blasting, during the Operation Phase to certain times of the day. Instantaneous charge per delay will be minimized to suit blast;
- Optimizing the design of the Access Road and Haul Road to minimize distance travelled;
- Ensuring equipment is turned off when not in use; and
- Conducting regular servicing of all mobile and stationary engines to maintain efficiency.

Mitigation measures typically reduce noise rather than eliminate it. Therefore, a residual effect will occur, resulting in measurable changes in noise levels during the Project’s Construction, Operation, and Reclamation and Closure Phases. The magnitude of residual effect is expected to be moderate, and the effects are reversible. Levels are expected to return to baseline levels after mine closure.

There is the potential for the Project and the proposed Bitter Creek Hydro Project to cumulatively affect Noise. Cumulative effects are predicted to be of moderate magnitude, reversible, and affect a local geographical extent within the LSA.

22.3.1.3 Summary of Hydrogeology Effects Assessment

Hydrogeology (groundwater flow system) is an IC. Effects on Hydrogeology caused by the proposed Project can potentially affect related aquatic VCs, such as Hydrology, Surface Water Quality, Aquatic Resources, and Fish and Fish Habitat.

The Technical Study Areas (TSAs) delineate the areas of the LSA where Bromley Humps (Figure 22.1-2) and the Mine Site (Figure 22.1-3) are anticipated to have an immediate potential effect on the hydrogeological system. The Mine Site TSA includes the proposed underground mine, the temporary Waste Rock Storage Area (WRSA), and the areas where water originates, at or near the Project, to where it drains or discharges. The Bromley Humps TSA comprises the physical structures and mine activities of the Project around Bromley Humps and surface waters that could be affected by seepage of mine contact water.

The mountainous terrain associated with the Project area has a major influence on the groundwater flow system, causing steep hydraulic gradients that drive groundwater flow from higher to lower elevations. The water table is generally a subdued replica of topography, with depths to groundwater typically greater in the uplands relative to the valley bottoms.

In addition to review of existing information, the methods used to characterize the hydrogeological conditions included the following activities:

- Borehole drilling and logging;
- Installation and development of groundwater monitoring wells;
- Hydraulic conductivity testing (packer tests and slug tests);
- Measurements of groundwater level in boreholes and wells; and
- Measurements of inflow rates and water levels in the existing decline and pressure heads in underground boreholes.

22.3.1.3.1 Assessment

The Project is expected to affect hydrogeological processes throughout the life of mine, from the Construction Phase through to the Post-Closure Phase. However, post-closure changes to groundwater will continue to occur beyond that period, until water levels in the flooded mine reach steady-state conditions.

Potential effects on Hydrogeology include changes to site drainage patterns and subsurface characteristics due to construction of infrastructure during the Construction and Operation Phases, changes to groundwater flow caused by mining and dewatering, and changes to groundwater flow when the underground mine is flooded during the Closure and Reclamation and Post-Closure Phases.

Activities likely to influence groundwater flows include development, dewatering, and re-flooding of the underground mine resulting from modifications to the subsurface characteristics and groundwater flow. The quantity of groundwater discharged into nearby creeks is a key issue and is likely to be affected by specific activities, such as excavation of the lower portal entrance and tunnel, lateral development of the mine, installation of bulkheads in the declines and ventilation exhaust raise, and flooding of the underground mine at closure.

During the Construction and Operation Phases, potential effects on groundwater flow are associated with drilling, blasting, excavation, and backfilling activities and by underground water management. No specific mitigation measures are proposed or currently planned to limit inflows to the mine workings. The mining and backfilling will be designed to minimize interaction with the hydraulic regime. If inflows are greater than expected, as determined by monitoring, additional measures may be needed: potential mitigation measures include the application of shotcrete to seal exposures of materials, the construction of additional plugs and seals in the underground workings, or barriers to limit the movement of groundwater.

During the Closure and Reclamation Phase, a hydraulic bulkhead will be constructed in the lower access ramp, and pumps/drains will be shut off to allow re-flooding of the mine. As the mine floods, the drawdown induced during operations will decrease, and the reductions in base flow to nearby streams will diminish over time. During the Post-Closure Phase, the groundwater system at the Mine Site will return to near baseline conditions.

The residual effect associated with Hydrogeology relates to changes to subsurface characteristics and groundwater flow caused by the mine development and dewatering. Overall, at the scale of the LSA and RSA, the residual effect on Hydrogeology is expected to be limited to a negligible reduction in base flow in Goldslide Creek, Rio Blanco Creek, and Bitter Creek during the Operation Phase, which will be offset by the discharges to these streams. For the Post-Closure Phase, the effect on base flow will be reversed and will consist of a negligible increase in base flow in Goldslide Creek, Rio Blanco Creek, and Bitter Creek.

Cumulative effects could result from activities related to current or proposed projects in the defined boundaries. The Bitter Creek Hydro Project involves the construction of an intake and diversion structure in the Bitter Creek valley, overlapping the Red Mountain and Bromley Humps TSAs, and could affect changes in base flow near Bitter Creek. However, even if the Bitter Creek Hydro Project is in operation when mining starts, the combined effect of these two projects to the groundwater base flow in Bitter Creek would be expected to be negligible during the Operation and Post-Closure Phases.

22.3.1.4 Summary of Groundwater Quality Effects Assessment

Groundwater is water that is held within soil and rocks. Groundwater Quality is considered an IC and is linked to VCs such as Surface Water Quality, Vegetation and Ecosystems, Wildlife and Wildlife Habitat, Fish and Fish Habitat, and Human Health.

Mine Site and Bromley Humps TSAs established for Hydrogeology were also used for Groundwater Quality.

22.3.1.4.1 Assessment

Information for the Groundwater Quality Effects Assessment was derived from baseline data collection, ongoing monitoring, technical reports, hydrogeologic modelling, and consultation with government, community members, Aboriginal Groups, stakeholders, and the public.

The Project will influence Groundwater Quality throughout the 22-year life of the mine and will extend beyond the Post-Closure Phase as changes to groundwater will continue until water levels in the mine reach steady-state. The primary measurement indicator for Groundwater Quality is changes in concentrations of water quality parameters compared to baseline and provincial or federal guidelines for freshwater aquatic life. Parameters include dissolved metals, anions, nutrients, alkalinity and acidity, pH, conductivity, and temperature.

Potential Project effects on Groundwater Quality include changes to groundwater quality resulting from metal leaching and acid rock drainage, blasting, and dewatering; changes to groundwater quality as a result of flooding at mine closure (Mine Site TSA); and changes caused by infiltration through water management features (Bromley Humps TSA).

During mining operations, the interaction of groundwater with waste rock backfill is the dominant effect on Groundwater Quality. At closure, a hydraulic bulkhead will be constructed in the lower access ramp, and pumps and drains will be shut off to allow re-flooding of the mine. Groundwater and water infiltrating through unflooded portions of the mine will mix with water in the re-flooded mine pool, which will contain soluble oxidation products generated during mine operations. The TMF will be lined, but some seepage of tailings process water into groundwater is expected to occur due to potential imperfections in the liner. The TMF seepage will have significantly elevated concentrations compared to baseline groundwater concentrations.

Key mitigation approaches involve minimizing potential changes to Groundwater Quality as a result of metal leaching/acid rock drainage (ML/ARD) during blasting, dewatering, and flooding, including cementing some of the waste rock and mixing talus with lime to reduce metals and acidity loading from the backfill. To limit seepage, the TMF will be fully lined and on closure it will be capped; these measures will limit infiltration, ingress of oxygen, acidic conditions, and the release of sulphate and metals during the re-flooding period.

After mitigation measures are implemented, two residual effects are expected:

- Changes to Groundwater Quality as a result of ML/ARD, blasting, and dewatering (Mine Site TSA): effect of backfill on Groundwater Quality during Construction and Operation; and

- Changes to Groundwater Quality as a result of flooding (Mine Site TSA): effect of backfill on Groundwater Quality during Closure and Reclamation and Post-Closure.

The magnitude of the effect from ML/ARD, blasting, and dewatering is considered low for all parameters except cadmium, which exceeds BC Contaminated Sites Regulation (CSR) standards for freshwater aquatic life. Overall, the magnitude for this effect was rated as moderate.

The magnitude of the effect to Groundwater Quality due to flooding was rated as moderate for alkalinity, calcium, cobalt, magnesium, manganese, mercury, and selenium and rated high for cadmium and chromium. Overall, the magnitude for this effect was rated as high.

Of the two residual effects, only the interaction between groundwater and the mine backfill is considered to have the potential for cumulative effects.

The Bitter Creek Hydro Project, which is a reasonably foreseeable future project in close proximity to the Project, is not expected to have any effect on Groundwater Quality and thus the residual cumulative effects assessment is the same as the residual effects assessment conducted for the Project alone.

22.3.1.5 Summary of Surface Water Quality Effects Assessment

Surface Water Quality is a VC that may have an effect on other identified VCs, such as Sediment Quality, Aquatic Resources, Fish and Fish Habitat, Wildlife and Wildlife Habitat, and Human Health.

Figure 22.3-3 below (Section 22.3.4 Assessment Boundaries) illustrates the spatial boundaries established for Surface Water Quality.

22.3.1.5.1 Assessment

The primary measurement indicators for Surface Water Quality are a change in parameter concentrations compared to baseline (background) and provincial and/or federal guidelines for freshwater aquatic life.

Effects on Surface Water Quality were generally discussed for three Project areas: the Mine Site (underground mine and portals), Bromley Humps (Process Plant, supporting infrastructure, and TMF), and the Access and Haul Roads.

Effects from the Access Road and Haul Road are generally from road runoff during the Construction and Operation Phases. Effects from the Mine Site are from the dewatering of the underground mine and the subsequent discharge into Goldslide Creek. Effects from Bromley Humps area are primarily from construction activities of the mine infrastructure and discharge of water from the TMF into Bitter Creek. A Water Treatment Plant will treat the water to federal requirements prior to release to the Bitter Creek receiving environment.

Key Surface Water Quality mitigation measures rely on design mitigation, BMPs, and monitoring and are primarily focused on the collection of all contact water for monitoring and treatment (if required) before release to the aquatic environment. Other measures include the following:

- Diverting non-contact water to the natural environment so that it does not mix with contact water;
- Limiting instream works and their duration to minimize erosion and sedimentation in watercourses;
- Intercepting seepage from the TMF and pumping it back to the TMF;
- Covering the TMF at closure to keep runoff clean; and
- Employing dust suppression measures to minimize aerial deposition and runoff into nearby watercourses.

Mitigation measures typically minimize the change in Surface Water Quality rather than eliminate it. Therefore, a residual effect will occur, resulting in measurable changes in Surface Water Quality concentrations during the Project's Construction, Operation, and Closure and Reclamation Phases. The magnitude of residual effects is expected to be low to moderate, with local extent, partially reversible, and are expected to return to close to baseline levels after mine closure. All residual effects were identified as not significant.

There is the potential for the Project and the proposed Bitter Creek Hydro Project to cumulatively affect Surface Water Quality. Although the Bitter Creek Hydro Project remains very early stage and in a proposal only, the cumulative effects, should it proceed, are predicted to be of low to moderate magnitude, partially reversible, and affect a local geographical extent within the LSA. All cumulative residual effects were identified as not significant.

The Aquatic Effects Management and Response Plan (AEMRP, see Volume 5, Chapter 29, Section 29.5), in conjunction with several other management plans, has been developed to monitor the effects of the Project on aquatic ecosystem components and to confirm the predictions of the effects assessments in the Application/EIS. Monitoring will also assess the efficacy of the implemented mitigation measures and ensure regulatory compliance. In the event that original predictions of effects and mitigation effectiveness are not as expected, adaptive management principles and strategies will be implemented.

22.3.1.6 Summary of Sediment Quality Effects Assessment

Sediment Quality is a VC that may have an effect on other identified VCs, such as Aquatic Resources, Fish and Fish Habitat, and Human Health. The spatial boundaries established for Sediment Quality were the same as those established for Surface Water Quality (Figure 22.3-3, presented in Section 22.3.4, Assessment Boundaries).

22.3.1.6.1 Assessment

The primary measurement indicator for Sediment Quality is a change in parameter concentrations compared to provincial and/or federal guidelines for freshwater aquatic life. Recent baseline sampling of Sediment Quality has been completed in watercourses in the Project area in 2014 and 2016. Elevated background concentrations of some metals are evident in Bitter Creek, Goldslide Creek, and Bear River receiving environments, as well as in the reference sites in Otter Creek and American Creek. Effects from the Access Road and Haul Road are generally from road runoff during the Construction and Operation Phases. Effects from the Mine Site are from the dewatering of the underground mine and the subsequent discharge into Goldslide Creek. Effects from the Bromley Humps area are primarily associated with construction activities of the mine infrastructure and discharge of water from the TMF into Bitter Creek. A Water Treatment Plant will be constructed on-site to treat the water to federal requirements prior to release to the Bitter Creek receiving environment.

Key Sediment Quality mitigation measures rely on design mitigation, BMPs, and monitoring and are primarily focused on minimizing the potential for erosion in runoff and on the collection of all contact water for monitoring and treatment (if required) before release to the aquatic environment. Other measures include the following:

- Diverting non-contact water to the natural environment so that it does not mix with contact water;
- Limiting instream works and their duration to minimize erosion and sedimentation in watercourses; and
- Employing dust suppression measures to minimize aerial deposition and runoff into nearby watercourses.

Mitigation measures typically minimize the change in Sediment Quality rather than eliminate it. Therefore, a residual effect will occur, resulting in measurable changes in sediment concentrations during the Project's Construction, Operation, and Closure and Reclamation Phases. The magnitude of residual effects is expected to be low, with a local extent, partially reversible, and is expected to return to close to baseline levels after mine closure. All residual effects were identified as not significant.

There is the potential for the Project and the proposed Bitter Creek Hydro Project to cumulatively affect Sediment Quality. Cumulative effects are predicted to be of low to moderate magnitude, partially reversible, and affect a local geographical extent within the LSA. All cumulative residual effects were identified as not significant.

The AEMRP, in conjunction with several other management plans, has been developed to monitor the effects of the Project on aquatic ecosystem components and to confirm the predictions of the effects assessments in the Application/EIS. Monitoring will also assess the efficacy of the implemented mitigation measures and ensure regulatory compliance. In the event that original predictions of effects and mitigation effectiveness are not as expected, adaptive management principles and strategies will be implemented.

22.3.1.7 Summary of Vegetation and Ecosystems Effects Assessment

The Ecosystems and Vegetation VCs included in the effects assessment are noted above. The Vegetation and Ecosystems VCs are linked to Landforms and Natural Landscapes, Wildlife and Wildlife Habitat, Fish and Fish Habitat, Air Quality, and Human Health through the consumption of country foods. Spatial boundaries for Vegetation and Ecosystems are similar to those established for Wildlife and Wildlife Habitat (Figure 22.3-5, presented in Section 22.3.4, Assessment Boundaries).

22.3.1.7.1 Assessment

The Project will interact with Vegetation and Ecosystems during the Construction, Operation, Reclamation and Closure, and Post- Closure Phases of the Project. Potential effects of Project interactions with Vegetation and Ecosystems include the following:

- Loss and alteration of soil quality and quantity through soil stripping, handling, stockpiling, and dust effects;

- Loss of ecosystem function, abundance, and/or distribution through surface clearing;
- Alteration of ecosystem function through edge effects and fragmentation, alteration of hydrological connectivity, dust effects, and introduction and/or spread of invasive plant species;
- Loss of known occurrences of rare plant and/or lichen habitat through surface clearing; and
- Alteration of rare plant/lichen habitat edge effects and fragmentation, alteration of hydrological connectivity, dust effects, and introduction and/or spread of invasive plant species.

Mitigation approaches are focused on reducing or avoiding disturbance of Vegetation and Ecosystems, including:

- Implementing ecosystem-based revegetation and progressive reclamation promptly to minimize erosion potential and to facilitate initiation of successional ecological processes;
- Developing soil-handling procedures specific to alpine and parkland soils;
- Conducting construction activities to ensure minimal risk to old and mature forest wildlife habitat during sensitive periods;
- Avoiding surface disturbance in areas with known rare plant and lichen populations and avoiding use of all herbicide sprays within 200 metres (m) of rare plant and lichen populations;
- Surveying and removing existing invasive plant populations to prevent the spread to adjacent areas;
- Reducing impacts to terrestrial ecosystems that depend on hydrological connectivity and flow through management by ensuring free passage of water through fill materials; and
- Ensuring that setback and buffer distances from surface water bodies and riparian features are implemented and maintained.

Potential residual effects include the following:

- Loss and degradation of ecologically valuable soil due to fugitive dust, declining stockpile soil quality, compaction, erosion, degradation of soil structure due to soil handling, and changes in soil moisture and nutrient regimes within reclaimed soils. Approximately 580 hectares (ha) of ecologically valuable soil may be subject to degradation, mainly due to fugitive dust. The amount of ecologically valuable soil predicted to be permanently lost is 139.5 ha;

- Loss of alpine and parkland ecosystems and old and mature forested ecosystems because of the time required to restore ecosystem function and extent to a level similar to that of baseline conditions;
- Loss of BC CDC-listed ecosystems (Blue-listed) due to clearing activities associated with construction; and
- Loss of rare plants and lichens due to clearing activities at the proposed Process Plant and Access and Haul Roads.

The effects on ecologically valuable soil are expected to last more than 22 years as the soils under the footprint of roads and infrastructure remaining after Closure will be permanently lost. These effects are limited in their geographic extent, occurring within and adjacent to proposed infrastructure.

Loss of alpine and parkland ecosystems is considered to be of moderate magnitude, but is not significant as Project effects are limited and occur within and immediately adjacent to the footprint of the Haul Road and Quarry. Loss of old and mature forests is considered to be of high magnitude but not significant. The Project is not expected to result in considerable changes to the distribution, abundance, or function of ecosystems or the ecological conditions that support old and mature forest ecosystems within the LSA.

The magnitude of loss of BC CDC-listed ecosystems ranges from negligible to high depending on the specific effect. Residual effects occur predominantly within the Project footprint and adjacent areas of the Quarry, Borrow, and Access Road. The effect is considered to be not significant based on the extent of loss and the discrete nature of the effect.

The magnitude of potential loss or alteration of rare mosses, lichens, vascular plants, liverworts, and their habitat ranges from negligible to high depending on the final design and activities of the Project and on the effectiveness of prevention measures.

Past, present, and potential activities occurring in the Vegetation and Ecosystems RSA have the potential to cause cumulative effects on Vegetation and Ecosystems affected by the Project. The following bullets summarize results of cumulative effects analysis for Vegetation and Ecosystems:

- Cumulative effects on rare plants and lichens are not expected to occur, as there is no overlap between the relevant species and projects within the RSA;
- Cumulative effects on ecologically valuable soil are considered to be not significant, as effects are not expected to influence the ecological conditions of other VCs;
- Cumulative effects on alpine and parkland ecosystems are considered to be not significant, as they are not expected to influence ecological conditions that support alpine and parkland vegetation;
- Cumulative effects on old and mature forest ecosystems are considered to be not significant, as effects fall within a range of natural variation that could be remediated over time; and

- Cumulative effects on two BC CDC-listed ecosystems are considered to be not significant, since the CDC-listed ecosystem in the RSA occurs in 13 BEC subzones, across a large geographic area, and represents only about 2% of the known provincial abundance.

22.3.1.8 Summary of Wildlife and Wildlife Habitat Effects Assessment

In gathering data to support the Wildlife and Wildlife Habitat Effects Assessment, IDM assessed existing data, conducted surveys to complete required baseline data, and compiled all data that was relevant to the Project. Wildlife and Wildlife Habitat may affect Human Health through the consumption of country foods. Spatial boundaries established for Wildlife and Wildlife Habitat are presented in Figure 22.3-5 below (Section 22.3.4 Assessment Boundaries).

Knowledge of existing conditions within the Project area was augmented through field investigations conducted from 2015 to 2017. Field surveys were conducted based on provincial inventory standard protocols and other published documents pertaining to data collection and analysis methods. Depending on the focal species, field surveys were conducted, including species-specific and opportunistic surveys, using a combination of ground and aerial methods. Field investigations were primarily focused on the LSA for all Wildlife VCs with the exception of the Mountain Goat. Aerial surveys were conducted in the RSA for the Mountain Goat in summer 2016 and March 2017. Habitat suitability models were developed to describe distribution and availability of suitable habitats. Habitat modeling was used to assess potential Project effects on identified Wildlife VCs within the regional study area. Habitat models were developed for all Wildlife VCs following the provincial standard for wildlife habitat ratings and were based on Terrestrial Ecosystem Mapping (TEM) in the LSA and Predictive Ecosystem Mapping (PEM) in the RSA. PEM and TEM mapping was completed as part of baseline studies for the Project and is also used in the Vegetation and Ecosystems Effects Assessment in Volume 3, Chapter 15. Vegetation and Ecosystems was one of several pathways identified for the Wildlife VCs. Wildlife habitat ratings that were based on Vegetation and Ecosystems form the basis of the Wildlife and Wildlife Habitat Effects Assessment. In total, wildlife habitat ratings were completed for 19 species and four guilds of migratory bird habitat.

Habitat modelling results were validated by field survey findings within the study areas. Alpine areas provided suitable habitat for the Mountain Goat, Grizzly Bear, Hoary Marmot, and Non-Migratory Game Birds. Low elevation areas within Bitter Creek valley were primarily forested providing suitable habitat for Furbearers, Grizzly Bear, Bats, Migratory Breeding Birds, Migratory Bird Species at Risk, and Raptors. Lake, wetland, and riparian habitat were limited within LSA. The only lake within the LSA was Clements Lake, situated at the northwest corner of the LSA near the confluence of Bitter Creek and Bear River. Few wetlands exist beyond the margins of Clements Lake and the floodplains of Bitter Creek.

22.3.1.8.1 Assessment

The assessment considered potential Project-related effects on habitat availability, habitat distribution, mortality, chemical hazards, and attractants. Potential effects on habitat availability included those occurring through direct habitat loss or alteration as well as sensory disturbances (e.g., noise). Chemical hazards included the potential effects of any Project-related chemicals that may cause adverse health effects on Wildlife VCs. Attractants included the potential effects of any Project-related features or materials that may interest or provide resources for Wildlife VCs that could lead to behavioral changes and potential human-wildlife conflicts.

Numerous mitigation measures were used to reduce potential effects on Wildlife and Wildlife Habitat. These measures followed the provincial mitigation hierarchy (i.e., avoid, minimize, restore, and offset) and all feasibly practicable measures have been considered and applied prior to moving to the next level. Many mitigation measures were implemented during the planning stages of the Project. These include Project design, such as siting and route selection, selection of best available technologies to-date for Project infrastructure and mining equipment, and a commitment to progressive reclamation. Other mitigation strategies focus on the implementation of widely recognized BMPs and development of procedural mitigation measures. These include a wildlife education program and wildlife protection measures designed to minimize disturbance, reduce barriers, prevent entrapment, and manage vehicle traffic, chemicals, and attractants.

The potential effects to habitat availability, habitat distribution, and mortality risk were predicted as residual effects within the assessment. All residual effects were identified as not significant. In general, residual effects were expected to be low to moderate in magnitude and occurring at either a discrete or local level. Residual effects were identified as being mainly long-term in duration, occurring from Construction to Post-Closure Phases, and primarily as reversible or partially reversible. Confidence in the effects assessment was high or moderate.

A cumulative effects assessment was conducted for Wildlife VCs where residual effects were predicted. The cumulative effects assessment considered past projects, such as Highway 37A, Stewart Bulk Terminal, Stewart World Port, and Long Lake Hydro Project. Past, present, and future forestry activities, mineral exploration, parks and protected areas, and recreational/commercial/subsistence harvest were also included. The Bitter Creek Hydro Project was the only reasonably foreseeable future project with potential to interact with the Project effects. Three effects, habitat availability, habitat distribution, and mortality, were predicted as residual cumulative effects within the assessment. All were identified as not significant. Residual cumulative effects were expected to be low to moderate in magnitude within the RSA. Residual cumulative effects were identified as being long-term in duration, occurring from Construction through Post-Closure Phases, and primarily as reversible or partially reversible. Confidence in the assessment was moderate and high.

The Wildlife Management Plan (see Volume 5, Chapter 29, Section 29.26), in conjunction with several other management plans, has been developed to minimize potential effects on Wildlife and Wildlife Habitat as a result of interactions with Project components or activities. While describing mitigation strategies in detail, the Wildlife Management Plan also outlines the development of monitoring programs to evaluate certain environmental assessment predictions, assess effectiveness of mitigation measures, and support an adaptive management approach to mitigating potential effects resulting from the Project. Monitoring programs are intended to assess the effectiveness of the mitigation and to detect unanticipated effects. The information from the monitoring program will be used to guide adaptive management protocols. In the event that original predictions of effects and mitigation effectiveness are not as expected, adaptive management principles and strategies will be implemented.

22.3.1.9 Summary of Fish and Fish Habitat Effects Assessment

Recent (2014 to 2016) baseline studies indicate Dolly Varden are present in Bitter Creek. Their distribution covers the entire fish-bearing section of Bitter Creek. Coastrange sculpin have been documented in Bitter Creek near the mouth. Bear River has a much more diverse fish community, with salmon species (Coho, Chinook, Chum, and Pink salmon), Steelhead/Rainbow Trout, Dolly Varden, Eulachon, and Coastrange Sculpin. Bitter Creek is a confined, heavily turbid mainstem comprising predominantly strong riffle habitat through steep valleys. Bitter Creek is fish bearing up to the first of seven physical barriers, located 13.8 km upstream from the confluence with Bear River. Bitter Creek has multiple tributaries, two of which are fish bearing within the lower reaches: Hartley Gulch and Roosevelt Creek.

Fish and Fish Habitat may affect Human Health through the consumption of country foods. The spatial boundaries associated with the Fish and Fish Habitat Effects Assessment are presented in Figure 22.3-4 below (Section 22.3.4 Assessment Boundaries).

22.3.1.9.1 Assessment

The primary measurement indicators for Fish are habitat loss and alteration, fish species presence or absence, fish population metrics, growth, survival, and reproduction of fish, and water quality. The primary measurement indicators for Fish Habitat are water quality, flows and flow timing, sediment quality, periphyton and benthic invertebrate community metrics, and channel morphology.

Potential effects were identified based on key interactions between the Project and Fish and Fish Habitat. The potential effects were assessed from habitat loss, increased fishing pressure, changes in aquatic resources, surface water quality, sediment quality and stream flows, and blasting activities.

Fish Habitat loss is expected along a short section of the Access Road that will be placed within the Bitter Creek high water mark. Changes in surface water quality are expected in Bitter Creek for a single water quality parameter: selenium. This effect was determined to be not significant, because potential effects on fish (Dolly Varden) will be localized and have no far-reaching effects on regional productivity or diversity. The effect is also seasonal (winter only), short-term (operations), and partially reversible. Changes in streamflow are predicted in Bitter Creek during the winter period. This effect was determined to be not significant; any effects on fish (Dolly Varden) will be localized and have no far-reaching effects on regional productivity or diversity. The effect is also seasonal (winter only), short-term (operations), and reversible

Key Fish and Fish Habitat mitigation rely on design mitigation, BMPs, and monitoring and are primarily focused on minimizing the potential for erosion in runoff and on the collection of all contact water for monitoring and treatment (if required) before release to the aquatic environment. Other measures include the following:

- Diverting non-contact water to the natural environment so that it does not mix with contact water;
- Matching, to the extent possible, the discharge from the TMF to the receiving environment hydrograph;
- Limiting instream works and their duration to minimize erosion and sedimentation in watercourses; and
- Employing dust suppression measures to minimize aerial deposition and runoff into nearby watercourses.

Mitigation measures typically minimize the effects to Fish and Fish Habitat rather than eliminate it. Therefore, a residual effect will occur, resulting in measurable changes in Fish and Fish Habitat during the Project's Construction, Operation, and Closure and Reclamation Phases. The magnitude of residual effects is expected to be low to moderate, with local extent, and partially reversible. All residual effects were identified as not significant.

There is the potential for the Project and the proposed Bitter Creek Hydro Project to cumulatively affect Fish and Fish Habitat. Cumulative effects are predicted to be of low magnitude, partially reversible, and affect a local geographical extent within the LSA. All cumulative residual effects were identified as not significant.

The AEMRP, in conjunction with several other management plans, has been developed to monitor the effects of the Project on aquatic ecosystem components and to confirm the predictions of the effects assessments in the Application/EIS. Monitoring will also assess the efficacy of the implemented mitigation measures and ensure regulatory compliance. In the event that original predictions of effects and mitigation effectiveness are not as expected, adaptive management principles and strategies will be implemented.

22.3.2 Input from Consultation

IDM is committed to open and honest dialogue with regulators, Aboriginal Groups, community members, stakeholders, and the public. IDM conducted consultation with regulators and Aboriginal Groups through the Working Group co-led by the EAO and the Agency. Where more detailed and technical discussions were warranted, IDM and Working Group members, including NLG representatives, held topic-focused discussions, the results of which were brought back to EAO and the Working Group.

Further consultation with Aboriginal Groups, community members, stakeholders, and the public was conducted as outlined by the Section 11 Order and EIS Guidelines. The results of those consultation efforts relevant to the assessment of potential effects of the Project on the Human Health VC have been summarized in Table 22.3-1.

More information on IDM's consultation efforts with Aboriginal Groups, community members, stakeholders, and the public can be found in Chapter 3 (Information Distribution and Consultation Overview), Part C (Aboriginal Consultation), Part D (Public Consultation), and Appendices 27-A (Aboriginal Consultation Report #2) and 28-A (Public Consultation Report #2). A record of the Working Group's comments and IDM's responses can be found in the comment-tracking table maintained by EAO.

Table 22.3-1: Summary of Consultation Feedback on Human Health

Topic	Feedback by*				Consultation Feedback	Response
	NLG	G	P/S	O		
Human Health		X			Health Canada suggested that Surface Water Quality and Groundwater Quality be considered in the HEA.	Surface Water Quality and Groundwater Quality have been included as pathway components in the HEA.
Human Health		X			Health Canada suggested that IDM collect data on country food consumption, or site-specific dietary surveys, to characterize the potential health risks from consumption of country foods.	Dietary surveys and data on country food consumption were not collected in respect of the Nisga'a Nation Treaty right to harvest and eat any food from their territory. Regarding TSKLH and MNBC, the Agency has determined that they are less potentially affected by the Project and therefore conducting dietary surveys in their communities would not be appropriate.
Human Health	X				NLG requested that Soil Quality be included as an IC under the Health pillar.	The assessment of Soil Quality has been carried forward into the HEA through the assessment of potential changes to country foods.
Human Health		X			Northern Health requested that the following pathways be considered in the HHRA: • Household dust inhalation • Dermal absorption • Contaminated foods; and • Volatilization.	All pathways are being considered; however, not all are being carried forward for evaluation. There are no homes in the area that will be affected by fugitive dust, therefore indoor dust is not being evaluated. It is possible that workers could bring home dust from work on their clothing; however, this is considered an occupational health and safety issue. Dermal absorption of soil was considered and is being quantitatively evaluated in the HHRA. Ingestion of contaminated food was considered, and is being quantitatively evaluated in the HHRA (Appendix 22-A). Volatilization of volatile contaminants was considered, to the extent it is considered in the Air Quality assessment. The estimated concentration of all volatile COPCs with the potential to be released

Topic	Feedback by*				Consultation Feedback	Response
	NLG	G	P/S	O		
						from the Project site as a result of normal site activities did not exceed residential air quality standards offsite.
Human Health	X				NLG requested that the Application be supported by a conceptual site model (CSM).	The Application/EIS includes CSMs that account for both human and ecological receptors. The CSMs are informed by the Screening Level Ecological Risk Assessment (Appendix 22-B), which focuses on ecological receptors, and the HHRA (Appendix 22-A), which focuses on human receptors.
Human Health	X				NLG suggested that incidental ingestion of sediment should be added as an exposure pathway in the HEA.	Incidental ingestion of sediment as an exposure pathway is considered at the problem formulation stage of the HHRA (Appendix 22-A).

*NLG = Nisga'a Lisims Government;
G = Government - Provincial or federal agencies;
P/S = Public/Stakeholder - Local government, interest groups, tenure and license holders, members of the public;
O = Other

22.3.3 Valued Component, Assessment Endpoints, and Measurement Indicators

There are several potential pathways through which the Project could result in effects on Human Health. Potential effects pathways start with Project activities (e.g., mine water discharge, infiltration, seepage, runoff, fugitive dust emissions, process Plant emissions, and atmospheric deposition) that can cause changes to the chemistry of air, soil, sediment, surface water, groundwater, fish, wildlife, and vegetation. Project activities may also affect noise, EMFs, and light. These, in turn, have the potential to alter the baseline health of exposed receptors. The key indicators used to evaluate the Human Health VC (Table 22.3-2) include the following:

- Health Effects related to chemical and non-chemical changes in air quality associated with the Project;
- Health Effects related to changes in chemical exposure associated with the Project. This includes a comparison of baseline measurements and predictions to applicable environmental quality screening thresholds (e.g., regulatory guidelines, criteria, and/or metrics for air quality, soil quality, surface water quality, groundwater quality, and sediment quality) to identify COPCs to humans, with the hazard quotient and incremental lifetime cancer risk metrics (risk estimates) being calculated for each COPC for each human receptor group;

- Health effects related to changes in noise associated with the Project; and
- Health effects related to changes in EMF associated with the Project.

As discussed above, because the Human Health LSA is sufficiently insulated from off-Project sources of light and as no worker residences will be present at the mine, no adverse effects to non-worker human health are anticipated as a result of light. Therefore, light is not discussed further in this report.

Table 22.3-2: Assessment Endpoint and Measurement Indicators for Human Health

VC	Pathways	Primary Measurement Indicators	Assessment Endpoint	Rationale for Selection
Human Health	The following pathways will inform the assessment of Human Health: • Air quality • Soil quality • Groundwater quality • Surface water quality • Sediment quality • Country foods quality • Noise • EMFs	• Baseline levels for COPCs in soil, surface water (for drinking water), groundwater (for drinking water), sediment, air (particulate and non-particulate), and air particulate deposition. • Chemical COPC baseline levels in country foods, such as consumed fish, plants (berries), birds, and mammals (combination of measuring and modeling).	Protection of human health is defined as changes to physiological health resulting from changes in the biophysical environment related to Project activities.	Human Health is a VC and is of importance to provincial and federal regulators, NLG, and the general public.

Baseline studies and effects assessment results for the indicators will be used to support the effects assessment for Human Health:

- Air Quality (Volume 3, Chapter 7and Volume 8, Appendices 7-A and 7-C)
- Surface Water Quality (Volume 3, Chapter 13 and Volume 8, Appendices 11-D and Appendix 14-C);
- Sediment Quality (Volume 3, Chapter 14);
- Groundwater Quality (Volume 3, Chapter 11 and Volume 8, Appendices 11-D and Appendix 14-C); and

- Noise (Volume 3, Chapter 8 and Appendix 8-D).

22.3.4 Assessment Boundaries

The following sections identify the spatial, temporal, and technical boundaries applicable to the HEA. There were no applicable administrative boundaries.

22.3.4.1 Spatial Boundaries

22.3.4.1.1 Local Study Area

The LSA for the HEA encompasses an area within a 50 km radius of the Project. The LSA includes the following communities:

- District of Stewart;
- Unincorporated settlements of Meziadin Junction and Bell II;
- Village of Gitlaxt'aamiks (formerly New Aiyansh);
- Village of Gitwinksihlkw (formerly Canyon City);
- Village of Laxgalts'ap (formerly Greenville); and
- Village of Gingolx (formerly Kincolith).

The potential health effects of the Project will not extend to any federal lands nor lands outside of Canada.

The Project is also within the Nass Area and the Nass Wildlife Area, as set out in the Nisga'a Final Agreement (NFA). Pursuant to the NFA, Nisga'a Nation, as represented by NLG, has Treaty rights to the management and harvesting of fish, wildlife, and migratory birds within the Nass Wildlife Area and the larger Nass Area. The Project is also within the asserted traditional territory of Tsetsaut Skii km Lax Ha (TSKLH) and is within an area where Métis Nation BC (MNBC) claims Aboriginal rights.

The LSA for the Human Health VC considers the following pathways that are anticipated to potentially interact with the Project: air contaminants, noise, EMFs, and constituents in surface water, sediment, fish, groundwater, soil, plants, and wildlife. LSA spatial boundary figures for the Air Quality VC, Surface Water Quality VC, Fish and Fish Habitat VC, and the Wildlife and Wildlife Habitat VC have been included in this chapter (Figure 22.3-2, Figure 22.3-3, Figure 22.3-4 and Figure 22.3-5) to put the LSA into the context of the measurement indicators supporting the assessment of the Health VC.

The LSA boundary for Noise is encompassed within the figure delineating the Air Quality spatial boundary. Spatial boundaries for Sediment Quality, Groundwater Quality, and Hydrogeology are encompassed within the figure delineating the Surface Water Quality spatial boundary. Spatial boundaries for Vegetation and Ecosystems are encompassed within the figure delineating the Wildlife and Wildlife Habitat spatial boundary.

All potential direct and indirect effects to Human Health identified in this chapter are linked to one or more of the abovementioned VCs or ICs. Thus, there are no potential effects to Human Health outside of the LSA boundaries for these VCs / ICs. One exception to this is any potential effect to country foods, where these country foods may be obtained from within the Bitter Creek valley, but consumed by someone elsewhere (e.g. country foods shared in one of the communities found within the Human Health LSA boundary).

22.3.4.1.2 Regional Study Area

The RSA is defined by the boundaries of the Regional District of Kitimat-Stikine (RDKS), which includes Terrace (Figure 22.3-1). The RSA for the Human Health VC provides regional context for the assessment of potential Human Health effects in the LSA.

Figure 22.3-1: Local and Regional Study Areas – Human Health

Figure 22.3-2: Air Quality Spatial Boundaries

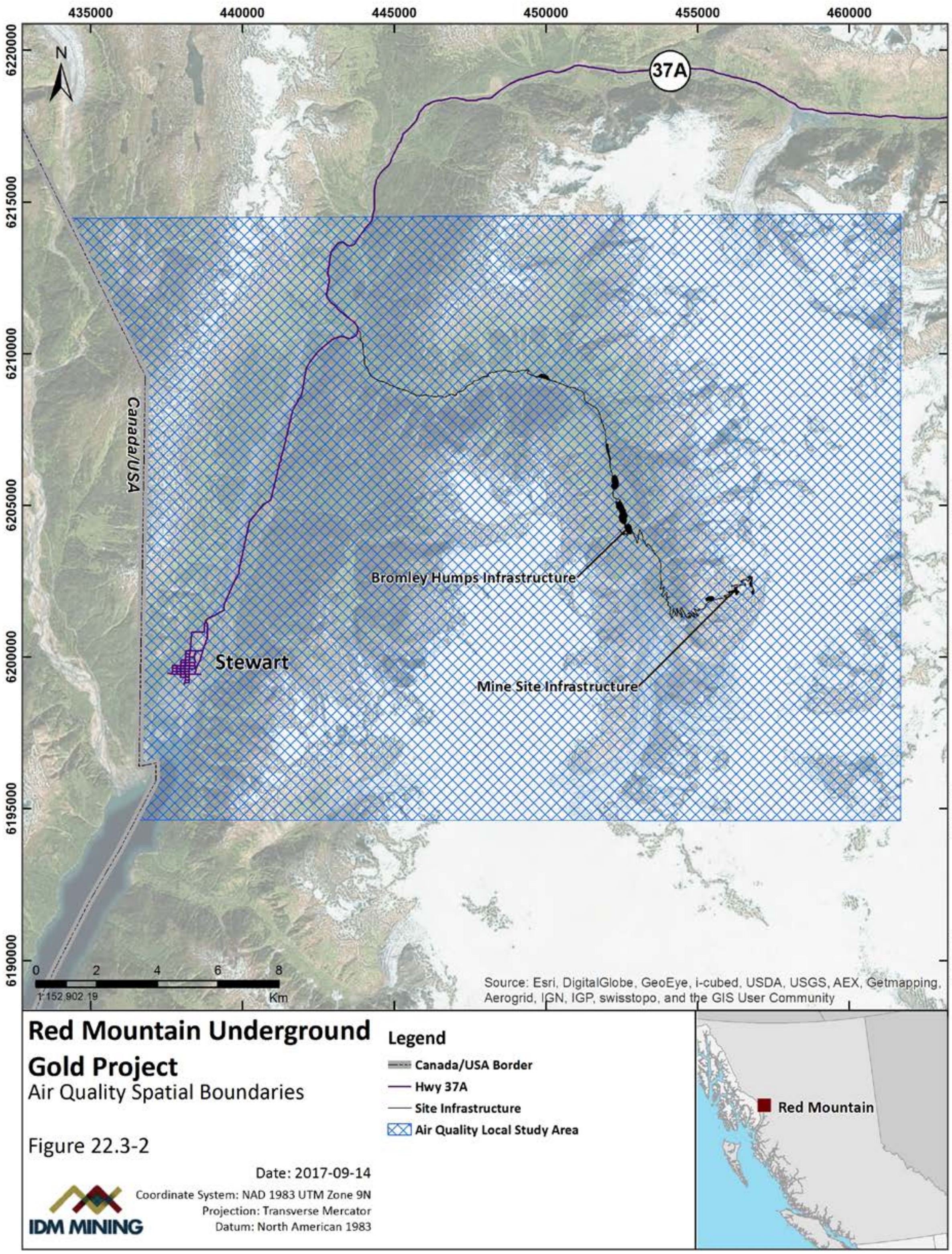


Figure 22.3-3: Surface Water Quality Spatial Boundaries

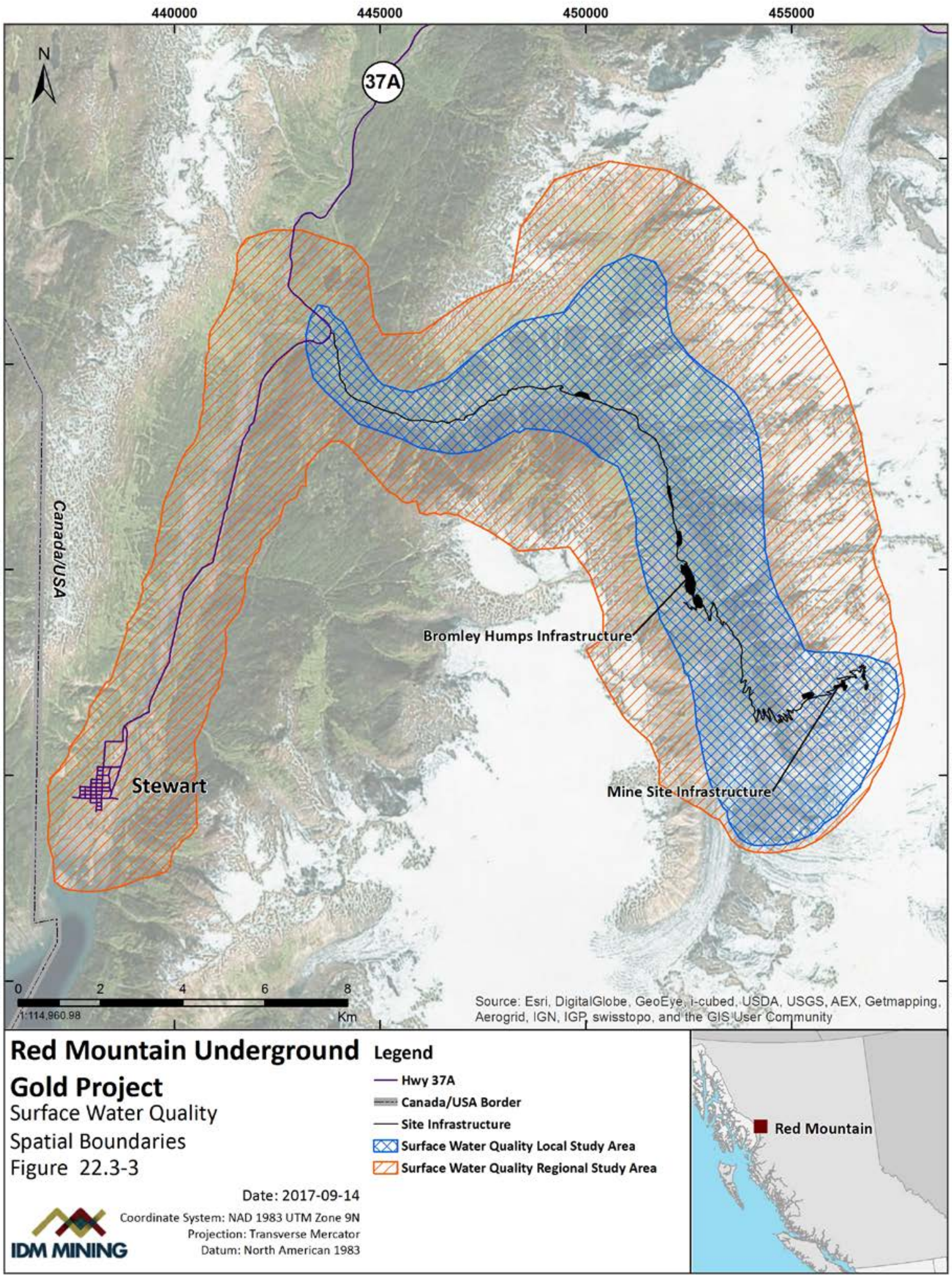


Figure 22.3-4: Fish and Fish Habitat Spatial Boundaries

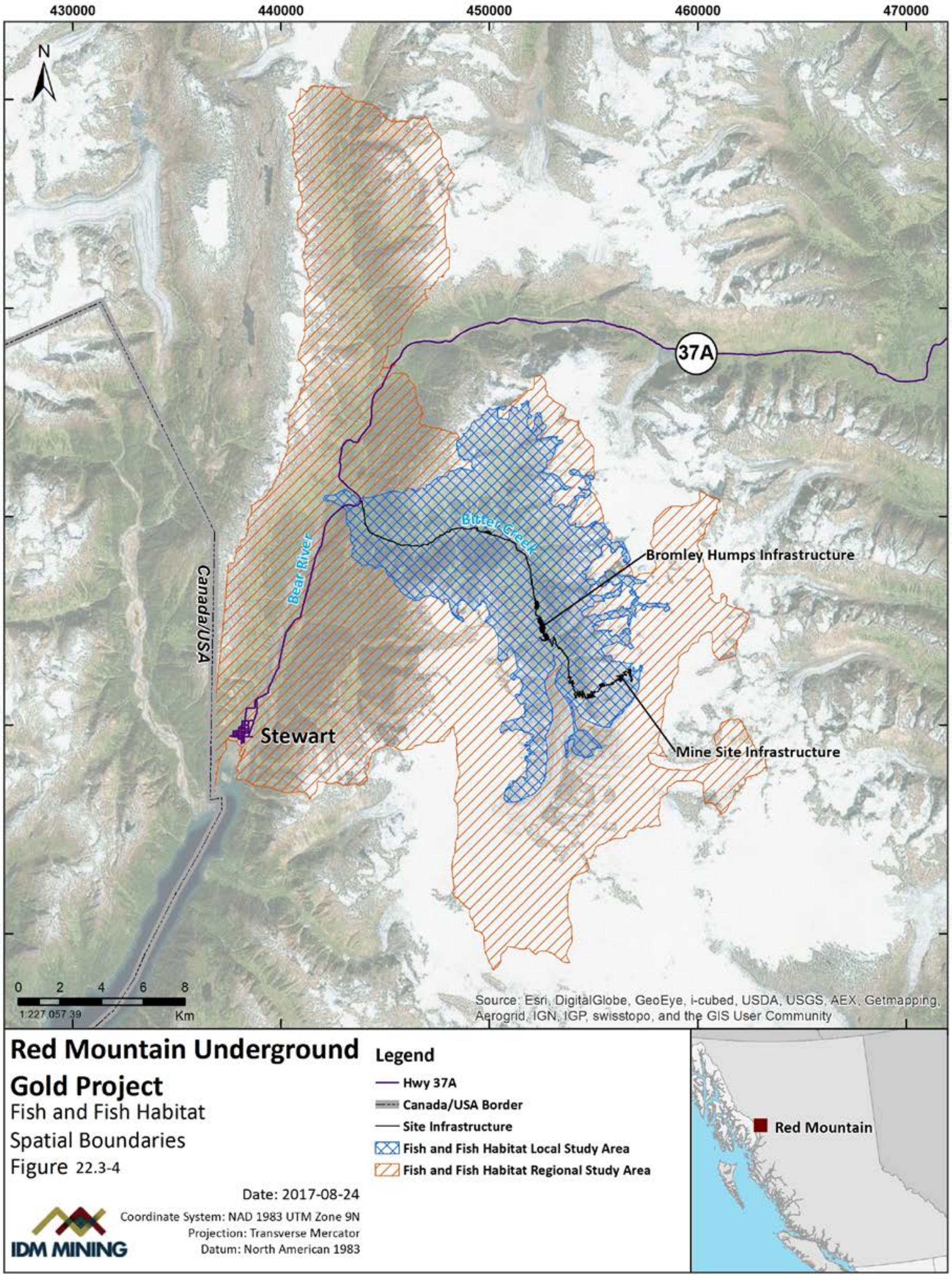
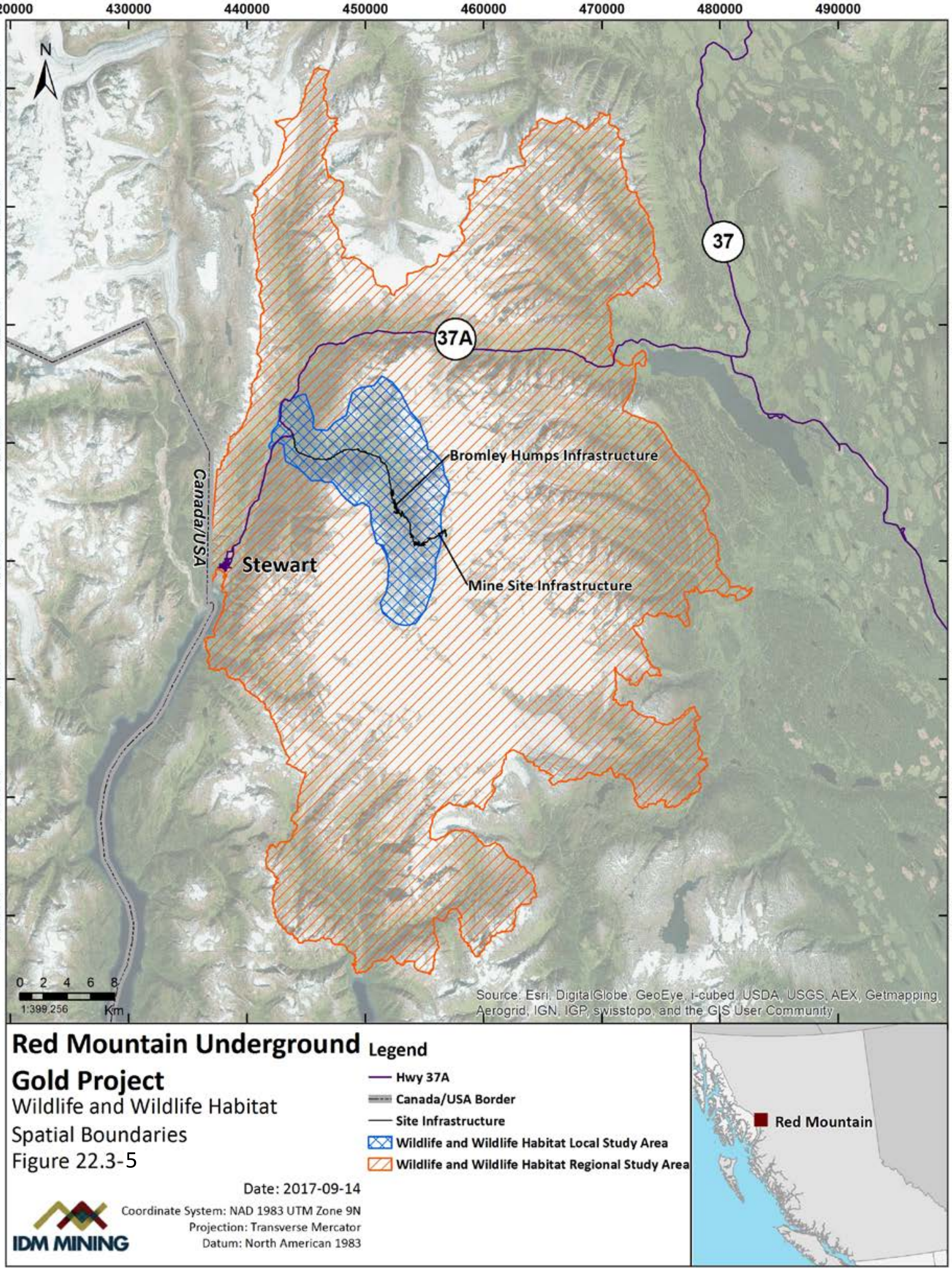


Figure 22.3-5: Wildlife and Wildlife Habitat Spatial Boundaries



22.3.4.2 Temporal Boundaries

The HEA considered the potential effects for the entire lifespan of the Project, extending out as far as the predictive modeling considered for each of the primary exposure media (i.e., future air, soil, and country foods quality [based on air particulate deposition modeling], and future drinking water and sediment quality [based on predictive modeling]).

Table 22.3-3: Temporal Boundaries for the Effects of Human Health

Phase	Project Year	Length of Phase	Description of Activities
Construction	Year -2 to Year 1	18 months	Construction activities and construction of: Access Road, Haul Road, Powerline, declines, power supply to the underground, water management features, water treatment facilities, Tailings Management Facility (TMF), Process Plant, ancillary buildings and facilities; underground lateral development and underground dewatering; ore stockpile and ore processing start-up; and receiving environmental monitoring.
Operation	Year 1 to Year 6	6 years	Ramp up to commercial ore production and maintain a steady state of production, underground dewatering, tailings storage, water treatment, gold ore shipping, environmental monitoring, and progressive reclamation.
Closure and Reclamation	Year 7 to Year 11	5 years	Underground decommissioning and flooding; decommissioning of infrastructure at portals, Process Plant, TMF, ancillary buildings and facilities; reclamation, water treatment; removal of water treatment facilities.
Post-Closure	Year 12 - 21	10 years	Receiving environment monitoring to ensure closure objectives are satisfied.

It should be noted that the HHRA considered all Phases of the Project including Baseline, Construction, Operation, Reclamation and Closure, and Post-Closure. The HHRA presents results for baseline and the worst-case future phases of the Project, when identifying COPCs, and calculating risk. All future activity phases (i.e., Construction Phase, Operation Phase, Reclamation and Closure Phase, and Post-Closure Phase) were considered, and the highest concentrations that were predicted were evaluated in the HHRA. Typically, the highest predicted concentrations were in the Operation Phase. Evaluating the worst-case scenario is a conservative approach for evaluating future conditions since the concentrations and calculated risks in the other phases will be lower.

22.3.4.3 Administrative and Technical Boundaries

22.3.4.3.1 Administrative Boundaries

No administrative boundaries apply to the HEA. Aboriginal Groups, hunters, trappers, and outfitters were assumed to hunt, fish, and collect country foods throughout the Human Health LSA and RSA and are not constrained by administrative boundaries. They are also not constrained by administrative boundaries established by other VCs and ICs.

The Project will not affect Human Health outside of Canada. As noted in Section 22.3.4.1.1, all potential direct and indirect effects to Human Health identified in this chapter are linked to one or more of the above-mentioned VCs or ICs. Thus, there are no potential effects to Human Health outside of the LSA boundaries for these VCs / ICs. One exception to this is any potential effect to country foods, where these country foods may be obtained from within the Bitter Creek valley, but consumed by someone elsewhere (e.g. country foods sold in one of the communities found within the Human Health LSA boundary).

22.3.4.3.2 Technical Boundaries

There were several technical boundaries relevant to the HEA. While the complete set of baseline surface water quality sampling locations were included for the identification of COPCs, only the locations for which predictive modelling was also completed were included in the estimation of risk levels. This was done to allow direct comparison between baseline and predicted future water quality and associated risks. This approach also increased the conservatism of the assessment, since the water quality modelling locations were in areas where the potential for change in water quality was highest (e.g., downstream of Project infrastructure and water discharges).

Several soil sampling locations were excluded based on sampling depths. Only baseline soil samples up to a depth of 20 centimetres (cm) were included because this is the unit with the greatest potential for dermal exposure and incidental soil ingestion. The shallower soils also correspond to the most relevant rooting depths of most plants, and the upper layer is what is most affected by dustfall (Health Canada 2010a).

In general, the HEA and associated HHRA (Volume 8, Appendix 22-A) rely on predictive models to estimate future COPC concentrations in relevant exposure media. Therefore, the results are inherently limited by the assumptions incorporated into the models. These assumptions (expressed in the relevant, above-mentioned chapters and appendices) were typically of a conservative nature and therefore contributed to increased conservatism in the HEA.

22.4 Existing Conditions

22.4.1 Overview of Existing Conditions

The Project area is characterized by rugged, steep terrain with weather conditions typical of the northern coastal mountains. The deposit is under the summit of Red Mountain at elevations ranging between 1,600 and 2,000 masl. Temperatures are moderated year-round by the coastal influence. The mean annual air temperature (MAAT) at an elevation of 1514 meters is −0.8°C, with monthly mean values ranging between −6.4°C in December and January and 6.9°C in August (Volume 8, Appendix 12-A, Baseline Climate and Hydrology Report). Precipitation is significant throughout the year; October is typically the wettest month and there is significant snow accumulation in the winter (JDS 2016). The snowfall, steep terrain, and frequently windy conditions present blizzard and avalanche hazards during the winter (JDS 2016). The climatic conditions at the Project site are described in Appendix 12-A.

A deactivated logging road extends from Highway 37A for approximately 13 km along the Bitter Creek valley; however, it is currently impassable for heavy equipment due to washouts caused by Bitter Creek, and at other creek crossings (JDS 2016).

The proposed underground mine is situated at the top of the Red Mountain cirque, a short, westerly trending hanging valley above the Bromley Glacier. The cirque is drained by Goldslide Creek. Goldslide Creek flows southwest into the east side of Bromley Glacier, which extends about 1 km to the Bitter Creek headwaters. Flows in Goldslide Creek peak during freshet (typically in June), and Goldslide Creek is not glacially-influenced. Goldslide and Rio Blanco Creeks are the two uppermost tributaries to Bitter Creek. Other Bitter Creek tributaries relevant to the baseline Surface Water Quality evaluation are Otter Creek and Roosevelt Creek. Otter Creek is glacially-influenced and its discharge peaks during summer (typically in July) because of glacial melt. The winter low flow period in Otter Creek is from November to April. Like Otter Creek, Bitter Creek is glacially-influenced, and its flows peak in summer (typically in July) and are low during November to April. Bitter Creek is a tributary to the Bear River, which then discharges into the Portland Canal near Stewart (Figure 22.3-3). Bear River's flows peak in summer (July/August).

There are currently no residences, summer cabins, hunter trapper cabins, or camp grounds in the Bitter Creek watershed. As mentioned, the closest residences are located in Stewart. Hunting, trapping, fishing, plant gathering, and recreational activities are known to occur in the Human Health LSA.

22.4.2 Past and Current Projects and Activities

The Bitter Creek valley has a history of mine explorations and mine operations. Highway 37A and a BC Hydro powerline cross the creek near the confluence with Bear River. Much of the area near Highway 37A has been, or is being, cleared or logged for various purposes. Small quarries and borrow pits associated with the highway or powerline construction occur along Highway 37A, and basic amenities have been developed for a recreation area at Clements Lake. An old, overgrown road runs parallel to much of Bitter Creek along the northern side on old floodplains and the toe of the slope. Several smaller old roads branch off up the slopes, and there are numerous old logged areas adjacent to the road. Additional roads occur in the vicinity of the old mine portal on Red Mountain. Current exploration activities include new roads in the alpine near the old portal, along with an exploration camp, helicopter pad, and numerous temporary drill pads.

22.4.3 Project-Specific Baseline Studies

Human Health is affected by several physio-chemical environmental components, namely by noise levels, EMFs, light, the quality of air that people breath, the quality of surface water and groundwater for drinking water, sediment quality, soil quality (which can affect human health through incidental ingestion or dermal contact), and the quality of foods (especially country foods for Aboriginal people). The baseline study results for these components were used to describe the existing environmental conditions that can affect baseline Human Health. The types of baseline studies conducted for the Project that apply to Human Health are described in the following sections.

22.4.3.1 Data Sources

No data were collected specifically for the HEA. However, a variety of baseline studies and modelling were carried out for the effects assessment for other VCs (referenced in Section 22.3.1), and these data were used to complete the HEA.

The primary reports that provided data and were used as information sources in the derivation of baseline Human Health risks (Appendix 22-A) include the following:

- *Geochemical Baseline Characterization of Waste Rock, Ore, and Talus* (Volume 7, Appendix 1-B): Baseline waste rock and ore material analytical data is presented in Section 4 and associated tables. The methodology for sample collection and analysis is explained in Section 3 of the same report.

- *Air Quality Effects Assessment and Air Quality Modelling Report* (Volume 3, Chapter 7, Section 7.5, and Volume 8, Appendix 7-A): Baseline Air Quality data collection for CO, O_3, SO_2, NO_2, and air particulate ($PM_{2.5}$, PM_{10}, and PM_{Total}) was not completed for the Project. Data from other studies were used to represent the baseline condition, as described in Section 5 of the Air Quality Modelling Report. Air modelling data output used to assess exposure to human receptors is presented in Appendices A and B of Appendix 7-A.

- Noise Effects Assessment (Volume 3, Chapter 8): Project-specific baseline studies were not conducted for the Noise Effects Assessment. The characterization of baseline noise to support the assessment relied on existing data, methods, and assumptions to define the baseline conditions for oil and gas activities in similar remote locations. The approach used to characterize baseline Noise has been accepted and verified at other mining projects in the region. The results of the Noise modelling are presented in Sections 6 and 7 of Chapter 8.

- Ecosystem, Vegetation, and Soils Baseline Report (Volume 8, Appendix 9-A): Soil sample collection and analysis is explained in Section 5.6. Methods for baseline plant tissue monitoring are presented in Section 5.7.

- Red Mountain Underground Gold Project - Mine Area Hydrogeology (Volume 8, Appendix 10-A): Section 3 documents the study methodology and field investigation completed in the Project area. Hydrogeological data is presented in Section 4.

- Red Mountain Underground Gold Project - Bromley Humps Baseline Hydrogeology Report (Volume 8, Appendix 10-B): The sample methodology, data, and data analysis are presented in Section 3.

- Red Mountain Underground Gold Project - Environmental Assessment Baseline Surface Water and Groundwater Quality Report (Volume 8, Appendix 14-A): Section 3 documents the study methodology and data analysis procedures. Surface water and groundwater data are presented in Section 4;

- Red Mountain Underground Gold Project - Water and Load Balance Model Report, (Volume 8, Appendix 14-C): Section 3 documents the study methodology and data analysis procedures. Predicted water quality results are presented in Section 4.

- Red Mountain Underground Gold Project - Baseline Wildlife Resources Report, (Volume 8, Appendix 16-A): The methodology for completing field surveys for wildlife is presented in Section 3. The results and discussion are presented in Section 4.

- Red Mountain Underground Gold Project - Baseline Fisheries and Aquatic Resources (Volume 8, Appendix 18-A): The methodology for completing field surveys for fish and fish habitat are presented in Section 3. The results and discussion are presented in Section 4. Whole body fish tissue analysis was completed for fish (personal communication May Mason 2017).

- Red Mountain Underground Gold Project - Human Health Risk Assessment (Volume 8, Appendix 22-A): Human Health Risk Assessment for assessment of chemical exposure risk to Human Health.

- No Baseline data was collected for EMFs. Knowing the voltage of the Powerline planned for the Project, it was possible to calculate the predicted EMFs using equations provided in Understanding Electric and Magnetic Fields (BC Hydro 2017). These equations are provided in Section 22.5.1.2.

Uncertainties associated with baseline data collection are incorporated into the uncertainty discussion provided in Section 22.5.4.1.3.

22.4.3.2 Primary Data Collection and Analysis Methods

As noted above, data used for the HEA were collected in support of the effects assessment of other VCs. The locations of baseline data collection and data analysis methods are provided in Section 22.4.3.1.

22.4.3.2.1 Analysis of Chemical Exposures and Risk

Health effects associated with exposure to chemicals was assessed in the HHRA (Volume 8, Appendix 22-A). The methodology used to complete the HHRA (Health Canada 2010a; 2010b) is summarized below:

1. Problem Formulation: This stage screened and identified the COPCs, identified potential human receptors, and identified the exposure routes. This information was summarized in a conceptual model.

2. Exposure Assessment: Exposure equations, COPC-specific characteristics, receptor characteristics, and the measured or modelled COPC concentrations in media (air, water, soil, sediment, and country foods) were presented in this section. The dose was calculated to estimate the exposure level for human receptors. For country foods with tissue concentrations that were not measured during baseline studies, food chain modelling was completed to estimate tissue concentrations. Food chain modelling of COPC uptake into wildlife tissue is generally a highly conservative approach relative to direct measurement, and has the potential to overestimate COPC tissue concentrations by orders of magnitude (Health Canada 2012b). This maintains the conservative nature of the HHRA and ensures with a high degree of certainty that risks will not be under-estimated or overlooked (Health Canada 2012b).

3. Toxicity Assessment: The Toxicological Reference Values (TRVs, levels of daily exposure that can be taken into the body without appreciable health risk) were identified in this section.

4. Risk Characterization: Hazard quotients (HQs) were calculated for threshold chemicals (i.e., non-carcinogens) and incremental lifetime cancer risks (ILCRs) for non-threshold chemicals. The exposure and effects assessments were integrated by comparing the dose with TRVs to produce quantitative risk estimates (HQs or ILCRs). HQs via multiple pathways were summed to estimate a hazard index (HI) for each COPC. The HI for COPCs with the same target organ was summed to estimate a target organ based HI.

5. Uncertainty Analysis: The assumptions made throughout the baseline HHRA and their effects on the confidence in the conclusions were evaluated.

6. Conclusions: The potential for risk to human health was described based on the results of the risk characterization, with qualitative consideration of uncertainties and data gaps that might influence the quantitative assessment.

22.4.3.2.2 Identification of COPCs

The following multi-step process was used to identify COPCs:

1. Compilation of data in each environmental media, for baseline and predicted future conditions;

2. Identification of upper percentile concentrations (e.g., 90^{th} or 95^{th} percentiles) or maximum concentrations for each constituent in each environmental media, if available.

3. Identification of appropriate media-specific screening levels such as the Canadian Council of Ministers of the Environment (CCME) Environmental Quality Guidelines (CCME 2017) and the British Columbia Contaminated Sites Regulation (BC CSR) Standards (BC 2017). In the absence of federal criteria or provincial criteria, use of screening criteria established by other jurisdictions will be considered for use such as USEPA. When soil quality criteria from sources other than federal or provincial are adopted for chemical screening purposes, they may need to be adjusted to be consistent with the health protection endpoints and the apportionment of the Non-Carcinogen Tolerable Daily Intake (TDI) recommended by HC and CCME. For example, for threshold contaminants, criteria from other jurisdictions, such as the US EPA's Regional Screening Levels (RSLs) (2017), may be based on an HQ of 0.1 or 1. These RSLs would be adjusted to make them approximately equivalent to Health Canada and CCME guidelines, which are generally based on an HQ of 0.2 for exposure in soil. If the health-based criteria for non-threshold contaminants were derived based on a target incremental cancer risk of 1×10^{-6} (one in one million), the criteria would be adjusted to a target incremental risk of 1×10^{-5} in accordance with Health Canada's essentially negligible risk level. If screening levels were not available, then the constituent was also considered a COPC.

4. Identification of regional background concentrations (i.e., 95th percentile of the baseline) in each environmental media, if available;

5. Comparison of constituent concentrations to screening levels. If the constituent concentrations were less than or equal to screening levels, the constituent was not carried forward as a COPC;

6. Evaluation of constituents to determine if there were additional reasons for their inclusion (e.g., parameters that can bioaccumulate in the food chain such as mercury, selenium, and cadmium) or exclusion (e.g., parameters that are typically non-toxic such as essential nutrients) as COPCs.; and

7. Identification of final COPCs.

If screening levels or background concentrations were not available, then the constituent was also considered a COPC.

The identification of COPCs in each potential exposure media (i.e., air**,** soil, surface water for drinking water, groundwater for drinking water, sediment, and country foods) is described in the subsections below.

For country foods, it was also necessary to develop screening levels as no country foods screening levels were available. Country foods screening levels were derived using an approach developed for deriving action levels for fish advisories (OHA 2016). Separate country foods screening levels were derived for fish and plants given the differences in consumption rates for these two food sources. The following equation was used for determining tissue screening levels for non-carcinogenic toxicological endpoint for humans:

$$SL = 0.2 \times \frac{(TDI \times BW)}{IR}$$

Where:

SL = Screening Level (mg/kg)
TDI = Tolerable Daily Intake (mg/kg-day) (chemical-specific)
BW = Body Weight (kg) = 70.7kg for adults and 16.5kg for toddlers
IR = Fish/Plant Ingestion Rate (kg/day) = 0.29 kg/day for adults and 0.091 kg/day for toddlers

The following equation was used for determining country foods screening levels for carcinogenic effects:

$$SL = \frac{(ARL \times BW)}{CSF \times IR \times ADAF}$$

Where:

SL = Screening Level (mg/kg)
ARL = Acceptable Risk Level (unit less) = $1x10^{-5}$
CSF = Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$
ADAF = Adjustment Age Dependent Adjustment Factor
BW and IR were same as noted above for non-carcinogens.

The country foods screening levels are presented in Volume 8, Appendix 22-A, Attachment A, Table A11.

Country foods include a wide range of animal, plant, and fungi species harvested for medicinal or nutritional use. The primary objective when assessing risk from ingestion of country foods is identifying the most relevant country foods to evaluate. Key considerations when selecting country foods included the following:

- Which country foods are currently hunted/harvested in the Human Health RSA;
- Whether representative country food species are co-located within areas predicted to be affected by potential Project-induced releases;
- How are the country foods used (i.e., food, medicine, or both);
- What part(s) of the country foods are consumed (i.e., specific organs, plant leaves or roots);
- What quantities of country foods are consumed; and,
- What the consumption frequencies are for each country food.

The Food Nutrition & Environment Study by Chan et al. (2011) lists over 200 traditional foods that are consumed by Aboriginal Groups in British Columbia. The Human Health spatial boundaries (i.e., LSA/RSA) overlap with Ecozones 4 and 6 (Volume 8, Appendix 22-A, Figure 13). Ecozone 4 information was used as the basis for the selection of species consumed by Aboriginal and non-Aboriginal persons. The top ten traditional food items consumed by Aboriginal Groups living in Ecozone 4 (Project area) as reported in Chan et al. (2011) include mammals, fish, and vegetation:

1. Moose meat
2. Soapberries
3. Blue huckleberry
4. Salmon (any type)
5. Trout (any type)
6. Balsam pitch
7. Red willow root
8. Poplar (cottonwood) inner bark
9. Salmon (Sockeye)
10. Black bear fat

As it is rarely possible to assess all potential country foods, one representative species is usually selected as a surrogate from each of the following groups of foods: large mammals, small mammals, birds, fish, and vegetation. If representative foods are determined to be safe for consumption, then all other foods within the group would also be considered safe for consumption.

22.4.3.2.3 Receptors

Consistent with the Health Canada (2012b) regulatory guidance, the human receptor groups carried forward with respect to baseline (and predicted future) exposure and risk levels, included:

- Hunter/Trapper/Fisher (teens and adults);
- Guide/Outfitter (teens and adults);
- Recreational User (infants, toddlers, children, teens, and adults);
- Summer Resident (infants, toddlers, children, teens, and adults);
- Year-Round Resident (toddlers and adults); and
- Country Foods Consumer.

The first four receptors were selected because they are known to or have a reasonable potential to occur in the Bitter Creek portion of the LSA. At this time, there are no residents or hunter/trapper/fisher cabins in the Bitter Creek portion of the LSA. This suggests that, with respect to living, hunting, trapping, and fishing, the area is likely used less for these activities than the surrounding areas.

The types of exposures for the guide/outfitter and the hunter/trapper/fisher are likely to be similar; however, the hunter/trapper/fisher are likely to spend more time in the watershed. Therefore, the hunter/trapper/fisher was carried forward as the ROC for quantitative evaluation in the HHRA. The assumption being that if the risk to the hunter/trapper/fisher resulting from exposure to Project stressors was acceptable, then the risk to the guide/outfitter would also be acceptable.

The Summer Resident receptor was assumed to present in the Bitter Creek valley during three of the snow-free months. They could live in temporary housing or a summer house. As we are assuming that this is occurring annually over multiple years, a permanent structure would likely be constructed. While living in the Bitter Creek valley, the Summer Resident drinks surface water from Bitter Creek, breathes the air, is exposed to the soil, and sources all of their country foods from the valley.

The Year Round Resident receptor is assumed to live in the lower portion of the valley, which is snow-free for a greater portion of the year. It was assumed that they live in a permanent structure and water is piped to the house from Bitter Creek. While living in the Bitter Creek valley, on a daily basis the Year Round Resident drinks surface water only from the Bitter Creek valley, breathes only the air within the valley, is exposed to only the soil within the valley, and sources the majority of their country foods from the valley.

It should be noted that the country food consumer ingests country foods but does not necessarily spend time in the area of the LSA affected by the project. They may be a resident of one the communities in the LSA, such as Stewart or the Village of Laxgalts'ap. It was assumed that the other receptors also eat country foods while in the Bitter Creek valley portion of the LSA.

22.4.3.2.4 Exposure Pathways

All applicable exposure pathways and routes to human populations likely to be exposed to Project-related physical stressors were evaluated. An exposure pathway is the potential route a substance may take to come in contact with a receptor for example, exposure to contamination via inhalation of air, and exposure to contamination via incidental ingestion of and dermal contact with soil.

Further details on the specific methodology and assumptions for assessing the baseline risk levels are presented in Section 6 of the HHRA (Volume 8, Appendix 22-A).

22.4.4 Baseline Characterization

The baseline characterization considers potential environmental effects and associated health risks under present, pre-Project conditions, including current ambient environmental conditions, existing sources of chemical emissions (existing facilities), and the contribution of future projects or activities that have been approved. The baseline case is assessed by evaluating the potential health risks associated with existing relevant physical stressors, obtained from the results of regional monitoring and/or the results of a project-specific baseline environmental sampling program.

Refer to Section 22.3.1 for a summary of information provided in other effects assessment chapters for VCs and ICs of relevance to the HEA, including baseline characterization. The purpose of the baseline characterization section presented in this chapter is not to repeat information provided in other relevant chapters, but rather to present information of relevance to the health effects assessment baseline discussion that has not been addressed elsewhere in the Application/EIS. The discussion below therefore focuses on the following:

- Consideration of metals in air particulate and non-threshold chemical endpoints associated with potential exposures to $PM_{2.5}$ and NO_2 (not addressed in the Air Quality Effects Assessment); and
- How baseline surface water quality, groundwater quality, air quality, and soil quality effect Human Health receptors.

A complete assessment of Noise from the perspective of Human Health was completed in the Noise Effects Assessment (Volume 3, Chapter 8). As a result, there is no further discussion of noise baseline characterization in this chapter. No baseline EMF information was available for the Project.

22.4.4.1 Chemical and Non-Chemical Air-Related Health Effects Baseline

The baseline concentrations for the Air Quality Effects Assessment use data from monitoring stations that are representative of remote project areas, typical of mining locations in northwest BC, including the Project location. The Project will be in an area that is similar to recent examples (Brucejack and Kemess; ERM 2014, 2016) and historical projects (KSM; Rescan 2012) that have used this approach to baseline characterization. Common traits of these areas include the following

- Remote, undeveloped locations;
- Located in complex terrain in steep valleys dominated by forest cover at lower elevations and rock, snow, and ice at higher elevations;
- No specific anthropogenic sources of emissions can be identified near the site beyond limited access for recreational or commercial activities along the Access Road from Highway 37A; and
- Located within the same Biogeoclimatic zone in BC and subject to similar seasonal climatic regimes.

Baseline concentrations (Table 22.4-1) were based on ambient concentrations from representative locations:

- The Canadian Air and Precipitation Monitoring Network (CAPMoN) site at Saturna off of the southern tip of Vancouver Island, in the middle of the Strait of Georgia, provides the best estimate of background concentration available for BC. Daily measurements of SO2 concentrations are available from the Saturna monitoring station from 1996 to 2002 (1997 is not available). The average annual SO_2 concentration for that period was reported as 2.3 micrograms per cubic metre (µg/m^3). Ambient NO_2 concentrations were not measured at the Saturna station.
- The Diavik Diamond Mine (Diavik) is in the Northwest Territories, located about 300 km northeast of Yellowknife. In the Diavik Diamond Mine EA (Cirrus 1998), ambient background concentrations for NO_2, SO_2, and particulates were estimated based on

surveys and assumptions. These ambient concentrations have been considered to be typical background concentrations for remote areas with few anthropogenic sources.

- The Galore Greek Mine Project (Galore) is located approximately 170 km northwest of the Project (Rescan 2006). The baseline monitoring conducted in 2005 included measurements of ambient PM_{10} and $PM_{2.5}$ concentrations.
- The Kitsault Mine Project (Kitsault) is located on the northwest coast of BC, approximately 140 km north of Prince Rupert and 60 km south of the Project. Total suspended particulates (TSP), PM_{10}, and $PM_{2.5}$ were measured on site (AMEC 2011).
- The Brucejack Gold Mine Project (Brucejack) is located approximately 65 km north-northwest of the Project. The EA relied on the same baseline air quality representation as presented above for Kitsault.
- The Kemess Underground Project is located approximately 225 km northeast of the Project and relied on the same baseline air quality representation as Brucejack and Kitsault.

Table 22.4-1: Regional Baseline Air Quality Concentrations Used to Determine Representative Baseline Concentrations for the Project Air Quality Assessment

Pollutant	Averaging Period	Concentration (µg/m³)					
		Brucejack	Saturna	Diavik	Galore	Kitsault	Baseline Representing the Project
Sulphur Dioxide (SO2)	1-hour	-	-	4.0	-	-	4.0
	24-hour	-	-	4.0	-	-	4.0
	30-day	0.13[a]	-	-	-	-	-
	Annual	-	2.3	2.0	-	-	2.0
Nitrogen Dioxide (NO2)	1-hour	-	-	21	-	-	21
	24-hour	-	-	21	-	-	21
	30-day	0.09 to 4.1	-	-	-	-	-
	Annual	-	-	5.0	-	-	5.0
Carbon Monoxide (CO)	1-hour	-	-	100	-	-	100
	8-hour	-	-	100	-	-	100
Total Suspended Particulates (TSP)	24-hour	-	-	10	-	3.5	10
	Annual	-	-	10	-	-	10

Pollutant	Averaging Period	Concentration (µg/m^3)					
		Brucejack	Saturna	Diavik	Galore	Kitsault	Baseline Representing the Project
Particulate Matter < 10 microns (PM_{10})	24-hour	-	-	10	3.4	2.5	3.4
Particulate Matter < 2.5 microns ($PM_{2.5}$)	24-hour	-	-	-	1.3	2.3	1.3

The air quality criteria considered in the evaluation were the BC Ambient Air Quality Objectives (AAQOs), which are a suite of ambient air quality criteria, including Provincial Air Quality Objectives (AQOs), National Ambient Air Quality Objectives (NAAQOs) and Canadian Ambient Air Quality Standards (CAAQS), with the strictest selected (Table 22.2-1).

Since the most recent development of NAAQOs and CAAQSs for $PM_{2.5}$ and NO_2, a body of research has been increasing the indicates that the current guidelines may not be protective of human health. The following studies were considered when determining whether $PM_{2.5}$ and NO_2 should be carried forward in the HHRA

Elliott and Copes (2017) estimated the burden of mortality attributable to long-term exposure to ambient fine particulate matter (PM2.5) among adults in the Interior and Northern region of BC. Elliot and Copes (2017) assumed a threshold concentration below which no mortality effects occur of 5 µg/m^3. The $PM_{2.5}$ of 5 µg/m^3 was considered when screening annual $PM_{2.5}$ levels. The annual maximum $PM_{2.5}$ estimated for the project was 4.4 µg/m. A review of figure D-8 in Chapter 7 illustrates isopleths of $PM_{2.5}$ air concentrations. Two areas had $PM_{2.5}$ greater than 2 µg/m^3. These two areas represent less than 1% of the Bitter Creek watershed. One of the two areas was at the Mine Site and the other was near Bromley Humps between Bromley Humps and the Mine Site. Non-mine worker use of these areas is not anticipated during the Construction or Operation Phases. Therefore, non-occupational exposure to $PM_{2.5}$ at the Bitter Creek valley will likely to be less than 2 µg/m^3.

Health Canada (2016) and the USEPA (2016) have recently reviewed air quality guidelines for NO_2 to assess whether they are still considered protective of Human Health. Both studies determined that: “There is likely to be a causal relationship between long-term NO_2 exposure and respiratory effects” (USEPA 2016).

Evidence is suggestive of, but not sufficient to infer, a causal relationship for short-term NO_2 exposure with cardiovascular effects and total mortality and for long-term NO_2 exposure with cardiovascular effects and diabetes, poorer birth outcomes, and cancer” (USEPA 2016).

The USEPA (2016) indicted that while there is continued or new supporting epidemiologic evidence, which suggests a lower guideline for NO_2 may need to be considered, a large uncertainty remains as to whether NO_2 exposure has an effect independent of traffic-related co-pollutants (SO_2, O_3, CO, $PM_{2.5}$). Epidemiologic studies have not adequately accounted for confounding factors, and there is a paucity of support from experimental studies that demonstrate that NO_2 is responsible for observed effects at these lower levels (USEPA 2016). Some recent experimental studies show NO_2-induced increases in systemic inflammation or oxidative stress (USEPA 2016). Such changes are not consistently observed or necessarily linked to any health effect, unlike the mode of action information available for asthma (USEPA 2016).

Health Canada (2016) acknowledges issues of confounding of co-pollutants, $PM_{2.5}$, SO_2, and CO, but feels that evidence suggests that we should consider updating the NO_2 guideline.

For this assessment, the current interim guidelines, established by the province to accommodate a stepwise approach to management of SO_2 and NO_2 in anticipation of new Canadian Standards coming out for these parameters, were considered to be acceptable. There is some uncertainty with regards to how the new Canadian Standards (coming into effect in 2020) will ultimately be used and applied (e.g., between various jurisdictions, by the regulatory authorities, at a project versus airshed level)

For metals, the Texas Commission on Environmental Quality Effects Screening Levels (1-hour and annual averaging period PM_{10}s; Texas CEQ 2014) and the Ontario Ministry of the Environment Ambient Air Quality Criteria (24-hour averaging period; Ontario MOE 2012). The lowest screening level was used when more than one screening value was available for a given averaging period. The annual averaging period screening values were compared to the annual modelled air concentrations. The 24-hour averaging period screening values were compared the 24-hour modelled air concentrations. The Texas CEQ 1-hour PM_{10} values are presented for comparison only.

Air constituent concentrations were compared to baseline concentrations to identify COPCs in air. Air constituents in excess of air screening levels were carried forward as COPCs in the HHRA.

No air COPCs were carried forward for quantitative evaluation in the HHRA as all baseline COPC concentrations in air were less than screening values.

22.4.4.2 Chemical-Related Health Effects Baseline (Excluding Air)

Baseline characterization of chemical-related health effects was completed following the methods described in Section 22.4.3.2. COPCs in each environmental media were identified, soil, surface water, sediment, groundwater, and country foods were identified and then selected receptors were identified. A more detailed description of COPC screening is provided in Section 6.3 Volume 8, Appendix 22-A.

22.4.4.2.1 Receptor Selection

As discussed above, consistent with the Health Canada (2010) regulatory guidance, the human receptor groups carried forward with respect to baseline (and predicted future) exposure and risk levels, included:

- Hunter/Trapper/Fisher (teens and adults);
- Recreational User (infants, toddlers, children, teens, and adults);
- Summer Resident (infants, toddlers, children, teens, and adults);
- Year Round Resident (toddlers and adults); and
- Country Foods Consumer (toddlers, children, teens, and adults; not including infants as they were assumed to not eat solid food).

22.4.4.2.2 Country Food Selection

Following the methods described in Section 22.4.3.2 the following species were selected as country foods:

- Moose, hare, and grouse, respectively, were the large mammal, small mammal, and bird country foods consumed in the greatest amount by Aboriginal Groups in Ecozone 4 (Chan *et al.* 2011):

- Salmon (any type) was the fish consumed in the greatest amount by Aboriginal Groups in the RSA; and

- Berries were the type of vegetation consumed in the greatest amount by Aboriginal Groups.

All of these country foods are present in the Human Health LSA and it is assumed they will be exposed to COPCs released by the Project.

Based on the information presented above, moose, hare, grouse, Dolly Varden, and Sitka willow were the surrogate country foods selected to represent food consumption by Aboriginal and non-Aboriginal receptors for the large mammal, small mammal, bird, fish, and vegetation food groups, respectively. Sitka willow was selected based on its importance to moose as a food source and its tendency to bioaccumulate metals at higher concentrations than in berries; willow and berry metal concentration data from two projects in the same geographic region (Brucejack - Rescan 2013a; KSM – Rescan 2013b) indicate that most metal concentrations in leaves tend to be at least 100% higher than concentrations in berries., Therefore, making the use of willow a more conservative estimate of human health risk than the analysis of berries.

These species were selected as country foods because they are present in and their home ranges can be found in the Human Health LSA, meaning they are potentially affected by the Project, and they are frequently consumed by Aboriginal Groups.

22.4.4.2.3 Exposure Pathways

The potential exposure pathways and routes to human populations at the LSA included the following:

- Inhalation of air;
- Incidental ingestion of and dermal contact with soil;
- Ingestion and dermal contact with surface water;
- Ingestion and dermal contact with groundwater;
- Incidental ingestion and dermal contact with sediment; and
- Consumption of country foods mammals, birds, plants, and fish.

Two chemical-related exposure pathways were determined to be incomplete and were not considered further (see Section 6.5 of the HHRA in Volume 8, Appendix 22-A for additional explanation on why these pathways are considered incomplete):

- Exposure to contamination via ingestion and dermal contact with groundwater as there are currently no drinking water wells currently in the Bitter Creek valley and hydraulic conductivity is low; and

- Exposure to contamination via incidental ingestion and dermal contact with sediment as contact with sediment in creeks was assumed to be minimal.

22.4.4.2.4 Exposure Assessment

The exposure assessment evaluates the ways people (human receptors) may be exposed (by exposure pathways) to COPCs (sources) and to what amount they could be exposed (dose). The exposure assessment follows Health Canada guidance and used reasonable maximum exposure (RME) methods. There are two primary tasks for an exposure assessment:

- Determine the estimated environmental concentrations (EECs) at the points of potential human contact, for all identified COPCs. For the baseline condition, EECs for soil, surface water, fish, and plants were derived from measured concentrations, and EECs for air particulate and terrestrial country foods were estimated from models. Predicted future EECs for all exposure media were estimated from models; and

- Estimate the dose for operable exposure pathways of potentially exposed populations (receptor groups). The doses were estimated using EECs and RME assumptions for variables such as exposure duration, ingestion rate, and other parameters that describe human receptor group activities.

The HHRA (Volume 8, Appendix 22-A) characterizes risk to Human Health associated with potential exposure to air, particulate, soil, surface water, and country foods that may be potentially contaminated as a result of the Project.

The EECs represent the chemical concentration in the exposure medium that the human receptor may potentially come into contact with during time spent in the Human Health

LSA. Section 7.1 of the HHRA explains how the EECS for exposure media were developed from measured data and models.

Receptor exposure factors consist of receptor type and age-specific characteristics as well as exposure assumptions associated with the duration and frequency of time spent in the LSA near the Project area. Section 7.2 of the HHRA explains how the receptors characteristics and exposure assumptions were developed and provides a summary of the values used to model exposure.

For ingestion and dermal contact exposure pathways, intake of COPCs by potentially exposed receptors was calculated by estimating the mass of COPC taken into the body per unit body weight per unit time (milligram per kilogram of body weight per day [mg/kg-day]). Organ consumption for moose was included in this calculation. For the inhalation exposure pathway, the intake of COPCs by potentially exposed receptors was calculated by estimating a time-weighted exposure concentration that considers the exposure time, frequency, and duration for each receptor as well as the period over which the exposure is averaged (i.e., the averaging time). The dose for each exposure pathway for each receptor was calculated using the media specific equation below. The equations are based on the exposure characteristics and exposure frequency and duration assumptions provided in Tables 7 and 8 of the HHRA.

For non-cancer COPCs, the dose is averaged over the duration of the exposure to the COPC. For evaluation of carcinogenic COPCs, the dose is averaged over the entire lifetime. The calculated carcinogenic dose for the adult recreational receptor is greater than the carcinogenic dose for the toddler recreational receptor because the length of exposure is greater for the adult compared to the toddler while the averaging time term is the same. In contrast, for non-cancer exposures, the dose for the child is greater than the dose for the adult because the averaging time terms are based on the exposure duration. As a result, the non-cancer hazards are greater for the child relative to the adult. Dose estimate equations are presented in Section 7.3 of the HHRA for inhalation of air particulate, inadvertent ingestion of soil, dermal contact with soil, ingestion of surface water, dermal contact with surface water, and ingestion of country foods.

22.4.4.2.5 Toxicity Assessment

The purpose of the toxicity assessment is to identify the toxic potential of the identified COPCs. Specifically, there are two major objectives:

- To identify the potential toxicological effects associated with the COPCs; and
- To identify the TRVs used to estimate risk.

The TRVs can take the form of (i) a tolerable exposure (TDI: also referred to as a reference dose [RfD]), (ii) a tolerable concentration (TC: also referred to as a reference concentration [RfC]), (iii) a risk-specific dose (RSD), or (iv) a toxic potency factor such as a cancer slope factor (SF). Health Canada (2010) was the preferred source of TRVs for this HHRA, with other sources selected, in order of priority as recommended by Health Canada:

- Health Canada;

- USEPA Integrated Risk Information System (IRIS);
- Netherlands National Institute of Public Health and the Environment (RIVM) – human toxicological maximum permissible risk levels;
- World Health Organization (WHO); and,
- US Agency for Toxic Substances and Disease Registry (ATSDR) – toxicological profiles.

Toxicity profiles for each chemical are provided in Attachment E of the HHRA (Volume 8, Appendix 22-A). A summary of the TRVs used for each of the COPCs is provided in Attachment A, Table A19, of the HHRA.

22.4.4.2.6 Calculating Non-Cancer Hazards

Non-carcinogens are considered to be threshold COPCs because a critical chemical dose must be exceeded before a health effect is observed. The likelihood of a potential adverse health effect from non-carcinogens is represented by the ratio of a COPC exposure concentration and the route-specific non-carcinogenic TRV:

$$HQ = \frac{Dose\ (or\ TADC_A)}{TRV}$$

Where:

HQ = non-cancer hazard quotient;
Dose = dose for each chemical of potential concern (mg/kg-day); and
$TDCA_A$ = time-adjusted daily air concentration (mg/m^3)
TRV = non-carcinogenic TRV (in mg/kg-day or mg/m^3)

As illustrated in the conceptual site models (Figure 22.5-1 and Figure 22.5-2), receptors were assumed to be exposed to COPCs in soil, surface water, and country foods via one or more of the following three exposure pathways:

- Ingestion (soil, surface water, and country foods);
- Dermal contact (soil and surface water); and
- Inhalation of air particulate and non-particulate.

Each of these pathways was initially evaluated separately for both the baseline condition and predicted future condition. Non-cancer HQs were calculated for each COPC and route-specific pathway combination. The additive hazard index (HI) was then calculated as the sum of HQs for a given COPC across all exposure routes (note: HQs were summed only when using the same TRV). The maximum country foods HQs were included the calculation of the HI, as a conservative approach.

To put the HIs into context, the Project Hazard was calculated as the difference between HIs for the baseline condition and predicted future condition. The Target Organ HI was also calculated as the sum of HIs for COPCs with similar target tissues. Only the ingestion and dermal contact Target Organ HIs are shown, since these pathways were evaluated with the same TRVs, as per Health Canada (2010).

The HQ and HI estimates for non-carcinogenic COPCs were initially compared with the Health Canada acceptable HQ threshold of 0.2 and the BC acceptable HI threshold of 1 (BC CSR 1997, Section 18.3). The Health Canada threshold of HQ=0.2 is set for individual chemical exposure (Health Canada 2010).

22.4.4.2.7 Calculating Cancer Risks

The increased likelihood of cancer from exposure to a chemical it is called the incremental lifetime cancer risk (ILCR). An impossible event has a 0 probability of occurring; a certain event has a probability of 1 of occurring. For carcinogens, the risk of cancer is assumed to be proportional to the dose, and any exposure results in a non-zero probability of risk. Cancer risk probabilities were calculated by multiplying the estimated dose by the CSF which, in this case, is the route-specific cancer slope factor for each carcinogen. The following formula was used to calculate risk estimates for carcinogenic adverse health effects (i.e., ILCR):

$$ILCR_{Lifestage\ i} = LADD_i \times SF \times ADAF_i$$

Where:

ILCR $_{Lifestage\ i}$ = incremental lifetime cancer risk during lifestage “i”;
LADDi = dose received during lifestage “i" averaged over a lifetime (mg/kg/day);
SF = Route- and chemical-specific cancer slope factor $(mg/kg\text{-}day)^{-1}$; and
ADAF $_i$ = age-dependent adjustment factors for lifestage “i”

As for the evaluation of non-cancer risk, each pathway was initially evaluated separately for both the baseline condition and predicted future condition. Arsenic was the only carcinogenic COPC identified via the ingestion exposure route. ILCRs were calculated for each ingestion exposure route and summed. As for non-cancer risk estimates, the maximum country foods ILCR was used to calculate the summed ILCR across all exposure pathways, as a conservative approach. Arsenic was the only COPC identified that was carcinogenic via the ingestion route (target organ = bladder-liver-lung), so there were no other carcinogens identified via the ingestion route to sum with arsenic.

Arsenic, cadmium, chromium, and nickel cancer risks were evaluated individually for the inhalation pathway, followed by summing of the ILCRs for these four COPCs for the inhalation pathway (target organ = lung).

22.4.4.2.8 Chemical Related Baseline Non-Cancer Health Effects

Attachment D of the HHRA (Volume 8, Appendix 22-A) provides detailed risk results for country foods exposure and Attachment F provides detailed risk results for soil and surface water exposure. Detailed risk results for the sum of all pathways are provided in Attachment G (except for the Country Foods Consumer receptor shown in Attachment D, where there is only one exposure pathway).

Some of the risk estimates in Attachment D assume that country foods are consumed 365 days per year (i.e., HQs in tables with "Year Round" in the title; these are not HQs for an identified receptor). However, the annual exposure shown in Attachment D tables in tables with "Year Round" in the title was amortized to reflect the amount of time each receptor was assumed to spend at the site, or, in the case of the Country Food Consumer, the number of days they consumed country foods. The amortization period for each country foods consumer and the frequency of consumption were provided in Table 8 of Appendix 22-A.

Several COPCs in the country foods exposure estimates had HQs that exceeded the Health Canada acceptable HQ threshold of 0.2 and the BC acceptable HQ threshold of 1 (Attachment D of Volume 8, Appendix 22-A) under the baseline condition.

A summary of the non-cancer risk estimate HI results for baseline conditions, which combine exposures across all pathways for each of the receptors, is provided in Table 22.4-2.

Table 22.4-2: Summary of Baseline Non-Cancer Risks

Receptor	Age Group	COPCs with Baseline HI >0.2
Hunter/ Trapper/ Fisher	Teen	Cadmium, Chromium, Cobalt, Iron, Manganese, Nickel, Selenium, Thallium, Zinc
Hunter/ Trapper/ Fisher	Adult	Arsenic, Cadmium, Chromium, Cobalt, Iron, Lead, Manganese, Nickel, Selenium, Thallium, Zinc
Recreational User	Infant	None
Recreational User	Toddler	Cadmium, Chromium, Cobalt, Iron, Lead, Manganese, Selenium, Thallium, Zinc
Recreational User	Child	Cadmium, Iron, Manganese, Selenium, Thallium, Zinc
Recreational User	Teen	Cadmium, Manganese, Selenium, Thallium
Recreational User	Adult	Cadmium, Iron, Manganese, Selenium, Thallium
Summer Resident	Infant	Chromium, Iron, Lead
Summer Resident	Toddler	Aluminum, Arsenic, Cadmium, Chromium, Cobalt, Iron, Lead, Manganese, Nickel, Selenium, Thallium, Zinc
Summer Resident	Child	Cadmium, Chromium, Cobalt, Iron, Lead, Manganese, Nickel, Selenium, Thallium, Zinc
Summer Resident	Teen	Cadmium, Chromium, Cobalt, Iron, Manganese, Nickel, Selenium, Thallium, Zinc
Summer Resident	Adult	Cadmium, Chromium, Cobalt, Iron, Manganese, Nickel, Selenium, Thallium, Zinc
Year Round Resident	Toddler	Aluminum, Arsenic, Barium, Boron, Cadmium, Chromium, Cobalt, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Thallium, Vanadium, Zinc
Year Round Resident	Adult	Aluminum, Arsenic, Barium, Cadmium, Chromium, Cobalt, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Thallium, Zinc

Receptor	Age Group	COPCs with Baseline HI >0.2
Country food Consumer	Toddler	Cadmium, Chromium, Cobalt, Iron, Lead, Manganese, Nickel, Selenium, Thallium, Zinc
Country food Consumer	Child	Cadmium, Cobalt, Iron, Lead, Manganese, Nickel, Selenium, Thallium, Zinc
Country food Consumer	Teen	Cadmium, Cobalt, Iron, Manganese, Selenium, Thallium, Zinc
Country food Consumer	Adult	Cadmium, Cobalt, Iron, Manganese, Nickel, Selenium, Thallium, Zinc

22.4.4.2.9 Uncertainty in Baseline Characterization

The uncertainty associated with baseline characterization is discussed in Section 22.5.3.5.3.

22.4.4.2.10 Chemical-Related Baseline Cancer Health Effects

Attachment D of the HHRA (Volume 8, Appendix 22-A) provides detailed risk results for country foods exposure (including for the Country Foods Consumer receptor). Attachment F provides detailed risk results for air, soil, and surface water exposure. Detailed risk results for the sum of all pathways for all receptors and life stages are provided in Attachment G (except for Country Foods Consumer receptor, where there is only one pathway and results are in Attachment D). As stated above, the Country Food Receptor spends no time in the Biter Creek Valley. Their only exposure to COPCs related to the Project is through consumption of country foods harvested from the Bitter Creek valley via hunting, fishing, and plant gathering.

Arsenic cancer risks for the sum of all ingestion pathways exceeded the cancer threshold of $1x10^{-5}$ (Attachment D) under the baseline condition (Table 22.4-3).

None of the ILCRs for any of the COPCS via the inhalation route were higher than $1x10^{-5}$ under baseline, nor was the sum of the ILCRs for the four carcinogenic metals via the inhalation route.

Table 22.4-3: Summary of Baseline Cancer Risks

Receptor	Age Group	COPCs with Baseline ILCR >$1x10^{-5}$
Hunter/ Trapper/ Fisher	Teen	Arsenic
Hunter/ Trapper/ Fisher	Adult	Arsenic
Recreational User	Infant	None
Recreational User	Toddler	Arsenic
Recreational User	Child	Arsenic
Recreational User	Teen	None

Receptor	Age Group	COPCs with Baseline ILCR >$1x10^{-5}$
Recreational User	Adult	Arsenic
Summer Resident	Infant	Arsenic
Summer Resident	Toddler	Arsenic
Summer Resident	Child	Arsenic
Summer Resident	Teen	Arsenic
Summer Resident	Adult	Arsenic
Year Round Resident	Toddler	Arsenic
Year Round Resident	Adult	Arsenic
Country food Consumer	Toddler	Arsenic
Country food Consumer	Child	Arsenic
Country food Consumer	Teen	Arsenic
Country food Consumer	Adult	Arsenic

22.5 Potential Effects

22.5.1 Methods

22.5.1.1 Detecting Project-related Incremental Change

Potential effects of the project to human health are analysed in the HHRA (Volume 8, Appendix 22-A) through characterization of risk. Risk characterization integrates the exposure and toxicity assessments to quantitatively estimate potential health risks to ROCs from exposure to the COPCs. Risk estimates were determined and discussed in the HHRA (Volume 8, Chapter 22-A) for both the baseline and future predicted conditions and considered individual routes of COPC exposures as well as additive effects. The risk characterization section of the HHRA integrates the exposure and toxicity assessments conditions and considered individual routes of COPC exposures as well as additive effects.

Risk characterization puts the estimated exposure into context by comparing potential Project risks to risks that are associated with baseline conditions. Risk estimates were compared to one digit after the decimal point (i.e., the differences between the risk estimates was rounded to one significant digit after the decimal point).

If the difference was greater than zero (rounded to one significant digit, i.e., ≥0.1), the exposure concentrations were compared to the applicable guidelines (e.g., water quality guideline) to provide a context for the estimated risk. If the exposure concentrations were less than the guideline, the risks were assumed to be acceptable and no further investigation was considered necessary. If the guideline was exceeded, the risks were considered further, and factors such as the source of the toxicity information, the nature of the effects associated with toxicity, and the magnitude of the guideline exceedance, were investigated to provide a more complete understanding of the risks.

The numerical risk estimates presented in this section should be interpreted in the context of uncertainties and the conservative assumptions associated with each step of the HHRA process and in the context of the data and models upon which the HHRA was developed.

22.5.1.2 Chemical-Related Health Effects

The same methodology was used to assess the potential effects (predicted future effects including the Project) associated with COPC exposures, as was used to assess the baseline health effects (described in Section 22.4.3.2).

The predicted future COPC exposure levels for Air Quality were calculated through modelling of air particulate emissions from mine features and activities, measurement and estimation of COPCs in emission sources, and estimation of weighted source contribution to the total emissions. Soil COPC concentrations were calculated through modelling of air particulate deposition (dustfall) rates and mixing of the dust with surface soil. Country food COPC concentrations were estimated by modelling uptake of COPCs into country foods and their food sources resulting from exposure to COPCs in soil and surface water. The methods noted above are described in detail in Attachment C of the HHRA for air and soil and Sections 7.1.3 to 7.1.5 of the HHRA for country foods. Predicted future risks were estimated for the same receptors using the same dose equations (Volume 8, Appendix 22-A, Section 7.3).

The same receptors and exposure pathways were evaluated for the baseline characterization and predicting potential effects.

22.5.1.3 Air

The same methodology as described in Section 22.4.3.2.1 was used to identify predicted COPC concentrations in air. Air screening levels were compared to predicted future concentrations to identify COPCs. Air constituents in excess of air screening levels were carried forward as COPCs in the HHRA.

No air COPCs were carried forward for quantitative evaluation in the HHRA as all constituent concentrations in air were less than screening values.

Volatile organic compounds (VOCs), diesel vapours, and ore processing reagents were not carried forward from the Air Quality Effects Assessment because these releases were deemed to be negligible. No dispersion modelling for VOCs was completed in the Air Quality modelling report (Volume 8, Appendix 7-A, Section 3, Table 3-2 and Table 3-3).

A diesel particulate matter (DPM) analysis was completed using data presented in the Air Quality Modelling Report (Volume 8 Appendix 7-A) and Health Canada (2016). The proportion of PM2.5 that was DPM was first estimated using data in Tables 3.2 and 3.3 of Volume 8, Appendix 7-A (Table 22.5-1). DPM accounted for 84% and 2% of the PM2.5 during the Construction Phase and Operation Phase annual emissions, respectively.

Table 22.5-1: Percent DPM

Air Contaminant	Construction Scenario Total (tonnes/year)	Operation Scenario Total (tonnes/year)
$PM_{2.5}$	2.5	17.2
DPM	2.1	0.41
%DPM	84%	2%

The 24-hour and annual DPM air concentrations were then estimated by applying the %DPM to the predicted $PM_{2.5}$ concentrations for both scenarios (Table 22.5-2). The maximum estimated DPM concentration was 3.5 µg/m^3 for the 24-hour Construction Scenario.

Table 22.5-2: Estimated DPM Concentrations

Calculation Basis & Averaging Time	Construction Scenario		Operation Scenario	
	Maximum $PM_{2.5}$ Concentration + Background Total (µg/m^3)	Estimated DPM Concentration (µg/m^3)	Maximum $PM_{2.5}$ Concentration + Background Total (µg/m^3)	Estimated DPM Concentration (µg/m^3)
98th Percentile of 24-hour Block Averages	4.1	3.5	18.6	0.44
Annual Maximum	1.7	1.4	4.4	0.10

The DPM concentrations were then compared to the DPM risk/guidance values from Health Canada (2016) (Table 22.5-3).

Table 22.5-3: Health Canada DPM Critical Effect Values

Health Outcome	Risk or Guidance Concentration	Critical Effect
Cancer	N/A	N/A
Non-cancer – chronic exposure	5 µg/m^3	Respiratory – inflammation, histopathological and/or functional changes
Non-cancer – short-term exposure	10 µg/m^3	Respiratory – increased airway resistance and inflammation

The maximum estimated DPM concentrations do not exceed the non-cancer chronic and short-term exposure risk/guidance values from Health Canada. Based on this analysis, project-related risks from DPM are considered negligible. Health Canada (2016) evaluated DPM for carcinogenic effects and concluded that the data available for DPM was inadequate to provide a carcinogenic toxicity value. Thus, the risk from DPM exposure was not assessed in the HHRA (Volume 8, Appendix 22-A). Currently available DPM guidance values do not account for a potential carcinogenic endpoint.

Predicted PM and NO_2 concentrations were compared to provincial and federal existing guidelines, and as a result were not screened into the HHRA. IDM acknowledges that even though NO2 and PM exposure concentrations related to the project are low they are within the range where there is some uncertainty regarding effects. Toxicity profiles for PM and NO2 have been developed and are presented Attachment E of the HHRA. The Air Quality and Dust Management Plan (Volume 5, Chapter 29) will include monitoring programs that will allow for real-time verification of the air quality modelling results and the effectiveness of applied mitigation measures.

VOCs, diesel vapours, ore processing reagents, as well as the predicted NO2 and PM emissions will be primarily a concern for workers on site during the construction and operation of the Project. As such, the potential effects will be managed and mitigated in accordance with the Occupational Health and Safety Plan (Volume 5, Chapter 29, Section 29.17).

22.5.1.4 Noise

A complete assessment of Noise from the perspective of Human Health was completed in Volume 3, Chapter 8. As a result, there is no further discussion of potential noise effects in this chapter.

22.5.1.5 EMF

Future EMF levels were assumed based on the proposed installation of a 138 kilovolt (kV) Powerline. Exposure to EMF involves two distinct components: electric fields and magnetic fields.

- Electric fields are produced by electric potential difference (i.e., voltage) and are expressed in Volts per metre (V/m). Electric fields are formed whenever a device is plugged into an outlet, regardless of whether it’s turned on. Electric fields are easily shielded by fencing, trees, and buildings (BC Hydro 2017).

- Magnetic fields are produced by a flow of electric charge (i.e., current) and are expressed in gauss (G) or tesla (T). Magnetic fields are only present when electric devices are plugged in and turned on. Magnetic fields are not easily shielded. Both electric and magnetic field strength dissipate rapidly with distance from the source.

The approximate EMF levels generated from the Project’s 138 kV power line are shown in Table 22.5-4.

Table 22.5-4: Typical Electric and Magnetic Fields Associated with a 138-kV Distribution Line in BC

Distance from 138-kV Power Line (m)	Magnetic Field (mG)	Electric Field (kV/m)
0	24	Maximum electric field approximately 4 kV/m*
2	23	
5	20	
10	12	
20	4	

Source: BC Hydro 2017.
* EMFs.info. 2017.

As noted above, exposure to very high levels of EMF may cause health problems as a result of electrical interference with the brain, nerves, and heart (Health Canada 2017; WHO 2007). Health Canada and WorkSafeBC do not have exposure limits for residential or occupational exposures to EMF; however, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has developed short-term exposure limits for EMF based on magnetic field, shown in Table 22.5-5 (Health Canada 2017; WHO 2007; WHO 2017). The ICNIRP has determined that there is insufficient evidence of health effects for long-term exposure and thus, the development of long-term exposure limits was deemed unnecessary. Health Canada and the WHO endorse the ICNIRP exposure guidelines for EMF (BC Hydro 2017; Health Canada 2017).

Table 22.5-5: Exposure Limits for EMF

Parameter	Residential	Occupational
Magnetic Field (mG)	2000	10000
Electric Field (kV/m)$_b$	30	

Source: BC Hydro 2017.

22.5.2 Project Interactions

It is anticipated that the following proposed Project components or activities (Table 22.5-6) have the potential to affect Human Health.

Table 22.5-6: Potential Project Interactions, Human Health

Project Component or Activity	Potential Interaction with Human Health
Construction	
Construct facilities, including offices, workshop, stores, emergency accommodation, backup diesel generators, and water supply	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Construct mine site access/haul road from Hwy 37a to portal entrance	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Install powerline from substation tie-in to portal entrance	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Excavate and secure lower portal entrance and access tunnel	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation, ML/ARD and/or blasting. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Construct portal facilities, including cut and fill, organics stockpiles, laydown areas, concrete batch plant, offices, workshop, and stores	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Install tank farm platform and fill with fuel	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Construct portal area water management infrastructure including sedimentation pond, pumphouse, runoff collection ditches, and clean water discharge ditch	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.

Project Component or Activity	Potential Interaction with Human Health
Construct mine site and portal area diversion ditches and swales	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration through water management features. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Initiate underground lateral development and cave gallery excavation	Changes to water quality resulting from ML/ARD and/or blasting. Drinking water ingestion and uptake in country foods and consumption.
Temporarily stockpile waste and ore in portal area	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration through water management features. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Install construction and permanent ventilation systems and underground water pumps	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Transport and deposit waste rock to Waste Rock Storage Area(s)	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Clear and prepare the TMF basin and plant site pad	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Establish diversion ditches for the TMF and Plant Site	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Construct the Plant Site and Ore Stockpile area	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.

Project Component or Activity	Potential Interaction with Human Health
Excavate rock and till from the TMF basin and local borrows for construction activities (e.g., dam construction for the TMF)	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation, ML/ARD and/or blasting. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Construct the TMF and supporting infrastructure	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Commence milling to ramp up to full production	Dust containing metals generated by equipment and vehicles. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Operation	
Use Access Road for personnel transport, haulage, and delivery of goods	Dust containing metals generated by equipment and vehicles. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Continue underground lateral development, including dewatering	Changes to water quality resulting from ML/ARD and/or blasting. Drinking water ingestion and uptake in country foods and consumption.
Maintain mine site Access/Haul Road, including grading and plowing as necessary	Dust containing metals generated by equipment and vehicles. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Haul waste rock from the declines to the WRSA (waste rock transport and storage) for disposal	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Extract ore from the underground load-haul-dump transport to Bromley Humps to ore stockpile (ore transport and storage)	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Process ore to gold ore	Dust containing metals generated by equipment and vehicles. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.

Project Component or Activity	Potential Interaction with Human Health
Progressively reclaim disturbed areas no longer required for the Project	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Closure and Reclamation	
Decommission underground infrastructure	Changes to water quality resulting from erosion and sedimentation. Drinking water ingestion and uptake in country foods and consumption.
Flood underground	Changes to water quality resulting from flooding. Drinking water ingestion and uptake in country foods and consumption.
Decommission portal access road	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Decommission and reclaim all remaining roads, lower portal area, and Powerline/access corridor infrastructure	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Decommission and reclaim all remaining mine infrastructure (except TMF) in accordance with Closure Plan	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion, sedimentation, and infiltration. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Conduct maintenance of mine drainage, seepage, and discharge	Changes to water quality resulting from infiltration. Drinking water ingestion and uptake in country foods and consumption.
Construct the closure spillway	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.
Post-Closure	
Remove discharge water line and water treatment plant	Dust containing metals generated by equipment and vehicles. Changes to water quality resulting from erosion and sedimentation. Inhalation of particulate, deposition of metals on environmental media, soil direct contact, incidental soil ingestion, drinking water ingestion, and uptake in country foods and consumption.

22.5.3 Discussion of Potential Effects

22.5.3.1 Sources, Release Mechanisms, and Transport Pathways of Project Related Chemicals

The main sources of contamination include the following:

- Construction and operations at the Mine Site will result in the excavation of tunnels, shafts, portals, ore deposits as well as the deposition of waste rock piles that are the sources of contamination releases. Contaminants migrate via various release mechanisms, for example erosion, dissolution, leaching, and various transport pathways, for example migration of water through bedrock fractures and migration of dust emissions in air.

- Ore processing at the Process Plant and at the TMF involves the crushing and grinding of ore material, thickening, pre-oxidation, cyanide leaching, electrowinning, cyanide destruction and tailings disposal (reagents include sodium cyanide, hydraulic chloric acid, caustic acid, copper sulphate, and sodium metabisulphate). Contaminants migrate via various release mechanisms, for example, emission from the Process Plant leakage from the TMF, and various transport pathways for example migration of water through bedrock fractures and migration of emissions in air.

- Roads constructed using material from borrow pits and quarries and haul truck driving on roads are sources of contamination releases. Contaminants migrate via various release mechanisms, for example wind erosion, vehicle emissions, and various transport pathways, such as migration of water through bedrock fractures and migration of dust emissions in air, and migration of emissions in air.

A more detailed discussion of sources release mechanisms and transport pathways is provided in Section 6.1 of the HHRA (Volume 8, Appendix 22-A).

22.5.3.2 COPCs Identified in Each Media

Table 22.5-7 identifies COPCs based on baseline and predicted data.

Table 22.5-7: COPCs Identified in Each Media

Constituent	Soil	Surface Water	Country Foods	Groundwater	Sediment	Air
Aluminum		X	X			
Antimony		X		X		
Arsenic	X	X	X	X	X	
Barium			X			
Bismuth	X	X	X		X	
Boron			X			
Cadmium	X	X	X	X	X	
Chromium		X	X			

Constituent	Soil	Surface Water	Country Foods	Groundwater	Sediment	Air
Cobalt		X	X	X	X	
Copper			X		X	
Iron	X	X	X		X	
Lead		X	X		X	
Manganese		X	X	X	X	
Mercury	X	X	X	X	X	
Nickel			X			
Nitrate				X		
Selenium	X	X	X	X	X	
Strontium			X			
Tellurium	X		X			
Thallium		X	X			
Uranium			X			
Vanadium		X	X			
Zinc			X			

22.5.3.3 Exposure Pathways

The potential exposure pathways associated with predicted effects are the same as though for baseline conditions, as summarized in Section 22.4.4.2.3.

- Inhalation of air;
- Ingestion and dermal contact with groundwater; and
- Incidental ingestion and dermal contact with sediment.

Exposure to contamination in air via inhalation of air in the Human Health LSA may be affected by the emissions of particulate (i.e., fugitive dust) from mining operations, roadways, and waste rock and emissions of particulate and non-particulate from the Process Plant. However, no air COPCs were identified in predicted future conditions resulting from the Project. Therefore, the air inhalation exposure pathway was considered to be incomplete.

Groundwater is currently not being used for drinking water purposes in the Bitter Creek valley, and its future use as a drinking water source is not anticipated in the two areas with the potential to be adversely affected by the Project (the Mine Site and the TMF). Groundwater wells installed at these two areas had relatively low hydraulic conductivity, ranging from 7.4×10^{-9} m/s to 2.9×10^{-5} m/s, with a geometric mean of 3.0×10^{-7} m/s, which is insufficient to provide adequate water to supply one home. Furthermore, these two high alpine locations are quite remote. It is recognized that remoteness in itself is not enough to discount future use of groundwater and that hydraulic conductivity, by itself, should not be used to determine water availability in bedrock environments. However, the combination of these factors makes it unlikely that groundwater will be used for drinking water in the area.

Therefore, the exposure pathways between groundwater and receptors were considered incomplete.

There are several surface water bodies (creeks) in the LSA. However, it is unlikely that significant exposure between sediment and receptors of concern will occur. Creeks in the LSA are very cold and are unlikely to be used for swimming or wading. The fish-bearing creeks were assumed to be used for fishing. However, contact with sediment as a result of fishing will be negligible. Furthermore, in absence of salmon being present the creeks of the Bitter Creek valley, Bitter Creek is not considered to be a prime fishing area. Therefore, the exposure pathways between receptors and sediment were considered to be incomplete.

22.5.3.4 Conceptual Site Model

A Conceptual Site Model was developed for the Project that integrates potential sources of stressors, affected media (transport pathways), exposure routes, and potential receptors. The complete (operable) exposure pathways are illustrated in Figure 22.5-1 and Figure 22.5-2.

Figure 22.5-1: Conceptual Site Model – Human Health

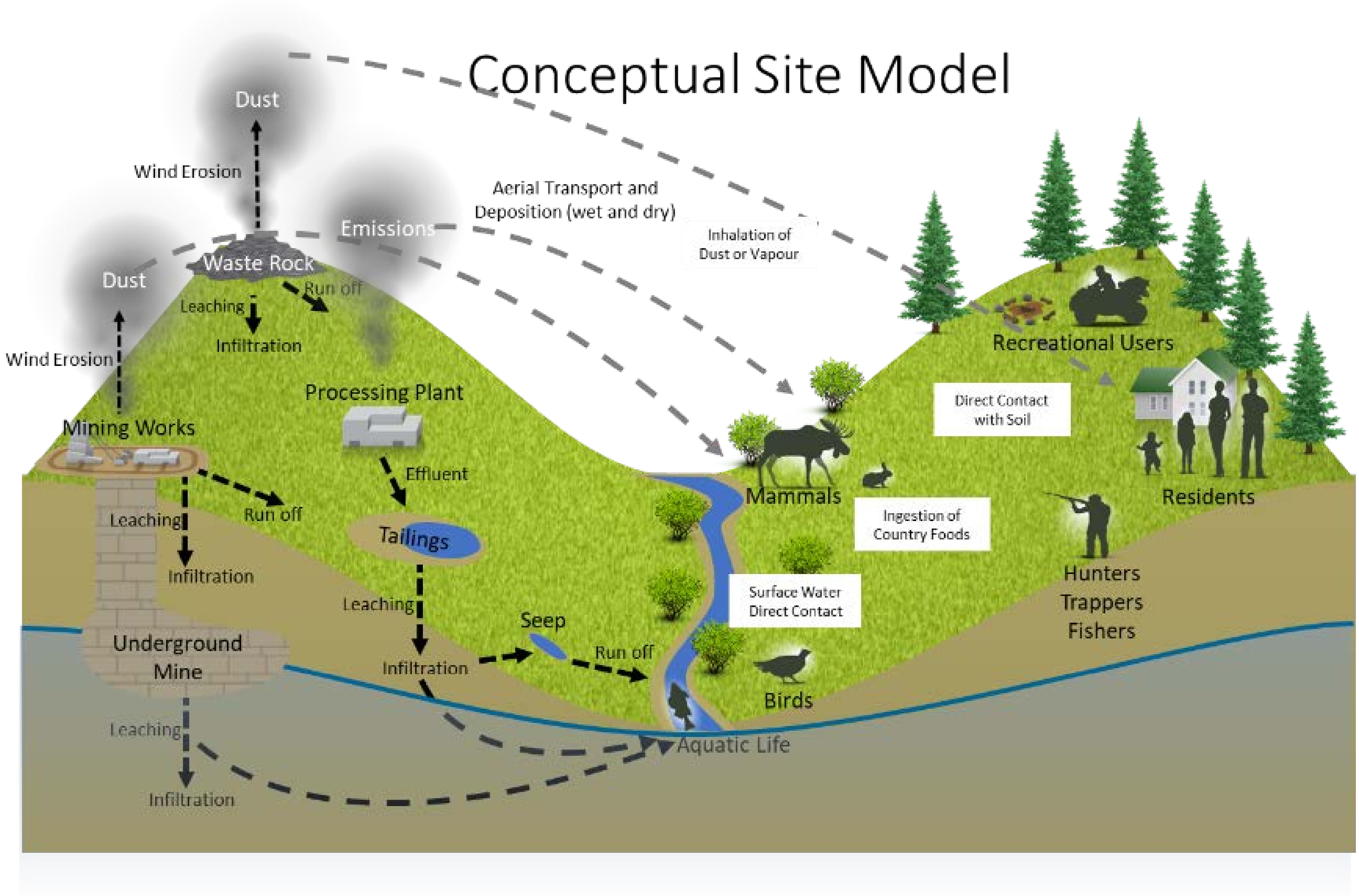
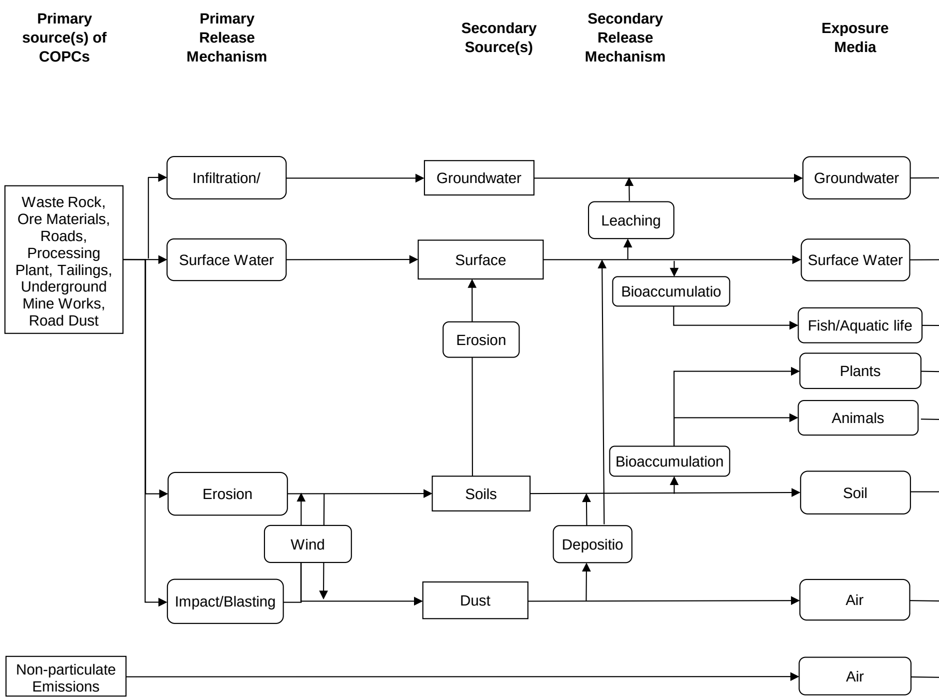


Figure 22.5-2: Box and Line Conceptual Site Model – Human Health



Exposure Media	Exposure Route	Hunter/Trapper/Fisher	Recreational User	Summer Resident	Country Food Consumer	Aquatic Life	Mammals	Birds	Soil Invertebrates	Plants
Groundwater	Ingestion	-	-	-	-	-	-	-	-	-
	Dermal Absorption	-	-	-	-	-	-	-	-	-
Surface Water	Ingestion	X	X	X	-	X	X	X	-	-
	Dermal Absorption	X	X	X	-	X	X	X	-	-
Fish/Aquatic life	Ingestion	X	X	X	X	-	-	-	-	-
Plants	Ingestion	X	X	X	X	-	-	-	-	-
Animals	Ingestion	X	X	X	X	-	-	-	-	-
Soil	Incidental Ingestion	X	X	X	-	-	X	X	X	X
	Dermal Absorption	X	X	X	-	-	X	X	X	X
Air	Inhalation of particulate	X	X	X	-	-	X	X	X	X
Air	Inhalation Vapours	-	-	-	-	-	X	X	X	-

X Exposure Route Probable
- Exposure Route not probable

A summary of the COPCs identified in each media after the exposure pathway assessment was completed is provided in Table 22.5-8. All COPCs identified were metals.

Table 22.5-8: COPCs Identified in Each Media after Exposure Pathway Assessment

Constituent	Soil	Surface Water	Country Foods
Aluminum		X	X
Antimony		X	
Arsenic	X	X	X
Barium			X
Bismuth	X	X	X
Boron			X
Cadmium	X	X	X
Chromium		X	X
Cobalt		X	X
Copper			X
Iron	X	X	X
Lead		X	X
Manganese		X	X
Mercury	X	X	X
Nickel			X
Selenium	X	X	X
Strontium			X
Tellurium	X		X
Thallium		X	X
Uranium			X
Vanadium		X	X
Zinc			X

To capture total risk associated with exposure to COPCs resulting from the Project, when a COPC was identified in one media, it was also evaluated in all media to which receptors were likely to be exposed (i.e., including air, where no COPCs were identified).

The specific methods for estimating the human health exposure and risk levels are presented in Sections 7 and 9 of the HHRA (Volume 8, Appendix 22-A).

Attachment D of the HHRA provides detailed risk results for country foods exposure and the Country Foods Consumer receptor. Attachment F provides detailed risk results for soil and surface water exposure. Detailed risk results for the sum of all pathways are provided in Attachment G of the HHRA (except for Country Foods Consumer receptor shown in Attachment D, where there is only one exposure pathway).

22.5.3.5 Chemical-Related Health Effects – Predicted (including Air)

22.5.3.5.1 Predicted Non-Cancer Health Effects

Risk estimates for several COPCs exceeded the threshold of 0.2 under both baseline and future predicted conditions. Six COPCs exhibited predicted HIs that were higher than the baseline condition by more than 0.05 (i.e., ≥0.1 when rounded up; Table 22.5-9).

Table 22.5-9: Summary of Non-Cancer Risks

ROC	Type	COPCs with Baseline HI >0.2*	COPCs with Predicted Future HI >0.2	COPCs with Detectable Incremental Change**
Hunter/ Trapper/ Fisher	Teen	Cadmium (2.7), Chromium (0.3), Cobalt (0.5), Iron (0.6), Lead (0.2), Manganese (1.4), Nickel (0.3), Selenium (1.0), Thallium (0.7), Zinc (0.5)	Cadmium (2.7), Chromium (0.3), Cobalt (0.8), Iron (0.7), Lead (0.3), Manganese (1.4), Nickel (0.3), Selenium (1.0), Thallium (0.7), Zinc (0.5)	Cobalt, Iron, Lead
Hunter/ Trapper/ Fisher	Adult	Arsenic (0.3), Cadmium (3.5), Chromium (0.4), Cobalt (0.6), Iron (0.7), Lead (0.3), Manganese (1.7), Nickel (0.5), Selenium (1.4), Thallium (1.0), Zinc (0.7)	Arsenic (0.3), Cadmium (3.5), Chromium (0.4), Cobalt (1.0), Iron (0.9), Lead (0.4), Manganese (1.7), Nickel (0.5), Selenium (1.4), Thallium (1.0), Zinc (0.7)	Cobalt, Iron, Lead
Recreational User	Infant	None	None	None
Recreational User	Toddler	Cadmium (1.6), Chromium (0.3), Cobalt (0.3), Iron (0.5), Lead (0.4), Manganese (0.9), Selenium (0.6), Thallium (0.5), Zinc (0.4)	Cadmium (1.6), Chromium (0.3), Cobalt (0.5), Iron (0.5), Lead (0.6), Manganese (0.9), Selenium (0.6), Thallium (0.5), Zinc (0.4)	Cobalt, Iron, Lead
Recreational User	Child	Cadmium (1.2), Cobalt (0.2), Iron (0.3), Lead (0.2), Manganese (0.7), Selenium (0.4), Thallium (0.3), Zinc (0.3)	Cadmium (1.2), Cobalt (0.4), Iron (0.3), Lead (0.4), Manganese (0.7), Selenium (0.4), Thallium (0.3), Zinc (0.3)	Cobalt, Iron***, Lead
Recreational User	Teen	Cadmium (0.9), Cobalt (0.2), Manganese (0.5), Selenium (0.3), Thallium (0.3)	Cadmium (0.9), Cobalt (0.3), Manganese (0.5), Selenium (0.3), Thallium (0.3)	Cobalt
Recreational User	Adult	Cadmium (1.2), Iron (0.3), Manganese (0.6), Selenium (0.5), Thallium (0.3)	Cadmium (1.2), Iron (0.3), Manganese (0.6), Selenium (0.5), Thallium (0.3)	None
Summer Resident	Infant	Chromium (0.3), Iron (0.3), Lead (0.3)	Chromium (0.3), Iron (0.4), Lead (0.3)	None
Summer Resident	Toddler	Aluminum (0.3), Arsenic (0.4), Cadmium (3.5), Chromium (0.7), Cobalt (0.7), Iron (1.0), Lead (0.9), Manganese (2.0), Mercury (0.2), Nickel (0.5), Selenium (1.3), Thallium (1.0), Zinc (0.8)	Aluminum (0.3), Arsenic (0.4), Cadmium (3.6), Chromium (0.7), Cobalt (1.1), Iron (1.1), Lead (1.2), Manganese (2.0), Mercury (0.3), Nickel (0.5), Selenium (1.3), Thallium (1.0), Zinc (0.8)	Cobalt, Iron, Lead
Summer Resident	Child	Cadmium (2.6), Chromium (0.4), Cobalt (0.5), Iron (0.6), Lead (0.5), Manganese (1.6), Nickel (0.3), Selenium (0.9), Thallium (0.7), Zinc (0.6)	Cadmium (2.6), Chromium (0.4), Cobalt (0.8), Iron (0.7), Lead (0.8), Manganese (1.6), Nickel (0.3), Selenium (0.9), Thallium (0.7), Zinc (0.6)	Cobalt, Iron, Lead

ROC	Type	COPCs with Baseline HI >0.2*	COPCs with Predicted Future HI >0.2	COPCs with Detectable Incremental Change**
Summer Resident	Teen	Cadmium (2.0), Chromium (0.3), Cobalt (0.4), Iron (0.4), Manganese (1.1), Nickel (0.3), Selenium (0.7), Thallium (0.5), Zinc (0.4)	Cadmium (2.0), Chromium (0.3), Cobalt (0.6), Iron (0.5), Manganese (1.1), Nickel (0.3), Selenium (0.7), Thallium (0.6), Zinc (0.4)	Cobalt, Iron,
Summer Resident	Adult	Cadmium (2.6), Chromium (0.3), Cobalt (0.5), Iron (0.5), Lead (0.2), Manganese (1.2), Nickel (0.3), Selenium (1.1), Thallium (0.7), Zinc (0.5)	Cadmium (2.6), Chromium (0.3), Cobalt (0.8), Iron (0.6), Manganese (1.2), Nickel (0.3), Selenium (1.1), Thallium (0.7), Zinc (0.5)	Cobalt, Iron, Lead
Year Round Resident	Toddler	Aluminum (0.6), Arsenic (0.8), Barium (0.4), Boron (0.3), Cadmium (7.1), Chromium (1.4), Cobalt (1.3), Iron (1.9), Lead (1.7), Manganese (3.9), Mercury (0.5), Nickel (1.0), Selenium (2.6), Strontium (0.1), Thallium (2.0), Vanadium (0.4), Zinc (1.6)	Aluminum (0.6), Arsenic (0.8), Barium (0.4), Boron (0.3), Cadmium (7.1), Chromium (1.4), Cobalt (2.2), Iron (2.2), Lead (2.4), Manganese (4.0), Mercury (0.5), Nickel (1.0), Selenium (2.6), Strontium (0.3), Thallium (2.0), Vanadium (0.4), Zinc (1.6)	Arsenic***, Cobalt, Iron, Lead, Manganese, Mercury***, Strontium
Year Round Resident	Adult	Aluminum (0.3), Arsenic (0.4), Barium (0.3), Cadmium (5.3), Chromium (0.6), Cobalt (0.9), Iron (1.1), Lead (0.4), Manganese (2.5), Mercury (0.4), Nickel (0.7), Selenium (2.1), Thallium (1.4), Zinc (1.0)	Aluminum (0.3), Arsenic (0.4), Barium (0.3), Cadmium (5.3), Chromium (0.7), Cobalt (1.5), Iron (1.3), Lead (0.6), Manganese (2.5), Mercury (0.4), Nickel (0.7), Selenium (2.1), Thallium (1.4), Zinc (1.0)	Cobalt, Iron, Lead,
Country Food Consumer	Toddler	Cadmium (3.5), Chromium (0.3), Cobalt (0.6), Iron (0.5), Lead (0.5), Manganese (1.9), Mercury (0.2), Nickel (0.4), Selenium (1.3), Thallium (0.9), Zinc (0.8)	Cadmium (3.5), Chromium (0.3), Cobalt (1.0), Iron (0.7), Lead (0.8), Manganese (1.9), Mercury (0.3), Nickel (0.4), Selenium (1.3), Thallium (0.9), Zinc (0.8)	Cobalt, Iron, Lead,
Country Food Consumer	Child	Cadmium (2.6), Cobalt (0.4), Iron (0.4), Lead (0.4), Manganese (1.6), Nickel (0.3), Selenium (0.9), Thallium (0.7), Zinc (0.6)	Cadmium (2.6), Cobalt (0.7), Iron (0.5), Lead (0.6), Manganese (1.6), Nickel (0.3), Selenium (0.9), Thallium (0.7), Zinc (0.6)	Cobalt, Iron, Lead,

ROC	Type	COPCs with Baseline HI >0.2*	COPCs with Predicted Future HI >0.2	COPCs with Detectable Incremental Change**
Country Food Consumer	Teen	Cadmium (2.0), Cobalt (0.3), Iron (0.3), Manganese (1.0), Selenium (0.7), Thallium (0.5), Zinc (0.4)	Cadmium (2.0), Cobalt (0.5), Iron (0.4), Manganese (1.0), Selenium (0.7), Thallium (0.5), Zinc (0.4)	Cobalt, Iron,
Country Food Consumer	Adult	Cadmium (2.6), Cobalt (0.4), Iron (0.4), Manganese (1.2), Nickel (0.3), Selenium (1.0), Thallium (0.7), Zinc (0.5)	Cadmium (2.6), Cobalt (0.7), Iron (0.5), Manganese (1.2), Nickel (0.3), Selenium (1.0), Thallium (0.7), Zinc (0.5)	Cobalt, Iron

* To enable easier comparison, COPCs with baseline HI≤0.2 were included in the table when the predicted future HI for that COPC was >0.2.

** Baseline and predicted HIs are rounded to one significant digit after the decimal, per Barnes and Dourson (1988) and Felter and Dourson (1998). In some cases, an apparent difference between predicted and baseline occurs as a result of rounding, even if there is no detectable difference between the two values (e.g., a baseline HI of 0.64 will round to 0.6 and a predicted HI of 0.66 would round to 0.7). An incremental change in HI from baseline conditions to predicted future was considered 'detectable' if the HI differed by >0.05. This is not intended to imply that the change would have a measurable effect on human health. This threshold of >0.05 was used to identify COPCs or pathways that required additional, more detailed evaluation.

*** – Although arsenic, iron, and mercury HQs for both baseline and predicted appear the same, the difference between the two values was 0.05; therefore it was identified as a COPC with detectable incremental change.

The elevated HIs and incremental changes > 0.05 were primarily driven by COPC (arsenic, cobalt, iron, lead, mercury, manganese, and strontium) ingestion from the country foods exposure pathway. Several COPCs in the country foods exposure estimates had HQs that exceeded the Health Canada acceptable threshold of 0.2 and the province of British Columbia acceptable threshold of 1 (Attachment D), under both the baseline and predicted future conditions. Non-carcinogenic risk (HIs) were driven by the consumption of country foods and for the most part was driven by consumption of fish (Attachment D, Tables D13 and D26) and plants (Tables D12 and D25). Elevated HIs were also associated with consumption to some degree for moose (Tables D15 and D28); however, for plants and moose the baseline and predicted HIs were similar and thus they did not contribute significantly to incremental changes between baseline and predicted future for each chemical. HIs associated with consumption of rabbit (Tables D14 and D27) and grouse (Tables D16 and D29) were less than 0.2 for all chemicals.

Additional consideration of the potential risks for the seven parameters with HIs higher than 0.2 and where the future HI is predicted to be higher than the baseline HI by >0.05 is provided in the following section (9.2.1.2).

22.5.3.5.2 Country Foods Basket Approach

The calculation of HQs, and thus the summing of HIs, was based on the use of the maximum HQ amongst the various classes of country foods (i.e., the highest HQ amongst fish, plants, moose, grouse, or rabbit). This conservatively assumed that all of a person’s daily country foods consumption was coming from the grouping of food with the highest COPC content, without consideration of the variety of country foods that people might eat (that contribute lesser amounts of COPCs if considered as part of a mixture of country foods).

However, the use of this assumption will significantly overestimate the potential for risk to receptors; since potential risks were identified, this assumption should be revisited to better understand and characterize the potential risk to receptors. Therefore, non-carcinogenic risks from arsenic, cobalt, iron, lead, manganese, mercury, and strontium were further re-evaluated using a country foods basket approach that considered the types and proportions of country foods identified in Chan et al (2011) that may be consumed aboriginals and non-aboriginals.

The focus of the reassessment was on toddlers because risks are highest for this age group. Both the toddler Year Round Resident and Summer Resident receptors were considered. The rationale for focusing the re-evaluation to the toddler Year Round Resident and Summer Resident was that they represent the maximum change in potential risks (i.e., the highest incremental change due to the Project) and all other receptors and life stages would have even lower potential risks. The Year Round Resident and Summer Resident receptors are hypothetical as there are currently no residents in the Project area, but they represent an upper case exposure scenario in the event that someone chooses to reside in the area in the future. If the incremental change in risk for the toddler Year Round Resident and/or Summer Resident is negligible or not detectable, then no change in human health would be predicted for any receptor.

Country foods food items listed in Chan et al. (2011) were classified based on the groupings used in the HHRA (large mammals, small mammals, birds, fish, and plants) using the baseline and predicted concentrations for each country food. Where baseline concentrations were higher than predicted future concentrations, the predicted future concentrations were made equal to the baseline concentration (i.e., the difference was zero).

The selected food items were those assumed to be applicable for exposure at the site. Although some fish types (e.g., salmon, ling cod, eulachon, cod) may be consumed by receptors from the site, it is unlikely that COPC body burdens in these fish will be a result of the Project as they spend all or a large part of their adult life in the marine environment. Concentrations for these food items in the country foods basket were therefore assumed to be zero. The 95th percentile consumption rates (average of all ages) presented in Chan et al (2011) for each food item were then normalized for daily toddler ingestion rates.

The results of the country foods basket calculations are presented in Tables G57-63 in Attachment G. Risks are presented for both the baseline and predicted future conditions. Among all the metals considered, the largest differences between the predicted future risk and the baseline risks was 0.08 (cobalt), 0.09 (lead), and 0.09 (manganese) for the Year Round Resident toddler. For the other COPCs, the incremental change for the Year Round Resident toddler is less than 0.05 when the HI (sum of all exposure pathways) is based on the country foods basket. For all COPCs for the Summer Resident toddler, the incremental change in the HI (considering all exposure pathways, including country foods) using the food basket approach is <0.05. This analysis indicates that risks from country foods exposure are negligible when less conservative exposure conditions are considered (i.e., when the country food basket approach is used, taking into consideration the consumption amount and frequency of a class of country foods and the concentration in that country food).

The country foods basket approach described in the preceding paragraphs is still conservatively based on upper percentile estimates of environmental COPC concentrations. When baseline and predicted HIs for soil, surface water, and air exposures were summed with the country food exposures, the largest difference between the predicted risk and the baseline risks was just under HI = 0.1 for cobalt for the Year Round Resident toddler. If average surface water concentrations (which would be more representative of annual exposure concentrations for a year-round resident) were used instead of 90th percentile concentrations the difference between predicted risk and the baseline risks would decrease by half that again, or more.

The difference between the baseline and predicted HQs for each COPCs is less than HQ=0.1 for all chemicals and for all receptors when the country food basket is applied and if mean concentrations were used for all exposure media less than half of that estimated. At these small incremental changes in HQ no difference in effect to receptors can be identified.

However, to provide additional context and information to further characterize risk, discussion of cobalt (HI=0.08), lead (HI=0.09), and manganese (HI=0.09) are provided in the following section.

22.5.3.5.3 Additional Evaluation of Potential Risks for Cobalt, Lead, and Manganese

Cobalt

Based on the HI calculated using the food basket approach for country foods, the maximum incremental change between baseline conditions and predicted future conditions is 0.08 for cobalt. This was based on the most sensitive receptor life stage (toddler) and the most conservative exposure scenario (Year Round Resident); all other receptor groups and life stages would have lower risk and smaller incremental changes.

Baseline and predicted cobalt hazard was driven by exposure to cobalt from fish consumption. Baseline cobalt concentration in fish tissue were measured in samples collected from Bitter Creek and nearby creeks. Predicted cobalt fish tissue concentrations were estimated using chemical-specific BCFs calculated from site baseline data. The approach used for this risk assessment assumed a linear relationship between the metal concentrations in surface water and metal concentrations in fish tissue (i.e., followed a linear relationship approach as described in USEPA (2005)). Therefore, when surface water metal concentrations increase, even if the increase is small, so will metal concentrations in fish tissue.

However, McGeer et al (2003) and Adams (2011) have demonstrated that for metals there is not a linear relationship, but instead an inverse relationship between BCF and metal water concentration. They go on to demonstrate how BCFs are higher when metal concentrations in water are lower and, conversely, when metal water concentrations are higher the BCFs are lower. Furthermore, aquatic organisms, and fish in particular, have the ability to regulate metals uptake (Adams 2011). According to Adams (2011) this is a problem for metal hazard assessments. Adams (2011) goes on further to say that larger than anticipated BCFs generally means “low exposure and low potential for chronic effects or secondary poisoning”. This has implications for predicting the potential for adverse effects to human health associated with the fish ingestion exposure pathway for all metals (not just cobalt), since assuming a linear relationship for the BCF will overestimate fish tissue concentrations as water concentrations increase. This will result in an overestimation of the potential risk to human consumers.

In addition, to the non-linearity of metal bioaccumulation in fish tissue, the estimated site specific BCF (644 L/kg) for cobalt was more than 3 times higher than the literature based experimental BCF of 200 L/kg (ORNL RAIS 2017). Using this lower literature-based BCF would have resulted in a fish tissue concentration very similar to the baseline cobalt fish tissue concentration and no incremental risk for cobalt would have been associated with cobalt fish tissue ingestion. Based on information provided in McGeer et al (2003); Adams (2011); DeForest et al (2007; Environment Canada 2011) for cobalt and other metals, little or no change in fish tissue concentration is anticipated for fish exposed to cobalt at the predicted levels estimated for Bitter Creek surface water concentrations.

Lead

Based on the HI calculated using the food basket approach for country foods, the incremental change between baseline conditions and predicted future conditions is 0.09 for lead. This was based on the most sensitive receptor life stage (toddler) and the most conservative exposure scenario (Year Round Resident); all other receptor groups and life stages would have lower risk and smaller incremental changes.

The Project HHRA uses a TDI of 0.0006 mg/kg that is based on the most sensitive endpoint (i.e., nervous system and brain development); Wilson and Richardson (2012) determined that a HQ of 1 relates to a 1-point decrease in IQ. Therefore, the HQ increase of 0.09 from baseline to predicted would translate to a change in IQ of 0.09. This change in IQ is unlikely to have a detectable or measurable effect in real-life situations, given that the accuracy of IQ measurements are ± 10% (i.e., the potential change is much lower than the analytical ability to measure such small changes) (Nature Editorial - Intelligent testing Science has a part to play in ensuring protection for defendants with intellectual disabilities 2014).

It is also unlikely that the predicted change in the surface water concentration of lead from baseline (0.00683 mg/L) to predicted (0.00778 mg/L) will cause the corresponding change in the fish tissue predicted. Predicted lead fish tissue concentrations were estimated using chemical-specific BCFs calculated from site baseline data. As noted previously for cobalt, the general assumption used in this risk assessment is that the relationship between the metal concentrations in surface water and metal concentrations in fish tissue is linear. However, as noted for cobalt, McGeer et al (2003) and Adams (2011) have demonstrated there is an inverse relationship between BCF and metal water concentration that aquatic organisms. Therefore, in contrast to what was predicted by the BCF model, little or no change in the fish tissue concentration is anticipated and lead concentrations in fish are not anticipated to increase substantively with respect to the baseline condition. This will result in negligible change in hazard associated with lead levels in fish as a result of the Project, and thus no difference in the potential effects associated with baseline and predicted conditions is anticipated.

Manganese

The highest manganese HI (and only occurrence where the incremental change was 0.1 or greater), baseline (was HI=3.9) and predicted (HI=4.0), was for the year-round resident toddler that eats fish from Bitter Creek every day. This corresponds to a change in the manganese HI of 0.1 as a result of the Project.

Neurotoxic effects from exposure to manganese are associated with a level of exposure causing a hazard quotient of 5. No evidence was identified indicating that the effects would be worse due to a change from an HQ of 3.9 to an HQ of 4.0 (ATSDR 2012; Brittany et al 2017).

The site-specific BCF used in the HHRA was 2 times greater than the literature based BCF from ORNL RAIS (2017) and 10 times greater than the BCF from USEPA (2007) Guidance for Developing Ecological Soil Screening Levels. Use of either of these values would result in an HQ that is less than 0.05. The high BCF is likely the result of the plant selected, Sitka willow a high accumulator of metals. Manganese in tissue residue concentrations in plants can vary significantly from plant to plant. Sitka willow was used as a surrogate for berries and it would also result in an overall reduction in the baseline and predicted HQ for consumption of plants by up to 10 times. Ninety-five percent of the HI for the Summer Resident toddler and the Year Round Resident toddler was related to consumption of plants. The HQ for the consumption of fish manganese was 18 times lower than that for the consumption of plants.

Using the country food basket approach resulted in a reduction of the manganese HI for baseline (HI=3.9) and predicted (HQ=4.0) to baseline HI=0.7 (0.67) and predicted HI=0.7 (0.75). Approximately 60 percent of this HI for manganese is related to the consumption of plants. Toxic effects would not be observed at these HIs. Considering that the surrogate plant was a high accumulator of metals and that the BCF used for manganese was likely biased high as a result, the true manganese HI is less than that estimated.

22.5.3.5.4 Target Organs

Information on the potential additive effects to target organs is presented in Attachment G based on ingestion (water, soil, country foods, and dermal contact) and inhalation exposure routes. Information is presented for each receptor and life stage based on calculations using the maximum country foods HQ (i.e., not considering the country foods basket approach). Data are also provided for the COPCs for the toddler Year Round Resident (i.e., the most conservative hypothetical receptor) target organ toxicity in Table G65 of Appendix G.

The results of summing the HIs for COPCs that act on the same target organ follows the same pattern as for individual COPCs. Using the results calculated based on inclusion of the country foods basket approach (Table G65), the incremental change between baseline and predicted target organ HIs is very small, with a maximum incremental change of less than 0.2 for the most conservative receptor (toddler Year Round Resident). Other receptors and life stages would have lower incremental changes; for receptors that are representative of the current land users (e.g., Recreational User, Hunter/Trapper/Fisher), the maximum incremental change would be negligible and not measurable.

Although the HIs for the various COPCs have been summed into an HI for target organs based on the critical effect, doing this summation may overestimate risk to receptors. This is because the mechanism of effect within a target organ system (e.g., neurological effects) may not be the same for each COPC. For example, aluminum, lead, and manganese have been identified as having the neurological system as the target organ for toxicity, but the types of effects and mechanisms that cause the effects are different. As described in Appendix E, the critical effect that underlies the TRV for each of the COPCs with a neurological target organ are:

- Aluminum: has 'minimal neurotoxicity' based on grip strengths and splay distance;
- Lead: based on potential to affect IQ; and
- Manganese: Parkinson-like neurotoxicity.

Since the critical effects are quite different, suggesting that the mechanisms underlying the critical effects are different, the assessment of target organ toxicity has greater uncertainty than the assessment of individual COPCs. Similar evaluation can be made of the other COPCs that are grouped together into the target organ toxicities.

In addition to the uncertainty associated with summing individual HIs into target organ toxicity HIs, the risk assessment also included a number of conservative assumptions. Some of the conservatisms include:

- The calculations are based on upper percentile baseline and predicted concentrations, which are intentionally conservative to ensure that exposure is over-estimated;
- The calculations assume that the receptor is exposed to the upper percentile concentrations for the entire exposure duration (e.g., 365 days per year for the Year Round receptor), which is not possible for exposures from surface water (where there is substantial seasonal variability in concentrations) or in soil (where there can be substantial variation in concentrations even within a small area);
- The calculations assume that all surface water is consumed untreated and that all particulate-bound metals are ingested, which would not occur if even minimal water treatment was applied (e.g., letting water sit in a container for a short period before drinking to allow a portion of suspended solids and particulate-bound metals to settle out);
- Exposure concentrations for air and soils for the entire Bitter Creek valley were represented by air and soil concentrations estimated to be present near the Mine site and Plant site;
- Air particulate deposition was assumed to build up in soil over time, with no loss due to erosive forces;
- Exposure to soils for the Year Round Resident was assumed to occur year round even though snow covers the ground for the majority of the year. There is also a significant reduction in dust levels during the winter months;
- Moose were assumed to live in the Bitter Creek valley year round; however, the Bitter Creek valley forms part of their summer home range, where they are located for approximately 4 months of the year. The remaining 8 months are spent in their winter range, which is found in areas south of the valley; and
- The calculations assume that all country foods come from within the study area (and more specifically, Blind Creek), which may not be a reasonable assumption as this is not known as a high quality fishing area. (Note, the country food basket approach did not assume marine fish come from Bitter Creek.)

Taking these factors into consideration and acknowledging that the maximum incremental change for any target organ toxicity in the most conservative receptor based on year round exposure is <0.2, the potential for adverse effects to human health based on target organ toxicity is negligible.

22.5.3.5.5 Predicted Cancer Health Effects

The HHRA (Volume 8, Appendix 22-A), Attachment D provides detailed risk results for country foods exposure and Attachment F provides detailed risk results for soil and surface water exposure. Detailed risk results for the sum of all pathways are provided in Attachment G.

A summary of the summed ILCR results, which combine exposures across all pathways, for each of the receptors, is provided in Table 22.5-7. Country foods ingestion is included in the combined exposure estimates for these receptors, but the frequency of ingestion is amortized as described in Sections 7.2.2 and 7.3 of the HHRA. Arsenic exceeded the threshold of $1x10^{-5}$ under both baseline and future predicted conditions for at least one receptor in each ROC class, and was detectably higher in the predicted condition for 12 receptors (Table 22.5-10).

None of the ILCRs for any of the COPCS via the inhalation route were higher than $1x10^{-5}$ under baseline or future predicted conditions, nor was the sum of the ILCRs for the four carcinogenic metals via the inhalation route.

Table 22.5-10: Summary of Cancer Risks

ROC	Type	COPCs with Baseline ILCR >1x10^{-5}	COPCs with Predicted ILCR >1x10^{-5}	COPCs with detectable incremental change in ILCR
Hunter/ Trapper/ Fisher	Teen	Arsenic (1.7 x 10^{-5})	Arsenic (1.9 x 10^{-5})	Arsenic
Hunter/ Trapper/ Fisher	Adult	Arsenic (8.1 x 10^{-5})	Arsenic (8.7 x 10^{-5})	Arsenic
Recreational User	Infant	None	None	None
Recreational User	Toddler	Arsenic (2.2 x 10^{-5})	Arsenic (2.4 x 10^{-5})	Arsenic
Recreational User	Child	Arsenic (1.1 x 10^{-5})	Arsenic (1.2 x 10^{-5})	Arsenic
Recreational User	Teen	None	None	None
Recreational User	Adult	Arsenic (2.9 x 10^{-5})	Arsenic (3.2 x 10^{-5})	Arsenic
Summer Resident	Infant	Arsenic (1.2 x 10^{-5})	Arsenic (1.3 x 10^{-5})	Arsenic
Summer Resident	Toddler	Arsenic (9.6 x 10^{-5})	Arsenic (1.0 x 10^{-4})	Arsenic
Summer Resident	Child	Arsenic (4.9 x 10^{-5})	Arsenic (5.3 x 10^{-5})	Arsenic
Summer Resident	Teen	Arsenic (2.7 x 10^{-5})	Arsenic (2.9 x 10^{-5})	Arsenic
Summer Resident	Adult	Arsenic (1.3x 10^{-4})	Arsenic (1.4 x 10^{-4})	Arsenic
Year-Round Resident	Toddler	Arsenic (3.8 x 10^{-4})	Arsenic (4.1 x 10^{-4})	Arsenic
Year-Round Resident	Adult	Arsenic (5.1x 10^{-4})	Arsenic (5.5 x 10^{-4})	Arsenic
County Food Consumer	Toddler	Arsenic (6.1 x 10^{-5})	Arsenic (6.1 x 10^{-5})	None
Country Food Consumer	Child	Arsenic (4.2 x 10^{-5})	Arsenic (4.2 x 10^{-5})	None
Country Food Consumer	Teen	Arsenic (2.5 x 10^{-5})	Arsenic (2.5 x 10^{-5})	None
Country Food Consumer	Adult	Arsenic (1.2 x 10^{-4})	Arsenic (1.2 x 10^{-4})	None

Note: For the country food consumer the predicted HQ for all receptor age groups will be less than the baseline, so the predicted HQ was set equal to the baseline HQ.

Incremental carcinogenic risk greater than 1×10^{-5} related to the Project releases was identified and for the most part was associated with exposure to surface water arsenic and to a lesser degree exposure to surface soils. The highest arsenic cancer risk, baseline (5.0 x 10^{-4}) and predicted (5.3 x 10^{-4}), was for the year-round resident adult that drinks unfiltered water from Bitter Creek every day and has daily exposure to surface soils in the Bitter Creek Valley. This corresponds to a change in the arsenic cancer risk of 3.9×10^{-5}.

The baseline and the predicted arsenic fish tissue concentrations were estimated to be equal, and thus no project related risk associated with consumption of fish tissue arsenic was identified.

Baseline (0.00845 mg/L) and predicted (0.00979 mg/L) 90th percentile total arsenic surface water exposure concentrations used to evaluate HQs for drinking water were less than the drinking water guideline for arsenic of 0.01 mg/L. The mean total arsenic concentrations in surface water for the predicted and baseline condition are approximately half of the 90^{th} percentile concentration. For a full-time year round resident, the average water concentration is more likely to approximate the annual exposure concentration rather than an upper percentile concentration given that there is substantial variability in arsenic concentrations throughout the year (e.g., increased particle-bound concentrations during spring freshet, lower concentrations during clear flow periods). Based on comparison of the minimum and maximum concentrations shown in Tables B2 to B15 in Attachment B, total arsenic concentration in surface water can vary by up to an order of magnitude. Using the upper-bound estimate of concentrations, as was done in the risk assessment, and assuming that is the exposure concentration on a daily basis over a lifetime is not realistic and greatly overestimates risk.

The risk assessment assumed that the arsenic concentrations remain high during the entirety of the Operation Phase and throughout Closure/Post-Closure (since higher of the predicted P90 concentrations between the Project phases was used). However, water quality modelling indicates that arsenic concentrations will reduce back to baseline concentrations almost immediately after the mine closes and experiences a very minor increase in arsenic surface water concentrations approximately 100 years later. The exposure to elevated arsenic levels, as predicted during the operation phase, will last for 7.5 years. The 7.5-year exposure period is 8 times shorter than the 60-year exposure period assumed in the risk assessment and would result in an incremental lifetime cancer risk that is less than $4.9 \times 10^{-6,}$ which is less than threshold of 1×10^{-5} (Volume 8, Appendix 14C, Appendix F). If the median concentrations for surface water arsenic are substituted for 90^{th} percentile concentrations the ILCR reduces by approximately half that again. Under these conditions the baseline and predicted ILCR for the Summer Resident receptor would be less than 1×10^{-5}.

Taken together, arsenic concentrations being below drinking water guidelines and the overestimation of the arsenic concentrations in the risk assessment indicates that surface water in the Bitter Creek can be used for drinking water. Should a home be constructed in the Bitter Creek Valley it is likely that water will be plumbed to the residence and as part of this it is assumed that some sort of filtration system will be installed, such as a sand filter or a UV water treatment system including pre-filters. This is consistent with Health Canada's recommendation that surface water should be treated prior to consumption (Health Canada 2016c). Filtration will remove the majority of suspended solids in the surface water samples (thus removing the particle-bound arsenic), reducing the cancer risk associated with consumption of surface water from Bitter Creek. If any sort of filtering is used for the residence of the Year Round Receptor, then the ILCR for the Year round receptor would also be less than $1x10^{-5}$ for the baseline and predicted conditions.

Given that : 1) the Project related cancer risk associated with exposure to arsenic in country food is less than $1x10^{-5}$; 2) arsenic surface water concentrations for baseline and predicted conditions are less than the surface water guidelines; 3) upper percentile exposure concentrations were used in the risk assessment; and 4) surface water arsenic can be considered to be elevated relative to baseline conditions for 7.5 years and not 60, arsenic releases related to the project will not pose a cancer risk in excess of the cancer risk threshold of $1x10^{-5}$.

22.5.3.5.6 Chemical-Related Change in Non-Cancer Human Health Hazards and Cancer Human Health Incremental Lifetime Cancer Risks Due to the Project

Incremental changes in non-cancer risk resulting from the Project were identified for several COPCs (cobalt, iron, lead, manganese, mercury, strontium), however, none of these incremental changes are anticipated to result in an increase in human health effects. Similarly, Project-related incremental increases in COPCs associated with cancer risk (i.e., arsenic) are not anticipated to result in a detectable increase in risk.

The risk estimates incorporate multiple conservative assumptions, which suggests that risks under the predicted conditions are likely overestimated, in particular those associated with consumption of fish. The potential for adverse health effects resulting from the Project is considered negligible.

22.5.3.5.7 Uncertainty Analysis

The interpretation of risk estimates is subject to uncertainties because of the numerous assumptions inherent in the risk assessment process. Risk estimates can most appropriately be viewed as upper-bound estimates of risks; actual risks may be substantially lower than those calculated using quantitative risk assessment techniques. Typically, sources of uncertainty in HHRAs can be categorized into those associated with standard risk assessment procedures (e.g., uncertainty factors used for derivation of TRVs, summing hazard quotients despite dissimilar target organs or mechanisms of toxicity) and those associated with site-specific factors (i.e., variability in analytical data, modeling results, and exposure parameter assumptions). The extensive use of modelling is also a significant source of uncertainty in this HHRA. Each of the primary uncertainties in this HHRA is discussed in the subsections below.

Uncertainties from Chemicals Not Evaluated

Exposure and risks were quantified only for a selected subset of COPCs detected in environmental media at the LSA. While the omission of other COPCs might tend to underestimate total risks, this is not a significant source of uncertainty because:

- The COPCs that were excluded were known to be present at concentrations that are well below a level of concern (methyl mercury, for example, is unlikely to be present at elevated concentrations since total mercury was found at very low concentrations and enhanced methylating conditions are unlikely);

- The COPCs that were excluded had concentrations in soil that were significantly below their crustal abundance; and/or
- The COPCs that were considered to be innocuous.

Uncertainties from Exposure Pathways Not Evaluated

Humans may be exposed to Project-related COPCs by a number of pathways, but not all of these pathways were evaluated quantitatively in the HHRA. This was because the contributions of the omitted pathways were believed to be minor compared to the other pathways evaluated. Omitted pathways may result in a small underestimation of exposure and risk, but the magnitude of this underestimation is expected to be insignificant.

Uncertainties in Estimated Environmental Concentrations

In all exposure calculations the desired input parameter is the true mean concentration of a contaminant within a medium, averaged over the area where exposure occurs. Due to the limited data set, upper percentile concentrations were used for soil and water, which may result in an overestimate of the true mean. Underestimation of the true mean is unlikely.

Modeling was used to estimate some of the EECs. For the baseline condition, EECs for air particulate and terrestrial country foods were estimated from models. Predicted future EECs for all exposure media were also estimated from models. The models include several parameters and assumptions regarding input values, some of which are discussed elsewhere, that lead to uncertainties in the estimated concentrations.

EECs for air particulate for the entire Bitter Creek Valley were based on modelled data from locations very close to the mine site and the plant site. Air particulate modelling indicated that during mine construction and operation, air particulate close to the mine site and plant site will be higher than background but decrease toward background levels with distance. It was also determined that metals in the air particulate will be higher in the air closer to the mine and the plant site. Thus, conservatively using modelled air concentrations for locations close to the mine and plant site to represent concentrations of particulate and metals in air across the Bitter Creek Valley has resulted in an overestimate in the EEC for air particulate concentrations, air metal concentrations, and for deposition of particulate metals from air. This also resulted in an overestimate of metals predicted to be in terrestrial country food.

Consumption of COPCs in fish and plants is the main pathway causing baseline and future non-carcinogenic risk to human receptors as a result of consumption of country foods. Estimates of plant EECs and fish EECs were affected by BCF estimates. The predicted exposure concentrations calculated using modelling, and their subsequent risk estimates, were often lower than baseline exposures and risks estimates. This is an artifact of using BCFs used to predict future COPC concentrations in food. This may occur when the baseline and predicted concentrations in environmental media are similar (i.e., are statistically the same).

For plants, site-specific BCFs were based on soil and plant (i.e., Sitka willow) analytical data from samples collected in the Bitter Creek watershed. Predicted plant tissue concentrations were based on predicted soil concentrations, and predicted country food (moose, hare, and grouse) tissue concentrations were based on soil and plant concentrations. Sitka willow is known to be a hyper-accumulator of multiple metals (Rescan 2013 and 2014) and is likely to have tissue concentrations higher than other plants that might be consumed by wildlife or people.

Dry weight BCFs were calculated using 90^{th} percentiles and averages for plants and soil. Because the soil and plant samples weren't paired (co-collected) and there were relatively few plant samples, the BCF ratios were calculated by dividing the average concentrations (i.e., average concentration in plant/average concentration in soil). When dry weight BCFs were used to predict future dry weight plant concentrations using average predicted concentrations in soil, all predicted exposure concentrations and HQs for moose, hare and rabbit were greater than the baseline levels. However, when 90^{th} percentile soil data were used, predicted plant tissue concentrations were determined to be 10% to 40% lower than baseline concentrations. This may have been a result of the small plant data set that has high uncertainty in the upper percentile concentration (i.e., the baseline upper statistics from measured plant concentrations are skewed high due to an outlier), or the BCF isn't representative of bioaccumulation patterns at higher concentrations (e.g., because the bioaccumulation rate is not linear, as assumed by calculating a ratio).

Dry weight data is used to estimate tissue residue concentrations in country foods; however, wet weight plant data is used to assess exposure by people eating plants. When the average moisture content in plants was used to convert predicted dry weight concentrations to wet weight, more than half of the plant wet weight metal concentrations were less than their baseline wet weight concentration. This occurred because the error (very small) caused by using an average wet weight was greater than the percent change in soil concentration for that metal. The apparent decrease in concentration between predicted and baseline is similar to that observed in before-and-after sample designs when there is no statistical difference in the before-and-after data sets.

It addition, Sitka willow is not consumed by people and was used as a surrogate for other plants that might be consumed (e.g., berries); this introduces uncertainty that could cause the risk estimates to be higher or lower than the true risk. However, the use of a hyper-accumulator plant has biased the risk to be high and has likely offset potential for underestimating the risk due to having a small plant data set and using the average predicted plant concentration.

To summarize, for the purposes of the risk assessment it was conservatively assumed that there was no detectable incremental change and that the tissue concentrations remain the same when predicted risk was less than baseline risk. Other conservative assumptions as outlined above were also included to ensure that risk was overestimated rather than underestimated. However, uncertainties were identified in the dataset and, therefore, monitoring of soil and plant metal concentrations in the area with the potential to be affected by the mine is recommended.

Similar to the description above for plants, calculation of BCFs for fish also resulted in predicted fish tissue concentrations that were often lower than baseline concentrations. Variability in three factors contributed to this result: 1) how much time Dolly Varden spent in Bitter Creek versus other creeks in the area; 2) how many Dolly Varden in Bitter Creek are anadromous; and 3) how many Dolly Varden overwinter in Bitter Creek. The less time Dolly Varden spend in Bitter Creek, the weaker the relationship between Bitter Creek water chemistry and Dolly Varden fish tissue chemistry. It is also possible that water concentrations of some metals may decrease downstream of the Project where water treatment of mine discharge is proposed. In all cases where the predicted risk is less than the baseline risk it implies that, effectively, there is no difference in the concentrations (i.e., conservatively assumed that there was no detectable incremental change and that the tissue concentrations remain the same).

In addition, available literature suggests that there is an inverse relationship between water concentrations and tissue concentrations in fish (Carriquiriborde et al 2004; McGeer et al 2003; and Adam 2011). The use of a linear BCF model in this risk assessment is expected to overestimate the tissue concentrations of most metals.

For this Project, it was assumed to be due to consumption of Dolly Varden. However, anecdotal information and available studies tell us that Sockeye and other types of salmon are much preferred to Dolly Varden. The Food Nutrition and Environment study by Chan *et al.* (2011) lists over 200 traditional foods that are consumed by Aboriginal Groups in British Columbia and Dolly Varden are only eaten by approximately 35% of the Aboriginal population in the area, whereas 99% consume salmon. Furthermore, even among those who eat Dolly Varden, receptors generally eat 15 to 50 times more salmon than they do Dolly Varden. This is an important consideration, as salmon do not reside in Bitter Creek and spend most of their adult lives in the marine environment; thus the only fish species available for consumption in the Bitter Creek watershed is Dolly Varden. It is unlikely that Aboriginal receptors and non-Aboriginal receptors will only eat Dolly Varden when salmon can be caught for consumption nearby. The assumption that receptors eat significant amounts of Dolly Varden is unlikely, resulting in a more conservative estimate of potential human health risk associated with fish consumption.

The intent of the modeling is to be both predictive and protective, but actual conditions in the future may be significantly different. By using conservative assumptions, as has been done in this HHRA, it is more likely that the risks are over-estimated than under-estimated. In addition, where uncertainties have been identified, monitoring has been proposed to identify potential changes in concentrations in the future.

Uncertainties in Human Exposure Parameters

Accurate calculation of risk values requires accurate estimates of the level of human exposure that is occurring. Many of the required exposure parameters are not known with certainty and must be estimated from limited data or knowledge. For example, little information was available about the frequency of use of the Bitter Creek valley for recreational activities. The local population within 50 km of Bitter Creek is small and the Bitter Creek valley is not known to be a destination location for potential recreational receptors. In general, when exposure data were limited or absent, the exposure parameters were chosen in a way that was intended to be conservative. Because of this generally conservative approach, the values selected are thought to more likely overestimate rather than underestimate actual exposure and risk it should also be noted that it was assumed that the bioavailability of most COPCs via the ingestion and inhalation routes of exposure was assumed to be 100 percent. This assumption would likely result in a conservatively high dose for the COPCs.

Uncertainties in Toxicity Values

Toxicity information for many chemicals is often limited. Therefore, there are varying degrees of uncertainty associated with TRVs (i.e., cancer slope factors, tolerable daily intakes). For example, uncertainties can arise from the following sources:

- Extrapolation from animal studies to humans;
- Extrapolation from high dose to low dose;
- Extrapolation from continuous exposure to intermittent exposure; and
- Limited availability of toxicity studies.

Uncertainty in TRVs is one of the largest sources of uncertainty in risk estimates. Because of the conservative methods Health Canada uses in dealing with uncertainties, it is much more likely that the uncertainty will result in an overestimation rather than an underestimation of risk.

Uncertainties in Risk Estimates

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

22.5.3.6 EMF-Related Health Effects – Assumed Future

The maximum electric field generated by a 138 kV powerline is 25 kV/m at 0 metres distance. Hydro Quebec reported that animals exposed to 30 kV/m electric fields were not harmed. They went on further to say that associated electric fields have virtually no adverse effects associated with them (Hydro Quebec 2017). Magnetic fields associated with the powerline for the project produce a maximum magnetic field of 20 milligauss (mG), which is much less than the ICNIRP guideline adopted by BC Hydro of 2000 mG.

No effects are therefore anticipated to Human Health as a result of exposure to powerline EMFs.

22.6 Mitigation Measures

Results from the review of best management practices, guidance documents, and mitigation measures conducted for similar projects, as well as professional judgment for the Project-specific effects and most suitable management measures, were considered in determining the mitigation measures. The approach to the identification of mitigation measures subscribed to the mitigation hierarchy, as described in the Environmental Mitigation Policy for British Columbia (http://www.env.gov.bc.ca/emop/). Technical and economic feasibility constraints dictated the highest level on the hierarchy that could be achieved for each potential effect and the identification of mitigation measures for managing these effects.

22.6.1 Key Mitigation Approaches

COPC exposure is a function of incremental dust deposition, mainly over the Construction and Operation Phases of the Project, and incremental increases in surface water COPC concentrations related to metal leaching and acid mine drainage. The mitigation measures discussed for Air Quality (Volume 3, Chapter 7) and Surface Water Quality (Volume 3, Chapter 13) can be applied here to reduce the levels of COPCs released by the Project and the potential for Human Health effects.

Improving air quality by reducing air emissions results in reduced deposition of air constituents, which in turn results in a lower increase in soil COPC (metals) concentrations. This in turn reduces the Project related increase in exposure of COPCs to country foods: plants, moose, hare, and grouse. This reduces COPCs air, soil, and country food exposures to human receptors.

Improving surface water quality by reducing COPC releases to surface water results in lower concentrations of COPCs in sediment, it also results in lower COPC concentrations in fish tissue, and therefore, country foods exposures to human receptors.

22.6.1.1 Chemical Related Exposures

Air quality and surface water quality mitigation measures are the major exposure pathways requiring mitigation to mitigate risk to Human Health.

22.6.1.1.1 Air Quality

Air quality mitigation will be targeted at reducing the direct release of emissions (from point or equipment sources) and the control of fugitive dust from mining and related activities. The majority of measures are relevant for the Construction, Operation, and Closure and Reclamation Phases of the Project and for all pollutants and are discussed in Chapter 7.

Approaches to manage and mitigate air quality will rely primarily on the following:

- Design Mitigation;
- Best Available Technology (BAT);
- BMPs; and

- Monitoring

Specific key mitigation measures are as follows:

- Water sprays and/or dust suppression measures will be used to the extent practical considering the temperature to suppress dust generation by equipment in the crushing facility;
- Application of water and/or dust suppressants to reduce dust from haul roads and material transfers, and construction areas as needed and when ambient air temperatures permit;
- Use of windbreaks around identified problem areas to limit dust emissions from components and activities observed to generate substantive windblown or re-entrained dust;
- Ensure roads are regularly maintained and kept in good repair;
- Vehicles will be driven at designated speeds on Project roads to limit dust emissions;
- The number of trips for ore and waste rock transport will be minimized along the Haul Road;
- Limit the drop heights from material transfer points;
- Use of emission control measures on point source and crusher transfer point emissions (i.e., scrubbers, dust collectors); and
- Tailings disposal methods have been designed to reduce beach/dust sources and generation. The operational supernatant pond volume in the Tailings Management Facility will be managed to ensure that the beaches are saturated, which will reduce the potential for dust generation. Refer to the Tailings Management Plan (Volume 5, Chapter 29) for further details.

One additional key mitigation measure that will be applicable to all potential effects on Air Quality is the implementation of an Air Quality and Dust Management Plan (AQDMP; Volume 5, Chapter 29). This plan outlines the aquatic effects management and response to be carried out during all Phases of the Project. The aspects of the AQDMP monitoring that are important to assessing COPC exposure to human receptors include the following:

- Monitoring air quality including fugitive dust emissions (TSP, PM10, PM2.5) and COPCs in the fugitive dust;
- Monitoring fugitive dust deposition; and
- Monitoring fish tissues.

22.6.1.1.2 Surface Water

Specific mitigation measures were identified in Chapter 13 and compiled for each category of potential effect on surface water quality. Mitigation measures included any action or Project design feature that will reduce or eliminate effects to surface water quality.

Key approaches to manage and mitigate surface water quality will rely primarily on the following:

- Design Mitigation;
- Regulatory Requirements;
- BMPs; and
- Monitoring.

Specific key mitigation measures are as follows:

- Machinery fording a watercourse to bring equipment required for construction to the opposite side will be limited to a one-time event (over and back) and shall occur only if an existing crossing at a nearby location is not available or practical to use;
- Efforts will be made during the final design stage to have the right-of-way cross each stream as close to perpendicular as possible to minimize the amount of riparian vegetation that may need to be disturbed during Construction;
- Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and transport of potentially poor quality water into freshwater;
- Only geochemically suitable material from rock quarries and borrow sources will be used to construct permanent structures (i.e., tailings dam). For roads, pads, and rock cuts, the following will be conducted to the extent possible:
    - Minimize cut-and-fill in areas with ML/ARD potential.
    - Free passage of water through fill materials (i.e., free-span bridges or culverts) and not through rock drains.
    - For pads, drainage will be collected using water diversions.
- Should a home be constructed in the Bitter Creek Valley it is likely that water will be plumbed to the residence and as part of this it is assumed that some sort of filtration system will be installed, such as a sand filter or a UV water treatment system including pre-filters. This is consistent with Health Canada's and Northern Health's recommendations that surface water should be treated prior to consumption (Health Canada 2016b).

One additional key mitigation measure that will be applicable to all potential effects on surface water quality is the implementation of an Aquatic Effects Management and Response Plan (AEMRP; Volume 5, Chapter 29). This plan outlines the aquatic effects management and response to be carried out during all phases of the Project. The aspects of the AEMRP that are important to assessing COPC exposure to human receptors will include the following:

- Monitoring surface water quality, and sediment quality, and
- Monitoring fish tissues.

22.6.2 Environmental Management and Monitoring Plans

Several Environmental Management Plans (EMPs) will be developed and implemented that will define the standard operating procedures, best management practices, adherence to existing environmental regulations, and the use of appropriate design criteria. The following list compiles the EMPs with a potential linkage to human health effects:

- Access Management Plan;
- Air Quality and Dust Management Plan;
- Aquatic Effects Management and Response Plan;
- Erosion and Sediment Control Plan;
- Explosives Management Plan;
- Fuel Management Plan;
- Groundwater Monitoring Plan;
- Hazardous Materials Management Plan;
- Material Handling and ML / ARD Management Plan;
- Site Water Management Plan;
- Spill Contingency Plan;
- Tailings Management Plan;
- Terrain and Soil Management Plan;
- Vegetation and Ecosystems Management Plan;
- Waste Management Plan; and
- Wildlife Management Plan.

22.6.3 Effectiveness of Mitigation Measures

The anticipated effectiveness of mitigation measures to minimize the potential for significant adverse effects is evaluated and classified as follows within this section:

- Low effectiveness: Proposed measure is experimental or has not been applied in similar circumstances.

- Moderate effectiveness: Proposed measure has been successfully implemented but perhaps not in a directly comparable situation.

- High effectiveness: Proposed measure has been successfully applied in similar situations.

- Unknown effectiveness: Proposed measure has unknown effectiveness because it has not been implemented elsewhere in a comparable project or environment.

The key measures available for mitigating Project effects on Air Quality and Surface Water Quality are outlined above and in Volume 3, Chapter 7, Table 7.6-1, and Volume 3, Chapter 13, Tables 13.6-1 through 13.6-5, respectively. In general, mitigation measures have moderate (i.e., the effect is moderately changed) or high (i.e., the effect is practically eliminated) effectiveness ratings. Table 22.6-1 refers to Air Quality and Surface Water Quality mitigation measures and identifies the residual effects that will be carried forward for residual effects characterization and significance determination.

Table 22.6-1: Proposed Mitigation Measures and Their Effectiveness

VC/IC	Potential Effects	Mitigation Measures	Rationale	Applicable Phase(s) [1]	Effectiveness[2]	Uncertainty[3]	Residual Effect
Human Health	Changes in air quality as a result of changes in metal concentrations in particulate emissions (potentially affecting soil quality and land-based country foods)	Mitigation measures to minimize emissions, as per Volume 3, Chapter 7, Section 7.6	All implemented mitigation measures for Air Quality will serve as mitigation for Human Health relative to this effect	C, O, CR	Moderate to High (see Volume 3, Chapter 7, Table 7.6-1 for more information)	Low	N
	Changes in releases to surface water (potentially affecting surface water quality for drinking water and both land- and aquatic-based country foods)	Mitigation measures to minimize surface water impacts from releases, as per Volume 3, Chapter 13, Section 13.6	All implemented mitigation measures for Surface Water Quality will serve as mitigation for Human Health relative to this effect	C, O, CR, PC	Moderate to High (see Volume 3, Chapter 13, Table 13.6-5	Low	N

[1]Applicable Phase: C - construction; O = operation; CR = closure and reclamation; PC = post-closure

[2]Effectiveness: Low = measure unlikely to result in effect reduction; Moderate = measure has a proven track record of partially reducing effects; High = measure has documented success (e.g., industry standard; use in similar projects in substantial effect reduction

[3]Uncertainty: Low = proposed measure has been successfully applied in similar situations; Moderate = proposed measure has been successfully implemented, but perhaps not in a directly comparable situation; High = proposed measure is experimental, or has not been applied in similar circumstances

22.7 Residual Effects Characterization

The assessment of the potential for residual effects on Human Health is based on the effects assessment described in Section 0, and on the risk characterization work completed and documented in the HHRA (Volume 8, Appendix 22-A). The HHRA analysis was undertaken assuming the mitigation measures as outlined in Section 22.6 and summarized in Table 22.6-1 would be implemented. Any potential changes to human health identified at the conclusion of the HHRA are considered as potential residual effects.

Using the risk characterization approach described in Section 22.5.3, no changes to human health as a result of the Project were predicted as the negligible change in risk levels between baseline and predicted future conditions is not expected to have a measurable effect on human health. Therefore, no residual impact from the Project on human health is anticipated.

22.8 Cumulative Effects

As no residual effects on Human Health have been identified, there is no potential for cumulative effects on Human Health in the Project area.

22.9 Follow–up Program

22.9.1 Air Quality Follow-up Program

The Air Quality and Dust Management Plan (Volume 5, Chapter 29) will include monitoring programs that will allow for real-time verification of the modelling results and the effectiveness of applied mitigation measures. These monitoring programs include the following:

- Passive air quality monitoring of NO_2, O3, and SO2;
- Dustfall monitoring of particulates, anions, cations, and total metals;
- Particulate monitoring of TSP, PM_{10} and $PM_{2.5}$; and
- Meteorological monitoring.

IDM is committed to further discussions regarding air quality objectives as they relate to human health concerns through the permitting phase. All reasonable efforts will be made to reduce emissions during project operation and closure.

22.9.2 Surface Water Quality Follow-up Program

Scientific uncertainty associated with the conclusions of the assessment of Project effects on Surface Water Quality will be addressed through the Aquatic Effects Management and Response Plan (Volume 5, Chapter 29). Monitoring that is important to predictions of the effects assessment regarding potential Project effects on Human Health Include the following:

- Surface water quality monitoring;
- Sediment quality monitoring; and
- Fish tissue sampling.

Key elements of the Aquatic Effects Management and Response Plan will be a robust study design to identify any deviations from baseline beyond those predicted in the effects assessment, and adaptive management to address any such un-anticipated effects.

22.9.3 Groundwater Quality Follow-up Program

Scientific uncertainty associated with the conclusion of the assessment of Project effects on Groundwater Quality will be addressed through the Site Water Management Plan (Volume 5, Chapter 29). Monitoring addressed under the Site Water Management Plan that is important to predictions of the effects assessment regarding potential Project effects on Human Health Includes groundwater quality modelling.

22.9.4 Human Health Follow-up Program

Scientific uncertainty associated with the conclusion of the assessment of Project effects on the Human Health VC will be addressed through the Aquatic Effects Management and Response Plan and the Air Quality and Dust Management Plan. IDM is committed to further discussion and consideration during Application Review of monitoring of relevance to the health effects assessment including but not limited to:

- Vegetation tissue sampling;
- Soil sampling; and
- Animal (e.g. hare and grouse) tissue sampling.

IDM will consult with Northern Health and NLG on the design of ongoing monitoring.

22.10 Conclusion

The HEA assessed the potential for adverse physical effects (risk) to the health of people exposed to potential future releases from the proposed Project. An HHRA was conducted to determine the predicted risk to Human Health as a result of the Project from exposure to COPCs within the Human Health LSA.

The potential interactions between Human Health and Project infrastructure, activities, or components were identified. Project activities that could affect air quality, water quality, soil quality, vegetation quality and country foods quality, also have the potential to cause a change in Human Health. Predictive models were developed to estimate concentrations of COPCs in air, water, soil, vegetation, and country foods. The results of the predictive modeling were used as inputs into the predicted future risk estimates, which used the same methodologies, approaches, study area, and assumptions as the baseline risk estimates.

Incremental changes in non-cancer risk resulting from the Project were identified for several COPCs (cobalt, iron, lead, mercury, selenium, strontium), however, none of these incremental changes are anticipated to result in an increase in human health effects. Similarly, Project-related incremental increases in COPCs associated with cancer risk (i.e., arsenic) are not anticipated to result in a detectable increase in risk.

The risk estimates incorporate multiple conservative assumptions, which suggests that risks under the predicted conditions are likely overestimated, in particular those associated with consumption of fish. The potential for adverse health effects resulting from the Project is considered negligible and no residual effects to the Human Health VC are anticipated.

Monitoring of air, air particulate deposition, soil, surface water, sediment, groundwater, mammal tissue, fish tissue, and plant tissue should be completed during mine development, operations and closure to confirm key exposure assumptions made in the risk assessment

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