# 25 Human Health

This chapter examines potential effects of the KSM Project (the Project) on human health. Project construction, operation, closure, and post-closure phases may affect environmental media, such as drinking water and air quality, the quality of country foods, and noise levels. Country foods are defined as animals, plants, or fungi used by people for medicinal or nutritional purposes that are harvested through hunting, gathering, or fishing.

All chemicals from anthropogenic or natural sources have the potential to cause toxicological health effects. However, three components have to be present in order for a health risk to exist and, therefore, for a risk assessment to be warranted:

1. An inherently toxic chemical has to be released at a sufficiently high concentration to cause toxicological effects.
2. A human receptor has to be present.
3. A pathway must exist from the point of release of the chemical to the human receptor, and the human receptor must be able to take up the chemical.

The Project area is an isolated part of northwestern British Columbia (BC) with limited road access, which supports limited hunting, fishing, trapping, and recreational activities by Aboriginal peoples, residents, and guide-outfitting operators. The southeast portion of the Project area is located within the Nass Area as defined in the *Nisga'a Final Agreement* (NFA; NLG, Province of BC, Government of Canada 1998). Project components and activities are in an area of overlapping asserted territories of the Tahltan Nation and wilp Skii km Lax Ha of the Gitxsan Nation (as identified within the Section 11 Order issued by the British Columbia Environmental Assessment Office [BC EAO]). The establishment of a mine and the associated activities—including blasting, road and camp construction, mine operation, and the transport and management of ore, chemicals, and tailing—have the potential to release chemicals in the dust and water, as well as emit noise, that could have effects on the health of humans using the area. Therefore, human health is a valued component (VC) in this Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS).

Off-duty workers must also be considered as potential human receptors (Health Canada 2010a). However, the human health effects assessment does not address occupational exposures. Safety and human health concerns for on-shift workers would be addressed separately in site- and/or activity-specific health and safety plans, which would be developed before construction and are required by law. Rather, this document applies to humans who could enter the Project and surrounding areas on an occasional and temporary basis (e.g., campers and hunters). People do not reside inside the Project area on a permanent basis. Potential effects on the non-physical health and quality of life of the people residing near the Project were evaluated in the social effects assessment (Chapter 22).

Baseline reports for the Project that relate to human health are described in Appendix 14-A, 2007-2011 Water Quality Baseline Report; Appendix 7-C, 2008 to 2011 Air Quality Baseline

Report; Appendix 18-A, 2009 Wildlife Characterization Baseline Report; Appendices 15-A, 15-C, 15-E, 15-G, and 15-I (Fish and Fish Habitat Baseline Reports for 2008, 2009, 2010, 2011, and 2012); Appendix 23-A, Non-traditional Land Use Baseline Report; Appendix 25-A, 2009 Country Foods Baseline Report; and Appendix 25-B, Baseline Country Foods Risk Assessment of Chinook Salmon in Teigen Creek, 2010.

For this assessment, potential effects on human health with respect to Project-related water quality, air quality, country foods quality, and noise levels are assessed independently. These assessments are presented in the following subsections:

- drinking and recreational water quality assessment (Section 25.1.3, Setting; Section 25.7.1, Effects Assessment; Section 25.8.2.1, Residual Effects Assessment; Section 25.9.2.2, Cumulative Effects Assessment);
- air quality assessment (Section 25.1.4, Setting; Section 25.7.2, Effects Assessment; Section 25.8.2.2, Residual Effects Assessment; Section 25.9.2.3, Cumulative Effects Assessment);
- contamination of country foods assessment (Section 25.1.5, Setting; Section 25.7.3, Effects Assessment; Section 25.8.2.3, Residual Effects Assessment; Section 25.9.2.4, Cumulative Effects Assessment); and
- noise effects assessment (Section 25.1.6, Setting; Section 25.7.4, Effects Assessment; Section 25.8.2.4, Residual Effects Assessment; Section 25.9.2.5, Cumulative Effects Assessment).

Chapters relevant to the above subsections on human health are Chapter 7, Air Quality; Chapter 12, Groundwater Quality; Chapter 14, Surface Water Quality; Chapter 19, Noise; and Chapter 23, Land Use.

Potential traffic-related effects to human health resulting from Project traffic along highways 37 and 37A are included in Appendix 22-C.

# 25.1 Human Health Setting

## 25.1.1 Regulatory Setting

The inclusion of human health into the environmental assessment (EA) in Canada has been recognized by the federal government and by the Province of BC under various legislation and requirements (Health Canada 2004a, 2010a):

- BC's *Environmental Assessment Act* (2002): "Effects" are defined as including health, and the purpose of the Act includes the assessment of "health effects"; and
- *Canadian Environmental Assessment Act* (1992): The definition of an "environmental effect" includes any changes in health or socio-economic conditions that are caused by a project's environmental effects.

### 25.1.2 Land Use

Land use is a descriptor of human presence and activity inside and near the Project area. It is an indication of the likelihood that human receptors are affected by Project activities. The following paragraphs summarize land use areas and land use activities. Details can be found in Chapter 23, Land Use; Chapter 29, Nisga'a Nation Interests; and Chapter 30, First Nations Interests.

The provincial parks closest to the Project area are Ningunsaw, roughly 15 km north of the proposed Tailing Management Facility (TMF), and Border Lake, 25 km southwest of the ore deposits. Another park, Lava Forks Provincial Park, lies adjacent to the westernmost section of the local study area (LSA), 30 km west of the ore deposit, and adjoins the Misty Fjords National Monument and Wilderness Area in the United States (US) at the Alaskan border (Figure 4.2-1 in Appendix 23-A). Parks are isolated, with little to no road access. Visitation rates are currently not available, and it is therefore unknown how many people visit these parks. Land uses in the provincial parks include backcountry camping and skiing, hunting, fishing, rafting, and canoeing.

Three guide-outfitting tenures overlap the LSA of the Land Use Baseline (Appendix 23-A, Figure 4.5-2). The Project's ore deposit area and proposed TMF occur within a guide-outfitting tenure. To the west, the LSA crosses a guide-outfitting licence currently held by Northwest Ranching and Outfitting. To the south, the LSA crosses the tenure held by Coast Mountain Outfitters. Much of the proposed Temporary Frank Mackie Glacier access route would traverse this latter tenure. The number of guided trips per year is variable, and information about the number of people accessing the traplines was unavailable. However, kills are taken for all uses (e.g., food, trophy, and hides), except grizzly bears, which are not taken for food. By comparison, ungulates are primarily taken for food (Appendix 23-A).

Northwest Ranching and Outfitting makes, on average, six trips into the tenure area per year. However, trips almost exclusively occur farther north within the tenure and outside of the LSA. No support infrastructure, such as cabins or camps, is used within the tenure area. Because it is difficult to access, resident hunting within the tenure is infrequent, and the tenure holder was unaware of anyone else using the area. Coast Mountain Outfitters hosted, on average, 70 to 90 trips per year between the last week of April and the last week of February, but only approximately 2 of these trips occurred within the LSA (Appendix 23-A).

The RSA or various portions thereof are claimed as traditional territory by the Skii km Lax Ha, Gitxsan Nation, and Tahltan Nation (Chapter 30). The KSM Project area is also subject to the constitutionally protected rights of Nisga'a Nation under the terms of the NFA (NLG, Province of BC, Government of Canada 1998). The traditional knowledge and use desk-based research reports describe where these First Nations and Nisga'a Nation use the proposed KSM Project area for hunting, trapping, and gathering (Chapters 29 and 30; Appendices 29-A, and 30-A to 30-D).

The Project's RSA overlaps seven trapping licences. Four trapline cabins are located at the South Unuk and Unuk rivers, which are accessed by helicopter (Appendix 23-A). The Skii km Lax Ha hunt around Meziadin Lake, Bell I, Bell-Irving River, and Bell II, and trap along the Highway 37 corridor. Skii km Lax Ha members hold two traplines directly overlapping the proposed KSM Project area (Teigen Creek, Treaty Creek, Bowser Lake, and the southern half of the TMF) and have trapline cabins at the Bell-Irving River East of the proposed TMF. Hunting, fishing, and plant collection sites lie nearby, upstream and downstream from the proposed TMF, and have the potential to be affected by the proposed Project. Fishing locations include the Cranberry River, the Bell-Irving River, the confluence of Treaty Creek and the Bell-Irving River, as well as the confluence of Snowbank Creek and Bell-Irving River. Gitxsan members fish for salmon in the Bell-Irving River up to Bowser Lake. The Bell-Irving River, a tributary of the Nass River, is a downstream receiving environment of the proposed KSM Project and is therefore of concern to the Gitxsan Nation, the Gitanyow First Nation, and Nisga'a Nation. Tahltan have traditionally and currently used wildlife, fish, plant, and berry resources near portions of the proposed KSM Project area.

### 25.1.3 Drinking and Recreational Water

Water quality is an essential component of the ecosystem, and is linked to human health through its consumption and through food web effects, including vegetation, fish, and wildlife. Water quality in local streams and lakes is highly valued by local people living close to the Project area (Gitxsan Chiefs, Issues Tracking Table, Appendix 3-P). Water quality is intimately linked to the conservation and productivity of fish and fish habitat resources (Chapter 15, Fish and Aquatic Habitat). It also relates to the maintenance of safe potable water sources for workers, the public, and local wildlife. Monitoring of water quality is therefore important in characterizing the normal patterns of the area prior to assessing any potential changes due to proposed development. A detailed surface water quality environmental setting is provided in Chapter 14, Surface Water Quality.

Thirty-six stream/river sites and four lake sites were monitored for water quality between 2007 and 2012 (Appendix 14-A). The sampled water quality sites were situated in all areas potentially affected by the proposed Project. This included the three proposed receiving environments: (1) Sulphurets Creek and Unuk River; (2) South Teigen Creek, Teigen Creek, and Bell-Irving River; and (3) North Treaty Creek, Treaty Creek, and Bell-Irving River. It also included proposed mine pits and mine infrastructure, ore and waste rock storage areas, the TMF, electric transmission line and diesel pipelines, access road alignments, and reference sites.

Water quality in Mitchell Creek and, to a lesser extent, in Sulphurets Creek is generally poor, having the greatest concentrations of particulate-associated and dissolved metals and sulphate concentrations due to the highly mineralized nature of their watersheds. The influence of the poor water quality (i.e., acidic pH and high metals) in these creeks was observed in the Unuk River below the mouth of Sulphurets Creek. However, the higher flow, and thus assimilative capacity, of the Unuk River reduced the effect of the poor water quality originating in the Mitchell and Sulphurets watersheds, although the waters of the Unuk River downstream of the mouth of Sulphurets Creek still regularly exceeded aquatic life guidelines for aluminum, cadmium, copper, iron, lead, and zinc. The water in the Teigen, Treaty, and Bell-Irving watersheds was of higher quality than in the Sulphurets and Mitchell watersheds.

Although no specific waterbodies were identified during land use interviews, it is assumed that surface water is used by people in the LSA for drinking and for recreation. Trappers, hunters, and recreational users likely consume surface water during multi-day backcountry trips in the summer. Similarly, clients participating in commercial recreation (guide-outfitting, river rafting, backcountry and mountaineering expeditions, and angling [Appendix 23-A]) will consume surface water and use water for recreational purposes. For instance, the Explorers League offers guided freshwater rafting tours along their tenure area, travelling down the Unuk River from near its confluence with Storie Creek into Alaska (Appendix 23-A).

Five water licences exist within the LSA: one active water licence owned by Barrick Gold Inc. at Eskay Creek Mine, and four in the application process (Appendix 23-A). A water licence is held by the Bell 2 Lodge on Hodder Creek on the east side of the Bell-Irving River; it falls outside of the LSA.

Water quality data collected from the Project area during baseline studies were compared to Guidelines for Canadian Drinking Water Quality (Health Canada 2012) and to the BC Water Quality Criteria for Drinking Water Supply (BC MOE 2006; Table 25.1-1).

Mitchell Creek had poor drinking water quality. Concentrations of arsenic, cadmium, lead, selenium, and fluoride were occasionally greater than the drinking water guidelines. Most frequent exceedances were observed for arsenic (18%, 2.8 times higher than BC drinking water guidelines), cadmium (34%, 1.1 times higher), and lead (30%, at guideline level). Some exceedances extended to Sulphurets Creek and Unuk River at the confluence with Sulphurets, but the much higher flows of the Unuk River reduced the effects of the poor drinking water quality at locations downstream of the confluence. The water in the Teigen, Treaty, Bell-Irving, South Unuk, and Scott Creek watersheds was of better drinking and recreational water quality than in the Sulphurets and Mitchell watersheds, with arsenic, chromium, and lead showing low incidence of exceedance at Treaty Creek.

### 25.1.4 Air Quality

Air quality was assessed during the 2008 to 2011 baseline studies (Appendix 7-C). Air quality in the Project area can generally be described as not affected, as there are limited anthropogenic sources. Existing air quality is only affected by natural sources and by traffic along Highway 37.

Air quality is measured in terms of criteria air contaminants (CACs). Background ambient total particulate matter (TPM), particular matter no greater than 2.5 µm ($PM_{2.5}$) or 10 µm ($PM_{10}$) in aerodynamic diameter, sulphur oxides ($SO_x$), nitrogen oxides ($NO_x$), and carbon monoxide (CO) were not measured because of the remoteness of the area, but rather were obtained from the closest monitoring station for the Canadian Air and Precipitation Monitoring Network or from monitoring stations at other project sites (Galore, Diavik, cited in Chapter 7).

The 24-hour average and annual averages for particulate concentrations in the Project area were 10 $\mu g/m^3$ of total suspended particulate (TSP), 3.4 $\mu g/m^3$ of $PM_{10}$, and 1.34 $\mu g/m^3$ of $PM_{2.5}$ (Table 7.1-4). These background concentrations are below BC air quality objectives (BC MOE 2009).

Dustfall levels were monitored inside the regional study area (RSA) during the summer months, which are typically the driest times of the year, when dustfall is not mitigated by precipitation. Monitoring was carried out at five sites in 2008, nine sites in 2009 and 2010, and ten sites in 2011 (Appendix 7-C). The dust deposition rates exceeded the BC dustfall deposition objective twice in August 2010; however, one exceedance was likely due to contamination. To obtain a representative background level, based on model guidelines, the 98th percentile of the dustfall rate at each station was calculated. The average of the 98th percentile values was

1.34 mg/dm$^2$/day, which was below the BC Pollution Objective for residential areas of 1.75 mg/dm$^2$/day (BC MOE 1979).

Some baseline metal deposition rates were monitored for future reference. The maximum copper deposition rates were 0.0055 mg/dm$^2$/day, 0.0016 mg/dm$^2$/day, 0.00065 mg/dm$^2$/day, and 0.0012 mg/dm$^2$/day for 2008, 2009, 2010, and 2011, respectively. For other elements, the maximum deposition rates during the reporting period of the baseline (2008 to 2011) were 0.00002 mg/dm$^2$/day for arsenic, 0.000011 mg/dm$^2$/day for cadmium, and 0.0049 mg/dm$^2$/day for lead. Mercury deposition rates were generally below detection limits, except for one measurement. Other metal deposition results, however, were difficult to calculate, because many of the total metal concentrations were at or below the detection limits.

Based on these findings, the current air quality at the KSM Project can be summarized as high quality and unlikely to have an effect on human health, where all monitored parameters were below the applicable objectives and guidelines.

For further information, refer to Section 7.1, Climate and Air Quality Setting.

### 25.1.5 Country Foods

Country foods are animals, plants, and fungi used by humans for nutritional or medicinal purposes that are harvested through hunting, fishing, or gathering of vegetation (Health Canada 2010a). Harvesting of country foods currently occurs in the proposed Project area, as recorded in land use baseline studies (Appendix 23-A; Chapter 30). Primary harvesters are Aboriginal peoples (members of the Tahltan Nation, wilp Skii km Lax Ha, Gitanyow First Nation, Nisga'a Nation, and Gitxsan Nation), trapline owners, public hunters, and commercial outfitters and their clients. Therefore, a baseline country foods risk assessment was conducted in 2009 (Appendix 25-A). The assessment estimated the quality of country foods prior to potential Project development, and thus was reflective of naturally occurring levels of metals. Although it did not predict future potential risks, it did provide a baseline for screening level risk assessments as required by the Application Information Requirements (AIR), and for additional future risk assessments if changes in soil, vegetation, and water quality are found in association with Project development and operation, if approved.

The following paragraphs present the main findings of the baseline assessment. Detailed methodology and results can be found in Appendix 25-A, 2009 Country Foods Baseline Report. A subsequent memorandum focused on a country food risk assessment for chinook salmon in Teigen Creek (Appendix 25-B, Baseline Country Foods Risk Assessment of Chinook Salmon in Teigen Creek, 2010). Tissue samples from Dolly Varden collected from South Teigen Creek and North Treaty Creek were available from 2008 to 2011. Based on the land use studies, fishing predominately occurs downstream of the TMF, with little to no fishing occurring downstream of the Mine Site on the Unuk River. Therefore potential human health risks from the consumption of Dolly Varden sampled from South Teigen Creek and North Treaty Creek was included in the screening level risk assessment (SLRA) for the Processing and Tailing Management Area (PTMA; Appendix 25-C). The methodology for the country foods baseline assessments and SLRA was based on Health Canada's guidelines (Health Canada 2010a) for assessing food issues in environmental impact assessments, and is described in detail in the appendices.

## Table 25.1-1. Frequency and Magnitude of Water Quality Concentrations that were Greater than Drinking and Recreational Water Quality Guidelines, KSM Project, 2007 to 2011

| Parameter | | pH | | Fluoride (F) | | Antimony (Sb) | | Arsenic (As) | | Arsenic (As) | | Barium (Ba) | | Boron (B) | | Cadmium (Cd) | | Chromium (Cr) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Guideline | | 5 - 9 | | 1.5 mg/L | | 0.006 mg/L | | 0.01 mg/L | | 0.025 mg/L | | 1 mg/L | | 5 mg/L | | 0.005 mg/L | | 0.05 mg/L | |
| Jurisdiction | | Canadian Recreational Water | | BC Maximum and Canadian MAC | | Canadian MAC | | Canadian MAC | | BCIMAC | | Canadian MAC | | BC and Canadian MAC | | Canadian MAC | | Canadian MAC | |
| Watershed | N | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor |
| Teigen Creek | 197 | 0.5 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Bell-Irving River | 29 | 0 | - | 0 | - | 0 | - | 3.4 | - | 3.4 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Treaty Creek | 157 | 0 | - | 0 | - | 0 | - | 9.5 | - | 3.2 | - | 0 | - | 0 | - | 0 | - | 1.3 | - |
| Reference Site (SCR) | 13 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Reference Site (SUNR) | 53 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Unuk River | 147 | 0 | - | 0 | - | 2.72 | - | 5.4 | - | 0.7 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Mitchell Creek | 170 | 24.3 | - | 2.4 | - | 0 | - | 39.4 | 2.79 | 17.6 | 1.12 | 0 | - | 0 | - | 34.1 | 1.1 | 0 | - |
| Sulphurets Creek | 152 | 0 | - | 0 | - | 0 | - | 17.1 | - | 4.6 | - | 0 | - | 0 | - | 2.0 | - | 0 | - |
| Bowser Lake | 6 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |

| Parameter | | Cyanide (CN)[1] | | Lead (Pb) | | Lead (Pb) | | Mercury (Hg) | | Molybdenum (Mo) | | Nitrate ($NO_3$ as N) | | Nitrite ($NO_2$ as N) | | Selenium (Se) | | Uranium (U) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Guideline | | 0.2 mg/L | | 0.01 mg/L | | 0.05 mg/L | | 0.001 mg/L | | 0.25 mg/L | | 10 mg/L | | 1 mg/L | | 0.01 mg/L | | 0.02 mg/L | |
| Jurisdiction | | BC and Canadian MAC | | Canadian MAC | | BC Maximum | | BC Maximum and Canadian MAC | | BC Maximum | | BC and Canadian MAC | | BC and Canadian MAC | | BC and Canadian MAC | | Canadian MAC | |
| Watershed | N | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor | Frequency (%) | Factor |
| Teigen Creek | 197 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Bell-Irving River | 29 | 0 | - | 3.44 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Treaty Creek | 157 | 0 | - | 6.37 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Reference site (SCR) | 13 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Reference site (SUNR) | 53 | 0 | - | 3.77 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Unuk River | 147 | 0 | - | 3.4 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Mitchell Creek | 170 | 0 | - | 30 | 0.97 | 2.94 | - | 0 | - | 0 | - | 0 | - | 0 | - | 2.9 | - | 0 | - |
| Sulphurets Creek | 152 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |
| Bowser Lake | 6 | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - | 0 | - |

**Notes:**
[1] Cyanide was measured as total cyanide.
Canadian recreational water guideline for pH is based on Health Canada's guidelines for Canadian recreational water quality (2011c).
BC Maximum = maximum allowable value that should not be exceeded under the BC ambient water quality criteria (BC MOE 2006) for raw untreated drinking water.
MAC = Maximum acceptable concentration for raw untreated drinking water.
IMAC= Interim maximum acceptable concentration for raw untreated drinking water.
N = number of samples.

The country foods evaluated were moose (*Alces alces*), snowshoe hare (*Lepus americanus*), grouse (*Phasianidae* sp.), chinook salmon (*Oncorhynchus tshawytscha*), Dolly Varden (*Salvelinus malma malma*), and highbush cranberry (*Viburnum edule*). The country foods baseline assessment focused on metals because the Project is a proposed metal mine (gold, copper, silver, and molybdenum). Seven metals were selected for evaluation in the baseline assessment, based on screening of the soil and surface water baseline data collected from the study area against the Canadian Council of Ministers of the Environment (CCME) guidelines (CCME 2010). The metals evaluated were aluminum, arsenic, cadmium, copper, lead, selenium, and zinc. Metal concentrations in foods were modelled for moose, snowshoe hare, and grouse muscle tissue, while the berries of ripened highbush cranberry and fish tissues were collected for laboratory analysis.

The results of the baseline assessment indicated that unacceptable risks are not present to human receptors from the consumption of moose, snowshoe hare, grouse, or highbush cranberry under the baseline exposure scenarios evaluated. Based on the empirical and estimated levels of metals in these foods, the amounts currently consumed are within the recommended maximum weekly intakes.

The exception was the elevation of some metals in salmon and Dolly Varden. Arsenic was naturally elevated in salmon from Teigen Creek and in Dolly Varden from North Treaty Creek. Mean selenium concentrations in Dolly Varden were slightly elevated above fish tissue guidelines in North Treaty and South Teigen creeks. Salmon are anadromous and spend most of their adult life in the marine environment. Also, they do not feed during their freshwater migration to spawn, and there is no evidence that migrating salmon accumulate metals during their migration or spawning. Therefore, the quality of salmon as food is a reflection of the marine environment and will not be affected by conditions in the proposed Project area. In addition, arsenic is stored in finfish muscle in a relatively non-toxic form (as organic arsenobetaine) and does not pose a threat to people who eat it at the consumption levels evaluated (Borak and Hosgood 2007). Selenium concentrations in Dolly Varden from the PTMA were similar to selenium concentrations in fish from the Elk River Valley. A detailed human health risk assessment of the Elk River fish concluded that no human health risks from the consumption of these selenium fish tissue concentrations existed (Lawrence and Chapman 2007). Dolly Varden are resident fish and are therefore exposed to local environmental baseline conditions. Based on the baseline assessment, the consumption of Dolly Varden will not pose a health risk at the low consumption frequencies expected to occur in the area.

### 25.1.6 Noise

The Project location is currently described as remote wilderness with limited noise effects relating to industrial activity. No baseline noise measurements have been recorded, and current noise levels are assumed to be that of a quiet rural community (most conservative), with a day-night sound level ($L_{dn}$) ranging between 25 dBA and 35 dBA (Table 25.1-2). This baseline noise level consists of environmental noise, such as wind, water, avalanches, and wildlife.

The construction and operation of the Project will introduce environmental noise sources, largely in the form of construction equipment, blasting activities, and vehicle and helicopter traffic. Effects to human health for noise-sensitive human receptors are assessed in accordance with the guideline published by Health Canada in April 2011, *Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise* (Health Canada 2011b).

### Table 25.1-2. Estimated Baseline Noise Levels

| Time Period | Noise Level (dBA) |
|---|---|
| Day ($L_d$) | 35 |
| Night ($L_n$) | 25 |
| Day-Night ($L_{dn}$) | 35 |

**dBA = decibels, A-weighted; $L_d$ = Level, day; $L_n$ = Level, night; $L_{dn}$ = Level, day-night**

The baseline noise is used to assess the changes in noise levels and hence the percent change in the “highly annoyed” population due to predicted Project activities. The $L_{dn}$ is an equivalent continuous sound level over 24 hours, with the nighttime (10 p.m. to 7 a.m.) contributions adjusted by +10 dBA to account for expected increased annoyance due to noise-induced sleep disturbance and the increased residential population at night relative to daytime. While there is no residential population currently living in the Project area, this is a conventional measure to describe the baseline sound levels.

## 25.2 Historical Activities

Potential effects on human health could result from changes in air quality; changes in drinking and recreational water quality; and altered quantity and quality of country foods due to past project and human activities in the Project area or in downstream watersheds. Noise is not considered in the historical cumulative effects assessment, because sound is only audible while an activity is occurring and does not persist in the environment.

The historical cumulative effects assessments for the human health VC (human health due to air quality, drinking and recreational water quality, and country foods quality) considers the spatial and temporal linkages with other projects and activities, as appropriate, that have been identified for:

- air quality (Section 7.2);
- terrain and soils (Section 8.2);
- surface water quality (Section 14.2);
- fish and aquatic habitat (Section 15.2);
- terrestrial ecosystems (Section 17.2);
- wildlife and wildlife habitat (Section 18.2); and
- land use (Section 23.2).

Historical projects and activities located inside or near the proposed Project area were considered for their potential effects to human health.

**Air quality:** Past vehicle exhaust and particulates from Eskay Creek Mine and Highway 37 may persist in the environment, and therefore may have a cumulative effect on dust-induced metal loading to soils and vegetation, affecting the quality of country foods.

**Terrain and soils:** Soils at Eskay Creek Mine require sufficient time to recover once reclamation activities are complete. The Eskay Creek Mine is considered in the cumulative effects assessment stage for terrain and soils (Chapter 8) to allow for consideration of past effects that may share spatial linkage with the KSM Project.

**Surface water quality:** If changes to water quality resulting from Eskay Creek and Granduc mine activities as well as from previous activity at Snowfield Project/Brucejack Mine persist, a temporal linkage between these past-producing projects and potential effects to water quality from the KSM Project may exist. This might affect drinking and recreational water quality in downstream watersheds and the quality of country foods.

**Fish and fish habitat:** The past projects and human activities that may affect fish and aquatic habitat and that spatially overlap potential effects from the KSM Project are:

- Eskay Creek Mine (effluent flows into the Unuk River above the Sulphurets Creek confluence);
- Granduc Mine (concentrator effluent follows the Bowser River Valley to Bowser Lake);
- fishing; and
- forestry activities in the Bell-Irving watershed.

The quality and quantity of fish can directly affect human health from the consumption of country foods.

Although relatively close in proximity to the KSM Project, the past projects Johnny Mountain Mine and Snip Mine are not included in the cumulative effects assessment for fish and aquatic habitat, as their effluent was discharged outside the boundaries of the watersheds potentially influenced by the KSM Project.

**Terrestrial ecosystems:** Effects to terrestrial ecosystems (vegetation) from past human actions and projects that have the potential to overlap temporally with effects to terrestrial ecosystems from the KSM Project are:

- mineral exploration (potential disturbance and use of access roads);
- recreation and tourism (use of access roads);
- forestry (timber clearing); and
- Eskay Creek Mine (potential disturbance and use of access roads).

Given that the Eskay Creek Mine was only recently closed (2008), and that affected terrestrial ecosystems require sufficient time to recover once reclamation activities are complete, this project is considered to have a temporal linkage to the KSM Project. Cumulative historical disturbance to terrestrial ecosystems affects human health due to the potential alteration of the quantity and quality of country foods (berries, medicinal plants, and input to wildlife food chain).

**Wildlife and wildlife habitat:** Past projects and activities considered further in the cumulative effects assessment are:

- fishing;
- guide-outfitting;
- forestry activities;
- mineral resource exploration;
- recreation and tourism;
- resident and Aboriginal country food harvest;
- Eskay Creek Mine;
- Granduc Mine;
- Johnny Mountain Mine; and
- Snip Mine.

Cumulative historical disturbance to wildlife affects human health due to the potential alteration of the quantity and quality of country foods (game meat).

**Land use:** Past project activity at the Eskay Creek Mine, Granduc Mine, and Kitsault Mine have opened access to the area for recreation, hunting, gathering, and fishing. This could have affected the quantity of available country foods due to increased harvesting pressures and wildlife disturbance, and has the potential for accidental releases of hazardous materials (e.g., diesel, oil, and siltation) into water used for drinking and recreation. As a result, human health may be affected from changes in the quantity of country food consumed and from changes in water quality.

## 25.3 Land Use Planning Objectives

Two resource management plans partially overlap the proposed Project area: the Cassiar Iskut-Stikine Land and Resource Management Plan (CIS LRMP; BC ILMB 2000) and the Nass South Sustainable Resource Management Plan (SRMP; BC MFLNRO 2012). Details of these plans are in Appendix 23-A.

Human health is considered in both resource management plans, either directly or indirectly, through the overall management goals for healthy ecosystems, of which humans are a part. The goals of the CIS LRMP include a healthy environment, healthy and sustainable communities, and sustainable development, with the stated objectives to maintain sustainable ecosystems, abundant fish and wildlife populations, communities with adequate health care, and a safe and secure environment. Further objectives relating to human health encompass a healthy, sustainable, well balanced use of resources, and development that respects local cultures and lifestyles. Hunting, trapping, guide-outfitting, and fishing are specifically mentioned as a management direction in the LRMP with the goal to maintain viable fish, game, and furbearer populations that continue to support the sustenance, cultural, economic, and recreational needs of Aboriginal peoples and local residents (BC ILMB 2000).

The CIS LRMP also includes area-specific resource management zones (RMZ). One of these RMZs (the Unuk River RMZ) overlaps part of the proposed Project area, specifically a small segment of the proposed mine access route. Management objectives for the Unuk River RMZ are to maintain high-value grizzly bear habitat and visual quality from the Unuk River, while allowing for adjacent logging and mineral development. In particular, public camping opportunities at the confluence of the South Unuk and Unuk rivers should be maintained (BC ILMB 2000). This implies that downstream effects from the Mine Site on drinking and recreational water quality must be minimized to maintain a healthy environment for people occupying the campsite.

The Nass South SRMP provides guidance on permitted land use activity in a 663,000-ha area in northwestern BC. Its northern finger intersects a portion of the proposed Project area. The SRMP's main function is to address sustainable management issues concerning land, water, and resources in the southern portion of the Nass Timber Supply Area while allowing for resource development. Resource use and permitted activities with the potential to affect human health include commercial recreation and tourism, guide-outfitting, hunting, fishing, trapping, and cultural land uses. Management objectives affecting human health include the restoration of water quality in damaged watersheds, and the maintenance of productive pine mushroom collection sites, wildlife habitat and wildlife populations, and fish habitat (BC MFLNRO 2012).

# 25.4 Spatial and Temporal Boundaries

## 25.4.1 Spatial Boundaries

The spatial boundaries for the human health assessment are defined by the spatial boundaries of the components that contribute to human health (water quality, air quality, country foods, and noise).

### 25.4.1.1 Drinking and Recreational Water

The spatial boundary for drinking and recreational water is consistent with the domain used in the water quality model (Chapter 14), and includes the closest drinking water locations identified in the land use baseline (Appendix 23-A) that are downstream of the Project, and any contemporary locations identified in the traditional knowledge/traditional use (TK/TU) studies (Appendices 30-A to 30-D).

### 25.4.1.2 Air Quality

The spatial boundary for air quality is consistent with the domain used in the air quality model (Chapter 7). The boundaries include sensitive receptor locations that could be affected by the Project based on the topography and the existing airsheds. The RSA of the air quality assessment covers a domain 100 km in an east-west direction and 60 km in a north-south direction. The centre of the RSA is roughly between the proposed Mine Site and the PTMA. Air quality along Highway 37 is assessed in the Highway Traffic Effects Assessment of the Traffic Study (Appendix 22-C).

#### 25.4.1.3 Country Foods

The spatial boundary for country foods assessment is based on the spatial boundary for the air quality effects assessment, and includes the sampling locations for tissue metal concentrations in vegetation and fish, and the sampling locations for water quality. To include the potential future effect of water quality on country foods, a zone extending from Project infrastructure downstream to the first identified receptor near a water quality monitoring station is used, on the assumption that the assessment of this zone will determine the highest potential concentration of any contaminant. The transmission line right-of-way follows the access road and will be assessed concurrently.

#### 25.4.1.4 Noise

The spatial boundary for noise is consistent with the domain used in the noise model (Chapter 19) and includes the closest receptor locations (i.e., permanent or temporary locations identified in the land use baseline (Appendix 23-A), any contemporary locations identified in the TK/TU studies, and receptor locations associated with the proposed mining activities). Noise along Highway 37 was assessed in the Highway Traffic Effects Assessment of the Traffic Study (Appendix 22-C).

### 25.4.2 Temporal Boundaries

Human health can potentially be affected throughout the life of the mine, including the construction, operation, closure, and post-closure phases. The assessment considered four Project phases:

- construction phase – 5 years;
- operation phase – 51.5 years;
- closure phase – 3 years (includes Project decommissioning and reclamation activities); and
- post-closure phase – 250 years (includes ongoing reclamation activities and post-closure maintenance monitoring).

Human health in this assessment is affected by drinking and recreational water quality, air quality, quality of country foods, and noise. Table 25.4.-1 indicates the phases during which potential effects to water quality, air quality, quality of country foods, and noise will likely occur.

**Table 25.4-1. Summary of Project Phases with Potential Effects to Human Health from Surface Water Quality, Air Quality, Quality of Country Foods, and Noise**

| | Construction | Operation | Closure | Post-closure |
|---|---|---|---|---|
| Drinking and Recreational Water Quality | x | x | x | x |
| Air Quality | x | x | x | - |
| Quality of Country Foods | x | x | x | x |
| Noise | x | x | x | - |

**X = Project phase with potential effect**

## 25.5 Valued Components

Health is defined by the World Health Organization (WHO) as a complete state of physical, mental, and social well-being and not merely the absence of disease or infirmity. The well-being of the community in the socio-economic and cultural context of health is assessed in Chapter 22. The physical component of human health is considered as a VC here because the physical health of humans working in, living downstream of, or travelling through the proposed Project area has the potential to be affected directly through either chemical means (water, air, country food) or physical means (noise). Humans and consequently human health have the potential to interact with Project components, and health is of high importance to society and individuals. Therefore, human health is included in the Application/EIS as a VC. Health effects from surface water quality, air quality, the consumption of country foods, and noise were considered as contributing to the human health VC.

### 25.5.1 Valued Components Included in Assessment

The proposed Project has the potential to adversely affect human health, directly and indirectly, during the construction, operation, closure, and post-closure Project phases. Human health as the VC can be affected by ingestion of surface water, inhalation of air, ingestion of country foods, and noise levels. The VC was screened for inclusion in the Application/EIS based on government guidelines, Aboriginal peoples' concerns, local stakeholder interviews, and literature (Table 25.5-1). The following sections present the four components that contribute to the human health VC and the rationale for their selection for each pathway of exposure.

**Table 25.5-1. Identification and Rationale for Human Health Valued Component Selection**

| Valued Component | Identified by* | | | | Rationale for Inclusion |
|---|---|---|---|---|---|
| | AG | G | P/S | O | |
| Health effects from surface water quality | x | x | x | x | Identified as one of the main indicators of environmental health and a component linked to other key ecosystem components, including fish and fish habitat, aquatic resources, wildlife, and human health. The area is used for recreation and fishing with the potential for human health effects from water quality. Identified by Tahltan, Nisg̲a'a Nation, Gitanyow Chiefs, wilp Wii'litsxw, Skii km Lax Ha, and government agencies. |
| Health effects from air quality | x | x | | | Identified as directly affecting off-duty workers' respiratory health and the quality of country foods by a government agency. Air quality concerns were raised by Tahltan, Wii'litsxw, and Gitanyow Chiefs. |
| Health effects from the consumption of country foods | x | x | x | | Contaminant levels in country foods have the potential to directly affect human health. Aboriginal peoples and local residents use the area for hunting, fishing, and gathering. Gitanyow Chiefs are interested in moose tissue analysis. Skii km Lax Ha, Gitanyow Chiefs, Wii'litsxw, and Nisg̲a'a Nation are concerned about Project effects on fishing, hunting, trapping, and gathering. The public expressed concern over access to the area for hunting or fishing. |
| Health effects from noise | x | x | | | Noise can affect human health physically or emotionally. Included as human health VC because off-duty workers live close to Project activities and may be affected. Noise may disturb wildlife, which contributes to a country foods diet and therefore to human health. |

***AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder; O = Other (e.g., legislation, professional judgement)**

Concerns about potential effects on human health by the Project have been raised by Aboriginal groups and by government, or were identified through scientific literature and technical expertise or professional judgment (Table 25.5-1). How and when these potential effects may arise due to the Project are detailed in Appendix 25-E and summarized in Table 25.6-1. A detailed description of the potential human health effects is provided in Section 25.7. Each effect is addressed in a separate section according to the human health VCs deemed to be of concern for that effect.

The selection of effects for evaluation (water quality, air quality, country foods quality, and noise) was based on Health Canada guidance (2010a). When evaluating the risks to human health from exposure to chemicals, the human receptor selection generally depends on the type of chemical evaluated. For instance, the receptor selected for chemicals that become toxic above a certain threshold but are not carcinogenic is the group that has the greatest exposure per unit body weight per day. Therefore, to quantify effects of these non-carcinogenic, threshold chemicals, the toddler life stage (i.e., six months to four years old) is generally selected as the most sensitive receptor. If the effects assessment finds effects to be acceptable for toddlers, then they would also be acceptable for all other life stages. For non-threshold, carcinogenic chemicals, adult receptors were selected. Adults are generally selected because exposure is estimated over an entire lifetime.

The nearest land users to the proposed Mine Site and access roads are individuals who temporarily access the trapping and hunting cabins along the Unuk and South Unuk rivers and the Teigen Creek, Bell-Irving River, and Treaty Creek corridors (Chapter 23, Land Use). For this assessment it was assumed that the people who frequent these areas are sensitive receptors, thus the health of these people was selected as the VC for this assessment.

The health of on-shift mine employees was not selected as a VC because worker health will be addressed in the Health and Safety Management Plan that will be developed during the permitting process. However, the health of off-duty employees residing on-site will be included in the assessment as recommended by Health Canada (2010a).

### 25.5.2 Valued Components Excluded from Assessment

Human health was the only VC considered for the effects assessment. A number of potential components that might contribute to the human health VC were considered for assessment but were not included. The rationale for their exclusion is presented in Table 25.5-2. For instance, Health Canada suggests providing information of radiological effects in the human health assessment within an environmental assessment (Health Canada 2010a). However, since this mine is a metal mine, radiological effects are not expected to occur and are therefore not included as a VC.

## 25.6 Scoping of Potential Effects for Human Health

Human health can be indirectly affected by Project-induced changes to water quality, air quality, and the quality of country foods. Noise that is emitted from the Project may affect human health directly. These potential Project effects are evaluated separately, although it is recognized that the combination of effects can act synergistically or additively to affect the overall health and feeling of well-being of people at the Project site and of temporary users of adjacent areas.

Appendix 25-E scopes the potential effects on human health from changes to water quality, air quality, country foods quality, and noise levels from Project area components during construction, operation, closure, and post-closure; potential effects are summarized in Table 25.6-1.

## Table 25.5-2. Rationale for Human Health Valued Components Considered and Excluded from Further Analysis

| Valued Component | Identified By* | | | | Rationale for Exclusion |
|---|---|---|---|---|---|
| | F | G | P/S | O | |
| Health effects from dermal exposure | | X | | X | Dermal exposure to chemicals or contaminated water is considered under occupational health hazards (Workplace Hazardous Materials Information System [WHMIS]) and will not be considered in this assessment. Off-duty workers are unlikely to be in contact with chemicals or contaminated water. |
| Health effects from incidental soil ingestion | | X | | | Mainly of concern for children. Children are not considered receptors at the proposed mine and would not be affected by mineralized dustfall on soil. |
| Health effects from electric and magnetic fields | | X | | X | Power lines can cause weak electric currents to flow through the human body. However, the magnitude of the currents in power lines is not associated with any known short- or long-term health risks. Children as sensitive receptors are not considered to be receptors at the proposed mine. |
| Radiological health effects | | X | | X | Radiation is not a VC because the proposed mine is a metal mine. |

***AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder; O = Other**

## Table 25.6-1. Potential Effects from the Project on Human Health

| Project Region | Project Area | Heath Effects due to Changes in Surface Water Quality | Health Effects due to Changes in Air Quality | Health Effects from the Consumption of Country Foods | Health Effects from Noise |
|---|---|---|---|---|---|
| Mine Site | Camp 3: Eskay Staging Camp | X | X | | X |
| | Camp 7: Unuk North Camp | X | X | | X |
| | Camp 8: Unuk South Camp | X | X | | X |
| | Coulter Creek Access Corridor | X | X | X | X |
| | Mitchell Operating Camp | X | X | | X |
| | McTagg Rock Storage Facility | X | X | X | X |
| | McTagg Twinned Diversion Tunnels | X | X | X | X |
| | McTagg Power Plant | | X | | X |
| | Mitchell Rock Storage Facility | X | X | X | X |
| | Camp 4: Mitchell North Camp (for MTT Construction) | X | X | | X |
| | Mitchell Ore Preparation Complex | X | X | X | X |
| | Mine Site Avalanche Control | | X | | X |
| | Iron Cap Block Cave Mine | X | X | X | X |

**(continued)**

## Table 25.6-1. Potential Effects from the Project on Human Health (continued)

| Project Region | Project Area | Heath Effects due to Changes in Surface Water Quality | Health Effects due to Changes in Air Quality | Health Effects from the Consumption of Country Foods | Health Effects from Noise |
|---|---|---|---|---|---|
| Mine Site *(cont'd)* | Mitchell Pit | X | X | X | X |
| | Mitchell Pit Block Cave Mine | X | X | X | X |
| | Mitchell Diversion Tunnels | X | X | X | X |
| | Upper Sulphurets Power Plant | | X | | X |
| | Mitchell Truck Shop | | X | | X |
| | Water Storage Facility | X | X | X | X |
| | Camp 9: Mitchell Initial Camp | X | X | | X |
| | Camp 10: Mitchell Secondary Camp | X | X | | X |
| | Water Treatment and Energy Recovery Area | X | X | X | X |
| | Sludge Management Facilities | X | X | X | X |
| | Sulphurets Laydown Area | X | X | X | X |
| | Sulphurets-Mitchell Conveyor Tunnel | X | X | X | X |
| | Sulphurets Pit | X | X | X | X |
| | Kerr Rope Conveyor | | X | | X |
| | Kerr Pit | X | X | X | X |
| | Camp 2: Ted Morris Camp | X | X | | X |
| | Explosives Manufacturing Facility | | X | | X |
| | Temporary Frank Mackie Glacier Access Route | X | X | X | X |
| | Camp 1: Granduc Staging Camp | X | X | | X |
| Processing and Tailing Management Area | Mitchell-Treaty Twinned Tunnels | X | X | X | X |
| | Construction Access Adit | X | X | X | X |
| | Mitchell-Treaty Saddle Area | X | X | X | X |
| | Camp 6: Treaty Saddle Camp | X | X | | X |
| | Camp 5: Treaty Plant Camp | X | X | | X |
| | Treaty Operating Camp | X | X | | X |
| | Treaty Ore Preparation Complex | X | X | X | X |
| | Concentrate Storage and Loadout | X | X | X | X |
| | North Cell Tailing Management Facility | X | X | X | X |
| | East Catchment Diversion | X | X | X | X |

**(continued)**

## Table 25.6-1. Potential Effects from the Project on Human Health (completed)

| Project Region | Project Area | Heath Effects due to Changes in Surface Water Quality | Health Effects due to Changes in Air Quality | Health Effects from the Consumption of Country Foods | Health Effects from Noise |
|---|---|---|---|---|---|
| Processing and Tailing Management Area *(cont'd)* | Centre Cell Tailing Management Facility | X | X | X | X |
| | South Cell Tailing Management Facility | X | X | X | X |
| | Treaty Creek Access Corridor | X | X | X | X |
| | Camp 11: Treaty Marshalling Yard Camp | X | X | | X |
| | Camp 12: Highway 37 Construction Camp | X | X | | X |
| Off-site Transportation | Highway 37 and 37A | X | X | X | X |

**X = interaction between component and effect**

## 25.6.1 Construction

During the five-year construction phase, health effects from a potential decrease in the quality of drinking and recreational water, air, and country foods, and from a potential increase in noise were considered as potential effects to human health. Potential effects would occur in association with construction of Project infrastructure within the Mine Site, PTMA, Mitchell-Treaty Twinned Tunnels (MTT), Treaty Creek Access Corridor, and Coulter Creek Access Corridor.

Most of the activities of the construction phase will involve the excavation, removal, and consecutive storage of large quantities of rock and soil. Exposure of rock-bearing sulphide minerals and, therefore, potentially acid-generating materials, will create a potential for metal leaching and acid rock drainage (ML/ARD). Therefore, effects to drinking and recreational water quality and the quality of country foods through the uptake of metals were included in the assessment. Surface runoff from the construction, excavation, grading, clearing, and rock storage areas may cause siltation and associated water chemistry effects. These can affect the quality of drinking water and country foods.

Blasting will be used where necessary to assist in rock removal. Blasting will also be used for avalanche control if necessary. Nitrogen residues from blasting may leach into the adjacent watersheds. Blasting will also create airborne particulates; intensive use of transport vehicles and machinery during construction will potentially produce dust and atmospheric emissions. Atmospheric emissions will also be created by garbage incineration for construction camps. This may lead to deposition of airborne material into water, causing alteration of water quality, and onto soils and plants, causing changes in soil chemistry, thereby affecting the quality of country foods. In addition, airborne material may directly be inhaled by people, affecting their respiratory health.

The construction phase will likely create a high level of noise due to blasting, use of helicopters, and large construction machinery. This creates the potential for human health effects due to noise, such as disturbed rest and sleep, loss of speech comprehension, or loss of hearing in extreme cases.

There is also potential for wastewater treatment effluent, sewage, garbage, seepage, and accidental spills to occur during the construction phase and to affect human health. Spills during transport and storage of fuel, chemicals, and explosives may be of special importance to human health due to the potential of contamination of drinking and recreational water and country foods. Routine Project-related traffic and in-water works (activities involving mechanized equipment in or near waterways, such as road, bridge, dam, or other infrastructure construction) have the potential for introducing oils and diesel fuels into the aquatic environment from spills and leaks, affecting fish (Chapter 15) and water quality (Chapter 14). The potential for spills and accidents involving large quantities of petroleum products are not considered here since this will be addressed in Chapter 35 (Environmental Effects of Accidents and Malfunctions).

### 25.6.2 Operation

The operation phase consists of mine development and ore processing, and will last for 51.5 years. It will likely create the highest potential for effects on human health due to potential effects on air quality (from continued blasting, and ore and concentrate transportation) and continued effects on water quality. Operation will include main components such as pit development; segregation of ore and non-ore mine rock; ore processing with production of copper-gold and molybdenum concentrates, gold, and silver; and waste management. Waste management will consist of non-ore rock storage, tailing management, and water management.

Potential for ML/ARD exists during the operation activities associated with the storage of waste rock, part of which may be potentially acid generating (PAG); tailing, which will include PAG components as well; groundwater seepage through the walls of the pits and tunnels; and surface runoff, which will transport metals from Project components and facilities and may adversely affect water quality in the receiving watersheds. This may have an effect on drinking and recreational water quality, as well as on country foods quality.

Blasting during mine operation will generate residues containing nitrogen compounds that will remain on the surface of pit slopes, waste rock, ore, tailing, and other mine components. These residues will be available to leach into contact water, thereby potentially affecting the quality of drinking and recreational water and country foods.

Blasting, as well as road traffic and the operation of machinery and garbage incinerators, will also create dust and particulate matter (PM), which may deposit on adjacent water, soils, and vegetation, affecting the quality of country foods and human respiratory health.

During operation there is a potential for mine effluent discharge from both the Mine Site and the PTMA. At the Mine Site, mine effluent, which will mainly consist of runoff from the rock storage facilities (RSFs), drainage from the MTT, and water from pit dewatering activities, will potentially affect Mitchell Creek, Sulphurets Creek, and, eventually, Unuk River watersheds. At the PTMA, the potential for effluent release is associated with tailing slurry water, TMF overflow due to excess water, groundwater seepage, and dam runoff. Effluent release may affect water quality in the South Teigen Creek watershed at the northern end of the TMF, and in the North Treaty Creek watershed at the southern end of the TMF.

The presence and operation of personnel camps, fuel supply lines and storage tanks, explosives storage, and water treatment facilities create potential for effects on water quality from sewage, seepage, and spills. Surface runoff from pits, ore and rock stockpiles, mine and plant operation areas, camps, roads, layout areas, and dams will potentially affect the quality of receiving water through siltation and associated changes in water chemistry. The effects to water quality have the potential to influence the quality of country foods and the quality of drinking and recreational waters downstream.

Noise from mining activities and road traffic may have an effect on human health by disrupting speech comprehension and normal sleep patterns for people residing in operation camps.

### 25.6.3 Closure

Upon closure of the Project, most of the Mine Site and PTMA facilities will be decommissioned, equipment and infrastructure removed, and surfaces reclaimed. Closure activities themselves may create some potential for water quality effects from surface runoff, siltation, chemical spills, airborne dust and emissions, and machine noise from decommissioning.

To return the surfaces to baseline equivalency, disturbed areas will be covered with till material to a depth of 50 cm to create a growth medium for re-vegetation. The movement and distribution of till may result in air quality health effects due to the development of dust. Machine noise will be relatively minor, and blasting is not anticipated to take place. Elevations above 1,100 m will become alpine barren habitat and will not be re-vegetated. Bridges and culverts will be removed. Effects on water quality from surface runoff and siltation during closure activities will be reduced by application of berms, soil, and re-vegetation of the Project area, and by special contouring of RSF slopes and routing non-contact water flows around the RSFs.

Closure activities will include construction of a dam at the Mitchell Pit to allow its flooding, and application of till and soil cover on the surface of the RSFs and the TMF dam and beaches, and their re-vegetation to reduce PAG-rock exposure. Measures will be taken to collect effluent water in the water storage facility (WSF) for monitoring and treatment before discharge into the receiving watersheds. Large boulders will be placed along the slopes to the WSF to discourage animals from accessing the WSF.

### 25.6.4 Post-closure

There will be no post-closure effects on human health from noise and changes in air quality, as most activities will have ceased. Minor traffic will be routed through the MTT to maintain the Water Treatment and Energy Recovery Area and to move treatment sludge to the TMF.

However, after closure, potential will remain for ML/ARD; the release of elevated levels of metals; and the leaching of nitrogen residues from blasting from the RSF, excavated pits, the MTT, and the TMF, which will remain on-site. These discharges are anticipated to be within legal discharge requirements, but may have the potential to affect drinking and recreational water quality in adjacent downstream watersheds (Unuk, Treaty, and Teigen) and the quality of country foods in the long term, especially fish.

Animals will likely have access to remaining mine infrastructure. Moose and other animals favouring aquatic habitats may enter the TMF and ingest water and vegetation covering the tailing. Animals may therefore be exposed to metals if they have been released to the water and taken up by wetland vegetation, grasses, and bushes. Pit lakes and pit walls (Kerr and Mitchell pits) create habitat for ducks, goats, marmots, and grizzly bears, all of which may be hunted and consumed by people. Large boulders will be placed along the shores of the WSF at the Mine Site, which will deter most animals (except waterfowl) from accessing the WSF (Chapter 18, Wildlife and Wildlife Habitat).

Plants used for re-vegetation of the TMF and the RSFs may be able to take up residual metals from tailing and waste rocks, thereby transferring metals into the food chain and affecting the quality of wildlife country foods. Re-vegetation of the TMF and natural succession may establish *Vaccinium* and other berry species that are attractive to wildlife and birds. People will not be allowed to access the Project area post-closure, and therefore the effects on human health through country foods consumption are expected to be minimal.

Potential effects from the Project during construction, operation, closure, and post-closure on the components of human health (surface water quality, air quality, quality of country foods, and noise) have been summarized in Table 25.6-1.

## 25.7 Potential for Residual Effects for Human Health

The following sections detail the potential for residual human health effects from changes to the quality of drinking water, air, country foods, and noise. Each section provides information on how these four effect pathways can affect the health of sensitive receptors, explains who the sensitive receptors are likely to be, discusses mitigation strategies that will eliminate or reduce the potential effects, and provides an assessment of the potential for residual effects after the mitigations are imposed within the context of the land use. Ingestion of contaminated drinking water and country foods or inhalation of contaminants in air can result in a toxicological health effect, either short-term (acute) or long-term (chronic), depending on the type and concentration of the contaminant taken up by the person, and on the duration and frequency of uptake. Metal toxicity can result in a variety of health effects depending on the individual metal. In addition, the inhalation of small PM can result in physical changes to the lungs, independent of toxicological effects, which can lead to serious permanent respiratory health impairment. Health effects from noise are generally different from health effects that originate from the intake of contaminated drinking water, country foods, or air. Noise can affect people’s health in a variety of ways, from interfering with speech comprehension, being an annoyance, leading to sleep disturbance, and potentially causing hearing loss (temporary or permanent) in extreme cases. The following sections will describe the potential for these human health effects in more detail.

### 25.7.1 Changes in Health due to Drinking and Recreational Water Quality

The purpose of the drinking water effects assessment was to evaluate the potential for Project activities to affect human health from the ingestion of water. The rationale for this evaluation was that people use the area downstream of or at the TMF, and less frequently, the area downstream of the Mine Site, for hunting, trapping, berry picking, and recreation, and will ingest untreated water during these activities.

Health Canada recommends that water collected from waterbodies always be treated before using it for drinking (Health Canada 2007), because surface water can contain naturally occurring bacteria, viruses, and protozoa. Although this is an effects assessment on potential changes to surface water quality with respect to safe consumption, it only evaluates mining-related activities that have the potential to make surface water unsafe to drink. Parameters that are regulated through strict permits (e.g., sewage discharge) and have no direct relation to mining activities were not evaluated.

The potentially affected individual or population, and the nature and extent of effects on drinking water and health are presented below.

The nearest land users to the proposed Project and its access roads are individuals who visit the trapping and hunting cabins along the Unuk and South Unuk rivers and the Teigen Creek, Bell-Irving River, and Treaty Creek corridors. The Project sites will be closed to the public, and therefore potential drinking water effects are only considered downstream of, but not within, the Mine Site and the PTMA. It is assumed that land users will consume water from streams and rivers downstream of the Project.

The Unuk River was identified as a destination for rafting during the land use studies (Chapter 23, Land Use), and therefore there is the potential for intentional or accidental immersion in water. A trapline and guide-outfitter licence overlaps with the Unuk/South Unuk rivers and Sulphurets Creek. Two cabins exist along the Unuk River downstream of the Mine Site. A campsite has been identified at the confluence of the South Unuk River with the Unuk River (CIS LRMP). Based on the identified land uses, it is likely that people will be exposed to and will consume water from the Unuk River downstream of the Mine Site on a seasonal and temporary basis.

Both Treaty Creek and Teigen Creek transect traplines held by members of the Skii km Lax Ha (Shelley Johnson in Teigen Creek, and Darlene Simpson and Martha Risdale in Treaty Creek, Bowser Lake, and the southern half of the TMF). It is anticipated that trapline holders will continue to access the traplines that have not been affected by infrastructure. Fishing locations include the Cranberry River, the Bell-Irving River, the confluence of Treaty Creek and the Bell-Irving River, as well as the confluence of Snowbank Creek and Bell-Irving River. Therefore, the potential exists for fishermen and users of the traplines to be exposed to and consume water from creeks downstream of the TMF on a seasonal and temporary basis.

Access to the PTMA and the TMF will be restricted to the public. However, during closure and post-closure phases of the Project, people may increasingly access the area downstream of the TMF as it is being reclaimed, and wildlife may start using the TMF as habitat. Therefore, the potential exists that people will accidentally or intentionally ingest water from creeks downstream of the TMF or from the TMF itself during the closure and post-closure phases.

Workers living in camps will receive drinking water from surface water or groundwater sources that will be monitored and treated as required to meet established provincial drinking water guidelines and criteria for chemical and bacteriological quality. Wells will be sited upstream of potential Project activities to reduce metal loadings to drinking water before treatment. All water treatment systems will obtain appropriate approval from the responsible authorities, and the type of treatment and the capacity of the facility will be able to achieve water quality standards as stated in the permit. After treatment, potable water will be distributed to the main facilities and the camps. Bottled water will be made available to workers in areas away from the main facilities. Drinking water quality health effects in the construction, operation, closure, and post-closure phases of the Project are not anticipated. Therefore, health effects from drinking water sources for on- and off-shift workers were not included in the assessment.

The (unincorporated) settlements closest to the Project (Bob Quinn Lake and Bell II) are upstream of the Project area and will not be affected by Project activities, and were therefore not included in the assessment.

Recreational water quality is based on bacterial counts in recreational waterbodies (e.g., Unuk River). Sewerage effluent can be a potential source for bacterial contamination. However, secondary wastewater treatment systems with disinfection will be installed at all camps and facilities, and this will allow safe discharge into the environment during the construction, operation, and closure phases of the Project. The Proponent will conduct monitoring and maintenance, which will reduce the potential that bacteria will enter the environment and affect human health due to ingestion of, or contact with, surface water. Recreational users in the waterbodies downstream of Project sites are unlikely to encounter bacterial contamination, and human health effects from contact with recreational waters have therefore been scoped out from the assessment.

Potential human health effects from the ingestion of surface water with elevated metal concentrations depend on the toxicity of the metal, whether the body is able to efficiently eliminate the metal, whether the metal can bioaccumulate, and the amount of water that is consumed. Due to the remoteness of the Project and the temporary and seasonal use of the areas near and downstream of proposed Project infrastructure, it is unlikely that consumption amounts will be high enough for metals to pose a human health risk. However, to determine the extent of potential residual human health effects, predicted changes to water quality were reviewed from Chapter 14 (Surface Water Quality). The modelled predictions (Appendix 14-H) include Project designs that will mitigate effects to water quality, such as water treatment and water diversions.

#### 25.7.1.1 Mitigation for Changes in Drinking and Recreational Water Quality

Mitigation to reduce effects to human health from the ingestion of drinking water relies on mitigation measures that reduce effects to water quality. The Project has been designed with the goal to minimize negative effects on water quality downstream of the Mine Site and the TMF. Mitigation measures that are additional to those outlined in other sections of the Application/EIS (Chapter 14) are not anticipated to be required. All contact and waste water as well as tailing slurry water will be treated before discharge and will meet discharge criteria.

Aboriginal peoples and other hunters, trappers, and recreationists are predicted to periodically access surface water for accidental or intended ingestion from waterbodies downstream of the Project during all phases of the Project. The access to the operating and closed Mine Site and PTMA is going to be controlled (Section 26.25, Traffic and Access Management Plan).

However, it is expected that the use of the area and the remaining Project roads in post-closure by hunters, trappers, and recreationists will increase after mine closure and reclamation.

Mitigation will include posting signs around the TMF indicating that the water is not potable and that no public access is permitted until after the mine is closed. Therefore, the potential for people to consume or be exposed to this water is unlikely during operation. Upon closure, water quality at the TMF will be monitored (Chapter 27, Closure and Reclamation) as part of a risk approach to wildlife use of the TMF. Should water quality unexpectedly decrease in the TMF, thereby creating a risk that concentrations in downstream creeks approach BC and Canadian drinking water guideline amounts, additional mitigation will be developed. A risk assessment may be considered to identify the safety of the water in downstream creeks for human use.

To quantify residual risks to human health due to metals of concern in surface waters downstream of the Mine Site, water quality monitoring is recommended according to the Aquatic Effects Monitoring Plan (Section 26.18) and the Closure and Reclamation Plan (Chapter 27) to ensure that effluent meets discharge permit limits.

On-site drinking water for workers will be treated to applicable drinking water guidelines and therefore will not affect the health of off-duty workers. Details of drinking water permits and monitoring plans will be provided in the permit application. If at some point during the Project the water fails to meet drinking water permit levels or there is a risk that the source will become contaminated, the contingency plan would likely include bringing bottled water to the site temporarily until the system is stabilized and restored.

#### 25.7.1.2 Potential for Residual Effects

A residual effects assessment was prepared to determine the extent of potential residual human health effects due to predicted changes to water quality (Chapter 14, Surface Water Quality; Appendix 14-H). The modelled predictions include Project designs that will mitigate potential effects to water quality.

Based on the areas of use, the spatial boundary for this effects assessment includes all watercourses downstream of the Mine Site and the TMF closest to the Project footprint and accessible to the public. The main area identified as having potential effects was the TMF in the PTMA, but only during closure and post-closure phases and only in the case that people are able to access the TMF.

To assess potential health effects from changes in surface drinking water quality, the predicted water quality data for metals and other contaminants (described in Chapter 14, Surface Water Quality; Appendix 14-H) in waterbodies accessed by the public downstream of the Project have been compared to approved BC water quality guidelines for drinking water (BC MOE 2006) and to guidelines for Canadian drinking water quality (Health Canada 2012). Drinking water guidelines are developed to be protective of public human health and were therefore selected as a benchmark.

The predicted maxima of monthly averages of water quality during base flow at likely water use sites downstream of Project components were used for a conservative comparison to the guidelines. Where predicted maxima were higher than guidelines, the contaminants of potential concern (COPC) were scoped into an SLRA, as required by the AIR. If modelled predictions were not higher than drinking water guidelines, risks to human health from drinking water would not exist and an SLRA was therefore not conducted.

Downstream of the TMF, receiving environment monitoring stations TEC2 (Teigen Creek 2) and TRC2 (Treaty Creek 2) were chosen as the sites closest to, but upstream of, known land use sites. The TMF (North Cell, South Cell, CIL) was included as the site of highest concern to water quality during and after the Project is closed. At the Mine Site, SC3 (Sulphurets Creek 3) and UR1 (Unuk River 1), which are close to the confluence of the two rivers, were chosen as water monitoring sites closest to documented land use sites. This approach provides a conservative estimate of the water quality that people may be exposed to.

Results for the Processing and Tailing Management Area

Table 25.7-1 provides a summary of predicted parameters and a factor describing how much higher than guideline the parameter is expected to be during certain Project phases, based on average source terms and base flow conditions. The maxima of the monthly averages were screened to provide a level of conservatism. The base flow is the condition that will most likely occur during the life of the Project.

The predicted concentrations of BC drinking water quality guideline metals, nutrients, and cyanide do not exceed the guidelines at TEC2 and TRC2 during operation, closure, and post-closure (Table 25.7-1). Based on the results, and on the temporary and seasonal nature of the land use, there is no concern for human health effects from the consumption of surface water from Teigen and Treaty creeks downstream of the TMF. Therefore the magnitude of effects is considered negligible at these locations.

Inside the TMF, the following predicted parameters were higher than BC drinking water guidelines (BC MOE 2006) during operation and closure: fluoride, antimony, arsenic, cyanide, nitrate, and selenium. All of these parameters are for health-based guidelines and are expected to be below guidelines by Year 55, during mine closure (Chapter 14, Surface Water Quality).

Although it is not expected that people will have access to and will drink from the TMF during operation and closure, a preliminary SLRA was performed for toddlers and adult receptors to assess any health concerns that may exist should people access the TMF accidentally. Water intake rates were based on Richardson (1997; 1.40 L/day and 0.65 L/day for adults and toddlers, respectively), and a daily dose was compared to the toxicity reference values (TRVs; Health Canada 2010c, US EPA IRIS 2012). Table 25.7-2 lists the resulting exposure ratios (ERs). An ER of less than 0.2 represents exposure that does not pose a significant health risk to human receptors (Health Canada 2010d). Health Canada considers an ER value of 0.2 appropriate, because only one exposure pathway is evaluated for human health, and it is assumed that people are exposed to COPC from multiple sources, such as food, soil, air, cigarettes, and cigarette second-hand smoke. ER values greater than 0.2 do not necessarily indicate that adverse health effects will occur, since the TRVs are conservative and protect human health based on the application of uncertainty factors. ERs are not a measure of actual risk, but are rather measures of level of concern (Tannenbaum, Johnson, and Bazar 2003).

**Table 25.7-1. Summary of Frequency and Magnitude that Predicted Water Quality Concentrations were Higher than Drinking and Recreational Water Quality Guidelines**

| Parameter | Fluoride (F) | | Antimony | | Arsenic (As) | | Barium (Ba) | | Boron (B) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Guideline | 1.5 mg/L | | 0.006 mg/L | | 0.025 mg/L | | 1 mg/L | | 5 mg/L | |
| Jurisdiction | BC Maximum and Canadian MAC | | Canadian MAC | | BC | | Canadian MAC | | BC and Canadian MAC | |
| Water Monitoring Station | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor |
| TRC2 | - | - | - | - | - | - | - | - | - | - |
| TEC2 | - | - | - | - | - | - | - | - | - | - |
| NC (TMF) | Operation | 6.3 | - | - | Operation | 1.8 | - | - | - | - |
| SC (TMF) | Operation, Closure | 5 | - | - | Operation, Closure | 1.5 | - | - | - | - |
| CIL (TMF) | - | - | Operation, Closure | 2.8 | - | - | - | - | - | - |
| SC3 | - | - | - | - | - | - | - | - | - | - |
| UR1 | - | - | - | - | - | - | - | - | - | - |

| Parameter | Cadmium (Cd) | | Chromium (Cr) | | SAD-Cyanide and Thiocyanate (CN)[1] | | Lead (Pb) | | Mercury (Hg) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Guideline | 0.005 mg/L | | 0.05 mg/L | | 0.2 mg/L | | 0.05 mg/L | | 0.001 mg/L | |
| Jurisdiction | Canadian MAC | | Canadian MAC | | BC and Canadian MAC | | BC Maximum | | BC and Canadian MAC | |
| Water Monitoring Station | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor |
| TRC2 | - | - | - | - | - | - | - | - | - | - |
| TEC2 | - | - | - | - | - | - | - | - | - | - |
| NC (TMF) | - | - | - | - | - | - | - | - | - | - |
| SC (TMF) | - | - | - | - | - | - | - | - | - | - |
| CIL (TMF) | - | - | - | - | Operation, Closure | 2.3 | - | - | - | - |
| SC3 | - | - | - | - | - | - | - | - | - | - |
| UR1 | - | - | - | - | - | - | - | - | - | - |

| Parameter | Molybdenum (Mo) | | Nitrate ($NO_3$ as N) | | Nitrite ($NO_2$ as N) | | Selenium (Se) | | Uranium (U) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Guideline | 0.25 mg/L | | 10 mg/L | | 1 mg/L | | 0.01 mg/L | | 0.02 mg/L | |
| Jurisdiction | BC Drinking Water | | BC and Canadian MAC | | BC and Canadian MAC | | BC and Canadian MAC | | Canadian MAC | |
| Water Monitoring Station | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor | Project Phase | Maximum Factor |
| TRC2 | - | - | - | - | - | - | - | - | - | - |
| TEC2 | - | - | - | - | - | - | - | - | - | - |
| NC (TMF) | - | - | Operation | 7.6 | - | - | Operation | 5.4 | - | - |
| SC (TMF) | - | - | Operation, Closure | 6.2 | - | - | Operation, Closure | 4.5 | - | - |
| CIL (TMF) | - | - | - | - | - | - | Operation, Closure | 5.3 | - | - |
| SC3 | - | - | - | - | - | - | - | - | - | - |
| UR1 | - | - | - | - | - | - | - | - | - | - |

**Notes: Predictions are based on monthly water quality concentrations for base flow and average source terms for operation, closure, and post-closure**

**MAC Health-based maximum acceptable concentration**

**[1] Weak-acid dissociable cyanide is modelled**

## Table 25.7-2. Exposure Ratios and Incremental Lifetime Cancer Risk for Parameters that are Higher than the British Columbia Drinking Water Guidelines

| Receptor | Monitoring Station | Phase | Exposure Ratio | | | | | | ILCR |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Fluoride** | **Nitrate** | **Cyanide** | **Antimony** | **Arsenic** | **Selenium** | **Arsenic** |
| Adult | North Cell | Operation | **1.78** | **0.945** | 0.046 | 0.168 | **3.03** | 0.189 | **8.17E-05** |
| | | Closure | 0.00418 | 0.000939 | 0.000453 | 0.00273 | 0.00333 | 0.0015 | 8.97E-09 |
| | South Cell | Operation | **1.78** | **0.945** | 0.046 | 0.168 | **3.03** | 0.189 | **8.17E-05** |
| | | Closure | 0.00418 | 0.000939 | 0.000453 | 0.00273 | 0.00333 | 0.0015 | 8.97E-09 |
| | CIL | Operation | **1.78** | **0.945** | 0.046 | 0.168 | **3.03** | 0.189 | **8.17E-05** |
| | | Closure | 0.00418 | 0.000939 | 0.000453 | 0.00273 | 0.00333 | 0.0015 | 9.02E-11 |
| Toddler | North Cell | Operation | **3.54** | **1.88** | 0.0915 | **0.333** | **6.03** | **0.344** | **1.63E-04** |
| | | Closure | 0.00831 | 0.00187 | 0.0009 | 0.00544 | 0.00661 | 0.00274 | 1.78E-08 |
| | South Cell | Operation | **3.54** | **1.88** | 0.0915 | **0.333** | **6.03** | **0.344** | **1.63E-04** |
| | | Closure | 0.00831 | 0.00187 | 0.0009 | 0.00544 | 0.00661 | 0.00274 | 1.78E-08 |
| | CIL | Operation | **3.54** | **1.88** | 0.0915 | **0.333** | **6.03** | **0.344** | **1.63E-04** |
| | | Closure | 0.00831 | 0.00187 | 0.0009 | 0.00544 | 0.00661 | 0.00274 | 1.78E-08 |

**Highlighted and bolded values indicate a HQ>1**

**Bolded values indicate a HQ>0.2**

Fluoride, nitrate, and arsenic have exposure ratios above 0.2 for adults, while fluoride, nitrate, antimony, arsenic, and selenium have ERs above 0.2 for toddlers during operation, but below 0.2 during closure for all receptors (Table 25.7-2). An exposure ratio above 0.2 does not necessarily indicate a risk, but confirms that mitigation must be in place to avoid potential health hazards, such as access restrictions and signage for the public.

An incremental lifetime cancer risk (ILCR) was calculated for arsenic, because Health Canada considers arsenic to be a cancer-causing agent (Health Canada 2006). The calculations rely on the formula provided by Health Canada (2010b):

$$ILCR = \text{Estimated lifetime daily exposure (mg/kg BW/day)} \times \text{Oral cancer slope factor (mg/kg BW/day)}^{-1}$$

Exceedance of an exposure ratio for arsenic of 0.2 and an ILCR of $10^{-5}$ are only predicted during operation, but not during closure. Because water quality further improves during post-closure, benchmark exceedance is not expected during post-closure.

Health Canada (2006) considers arsenic a cancer-causing agent for people consuming water with very high levels of arsenic over a lifetime. Short-term exposure to high levels of arsenic can cause a variety of non-cancer health effects. The temporary use of the area and the predicted low concentrations after closure make these health effects from arsenic unlikely, given that for most Canadians, the primary source of exposure to arsenic is food (Health Canada 2006).

High doses of fluoride can cause skeletal fluorosis, but again the temporary nature of the use of the area and the predicted low concentrations after closure make this health effect from fluoride unlikely.

Nitrate is considered of low toxicity, but the endogenous reduction to nitrite and N-nitroso compounds can cause toxicity (methemoglobinemia), especially in infants, during long-term exposure. However, the temporary nature of the use of the area, mostly by adults, and the predicted low concentrations after closure make any health effect from nitrate unlikely.

People using the area at the TMF in the post-closure phase of the Project only have the potential for residual health effects should they consume the water on a regular basis, and should concentrations of metals and cyanide be higher than predicted by the model and higher than guideline concentrations. Posted signs will clearly indicate that water in the TMF is not potable. Hazard quotients for assessed parameters decrease to below 0.2 during closure and are expected to remain below 0.2 during post-closure based on modelled predictions. Health risks are therefore expected to be negligible during operation and closure (no public access), but estimated as low during post-closure due to an increase in uncertainty in predictions and permitted access. A summary of potential effects to human health from changes in drinking water quality is provided in Table 25.7-3.

<u>Results for Downstream of Mine Site</u>

The predicted concentrations (Appendix 14-H) of metals, nutrients, and cyanide do not exceed BC and Canadian drinking water guidelines (BC MOE 2006, Health Canada 2012) at SC3 and UR1 during operation, closure, and post-closure.

If metal and nutrient concentrations at monitoring stations closest to the infrastructure are not higher than BC and Canadian drinking water guidelines, concentrations at stations downstream (Unuk River) will also not be higher than guidelines. BC and Canadian drinking water guidelines are protective of human health. People hunting, trapping, or recreating in the Unuk River Valley are unlikely to be exposed to concentrations of metals or nutrients above drinking water criteria. Given the infrequent and temporary access to the area by the public, especially downstream of the Mine Site, residual effects to human health due to the ingestion of surface water at these sites are considered negligible during all phases of the Project. A summary of potential effects to human health from changes in drinking water quality is provided in Table 25.7-3.

Summary

Aboriginal peoples and other hunters, trappers, and recreationists are predicted to periodically access surface water for accidental or intended ingestion from waterbodies downstream of the Project. The human health effects assessment demonstrated that water should be safe to consume, provided water is boiled and access restrictions to the TMF and Mine Site are in place during operation and closure activities. Health Canada advises that surface water should never be consumed without treatment (Health Canada 2011c). This is the standard protocol for any natural waterbody that is used for consumption, as no waterbody is technically potable, independent of whether a mine is present. However, water metal concentration levels and land use will be monitored throughout the life of the mine.

### 25.7.2 Changes in Health due to Air Quality

The purpose of the air quality effects assessment was to evaluate the potential for Project activities to affect human health through the inhalation of air contaminants. The rationale for this evaluation was that people use the area near the PTMA and, less frequently, the area near the Mine Site for hunting, trapping, berry picking, and recreation, and will inhale potential contaminants in the air that could be emitted from the Project.

Although everyone is at risk from the health effects of air pollution, certain individuals are more susceptible (Health Canada 2004b). Sensitive individuals who are more susceptible to respiratory pollution may feel the effects more acutely, or at lower levels than the average person in the population. Typically children, the elderly, and people with cardio-respiratory health problems (e.g., asthma or chronic bronchitis) are the most susceptible (Health Canada 2009). However, the Project is in a remote location, and children and the elderly are highly unlikely to be in the vicinity of dust and other potential air quality effects from the Project. Public access to the Project sites will be controlled. Subsequently, health effects from the exposure to air pollution will be assessed for individuals that are present near the Project sites during construction and operation, who are adults with a sensitivity to air pollution of an average normal population. Construction and operation phases are predicted to have the highest air emissions and therefore, closure and post-closure phases were not included in the assessment.

The nearest land users to the proposed Mine Site and access roads are individuals who frequent the trapping and hunting cabins along the Unuk and South Unuk rivers and the Teigen Creek, Bell-Irving River, and Treaty Creek corridors and residents of Bell II and Bob Quinn Lake. Off-shift mine employees residing in mining camps at the Project sites will also be exposed to changes in air quality and will be included in the air quality effects assessment. On-shift mine employees were not selected as VCs because worker health will be addressed in the Health and Safety Management Plan that will be developed during the permitting process.

The potential human health effects resulting from poor air quality involve the body's respiratory and cardiovascular systems, and may range from subtle biological and physical changes to difficulty breathing, wheezing, coughing, and aggravation of existing respiratory and cardiac conditions. Individual reactions depend on the type of air pollutant, the degree of exposure, and the individual's health status and genetics. These effects can result in increased medication use, increased doctor and emergency room visits, a higher number of hospital admissions, and even premature death (Health Canada 2004b). The following is a list of the major air pollutants that were modelled for the construction and operation phases of the Project (Chapter 7), and their potential human health effects at elevated concentrations:

- nitrogen oxides ($NO_x$): Exposure to elevated levels can decrease lung function and lung function growth in children, irritate the respiratory system, and make breathing difficult;
- sulphur dioxide ($SO_2$): Causes increased breathing resistance, wheezing, shortness of breath, coughing, and sore throat. $SO_2$ can cause breathing problems in people with asthma;
- airborne particles: Fine particles (i.e., $PM_{2.5}$ and $PM_{10}$) pose a great threat to human health as they can travel into and lodge themselves deeply in the lungs. They cause coughing, breathing difficulties, reduced lung function, an increased use of asthma medication, and irritation of the eyes and nose, and can cause lung cancer; and
- carbon monoxide (CO): CO can decrease athletic performance and aggravate cardiac symptoms. It can also cause flu-like symptoms such as headache, fatigue, nausea, vomiting, increased heart rate, and impaired mental and cognitive function.

Other air contaminants, including toxic metals (e.g., cadmium, chromium, nickel, and manganese), contribute to specific metal toxicity and can cause cancer by inhalation. Ozone was not modelled for the Project because it is not a primary pollutant emitted from Project activities (Chapter 7). Ozone is generated in the atmosphere as a secondary pollutant, which is formed when sunlight reacts with volatile organic compounds and oxides of nitrogen. The model on which the air emissions were based is not appropriate for estimating secondary products. In addition, the air quality modellers suggest that the formation of secondary pollutants due to the emissions of primary pollutants would be negligible.

The potential health effects listed above do not represent an exhaustive list, but the most common direct health effects are listed to provide rationale for their inclusion in the health effects assessment. Indirect effects from air pollution generally include restricted activity days, lost school days, lost work days, unscheduled hospital admissions, and an increase in mortality. These indirect effects can be a result of air pollution–related illnesses.

## Table 25.7-3. Potential Residual Effects on Human Health Due to Changes in Drinking Water Quality

| VC | Timing Start | Project Area(s) | Component(s) | Description of Effect due to Component(s) | Type of Project Mitigation | Project Mitigation Description | Potential Residual Effect | Description of Residuals |
|---|---|---|---|---|---|---|---|---|
| Health of public (hunters, trappers, recreationists) | Operation, Closure, Post-closure | PTMA and Mine Site | Effluents from water treatment plant, run-off and seepage from RSF, TMF, ore preparation complex, and access roads | Negative acute and chronic health effects from the ingestion of metals in surface water downstream of Project infrastructure and activities | Alternative, Design Change, Management Practices, Monitoring and Adaptive Management | Drinking water for camps (well or surface) will be treated to applicable drinking water guidelines.<br>Surface water quality will be monitored, mitigation strategies will be adjusted accordingly to meet applicable guidelines according to the Aquatic Effects Monitoring Plan.<br>Control, monitor and treat run off and leachate from rock storage sites, ore preparation complex and other sites with exposed rock.<br>Control potential spills according to the Spill Prevention and Emergency Response Plan.<br>Control public access to Project sites according to the Land Use Management Plan. | Yes | Negative acute and chronic health effects (ER, ILCR) from the ingestion of metals in surface water from the TMF and downstream of Mine site |

Combustion sources of $PM_{2.5}$ are of particular concern when examining air quality and human exposure. They are produced during the combustion of diesel and other fuels. Epidemiological and toxicological studies have shown combustion-derived particles (e.g., from incinerators and diesel engines) are more toxic than non-combustion derived particles (e.g., road dust or fugitive dust). Some of the potential effects associated with inhaling combustion particulates include:

- lung inflammation and increasing response to an inhaled allergen;
- acute respiratory illnesses in children; and
- lung cancer.

The fraction of PM recognized as having the greatest effect on human health is the fine fraction, $PM_{2.5}$. There is no recognized threshold of health effects for $PM_{2.5}$, and there is evidence that adverse health effects occur at current levels of exposure commonly found in- or outdoors in Canada (Health Canada 2011a).

Predominant Project emissions are expected from the use of diesel as a fuel, from travel along unpaved roads, from blasting and ore preparation, and from the combustion of solid wastes at the camps. Diesel engines emit hydrocarbons, carbon monoxide, and fine PM harmful to human health, and were an input parameter to the air quality model. The Project is expected to contribute to air emissions from the combustion of diesel for transportation throughout the Project time frame, and for power generation during construction and operation. Diesel emissions will be reduced during the closure and post-closure phases of the Project.

Incinerators will be used at all camps during construction and operation to manage combustible solid wastes and to reduce the need for transportation and disposal of solid wastes off-site. Combustion of wastes will result in the release of air contaminants to the environment during construction, operation, and closure, and can have potential effects to human respiratory health.

Air quality health effects may also result from rock blasting in Mine Site pits and at the Mitchell Ore Preparation Complex (OPC). The detonation of explosives generates potentially harmful gases such as carbon monoxide, oxides of nitrogen, ammonia, and sulphur dioxide. Blasting will also create PM that is potentially harmful to human health and high in metal concentrations. However, it is expected that blasting effects will be localized (Chapter 7) and will therefore have a very limited effect on the health of off-duty workers and off-site people. PM can be generated from blasting, from transportation along unpaved roads (from the road dust itself, from dust emissions from the concentrate, or from the combustion of diesel), and from the moving and crushing of rock and ore. While $PM_{10}$ is produced primarily by mechanical processes (e.g., construction activities, blasting, road dust re-suspension, and wind), $PM_{2.5}$ originates primarily from combustion sources. Of special concern are heavy metals, as they are persistent in the environment, bioaccumulative in food chains, and can have direct toxic effects due to inhalation. Since copper is the ore in the area, copper deposition rates and concentration in air could increase after Project commencement if dust increases, and may have negative effects on human respiratory health.

### 25.7.2.1 Mitigation for Changes in Air Quality

Mitigation to reduce effects to human health from the inhalation of air contaminants relies on mitigation measures that reduce effects to air quality. Mitigation will be applied at the source of the emissions. Source mitigation will be applied with the goal to reduce emissions and fugitive dust due to Project activities. Both an Emissions Management Plan (Section 26.11.1) and a Fugitive Dust Emissions Management Plan (Section 26.11.2) will be implemented to meet the BC Ministry of Environment's (BC MOE 2009) Air Quality Standards. Emission control systems (e.g., scrubbers, baghouses, and filters) will be used on stacks and relevant ventilation systems to reduce emissions. Vehicles will be maintained regularly, low sulphur diesel will be used, and catalytic converters and diesel particulate filters will be installed on diesel engines. A no-idling policy will be implemented. Access roads and site roads will be managed, such as with water sprays and maintenance of an appropriate surface material, to limit generation of fugitive dust. Hauled concentrate will be covered. The drop-down distances between conveyer belt and stockpiles will be reduced as much as feasible and/or dust skirts will be used. Fugitive dust will be minimized at stockpiles and concentrate load-out facilities as much as possible.

Mitigation for human receptors will include the monitoring of air quality and fugitive dust emissions associated with the site activities during construction and operation (Air Quality Management Plan, Section 26.11). Emissions will be monitored and equipment tested to establish the emissions associated with the Project activities. Fugitive dust will be monitored at ten key locations over 30-day periods during summer and fall in conjunction with air quality monitoring. Details of any adverse findings will be recorded and reported as required by regulatory authorities. If a particular area or process becomes an issue, adaptive management policies will be implemented.

### 25.7.2.2 Potential for Residual Effects

To assess the potential for residual air quality effects on human health, data from the CALPUFF air dispersion model was used (Section 7.8.1). A description and interpretation of the results of the modelling is presented in Chapter 7, and in Tables 25.7-4 and 25.7-5. The nearest sensitive human receptor sites were modelled to represent human receptors at the communities of Bell II and Bob Quinn Lake, trapline cabins, hunting cabins, and the Project camps. Figure 25.7-1 represents the sensitive human health receptors and model results for annual total $PM_{2.5}$ during operation.

For the human health residual effects assessment, four different endpoints were evaluated. First, effects were based on comparison of background and modelled air contaminant concentrations ($NO_2$, $SO_2$, CO, TPM, $PM_{2.5}$, $PM_{10}$) to BC and Canada air quality objectives and standards (BC MOE 2009).

Second, consistent with the AIR, baseline data and predicted levels of air contaminants were assessed using Health Canada's guidance document on estimating the number of excess deaths in Canada due to air pollution ($PM_{2.5}$), since $PM_{2.5}$ is considered a no-threshold pollutant. This assessment is based on 43 regression studies that show that daily or short-term variations in small PM were significantly associated with increases in non-accidental mortality in 20 cities across North America, South America, and Europe (Health Canada 1999).

Third, the modelled dust metal concentrations were defined as risks or as a hazard quotient (HQ) for the potential human health effects for the inhalation of metals.

## Table 25.7-4. Air Quality Background and Model Results for the Construction Phase for Sensitive Human Receptors

| Pollutant | | Averaging Period | Criteria: Canadian Standards | Criteria: BC Objectives | Background | Off-site: Existing Exploration Camp | Off-site: Existing Exploration Camp | Off-site: Municipality Bob Quinn Lake | Off-site: Community Bell II | Off-site: Trapline Cabin | Off-site: Trapline Cabin | Off-site: Trapline Cabin | Off-site: Trapline Cabin | Off-site: Bowser Lake Hunting Cabin | Off-site: Skii km Lax Ha Cabin East | Off-site: Skii km Lax Ha Cabin West |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Concentrations (µg/m³) | | | | | | | | | | | | | |
| $SO_2$ | | 1-hour | 450 | 450 | 4 | 7.50 | 4.56 | 4.05 | 4.37 | 5.17 | 5.82 | 4.56 | 4.37 | 4.23 | 4.26 | 4.33 |
| | | 24-hour | 150 | 160 | 4 | 4.29 | 4.07 | 4.01 | 4.07 | 4.09 | 4.20 | 4.08 | 4.06 | 4.03 | 4.04 | 4.04 |
| | | Annual | 30 | 25 | 2 | 2.02 | 2.01 | 2.00 | 2.01 | 2.01 | 2.01 | 2.01 | 2.00 | 2.00 | 2.00 | 2.00 |
| $NO_2$ | | 1-hour | 400 | - | 21 | 70.2 | 48.0 | 21.8 | 33.8 | 39.7 | 49.2 | 34.8 | 27.0 | 25.5 | 25.1 | 26.0 |
| | | 24-hour | 200 | - | 21 | 25.3 | 23.7 | 21.1 | 22.7 | 22.4 | 23.9 | 22.0 | 21.9 | 21.7 | 21.8 | 21.8 |
| | | Annual | 60 | - | 5 | 5.20 | 5.32 | 5.00 | 5.12 | 5.08 | 5.14 | 5.06 | 5.04 | 5.06 | 5.08 | 5.09 |
| CO | | 1-hour | 15,000 | 14,300 | 100 | 481 | 152 | 103 | 136 | 191 | 319 | 145 | 122 | 118 | 113 | 117 |
| | | 8-hour | 6,000 | 5,500 | 100 | 179 | 114 | 101 | 114 | 118 | 146 | 113 | 108 | 105 | 106 | 106 |
| Fuel combustion (or non-fugitive) | TSP | 24-hour | 120 | 150 | 10 | 10.9 | 10.3 | 10.0 | 10.2 | 10.3 | 10.6 | 10.2 | 10.2 | 10.1 | 10.1 | 10.1 |
| | | Annual | 60 | 60 | 10 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 4.22 | 3.68 | 3.43 | 3.59 | 3.63 | 3.90 | 3.58 | 3.55 | 3.48 | 3.50 | 3.50 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 1.61 | 1.48 | 1.31 | 1.40 | 1.44 | 1.55 | 1.40 | 1.38 | 1.36 | 1.38 | 1.38 |
| | | Annual | - | 8 | 1.3 | 1.33 | 1.33 | 1.30 | 1.32 | 1.32 | 1.32 | 1.31 | 1.31 | 1.31 | 1.31 | 1.31 |
| Fugitive | TSP | 24-hour | 120 | 150 | 10 | 21.5 | 12.1 | 10.3 | 12.1 | 12.7 | 16.2 | 12.2 | 11.2 | 10.9 | 11.0 | 11.0 |
| | | Annual | 60 | 60 | 10 | 10.4 | 10.3 | 10.0 | 10.1 | 10.2 | 10.3 | 10.1 | 10.1 | 10.1 | 10.1 | 10.1 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 7.71 | 4.13 | 3.50 | 4.17 | 4.39 | 5.66 | 4.19 | 3.85 | 3.72 | 3.75 | 3.76 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 1.56 | 1.37 | 1.31 | 1.35 | 1.38 | 1.47 | 1.36 | 1.33 | 1.33 | 1.33 | 1.33 |
| | | Annual | - | 8 | 1.3 | 1.32 | 1.31 | 1.30 | 1.31 | 1.31 | 1.32 | 1.31 | 1.30 | 1.30 | 1.31 | 1.31 |
| Total | TSP | 24-hour | 120 | 150 | 10 | 22.4 | 12.4 | 10.3 | 12.3 | 13.0 | 16.8 | 12.4 | 11.3 | 11.0 | 11.1 | 11.1 |
| | | Annual | 60 | 60 | 10 | 10.5 | 10.3 | 10.0 | 10.2 | 10.2 | 10.4 | 10.2 | 10.1 | 10.1 | 10.1 | 10.1 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 8.53 | 4.37 | 3.53 | 4.34 | 4.62 | 6.15 | 4.35 | 3.95 | 3.79 | 3.84 | 3.85 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 1.85 | 1.55 | 1.32 | 1.45 | 1.52 | 1.72 | 1.45 | 1.41 | 1.37 | 1.41 | 1.42 |
| | | Annual | - | 8 | 1.3 | 1.35 | 1.35 | 1.30 | 1.33 | 1.32 | 1.34 | 1.32 | 1.31 | 1.31 | 1.32 | 1.32 |
| Dust deposition (mg/m³/day) | | 30-day | - | 1.7 to 2.9 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 |
| Acid deposition (eq/ha/yr) | | annual | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |

| Pollutant | | Averaging Period | Criteria: Canadian Standards | Criteria: BC Objectives | Background | Camps: 5 | Camps: 6 | Camps: 10 | Camps: 11 | Camps: 1 | Camps: 2 | Camps: 3 | Camps: 4 | Camps: 7 | Camps: 8 | Camps: 9 | Camps: 12 | Camps: Mitchell | Camps: Treaty |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Concentrations (µg/m³) | | | | | | | | | | | | | | | | |
| $SO_2$ | | 1-hour | 450 | 450 | 4 | 4.90 | 4.93 | 13.77 | 4.18 | 4.08 | 7.79 | 5.29 | 11.2 | 6.25 | 5.99 | 14.07 | 4.17 | 7.13 | 4.95 |
| | | 24-hour | 150 | 160 | 4 | 4.16 | 4.14 | 5.47 | 4.03 | 4.02 | 4.40 | 4.18 | 5.32 | 4.27 | 4.25 | 5.54 | 4.03 | 4.39 | 4.15 |
| | | Annual | 30 | 25 | 2 | 2.03 | 2.02 | 2.05 | 2.01 | 2.00 | 2.02 | 2.01 | 2.12 | 2.02 | 2.01 | 2.06 | 2.00 | 2.02 | 2.02 |
| $NO_2$ | | 1-hour | 400 | - | 21 | 157 | 93.8 | 100 | 26.3 | 22.1 | 74.6 | 51.0 | 96.9 | 54.9 | 50.9 | 106 | 24.9 | 62.0 | 174 |
| | | 24-hour | 200 | - | 21 | 92.3 | 41.3 | 60.3 | 21.9 | 21.5 | 27.6 | 27.5 | 40.8 | 25.2 | 24.9 | 51.1 | 21.7 | 26.7 | 91.5 |
| | | Annual | 60 | - | 5 | 33.2 | 7.09 | 9.05 | 5.14 | 5.02 | 5.22 | 5.70 | 7.02 | 5.27 | 5.20 | 8.48 | 5.08 | 5.26 | 27.0 |
| CO | | 1-hour | 15,000 | 14,300 | 100 | 311 | 157 | 1244 | 118 | 107 | 514 | 168 | 871 | 329 | 274 | 1361 | 109 | 507 | 363 |
| | | 8-hour | 6,000 | 5,500 | 100 | 157 | 128 | 484 | 109 | 105 | 256 | 121 | 499 | 167 | 160 | 541 | 105 | 187 | 158 |
| Fuel combustion (or non-fugitive) | TSP | 24-hour | 120 | 150 | 10 | 11.7 | 10.9 | 21.6 | 10.1 | 10.1 | 12.1 | 10.5 | 29.3 | 10.8 | 10.7 | 26.8 | 10.1 | 11.1 | 11.6 |
| | | Annual | 60 | 60 | 10 | 10.6 | 10.1 | 10.6 | 10.0 | 10.0 | 10.0 | 10.1 | 11.4 | 10.0 | 10.0 | 10.7 | 10.0 | 10.1 | 10.4 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 4.98 | 4.19 | 13.6 | 3.51 | 3.50 | 5.27 | 3.85 | 20.4 | 4.09 | 4.03 | 18.2 | 3.49 | 4.37 | 4.79 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 2.43 | 1.66 | 7.36 | 1.37 | 1.34 | 1.61 | 1.64 | 7.23 | 1.59 | 1.61 | 8.90 | 1.36 | 1.70 | 2.27 |
| | | Annual | - | 8 | 1.3 | 1.78 | 1.39 | 1.75 | 1.32 | 1.30 | 1.34 | 1.37 | 2.51 | 1.34 | 1.33 | 1.86 | 1.31 | 1.34 | 1.69 |
| Fugitive | TSP | 24-hour | 120 | 150 | 10 | 17.7 | 15.4 | 53.5 | 13.2 | 10.7 | 29.4 | 13.0 | 54.7 | 19.4 | 18.0 | 55.8 | 10.9 | 23.6 | 17.9 |
| | | Annual | 60 | 60 | 10 | 12.1 | 10.6 | 11.3 | 10.7 | 10.0 | 10.5 | 10.5 | 13.0 | 11.0 | 10.6 | 11.5 | 10.1 | 10.6 | 12.0 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 5.73 | 5.05 | 19.5 | 4.31 | 3.66 | 10.7 | 4.45 | 19.9 | 6.73 | 6.29 | 20.3 | 3.73 | 8.40 | 5.78 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 1.88 | 1.52 | 1.66 | 1.37 | 1.31 | 1.45 | 1.39 | 2.07 | 1.49 | 1.48 | 1.69 | 1.33 | 1.56 | 1.94 |
| | | Annual | - | 8 | 1.3 | 1.47 | 1.36 | 1.36 | 1.32 | 1.30 | 1.32 | 1.32 | 1.43 | 1.34 | 1.33 | 1.37 | 1.31 | 1.33 | 1.48 |
| Total | TSP | 24-hour | 120 | 150 | 10 | 18.5 | 16.2 | 63.2 | 13.2 | 10.8 | 31.5 | 13.5 | 62.6 | 20.2 | 18.7 | 70.3 | 11.0 | 24.6 | 18.7 |
| | | Annual | 60 | 60 | 10 | 12.7 | 10.7 | 11.9 | 10.8 | 10.0 | 10.5 | 10.6 | 14.4 | 11.1 | 10.7 | 12.2 | 10.1 | 10.6 | 12.5 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 6.47 | 5.84 | 28.1 | 4.32 | 3.76 | 12.6 | 4.86 | 27.0 | 7.42 | 6.92 | 33.2 | 3.81 | 9.29 | 6.46 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 2.65 | 1.88 | 8.63 | 1.43 | 1.35 | 1.84 | 1.72 | 7.91 | 1.78 | 1.81 | 10.3 | 1.39 | 1.91 | 2.59 |
| | | Annual | - | 8 | 1.3 | 1.95 | 1.45 | 1.81 | 1.34 | 1.31 | 1.36 | 1.39 | 2.64 | 1.37 | 1.36 | 1.93 | 1.32 | 1.37 | 1.87 |
| Dust deposition (mg/m³/day) | | 30-day | - | 1.7 to 2.9 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 |
| Acid deposition (eq/ha/yr) | | annual | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |

# Table 25.7-5. Air Quality Background and Model Results for the Operation Phase for Sensitive Human Receptors

| Pollutant | | Averaging Period | Concentrations ($\mu g/m^3$) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Criteria | | | Off-site | | | | | | | | | | |
| | | | Canadian Standards | BC Objectives | Background | Existing Exploration Camp | Existing Exploration Camp | Municipality Bob Quinn Lake | Community Bell II | Trapline Cabin | Trapline Cabin | Trapline Cabin | Trapline Cabin | Bowser Lake Hunting Cabin | Skii km Lax Ha Cabin East | Skii km Lax Ha Cabin West |
| $SO_2$ | | 1-hour | 450 | 450 | 4 | 8.29 | 4.67 | 4.06 | 4.45 | 5.43 | 6.23 | 4.68 | 4.45 | 4.28 | 4.31 | 4.41 |
| | | 24-hour | 150 | 160 | 4 | 4.38 | 4.09 | 4.01 | 4.08 | 4.10 | 4.25 | 4.09 | 4.08 | 4.04 | 4.05 | 4.05 |
| | | Annual | 30 | 25 | 2 | 2.02 | 2.01 | 2.00 | 2.01 | 2.01 | 2.01 | 2.01 | 2.00 | 2.00 | 2.01 | 2.01 |
| $NO_2$ | | 1-hour | 400 | - | 21 | 102 | 64.0 | 21.5 | 93.6 | 38.5 | 55.3 | 31.2 | 59.4 | 27.7 | 87.7 | 29.2 |
| | | 24-hour | 200 | - | 21 | 64.1 | 23.7 | 21.1 | 27.4 | 23.1 | 24.0 | 26.0 | 25.4 | 22.1 | 24.2 | 22.4 |
| | | Annual | 60 | - | 5 | 6.69 | 5.31 | 5.01 | 5.22 | 5.14 | 5.22 | 5.19 | 5.16 | 5.08 | 5.14 | 5.11 |
| CO | | 1-hour | 15,000 | 14,300 | 100 | 505 | 172 | 103 | 207 | 197 | 330 | 145 | 134 | 117 | 134 | 117 |
| | | 8-hour | 6,000 | 5,500 | 100 | 256 | 116 | 101 | 119 | 119 | 146 | 112 | 109 | 105 | 106 | 106 |
| Fuel combustion (or non-fugitive) | TSP | 24-hour | 120 | 150 | 10 | 14.8 | 10.6 | 10.0 | 10.7 | 10.1 | 10.3 | 10.3 | 10.2 | 10.1 | 10.2 | 10.1 |
| | | Annual | 60 | 60 | 10 | 10.1 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 8.05 | 3.95 | 3.43 | 4.06 | 3.54 | 3.68 | 3.65 | 3.64 | 3.49 | 3.61 | 3.52 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 2.97 | 1.52 | 1.31 | 1.46 | 1.39 | 1.44 | 1.39 | 1.45 | 1.35 | 1.42 | 1.37 |
| | | Annual | - | 8 | 1.3 | 1.43 | 1.34 | 1.30 | 1.32 | 1.31 | 1.32 | 1.31 | 1.31 | 1.31 | 1.32 | 1.31 |
| Fugitive | TSP | 24-hour | 120 | 150 | 10 | 31.3 | 13.3 | 10.5 | 13.8 | 15.0 | 21.5 | 14.1 | 12.2 | 11.6 | 11.7 | 11.8 |
| | | Annual | 60 | 60 | 10 | 10.8 | 10.4 | 10.0 | 10.2 | 10.3 | 10.6 | 10.3 | 10.1 | 10.1 | 10.2 | 10.2 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 12.4 | 4.73 | 3.60 | 4.98 | 5.44 | 8.05 | 5.04 | 4.31 | 4.05 | 4.08 | 4.12 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 1.74 | 1.40 | 1.31 | 1.36 | 1.43 | 1.57 | 1.39 | 1.35 | 1.34 | 1.34 | 1.35 |
| | | Annual | - | 8 | 1.3 | 1.33 | 1.32 | 1.30 | 1.31 | 1.31 | 1.32 | 1.31 | 1.31 | 1.31 | 1.31 | 1.31 |
| Total | TSP | 24-hour | 120 | 150 | 10 | 36.1 | 13.5 | 10.5 | 14.0 | 15.1 | 21.8 | 14.2 | 12.3 | 11.6 | 11.7 | 11.9 |
| | | Annual | 60 | 60 | 10 | 11.0 | 10.4 | 10.0 | 10.3 | 10.3 | 10.6 | 10.3 | 10.2 | 10.1 | 10.2 | 10.2 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 17.0 | 5.09 | 3.61 | 5.15 | 5.57 | 8.33 | 5.16 | 4.46 | 4.09 | 4.15 | 4.20 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 3.17 | 1.57 | 1.32 | 1.55 | 1.52 | 1.71 | 1.48 | 1.47 | 1.39 | 1.44 | 1.41 |
| | | Annual | - | 8 | 1.3 | 1.47 | 1.36 | 1.30 | 1.33 | 1.32 | 1.34 | 1.33 | 1.32 | 1.31 | 1.32 | 1.32 |
| Dust deposition ($mg/m^3$/day) | | 30-day | - | 1.7 to 2.9 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 |
| Acid deposition (eq/ha/yr) | | annual | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 |

| Pollutant | | Averaging Period | Concentrations ($\mu g/m^3$) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Criteria | | | Camps | | | | | | | | | | | | | |
| | | | Canadian Standards | BC Objectives | Background | 5 | 6 | 10 | 11 | 1 | 2 | 3 | 4 | 7 | 8 | 9 | 12 | Mitchell | Treaty |
| $SO_2$ | | 1-hour | 450 | 450 | 4 | 5.06 | 5.11 | 15.9 | 4.22 | 4.09 | 9.08 | 5.58 | 12.8 | 6.75 | 6.42 | 16.28 | 4.21 | 7.83 | 5.13 |
| | | 24-hour | 150 | 160 | 4 | 4.18 | 4.17 | 5.86 | 4.04 | 4.02 | 4.52 | 4.22 | 5.70 | 4.34 | 4.31 | 5.97 | 4.04 | 4.51 | 4.17 |
| | | Annual | 30 | 25 | 2 | 2.02 | 2.02 | 2.07 | 2.01 | 2.00 | 2.02 | 2.02 | 2.18 | 2.02 | 2.02 | 2.08 | 2.00 | 2.03 | 2.02 |
| $NO_2$ | | 1-hour | 400 | - | 21 | 98.3 | 38.7 | 115 | 88.1 | 22.8 | 116 | 64.7 | 166 | 57.6 | 54.5 | 119 | 27.2 | 98.9 | 90.3 |
| | | 24-hour | 200 | - | 21 | 68.6 | 25.0 | 88.9 | 24.7 | 21.4 | 63.4 | 25.5 | 96.8 | 27.2 | 25.6 | 90.4 | 22.5 | 76.7 | 29.4 |
| | | Annual | 60 | - | 5 | 11.3 | 5.40 | 11.1 | 5.21 | 5.02 | 6.50 | 5.55 | 24.5 | 5.50 | 5.34 | 13.2 | 5.10 | 6.83 | 6.98 |
| CO | | 1-hour | 15,000 | 14,300 | 100 | 206 | 153 | 1210 | 138 | 107 | 743 | 167 | 876 | 312 | 280 | 1223 | 109 | 458 | 211 |
| | | 8-hour | 6,000 | 5,500 | 100 | 129 | 117 | 490 | 114 | 105 | 303 | 118 | 454 | 166 | 160 | 515 | 105 | 208 | 121 |
| Fuel combustion (or non-fugitive) | TSP | 24-hour | 120 | 150 | 10 | 12.4 | 10.6 | 15.2 | 10.2 | 10.1 | 13.7 | 10.4 | 19.5 | 10.5 | 10.4 | 16.1 | 10.1 | 14.0 | 12.7 |
| | | Annual | 60 | 60 | 10 | 10.5 | 10.1 | 10.4 | 10.0 | 10.0 | 10.1 | 10.1 | 11.1 | 10.0 | 10.0 | 10.5 | 10.0 | 10.1 | 10.5 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 5.82 | 4.02 | 8.43 | 3.63 | 3.49 | 7.04 | 3.78 | 12.7 | 3.86 | 3.77 | 9.34 | 3.49 | 7.34 | 6.11 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 2.73 | 1.51 | 5.27 | 1.40 | 1.33 | 2.69 | 1.52 | 6.48 | 1.51 | 1.45 | 5.07 | 1.36 | 2.30 | 2.69 |
| | | Annual | - | 8 | 1.3 | 1.68 | 1.34 | 1.67 | 1.32 | 1.30 | 1.41 | 1.35 | 2.37 | 1.33 | 1.32 | 1.78 | 1.31 | 1.42 | 1.66 |
| Fugitive | TSP | 24-hour | 120 | 150 | 10 | 16.1 | 15.2 | 91.4 | 12.0 | 11.2 | 46.3 | 15.3 | 93.2 | 26.5 | 24.6 | 95.5 | 11.6 | 35.4 | 15.8 |
| | | Annual | 60 | 60 | 10 | 11.2 | 10.7 | 12.4 | 10.3 | 10.1 | 10.8 | 10.7 | 15.5 | 11.3 | 10.9 | 12.8 | 10.2 | 11.0 | 11.1 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 5.72 | 5.51 | 37.1 | 4.16 | 3.92 | 18.74 | 5.50 | 37.8 | 9.99 | 9.32 | 38.8 | 4.03 | 13.85 | 5.63 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 1.47 | 1.46 | 1.90 | 1.35 | 1.32 | 1.55 | 1.43 | 2.61 | 1.60 | 1.58 | 1.96 | 1.34 | 1.74 | 1.46 |
| | | Annual | - | 8 | 1.3 | 1.35 | 1.33 | 1.40 | 1.31 | 1.30 | 1.33 | 1.33 | 1.52 | 1.35 | 1.34 | 1.41 | 1.31 | 1.34 | 1.35 |
| Total | TSP | 24-hour | 120 | 150 | 10 | 16.6 | 15.5 | 95.6 | 12.1 | 11.3 | 50.0 | 15.6 | 98.6 | 27.0 | 25.0 | 101 | 11.6 | 36.9 | 16.4 |
| | | Annual | 60 | 60 | 10 | 11.6 | 10.7 | 12.7 | 10.4 | 10.1 | 11.0 | 10.8 | 16.6 | 11.3 | 11.0 | 13.3 | 10.2 | 11.1 | 11.5 |
| | $PM_{10}$ | 24-hour | - | 50 | 3.4 | 6.27 | 5.76 | 41.15 | 4.24 | 4.01 | 22.4 | 5.76 | 43.0 | 10.4 | 9.69 | 43.9 | 4.11 | 15.37 | 6.40 |
| | $PM_{2.5}$ | 24-hour | 30 | 25 | 1.3 | 2.78 | 1.67 | 5.79 | 1.44 | 1.35 | 2.72 | 1.64 | 7.34 | 1.80 | 1.73 | 6.70 | 1.40 | 2.78 | 2.69 |
| | | Annual | - | 8 | 1.3 | 1.73 | 1.37 | 1.76 | 1.33 | 1.31 | 1.45 | 1.37 | 2.59 | 1.38 | 1.36 | 1.89 | 1.32 | 1.46 | 1.71 |
| Dust deposition ($mg/m^3$/day) | | 30-day | - | 1.7 to 2.9 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 | 1.34 |
| Acid deposition (eq/ha/yr) | | annual | | | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 125 | 126 | 125 | 125 | 125 | 125 | 125 | 125 |

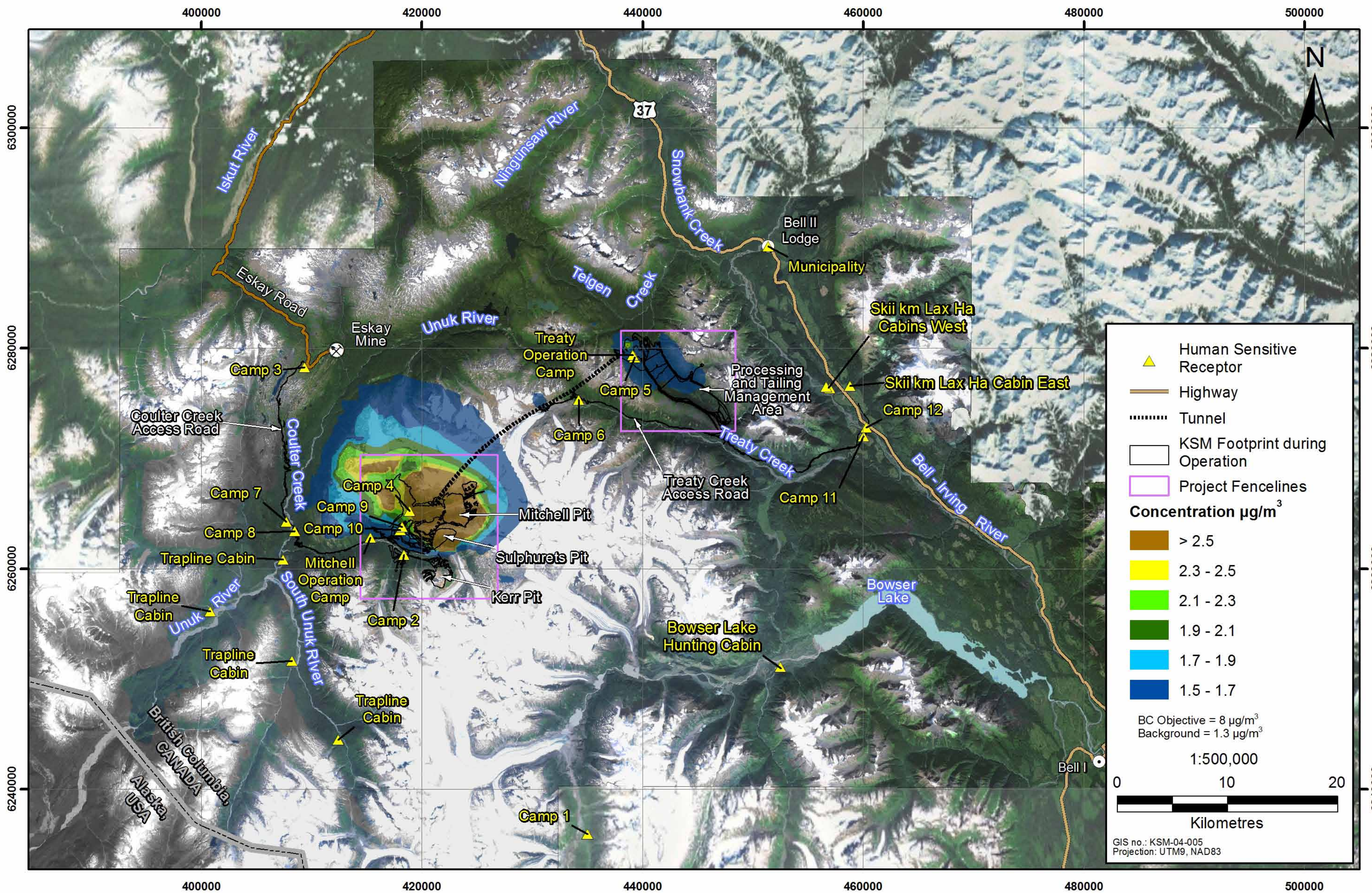


Figure 25.7-1

SEABRIDGE GOLD
KSM PROJECT

# Human Sensitive Receptor Locations and Annual Total $PM_{2.5}$ Concentration during Operation

Figure 25.7-1

Rescan
Engineers & Scientists

Lastly, the ILCR for inhalation of arsenic, cadmium, chromium, nickel, and combustion $PM_{2.5}$ was based on inhalation slope factors (ISF) from Health Canada (2010c) and the California Environmental Protection Agency (Cal EPA; 2005). HQs were calculated based on TRVs obtained from Health Canada (2010c) or the US Environmental Protection Agency (US EPA) Integrated Assessment Information System (US EPA 1985).

For the human health residual effects-based assessment, it is recognized that the BC air quality objectives and Canada-wide standards are not "pollute-up to objectives" and that health effects have been observed at concentrations less than the objectives and standards. This is particularly true for $PM_{2.5}$, where adverse health effects and incremental increases (even 1 $\mu g/m^3$) have been associated with both mortality and morbidity in epidemiological studies. Subsequently, for the human health assessment, the extent of health effects was estimated down to background levels. This approach is based on Health Canada (2004a).

The following three scenarios were evaluated:

1. Health estimates down to background based on the baseline concentrations (baseline).
2. Health estimates down to background based on the baseline concentrations plus the Project construction-related emission concentrations (baseline and construction).
3. Health estimates down to background based on the baseline concentrations plus the Project operation-related emission concentrations (baseline and operation).

The following sections will discuss the results of the human health residual effects assessment for the four endpoints: a comparison with air quality standards, an estimate of increased number of deaths, the HQ for metal inhalation, and the ILCR for metal inhalation.

Comparisons with Objectives and Standards for $NO_2$, $SO_2$, CO, TSP, $PM_{2.5}$, and $PM_{10}$

The concentrations of CACs for construction and operation reflect the predicted concentrations that would actually be inhaled by the people in the Project area (i.e., construction and operation concentrations include the baseline concentrations) during the years of highest Project activity (Year -1 and Year 4). Modelled air quality results did not exceed applicable objectives and standards at sensitive human receptor locations (Tables 25.7-4 and 25.7-5) either during construction or operation inside (camps) and outside (municipalities, trapline cabins, and Skii km Lax Ha hunting cabins) the Project area. Closure and post-closure were not modelled because air quality effects would be most significant during construction and operation. The magnitude of health effects related to air quality based on guidelines for $NO_2$, $SO_2$, CO, TSP, $PM_{2.5}$, $PM_{10}$ can be described as low (i.e., the change in air quality parameters is less than 10% above baseline concentrations and is below a guideline). It is emphasized that due to inter-individual variability and scientific evidence that PM has no threshold below which no adverse health effects are anticipated, adherence to the PM guideline is unlikely to lead to complete protection for all individuals. Quantitative risk assessment offers a way of estimating residual risk associated with emissions of PM. The following section provides a risk-based estimate for PM.

Estimated Number of Excess Deaths due to an Increase in Particulate Matter

Following Health Canada's (1999) guidance on risk assessment for PM, the increase in $PM_{2.5}$ above background was related to an estimate of numbers of excess deaths. It has generally been accepted that there is an association between respiratory health and increasing levels of particulate air pollution, and that $PM_{2.5}$ is a no-threshold particulate (Health Canada 1998). The lack of a threshold down to low concentrations suggests that it is difficult to identify a level at which no adverse effects would be expected to occur as a result of exposure to PM. Therefore, the number of excess deaths was estimated despite model results showing $PM_{2.5}$ levels below guidelines, but higher than background. Epidemiological studies of the effects of PM on human health explore statistical associations between changes in ambient levels of PM and changes in the occurrence of cardiorespiratory health problems in the general population. The calculations are based on Health Canada (1998, 1999), which indicated that there is a 1.5% increase in mortality per 10 $\mu g/m^3$ increase in $PM_{2.5}$ (based on a 24-hour average) and a 2.5-9.6% increase in hospitalization for respiratory causes. The concentration-response relationship between $PM_{2.5}$ and daily deaths is generally linear (Schwartz, Laden, and Zanobetti 2002), and the same has been assumed for hospitalization rates. The risks of excess mortality due to the Project were calculated by multiplying the increase in $PM_{2.5}$ at human receptor sites by the increase in mortality (Health Canada 1999). The approach assumes that the population residing in the camps, unincorporated communities of Bell II and Bob Quinn Lake, and the trappers and hunters frequenting the trapline and hunting cabins are similar to the population in large urban centers, on which the epidemiological studies were based.

There was an increase in risk of mortality associated with Project activities during closure and operation because the modelled $PM_{2.5}$ concentrations increase (Table 25.7-6). The increases were higher at Project locations (camps, 0.007-1.351%) than at off-site locations (trapline cabins, hunting cabins, and municipalities, 0.002-0.25%). Construction and operation camp locations were modelled because off-duty workers will reside at the camps during the night when not on shift. It can be conservatively assumed that air contaminant concentrations will be lower at night and indoors than the 24-hour averages used for these calculations. However, as outlined above, none of the increases in $PM_{2.5}$ are expected to exceed BC or Canadian air quality standards, which are protective of public health. Therefore, significant adverse health effects from these increases in risk are not predicted.

There is uncertainty associated with this assessment. Notably, the potency estimates for mortality provided by Health Canada are for those of urban areas and not of remote rural areas. By using the potency estimates provided by Health Canada it was inherently assumed that the demographics of the population in the assessment area are the same as the major cities (i.e., same percentage of young and elderly, same percentages of pre-existing respiratory problems). Given the remoteness of the Project and its limited use, the demographics are likely quite different than those of major cities. The demographics of the workforce living at the Project camps are also different from the urban population. Notwithstanding, the purpose of the assessment was to evaluate those who may be the most sensitive with respect to air pollution. Thus, by using a potency estimate that was derived using a demographic that likely has a higher percentage of sensitive receptors, there is likely conservatism in the risks predicted in this assessment. As such, the assessment is considered to have assessed possible sensitive receptors in the Project area.

$PM_{10}$ is not considered in the Health Canada guidance on predicting effects to background; this may underestimate the risk predictions. Despite the uncertainties associated with the risk predictions, the health effects from Project related emissions of $PM_{2.5}$, expressed as potency estimates for mortality, are considered low.

## Table 25.7-6. Increased Risk of Mortality per Person due to Predicted Increase in $PM_{2.5}$ Concentration in Air (Construction and Operation minus Background)

| | | Off-site | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Endpoint** | **Phase** | **Municipality Bob Quinn Lake** | **Community Bell II** | **Trapline Cabin** | **Trapline Cabin** | **Trapline Cabin** | **Trapline Cabin** | **Bowser Lake Hunting Cabin** | **Skii km Lax Ha Cabin East** | **Skii km Lax Ha Cabin West** |
| Excess death from $PM_{2.5}$ | Construction | 0.002% | 0.022% | 0.033% | 0.062% | 0.022% | 0.017% | 0.011% | 0.016% | 0.018% |
| | Operation | 0.003% | 0.037% | 0.032% | 0.061% | 0.027% | 0.025% | 0.013% | 0.021% | 0.017% |
| Hospitalization from $PM_{2.5}$ | Construction | 0.01% | 0.09% | 0.13% | 0.25% | 0.09% | 0.07% | 0.05% | 0.07% | 0.07% |
| | Operation | 0.01% | 0.15% | 0.13% | 0.25% | 0.11% | 0.10% | 0.05% | 0.08% | 0.07% |

| | | Camps | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Endpoint** | **Phase** | **5** | **6** | **10** | **11** | **1** | **2** | **3** | **4** | **7** |
| Excess death from $PM_{2.5}$ | Construction | 0.203% | 0.087% | 1.10% | 0.019% | 0.007% | 0.081% | 0.064% | 0.991% | 0.072% |
| | Operation | 0.222% | 0.055% | 0.674% | 0.020% | 0.007% | 0.213% | 0.051% | 0.906% | 0.075% |
| Hospitalization from $PM_{2.5}$ | Construction | - | - | - | - | - | - | - | - | - |
| | Operation | - | - | - | - | - | - | - | - | - |

| | | Camps | | | | |
|---|---|---|---|---|---|---|
| **Endpoint** | **Phase** | **8** | **9** | **12** | **Mitchell** | **Treaty** |
| Excess death from $PM_{2.5}$ | Construction | 0.076% | 1.351% | 0.014% | 0.092% | 0.194% |
| | Operation | 0.065% | 0.810% | 0.015% | 0.223% | 0.208% |
| Hospitalization from $PM_{2.5}$ | Construction | - | - | - | 0.37% | 0.78% |
| | Operation | - | - | - | 0.90% | 0.84% |

Hazard Quotients for Inhalation of Metals

The average metal content in deposit and non-deposit rocks (Appendix 10-A) and the modelled concentration of fugitive dust ($PM_{10}$) were used to calculate the metal inhalation exposure dose for adults and toddlers at sensitive receptor sites. The exposure dose was compared to the TRV for inhalation to estimate the HQ for each individual metal. A conservative HQ of 0.2 is assumed to have negligible health effects and takes into account exposure from other sources (food, water, and dermal contact). Non-carcinogenic effects were calculated using the following equation:

$$HQ = \frac{\text{Daily Inhalation } (\mu g/kg\ BW/day) \times \text{Fraction of Time Exposed}}{\text{Toxicity Reference Value } (\mu g/kg\ BW/day)}$$

**Note: *BW* = body weight**

Tables 25.7-7 and 25.7-8 present the HQs for the construction and operation phases for toddlers only. Because toddlers are more sensitive than adults and the HQs do not exceed 0.2, there is no risk to adults. Therefore, adverse health effects from the inhalation of assessed metals based on an HQ approach are low.

Incremental Lifetime Cancer Risks due to Inhalation of Metals and Combustion $PM_{2.5}$

The ILCR for inhalation of arsenic, cadmium, chromium, nickel, and combustion $PM_{2.5}$ was based on ISFs from Health Canada (2010) for metals and on the cancer unit risk factor from the Cal EPA (2005) for diesel PM. The slope factor is the result of application of a low-dose extrapolation procedure and is presented as the risk per mg/kg/day. The unit risk is the quantitative estimate in terms of risk per $\mu g/m^3$ air breathed. In Canada, cancer risks are deemed to be essentially negligible when the estimated ILCR is less than or equal to $1 \times 10^{-5}$ (Health Canada 2010d). The US EPA's revised draft 1999 Guidelines for Carcinogen Risk Assessment (US EPA 1999) states that diesel exhaust is likely to be carcinogenic to humans by inhalation from environmental exposures. However, the US EPA's Integrated Risk Information System (IRIS; 1985) has refrained from providing a quantitative estimate of carcinogenic inhalation risk (a slope factor) for diesel PM because of the absence of adequate data to develop a sufficiently confident dose-response relationship from the epidemiologic studies. Therefore the highly conservative slope factor from the Cal EPA was used as a benchmark. Carcinogenic risks were estimated as ILCR estimates according to the following formula:

$$ILCR = \text{Air Concentration } (\mu g/m^3) \times \text{Fraction of Time Exposed} \times \text{Cancer Unit Risk } (\mu g/m^3)^{-1}$$

Potential effects from inhaling Project-related metals and particulates were evaluated for adults. To estimate the fraction of time exposed, it was assumed that the human receptors occupy the Project construction and operation camp areas for 24 hours per day, while off-site receptors occupy municipalities, trapline cabins, and hunting camps 12 hours per day. These occupants were selected for evaluation as they include off-duty workers and the members of the general public that are closest to the emissions from the mine operation. The off-duty workers were assumed to be exposed to the emission for 7.2 months per year, trapline holders and hunters for 3 months per year, and the general public in the municipalities for 12 months per year. These exposure durations are considered a conservative estimate. It is assumed that people will be exposed to Project-related emissions for 5 years during construction, and 51.5 years during operation. This is a highly conservative estimate as it is unlikely that a person will spend his or her entire career at this Project site. It is further assumed that particles with sizes of 2.5 µm or less make up the largest constituent of diesel PM and that non-fugitive combustion $PM_{2.5}$ model data consisted predominately, and are therefore representative, of diesel PM. Diesel PM is generally not measured as part of air quality monitoring programs. Given that the Project is in an undeveloped area and more than 20 km away from any major sources of fuel combustion, it is likely that the PM from combusted diesel would be very low or negligible at the Project site. The modelling tools and inputs described in Chapter 7 allowed $PM_{2.5}$ to be predicted from model simulations. The air quality model predicted 24-hour and annual average $PM_{2.5}$ concentrations from Project-related emissions during construction and operation.

Table 25.7-9 provides the risk estimates for ILCR due to the inhalation of carcinogenic metals and combustion $PM_{2.5}$ during construction and operation. The total ILCR caused by the inhalation of metals did not exceed $10^{-5}$, and therefore cancer risks due to inhalation of metals are considered negligible.

The ILCR caused by the inhalation of combustion $PM_{2.5}$ was above $10^{-5}$ at all assessed locations. However, when applicable BC objectives for air quality were assessed using the Cal EPA unit risk factor, the ILCR for the $PM_{2.5}$ guideline concentration exceeded the $10^{-5}$ incremental risk and was higher than the ILCR at most sensitive human receptor sites. Because the air quality objectives are designed to be protective of public human health, the ILCR due to the inhalation of Project-related combustion $PM_{2.5}$ is considered low. The Cal EPA unit risk factor is characterized by the Scientific Review Panel as “reasonable estimate” and the US EPA considers the weight-of-evidence for a lung cancer hazard as strong. However, major uncertainties for a hazard assessment remain, and neither the US EPA nor Health Canada has set a unit risk or slope factor for diesel exhaust PM. Therefore, the ILCR based on Cal EPA unit risk factors likely overestimates any potential risks due to inhalation of combustion $PM_{2.5}$.

The Project camp combustion $PM_{2.5}$ concentrations are predicted to be higher than the other receptor locations; the concentrations decrease sharply with distance from the Mine Site. People would spend time at each camp when they are off shift. Sleeping indoors will reduce exposure to combustion PM emissions. The assessment is therefore likely overestimating risks to human health. However, because the total incremental lifetime cancer risks caused by the inhalation of $PM_{2.5}$ and metals exceeded $10^{-5}$, there may be low residual health effects at the Mitchell and Treaty operating camps.

Summary

Potential residual effects to human health from changes to air quality are presented in Table 25.7-10. The air quality model predicted Project air emissions that did not exceed Canadian and BC standards for air quality, which are designed to be protective of human health. The extent of non-carcinogenic health effects associated with modelled increases in $SO_2$, $NO_2$, CO, and metal concentrations was found to be low. There may be a low residual ILCR due to the increase in combustible $PM_{2.5}$ from Project-related activities near infrastructure and activities; however, background and guideline $PM_{2.5}$ concentrations are associated with similar or higher risks.

## Table 25.7-7. Hazard Quotients for the Inhalation of Metals at Sensitive Receptor Sites for Toddlers during Construction

| | | Off-Site | | | | | | Camps | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Background | Municipality Bob Quinn Lake | Community Bell II | Trapline Cabin | Trapline Cabin | Trapline Cabin | Trapline Cabin | 5 | 6 | 10 | 11 | 1 | 2 | 3 | 4 | 7 | 8 | 9 | 12 | Mitchell | Treaty |
| Aluminum | 2.49E-04 | 2.56E-04 | 3.05E-04 | 3.21E-04 | 4.14E-04 | 3.06E-04 | 2.82E-04 | 4.19E-04 | 3.69E-04 | 1.43E-03 | 3.15E-04 | 2.67E-04 | 7.82E-04 | 3.26E-04 | 1.46E-03 | 4.92E-04 | 4.60E-04 | 1.49E-03 | 2.73E-04 | 6.14E-04 | 4.22E-04 |
| Boron | 5.73E-05 | 5.89E-05 | 7.02E-05 | 7.39E-05 | 9.53E-05 | 7.06E-05 | 6.49E-05 | 9.65E-05 | 8.50E-05 | 3.28E-04 | 7.26E-05 | 6.16E-05 | 1.80E-04 | 7.50E-05 | 3.35E-04 | 1.13E-04 | 1.06E-04 | 3.42E-04 | 6.28E-05 | 1.42E-04 | 9.73E-05 |
| Barium | 4.41E-09 | 4.54E-09 | 5.41E-09 | 5.70E-09 | 7.34E-09 | 5.44E-09 | 5.00E-09 | 7.44E-09 | 6.56E-09 | 2.53E-08 | 5.60E-09 | 4.75E-09 | 1.39E-08 | 5.78E-09 | 2.58E-08 | 8.74E-09 | 8.16E-09 | 2.64E-08 | 4.84E-09 | 1.09E-08 | 7.50E-09 |
| Cadmium | 7.65E-05 | 7.86E-05 | 9.38E-05 | 9.87E-05 | 1.27E-04 | 9.43E-05 | 8.67E-05 | 1.29E-04 | 1.14E-04 | 4.38E-04 | 9.70E-05 | 8.23E-05 | 2.41E-04 | 1.00E-04 | 4.48E-04 | 1.51E-04 | 1.41E-04 | 4.57E-04 | 8.39E-05 | 1.89E-04 | 1.30E-04 |
| Chromium | 6.53E-04 | 6.71E-04 | 8.01E-04 | 8.43E-04 | 1.09E-03 | 8.05E-04 | 7.40E-04 | 1.10E-03 | 9.70E-04 | 3.74E-03 | 8.28E-04 | 7.03E-04 | 2.06E-03 | 8.55E-04 | 3.82E-03 | 1.29E-03 | 1.21E-03 | 3.91E-03 | 7.16E-04 | 1.61E-03 | 1.11E-03 |
| Copper | 2.33E-08 | 2.40E-08 | 2.86E-08 | 3.01E-08 | 3.88E-08 | 2.87E-08 | 2.64E-08 | 3.93E-08 | 3.46E-08 | 1.34E-07 | 2.96E-08 | 2.51E-08 | 7.34E-08 | 3.05E-08 | 1.36E-07 | 4.62E-08 | 4.31E-08 | 1.39E-07 | 2.56E-08 | 5.76E-08 | 3.96E-08 |
| Mercury | 7.07E-06 | 7.27E-06 | 8.67E-06 | 9.12E-06 | 1.18E-05 | 8.71E-06 | 8.01E-06 | 1.19E-05 | 1.05E-05 | 4.05E-05 | 8.97E-06 | 7.61E-06 | 2.23E-05 | 9.26E-06 | 4.14E-05 | 1.40E-05 | 1.31E-05 | 4.23E-05 | 7.75E-06 | 1.75E-05 | 1.20E-05 |
| Manganese | 1.88E-07 | 1.93E-07 | 2.30E-07 | 2.42E-07 | 3.12E-07 | 2.31E-07 | 2.13E-07 | 3.16E-07 | 2.79E-07 | 1.08E-06 | 2.38E-07 | 2.02E-07 | 5.90E-07 | 2.46E-07 | 1.10E-06 | 3.72E-07 | 3.47E-07 | 1.12E-06 | 2.06E-07 | 4.64E-07 | 3.19E-07 |
| Molybdenum | 1.55E-09 | 1.59E-09 | 1.89E-09 | 1.99E-09 | 2.57E-09 | 1.90E-09 | 1.75E-09 | 2.60E-09 | 2.30E-09 | 8.86E-09 | 1.96E-09 | 1.66E-09 | 4.86E-09 | 2.02E-09 | 9.05E-09 | 3.06E-09 | 2.86E-09 | 9.24E-09 | 1.69E-09 | 3.82E-09 | 2.63E-09 |
| Nickel | 3.23E-06 | 3.32E-06 | 3.96E-06 | 4.17E-06 | 5.38E-06 | 3.98E-06 | 3.66E-06 | 5.45E-06 | 4.80E-06 | 1.85E-05 | 4.10E-06 | 3.48E-06 | 1.02E-05 | 4.23E-06 | 1.89E-05 | 6.40E-06 | 5.98E-06 | 1.93E-05 | 3.54E-06 | 7.99E-06 | 5.49E-06 |
| Lead | 1.14E-05 | 1.17E-05 | 1.39E-05 | 1.47E-05 | 1.89E-05 | 1.40E-05 | 1.29E-05 | 1.92E-05 | 1.69E-05 | 6.52E-05 | 1.44E-05 | 1.22E-05 | 3.58E-05 | 1.49E-05 | 6.66E-05 | 2.25E-05 | 2.10E-05 | 6.80E-05 | 1.25E-05 | 2.81E-05 | 1.93E-05 |
| Selenium | 1.02E-06 | 1.04E-06 | 1.25E-06 | 1.31E-06 | 1.69E-06 | 1.25E-06 | 1.15E-06 | 1.71E-06 | 1.51E-06 | 5.82E-06 | 1.29E-06 | 1.09E-06 | 3.20E-06 | 1.33E-06 | 5.95E-06 | 2.01E-06 | 1.88E-06 | 6.08E-06 | 1.11E-06 | 2.51E-06 | 1.73E-06 |
| Thallium | 4.09E-05 | 4.21E-05 | 5.02E-05 | 5.28E-05 | 6.81E-05 | 5.05E-05 | 4.64E-05 | 6.90E-05 | 6.08E-05 | 2.35E-04 | 5.19E-05 | 4.40E-05 | 1.29E-04 | 5.36E-05 | 2.40E-04 | 8.11E-05 | 7.57E-05 | 2.45E-04 | 4.49E-05 | 1.01E-04 | 6.96E-05 |
| Uranium | 3.43E-06 | 3.53E-06 | 4.21E-06 | 4.43E-06 | 5.71E-06 | 4.23E-06 | 3.89E-06 | 5.78E-06 | 5.10E-06 | 1.97E-05 | 4.35E-06 | 3.69E-06 | 1.08E-05 | 4.50E-06 | 2.01E-05 | 6.80E-06 | 6.35E-06 | 2.05E-05 | 3.76E-06 | 8.48E-06 | 5.83E-06 |
| Zinc | 2.94E-07 | 3.02E-07 | 3.60E-07 | 3.79E-07 | 4.89E-07 | 3.62E-07 | 3.33E-07 | 4.95E-07 | 4.36E-07 | 1.68E-06 | 3.72E-07 | 3.16E-07 | 9.24E-07 | 3.85E-07 | 1.72E-06 | 5.82E-07 | 5.43E-07 | 1.76E-06 | 3.22E-07 | 7.26E-07 | 4.99E-07 |

## Table 25.7-8. Hazard Quotients for the Inhalation of Metals at Sensitive Receptor Sites for Toddlers during Operation

| | | Off-Site | | | | | | | | | Camps | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Background | Municipality Bob Quinn Lake | Community Bell II | Trapline Cabin | Trapline Cabin | Trapline Cabin | Trapline Cabin | Bowser Lake Hunting Cabin | Skii km Lax Ha Cabin East | Skii km Lax Ha Cabin West | Mitchell | Treaty |
| Aluminum | 2.49E-04 | 2.63E-04 | 3.64E-04 | 3.97E-04 | 5.89E-04 | 3.69E-04 | 3.15E-04 | 2.96E-04 | 2.98E-04 | 3.01E-04 | 1.01E-03 | 4.11E-04 |
| Boron | 5.73E-05 | 6.06E-05 | 8.39E-05 | 9.15E-05 | 1.36E-04 | 8.50E-05 | 7.26E-05 | 6.81E-05 | 6.86E-05 | 6.94E-05 | 2.33E-04 | 9.48E-05 |
| Barium | 4.41E-09 | 4.67E-09 | 6.47E-09 | 7.06E-09 | 1.05E-08 | 6.55E-09 | 5.60E-09 | 5.25E-09 | 5.29E-09 | 5.35E-09 | 1.80E-08 | 7.30E-09 |
| Cadmium | 7.65E-05 | 8.09E-05 | 1.12E-04 | 1.22E-04 | 1.81E-04 | 1.13E-04 | 9.70E-05 | 9.10E-05 | 9.17E-05 | 9.27E-05 | 3.12E-04 | 1.27E-04 |
| Chromium | 6.53E-04 | 6.91E-04 | 9.57E-04 | 1.04E-03 | 1.55E-03 | 9.69E-04 | 8.28E-04 | 7.77E-04 | 7.83E-04 | 7.92E-04 | 2.66E-03 | 1.08E-03 |
| Copper | 2.33E-08 | 2.47E-08 | 3.42E-08 | 3.73E-08 | 5.52E-08 | 3.46E-08 | 2.96E-08 | 2.77E-08 | 2.79E-08 | 2.83E-08 | 9.50E-08 | 3.86E-08 |
| Mercury | 7.07E-06 | 7.48E-06 | 1.04E-05 | 1.13E-05 | 1.67E-05 | 1.05E-05 | 8.97E-06 | 8.41E-06 | 8.47E-06 | 8.57E-06 | 2.88E-05 | 1.17E-05 |
| Manganese | 1.88E-07 | 1.98E-07 | 2.75E-07 | 3.00E-07 | 4.44E-07 | 2.78E-07 | 2.38E-07 | 2.23E-07 | 2.25E-07 | 2.27E-07 | 7.64E-07 | 3.10E-07 |
| Molybdenum | 1.55E-09 | 1.64E-09 | 2.27E-09 | 2.47E-09 | 3.66E-09 | 2.29E-09 | 1.96E-09 | 1.84E-09 | 1.85E-09 | 1.87E-09 | 6.30E-09 | 2.56E-09 |
| Nickel | 3.23E-06 | 3.42E-06 | 4.74E-06 | 5.17E-06 | 7.65E-06 | 4.79E-06 | 4.10E-06 | 3.85E-06 | 3.87E-06 | 3.92E-06 | 1.32E-05 | 5.35E-06 |
| Lead | 1.14E-05 | 1.20E-05 | 1.67E-05 | 1.82E-05 | 2.69E-05 | 1.69E-05 | 1.44E-05 | 1.35E-05 | 1.36E-05 | 1.38E-05 | 4.64E-05 | 1.88E-05 |
| Selenium | 1.02E-06 | 1.07E-06 | 1.49E-06 | 1.62E-06 | 2.41E-06 | 1.51E-06 | 1.29E-06 | 1.21E-06 | 1.22E-06 | 1.23E-06 | 4.14E-06 | 1.68E-06 |
| Thallium | 4.09E-05 | 4.33E-05 | 6.00E-05 | 6.55E-05 | 9.70E-05 | 6.07E-05 | 5.19E-05 | 4.87E-05 | 4.91E-05 | 4.96E-05 | 1.67E-04 | 6.77E-05 |
| Uranium | 3.43E-06 | 3.63E-06 | 5.03E-06 | 5.49E-06 | 8.13E-06 | 5.09E-06 | 4.35E-06 | 4.09E-06 | 4.11E-06 | 4.16E-06 | 1.40E-05 | 5.68E-06 |
| Zinc | 2.94E-07 | 3.11E-07 | 4.31E-07 | 4.70E-07 | 6.96E-07 | 4.36E-07 | 3.73E-07 | 3.50E-07 | 3.52E-07 | 3.56E-07 | 1.20E-06 | 4.86E-07 |

## Table 25.7-9. Incremental Lifetime Cancer Risks due to Inhalation of Metals at Sensitive Human Receptor Sites

| | | ILCR based on Guidelines | | | Off-site | | | | | | | | | Camps | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | COPC | Canadian Standards | BC Objectives | Background | Municipality Bob Quinn Lake | Community Bell II | Trapline Cabin | Trapline Cabin | Trapline Cabin | Trapline Cabin | Bowser Lake Hunting Cabin | Skii km Lax Ha Cabin East | Skii km Lax Ha Cabin West | 5 | 6 | 10 |
| Construction | Arsenic | - | - | 2.85E-08 | 2.93E-08 | 3.50E-08 | 3.68E-08 | 4.75E-08 | 3.52E-08 | 3.23E-08 | 3.11907E-08 | 3.1459E-08 | 3.15603E-08 | 4.81E-08 | 4.24E-08 | 1.64E-07 |
| | Cadmium | - | - | 1.08E-09 | 1.11E-09 | 1.33E-09 | 1.40E-09 | 1.80E-09 | 1.33E-09 | 1.23E-09 | 1.18287E-09 | 1.19305E-09 | 1.19689E-09 | 1.82E-09 | 1.61E-09 | 6.20E-09 |
| | Chromium | - | - | 1.03E-07 | 1.06E-07 | 1.26E-07 | 1.32E-07 | 1.71E-07 | 1.26E-07 | 1.16E-07 | 1.12238E-07 | 1.13204E-07 | 1.13568E-07 | 1.73E-07 | 1.52E-07 | 5.88E-07 |
| | Nickel | - | - | 3.11E-09 | 3.20E-09 | 3.81E-09 | 4.01E-09 | 5.18E-09 | 3.83E-09 | 3.53E-09 | 3.40244E-09 | 3.43171E-09 | 3.44276E-09 | 5.24E-09 | 4.62E-09 | 1.78E-08 |
| | $PM_{2.5}$ Annual | - | **1.50E-04** | **2.44E-05** | **1.22E-05** | **1.24E-05** | 3.08E-06 | 3.11E-06 | 3.08E-06 | 3.07E-06 | **1.47217E-05** | **1.47786E-05** | **1.47816E-05** | **2.00E-05** | **1.56E-05** | **1.97E-05** |
| Operation | Arsenic | - | - | 2.57E-07 | 2.72E-07 | 3.76E-07 | 4.10E-07 | 6.08E-07 | 3.81E-07 | 3.26E-07 | 3.05453E-07 | 3.0761E-07 | 3.11116E-07 | - | - | - |
| | Cadmium | - | - | 9.73E-09 | 1.03E-08 | 1.43E-08 | 1.56E-08 | 2.31E-08 | 1.44E-08 | 1.23E-08 | 1.15839E-08 | 1.16657E-08 | 1.17987E-08 | - | - | - |
| | Chromium | - | - | 9.24E-07 | 9.77E-07 | 1.35E-06 | 1.48E-06 | 2.19E-06 | 1.37E-06 | 1.17E-06 | 1.09916E-06 | 1.10692E-06 | 1.11954E-06 | - | - | - |
| | Nickel | - | - | 4.98E-08 | 5.27E-08 | 7.30E-08 | 7.96E-08 | 1.18E-07 | 7.39E-08 | 6.31E-08 | 5.92362E-08 | 5.96544E-08 | 6.03344E-08 | - | - | - |
| | $PM_{2.5}$ Annual | - | **1.35E-03** | **2.19E-04** | **1.10E-04** | **1.12E-04** | **2.77E-05** | **2.78E-05** | **2.77E-05** | **2.77E-05** | **1.32E-04** | **1.33E-04** | **1.33E-04** | - | - | - |

| | | ILCR based on Guidelines | | | Camps | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | COPC | Canadian Standards | BC Objectives | Background | 11 | 1 | 2 | 3 | 4 | 7 | 8 | 9 | 12 | Mitchell | Treaty |
| Construction | Arsenic | - | - | 2.85E-08 | 3.62E-08 | 3.07E-08 | 8.98E-08 | 3.74E-08 | 1.67E-07 | 5.65E-08 | 5.28E-08 | 1.71E-07 | 3.13E-08 | 7.05E-08 | 4.85E-08 |
| | Cadmium | - | - | 1.08E-09 | 1.37E-09 | 1.16E-09 | 3.40E-09 | 1.42E-09 | 6.33E-09 | 2.14E-09 | 2.00E-09 | 6.47E-09 | 1.19E-09 | 2.67E-09 | 1.84E-09 |
| | Chromium | - | - | 1.03E-07 | 1.30E-07 | 1.10E-07 | 3.23E-07 | 1.34E-07 | 6.01E-07 | 2.03E-07 | 1.90E-07 | 6.14E-07 | 1.13E-07 | 2.54E-07 | 1.74E-07 |
| | Nickel | - | - | 3.11E-09 | 3.94E-09 | 3.35E-09 | 9.79E-09 | 4.08E-09 | 1.82E-08 | 6.16E-09 | 5.75E-09 | 1.86E-08 | 3.41E-09 | 7.69E-09 | 5.29E-09 |
| | $PM_{2.5}$ Annual | - | **1.50E-04** | **2.44E-05** | **1.48E-05** | **1.47E-05** | **1.50E-05** | **1.54E-05** | **2.82E-05** | **1.50E-05** | **1.50E-05** | **2.10E-05** | **1.48E-05** | **1.51E-05** | **1.90E-05** |
| Operation | Arsenic | - | - | 2.57E-07 | - | - | - | - | - | - | - | - | - | 1.05E-06 | 4.25E-07 |
| | Cadmium | - | - | 9.73E-09 | - | - | - | - | - | - | - | - | - | 3.97E-08 | 1.61E-08 |
| | Chromium | - | - | 9.24E-07 | - | - | - | - | - | - | - | - | - | 3.76E-06 | 1.53E-06 |
| | Nickel | - | - | 4.98E-08 | - | - | - | - | - | - | - | - | - | 2.03E-07 | 8.24E-08 |
| | $PM_{2.5}$ Annual | - | **1.35E-03** | **2.19E-04** | - | - | - | - | - | - | - | - | - | **1.44E-04** | **1.68E-04** |

**Highlighted cells indicate ILCR > $10^{-5}$ based on the Cancer Unit Risk Factor of $(0.0003\ mg/m3)^{-1}$ from the California Environmental Protection Agency (2005).**

**Duration of Exposure for Construction = 60% of the time spent at camp locations, or 12.5% of the time spent at cabins, or 50% of the time spent at municipalities during the operation period of 5 years with an 80 years life expectancy.**

**Duration of Exposure for Operations = 60% of the time spent at camp locations, or 12.5% of the time spent at cabins, or 50% of the time spent at municipalities during the operation period of 51.5 years with an 80 years life expectancy.**

## Table 25.7-10. Potential Residual Effects on Human Health Due to Changes in Air Quality

| VC | Timing Start | Project Area(s) | Component(s) | Description of Effect due to Component(s) | Type of Project Mitigation | Project Mitigation Description | Potential Residual Effect | Description of Residuals |
|---|---|---|---|---|---|---|---|---|
| Respiratory Health of sensitive person | Construction | Mine Site, PTMA, Roads | All components under construction: Camps, Mining equipment and activities, access roads, clearing and debris burning, Ore/Overburden Stockpile and RSF, Mitchell Treaty Tunnel, Highway 37 | Negative respiratory health effects to workers, visitors, hunters, and recreationists due to inhalation of dust and diesel particulates | Management Practices, Monitoring and Adaptive Management Pans | Air quality will be monitored, mitigation strategies will be adjusted accordingly to meet BC MOE Air Quality Standards and the Air Quality Management Plan.<br>Fugitive dust emissions will be monitored, reported and if required, mitigation strategies will be adjusted accordingly.<br>Emission control systems (e.g. scrubbers, baghouses, and filters) will be used on stacks and relevant ventilation systems to reduce emissions.<br>Vehicles will be maintained regularly, low sulphur diesel will be used, and catalytic converters and diesel particulate filters will be installed on diesel engines. A no idling policy will be implemented.<br>Dust management on roads by using water sprays regularly during dry weather.<br>Hauled concentrate will be covered (with a rigid cover).<br>Drop down distances between conveyer belt and stockpiles will be reduced as much as feasible and/or dust skirts will be used.<br>Fugitive dust will be minimized at stockpiles and concentrate load-out facilities as much as possible. | Yes | Emissions of $NO_2$, $SO_2$, CO, TSP, $PM_{2.5}$, and $PM_{10}$ related to Project rise above background;<br>HQ for Metal Inhalation;<br>Increase in ILCR due to $PM_{2.5}$;<br>Increase in excess mortality due to $PM_{2.5}$ |
| Respiratory Health of sensitive person | Operation | Mine Site, PTMA, Roads | Camps, Mining equipment and activities, access roads, clearing and debris burning, Ore/Overburden Stockpile and RSF, Ore Preparation Complex, Mitchell Treaty Tunnel, Highway 37 | Negative respiratory health effects to workers, visitors, hunters, and recreationists due to inhalation of dust and diesel particulates | Management Practices, Monitoring and Adaptive Management Pans | Air quality will be monitored, mitigation strategies will be adjusted accordingly to meet BC MOE Air Quality Standards and the Air Quality Management Plan.<br>Fugitive dust emissions will be monitored, reported and if required, mitigation strategies will be adjusted accordingly.<br>Emission control systems (e.g. scrubbers, baghouses, and filters) will be used on stacks and relevant ventilation systems to reduce emissions.<br>Vehicles will be maintained regularly, low sulphur diesel will be used, and catalytic converters and diesel particulate filters will be installed on diesel engines. A no idling policy will be implemented.<br>Dust management on roads by using water sprays regularly during dry weather.<br>Hauled concentrate will be covered (with a rigid cover).<br>Drop down distances between conveyer belt and stockpiles will be reduced as much as feasible and/or dust skirts will be used.<br>Fugitive dust will be minimized at stockpiles and concentrate load-out facilities as much as possible. | Yes | Emissions of $NO_2$, $SO_2$, CO, TSP, $PM_{2.5}$, and $PM_{10}$ related to Project rise above background;<br>HQ for Metal Inhalation;<br>Increase in ILCR due to $PM_{2.5}$;<br>Increase in excess mortality due to $PM_{2.5}$ |

### 25.7.3 Changes in Health due to Country Foods Quality

The purpose of the country foods effects assessment was to evaluate the potential for Project activities to affect human health from the consumption of country foods. The rationale for this evaluation was that people use the area downstream near the PTMA and, less frequently, the area downstream of the Mine Site for hunting, trapping, and berry picking.

Country foods are animals, plants, and fungi used by humans for nutritional or medicinal purposes and that are harvested through hunting, fishing, or gathering of vegetation (Health Canada 2010a). People obtaining country foods by hunting, trapping, and collecting berries, mushrooms, and medicinal plants from the Project area, and by fishing inside and downstream of the Project area, can be affected by the quality of the country foods they consume. There are no permanent residents living in the Project area; however, limited seasonal and temporary use of the area does occur (described in Chapter 23, Land Use, Chapter 29, Nisga'a Nation Interests, and Chapter 30, First Nations Interests). Harvest data are available for non-Aboriginal resident hunters based on studies conducted for the land use baseline report (Appendix 23-A) and are presented in Table 25.7-11. Specific data on hunting activities and species harvested were not available for Aboriginal hunters, as they are not required to apply for wildlife tags or to record their harvests with the Fish and Wildlife Branch. However, Aboriginal hunters, trappers, and gatherers are likely the most frequent users of the area and are therefore the focus of the assessment. Trapping occurs predominately for pelts (marten, squirrel, beaver, lynx, weasel, mink, and wolverine) and not for food, and therefore trapping statistics have not been included in the country foods assessment.

**Table 25.7-11. Harvest Data for Non-Aboriginal Hunters**

| Wildlife Management Unit | Proportion of WMU in Land Use LSA Boundary | Meat per Non-Aboriginal Hunter in the LSA per Year (kg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Moose | Sheep | Goat | Black Bear | Grizzly Bear | Wolf |
| 6-16 (relevant for PTMA) | 26.5% | 1.04 | no data | 0.15 | 0.60 | 0.53 | 0.13 |
| 6-21 (relevant for Mine Site) | 9.2% | 0.46 | 0.05 | 0.10 | 0.13 | 0.13 | 0.02 |

An assessment of the quantity and accessibility of country foods is not provided, because the assessment focuses on country food quality and potential impacts to human health due to levels of COPC. An assessment of culturally important plants and the potential loss and degradation of individual ecosystems is provided in Appendix 17-C. The potential change in accessibility of country foods due to road construction is assessed in Chapter 23. Loss of wildlife habitat is assessed in Chapter 18.

Because country foods take up chemicals from environmental media (i.e., water, soil, and vegetation), the quality of the foods is directly related to concentrations in the media. To determine the potential effects to country foods, predicted changes to the environmental media were reviewed from other relevant, discipline-specific sections of this Application/EIS (i.e., water, soil, and vegetation effects assessment chapters). If there were no predicted decreases in quality of the environmental media, there would be no predicted decreases in the quality of country foods. For mine components and phases where environmental media quality was predicted to change, an SLRA was performed (Appendices 25-C and 25-D). Monitoring these media during operation and closure will be essential to conducting future ecological and human health risk assessments and adaptive management should media quality decrease.

The Project is a metal mine and is located in a highly mineralized area. Therefore, the COPC affecting human health considered here are metals and process chemicals. The assessment for country foods included the following metals: aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, tin, vanadium, and zinc. These metals were selected based on their baseline and/or modelled concentrations being higher than guideline concentrations in water and sediments during operation and closure of the PTMA and Mine Site (Tables 25.7-12 and 25.7-13). Even though country foods may be affected during construction and post-closure, it is anticipated that operation and closure phases have the highest effects. Therefore, the assessment of operation and closure phases was the most conservative approach. The following paragraphs describe briefly the potential health effects to humans due to ingestion of these COPC.

Potential Effects of Contaminants of Potential Concern

Aluminum is the most prevalent metal in the earth's crust and is ubiquitous in diet and drinking water. It is not a significant concern in persons with normal elimination capacity. High doses of aluminum compounds have the potential to affect the reproductive system and the developing nervous system (JECFA 2007). Acute intoxication is extremely rare; however, it can be a significant source of pathology in persons with impaired aluminum clearance.

Arsenic is considered carcinogenic through the ingestion pathway. The major cause of human arsenic toxicity is from contamination of drinking water from natural geological sources (Ratnaike 2003). Arsenic occurs in two oxidation states: a trivalent form, arsenite ($As_2O_3$; As III) and a pentavalent form, arsenate ($As_2O_5$; As V). Arsenite is 60 times more toxic than arsenate. Organic arsenic is bioaccumulative but non-toxic, whereas inorganic arsenic is toxic. Arsenic toxicity inactivates up to 200 enzymes, most notably those involved in cellular energy pathways and DNA replication and repair. It is also substituted for phosphate in high energy compounds such as ATP (adenosine triphosphate). Acute poisoning is rare, but chronic poisoning predominantly affects the skin and the gastrointestinal, neurological, and cardiovascular systems, and causes malignant diseases.

Barium toxicity strongly depends on the solubility of barium salts (ATSDR 2007). Insoluble barium is generally non-toxic and used in medical applications (barium sulphate). Soluble barium can be toxic at higher doses and can cause hypokalemia (low levels of potassium in the blood). The available animal data provide strong evidence that the most sensitive adverse effect of barium at lower concentrations is renal toxicity. Barium is not considered carcinogenic.

Beryllium is predominantly toxic when entering the lungs at high concentrations (ATSDR 2002). It causes pneumonia-like symptoms, and the condition is known as acute beryllium disease. People can also develop a hypersensitivity (allergy) to beryllium, which is called chronic beryllium disease. Beryllium is considered a probable human carcinogen through inhalation. Swallowing beryllium has not been reported to cause effects in humans, because very little beryllium can move from the stomach or intestines into the bloodstream.

## Table 25.7-12. Metals Evaluated and Rationale for Inclusion as Contaminants of Potential Concern into the Screening Level Risk Assessment for the Processing and Tailing Management Area

| | Maximum Soil Concentration[1] | CCME Soil Guideline (Agricultural) | Mean Rougher Tailings Concentration in TMF | CCME Sediment Guideline ISQG | BC Sediment Guideline | Maximum Water Concentration at Baseline in Teigen and Treaty (STE1[2], STE1A, NTR1, NTR1A, 2007-2011) | Predicted Water Concentration in TMF[3] Max for Operation years 1-50 North Cell | CIL | South Cell | Max for Closure years 51-65 North Cell | CIL | South Cell | CCME Water Guideline Freshwater Aquatic Life | BC Max. Water Criteria Freshwater Aquatic Life | Inclusion in SLRA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mg/kg | | | mg/kg | | mg/L (total metals) | mg/L | | | mg/L | | | mg/L | | |
| Aluminum (Al) | 39,300 | - | 70,979 | - | - | **1.9** | **0.767** | 0.0809 | **0.602** | 0.042 | 0.0376 | **0.451** | 0.1 | 0.1 | Y |
| Antimony (Sb) | 15.0 | - | 2.74 | - | - | 0.0001 | 0.00338 | 0.0166 | 0.00339 | 0.0000552 | 0.00893 | 0.00337 | - | - | N |
| Arsenic (As) | **169** | 12.0 | **5.95** | 5.9 | 5.9 | 0.0007 | **0.0459** | **0.0133** | **0.0369** | 0.0000503 | **0.00623** | **0.0278** | 0.005 | 0.005 | Y |
| Barium (Ba) | **1,110** | 750 | 2,443 | - | - | 0.04 | 0.412 | 0.0658 | 0.329 | 0.0121 | 0.0305 | 0.247 | - | - | Y |
| Beryllium (Be) | **6.47** | 4 | 0.943 | - | - | 0.0003 | 0.000684 | 0.000318 | 0.000564 | 0.000207 | 0.000164 | 0.000453 | - | - | Y |
| Bismuth (Bi) | 10.0 | - | 5.17 | - | - | 0.0003 | - | - | - | - | - | - | - | - | N |
| Cadmium (Cd) | **1.52** | 1.4 | 0.319 | 0.6 | 0.6 | 0.0001 | 0.0000629 | 0.000133 | 0.0000547 | 0.00000658 | 0.0000712 | 0.0000459 | 0.000043-0.000344 | - | Y |
| Calcium (Ca) | 16,000 | - | 11,876 | - | - | 38.6 | 300 | 300 | 300 | 12.9 | 275 | 300 | - | - | N |
| Chromium (Cr) | **288** | 64 | 30.4 | 37.3 | 37.3 | 0.007 | 0.00548 | 0.000742 | 0.00438 | 0.000222 | 0.000368 | 0.0033 | 0.0089 | - | Y |
| Cobalt (Co) | **123** | 40 | 14.2 | - | - | 0.001 | 0.00318 | 0.0118 | 0.00302 | 0.0000445 | 0.00632 | 0.00278 | - | 0.11 | Y |
| Copper (Cu) | **1,060** | 63 | **382** | 35.7 | 35.7 | 0.0052 | 0.00743 | 0.0614 | 0.00754 | 0.000570 | 0.0334 | 0.00827 | 0.0076-0.0364 | 0.015-0.0804 | Y |
| Iron (Fe) | 373,000 | - | **33,288** | ng | 21,200 | **2.1** | 0.0590 | 0.0215 | 0.033 | 0.0330 | 0.0119 | 0.0271 | 0.3 | 1 | N |
| Lead (Pb) | 69.0 | 70 | 23.5 | 35 | 35 | 0.0005 | 0.00109 | 0.000201 | 0.000866 | 0.0000278 | 0.0000908 | 0.000651 | 0.0046-0.0474 | 1.12-1.214 | N |
| Lithium (Li) | 55.4 | - | 13.6 | - | - | 0.0025 | 0.0287 | 0.0181 | 0.0235 | 0.00208 | 0.00926 | 0.0182 | - | - | N |
| Magnesium (Mg) | 30,500 | - | 9,479 | - | - | 10.1 | 19.1 | 9.75 | 15.4 | 2.77 | 4.93 | 12.0 | - | - | N |
| Manganese (Mn) | 13,200 | - | 709 | - | - | 0.06 | 0.169 | 0.0475 | 0.133 | 0.00876 | 0.0221 | 0.0999 | - | 0.69-1.454 | N |
| Mercury (Hg) | 2.72 | 6.6 | 0.0599 | 0.2 | 0.2 | **0.00003** | **0.000269** | **0.00003** | **0.000214** | 0.00000430 | 0.0000136 | **0.00016** | 0.000026 | - | Y |
| Molybdenum (Mo) | **154** | 5 | 8.11 | - | - | 0.0007 | 0.247 | 0.207 | 0.204 | 0.000277 | 0.108 | 0.158 | 0.073 | 2 | Y |
| Nickel (Ni) | **120** | 50 | **396** | - | 16 | 0.0069 | 0.00584 | 0.00381 | 0.00474 | 0.000575 | 0.00199 | 0.00369 | 0.12-0.474 | - | Y |
| Phosphorus (P) | 8,510 | - | 1,294 | - | - | 0.15 | | | | | | | - | - | N |
| Potassium (K) | 4,060 | - | 34,603 | - | - | 0.69 | | | | | | | - | - | N |
| Selenium (Se) | **10.8** | 1 | **5.44** | - | 5 | **0.0016** | **0.0542** | **0.0527** | **0.0451** | 0.000431 | **0.0276** | **0.0351** | 0.001 | - | Y |
| Silver (Ag) | 5.00 | 20 | **0.847** | - | 0.5 | 0.00003 | 0.000113 | 0.0000842 | 0.0000929 | 0.00000430 | 0.0000438 | 0.0000721 | 0.0001 | 0.003 | Y |
| Sodium (Na) | 4,650 | - | 4,482 | - | - | 3.1 | | | | | | | - | - | N |
| Strontium (Sr) | 270 | - | 174 | - | - | 0.4 | | | | | | | - | - | N |
| Thallium (Tl) | 0.50 | 1 | 2.05 | - | - | 0.00005 | 0.000295 | 0.0000549 | 0.000235 | 0.0000412 | 0.0000302 | 0.00018 | 0.0008 | - | N |
| Tin (Sn) | **21.3** | 5 | 6.21 | - | - | 0.00005 | | | | | | | - | - | N |
| Titanium (Ti) | 6,760 | - | 1,917 | - | - | 0.061 | | | | | | | - | - | N |
| Vanadium (V) | **351** | 130 | 180 | - | - | 0.0055 | 0.0270 | 0.00451 | 0.0216 | 0.000430 | 0.00203 | 0.0162 | - | - | Y |
| Zinc (Zn) | **236** | 200 | 120 | 123 | 123 | 0.010 | 0.0282 | 0.0257 | 0.0236 | 0.000946 | 0.0135 | 0.0185 | 0.03 | 0.067-0.5884 | Y |
| WAD-Cyanide (WAD-CN) | nd | - | nd | - | - | 0.0005 | **0.0465** | **0.455** | **0.0505** | 0.000457 | **0.247** | **0.0555** | - | 0.01 | N |
| Fluoride (F) | nd | - | nd | - | - | 0.047 | **9.42** | 1.05 | **7.50** | 0.0222 | 0.443 | **5.59** | 0.12 | 1.45-2.184 | Y |
| Nitrate ($NO_3$) | nd | - | nd | - | - | 1.170 | **76.3** | 7.51 | **62.3** | 0.0758 | 3.14 | **45.5** | 2.935 | 32.8 | N |
| Sulphate ($SO_4$) | nd | - | nd | - | - | 95.800 | **2,280** | **1,620** | **1,870** | 27.1 | **832** | **1,440** | - | 100 | N |

**- no guideline**
**nd = not determined**
**WAD weak acid dissociable**
**[1] Maximum soil concentration in 0-10 cm, n=59 (2009)**
**[2] High outlier STE1A, September 4, 2011, excluded**
**[3] Maximum of modelled monthly predictions using the mean water quality data as source term and assuming normal flow**
**[4] Guideline is hardness-dependent and applicable range is provided**
**Highlighted and bolded numbers indicate guideline exceedance**

## Table 25.7-13. Metals Evaluated and Rationale for Inclusion as Contaminants of Potential Concern into the Screening Level Risk Assessment for the Mine Site

| | Maximum Soil Concentration in 0-10 cm, n=59 (2009) | CCME Soil Guideline (Agricultural) | Maximum Sediment Concentration Unuk River, n=64 (2008-2012) | CCME Sediment Guideline ISQG | BC Sediment Guideline | Maximum Water Concentration at Baseline in Sulphurets Cr. and Unuk R.[1] (2007-2011) | Water Concentration at Mine Site[2] Operation years 1-50 | Closure years 51-55 | CCME Water Guideline Freshwater Aquatic Life | BC Max. Water Criteria Freshwater Aquatic Life | Inclusion in SLRA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | mg/kg | | mg/kg | | | mg/L (total metals) | mg/L (total metals) | | mg/L | | |
| Aluminum (Al) | 39,300 | ng | 23,200 | ng | ng | **22.4** | **7.35** | **7.98** | 0.10 | ng | Y |
| Antimony (Sb) | 15.0 | ng | 26.0 | ng | ng | 0.00867 | 0.00146 | 0.0015 | ng | ng | N |
| Arsenic (As) | **169** | 12 | **117** | 5.9 | 5.9 | **0.0590** | **0.01200** | **0.0129** | 0.01 | 0.05 | Y |
| Barium (Ba) | **1,110** | 750 | 589 | ng | ng | 0.410 | 0.157 | 0.168 | ng | ng | Y |
| Beryllium (Be) | **6.47** | 4 | 1.20 | ng | ng | 0.000840 | 0.00087 | 0.000847 | ng | ng | Y |
| Bismuth (Bi) | 10.0 | ng | 10.0 | ng | ng | 0.000730 | - | - | ng | ng | N |
| Cadmium(Cd) | **1.52** | 1.4 | **25.4** | 0.60 | 0.60 | **0.00559** | **0.001140** | **0.00122** | 0.00001-0.00007[3] | ng | Y |
| Calcium (Ca) | 16,000 | ng | 40,000 | ng | ng | 80.0 | 60.4 | 61.2 | ng | ng | N |
| Chromium (Cr) | **288** | 64 | **80.6** | 37.3 | 37.3 | **0.0387** | **0.0105** | **0.0112** | 0.01 | ng | Y |
| Cobalt (Co) | **123** | 40 | 32.0 | ng | ng | 0.0159 | 0.00526 | 0.00568 | ng | 0.11 | Y |
| Copper (Cu) | **1,060** | 63 | **214** | 35.7 | 35.7 | **0.432** | **0.116** | **0.126** | 0.002-0.048[3] | 0.002-0.0236[3] | Y |
| Iron (Fe) | 373,000 | ng | **78,100** | ng | 21,200 | **36.6** | **12.2** | **13.2** | 0.30 | 1.00 | N |
| Lead (Pb) | 69.0 | 70 | 36.0 | 35 | 35 | **0.0334** | **0.00624** | **0.00674** | 0.001-0.0092[3] | 0.125-0.955[3] | Y |
| Lithium (Li) | 55.40 | ng | 43.2 | ng | ng | 0.0138 | 0.00551 | 0.00571 | ng | ng | N |
| Magnesium (Mg) | 30,500 | ng | 18,100 | ng | ng | 13.7 | 6.15 | 6.45 | ng | ng | N |
| Manganese (Mn) | 13,200 | ng | 1,520 | ng | ng | 0.973 | 0.31 | 0.333 | ng | 0.54-3.075[3] | N |
| Mercury (Hg) | 2.72 | 6.6 | 0.56 | 0.17 | 0.17 | **0.0000960** | **0.000033** | **0.0000343** | 0.000026 | ng | Y |
| Molybdenum (Mo) | **154** | 5 | 20.3 | ng | ng | 0.00830 | 0.00406 | 0.00336 | 0.07 | 2.00 | Y |
| Nickel (Ni) | **120** | 50 | **157** | ng | 16 | 0.0289 | 0.00938 | 0.0101 | 0.034-0.180[3] | ng | Y |
| Phosphorus (P) | 8,510 | ng | 2,320 | ng | ng | 1.41 | - | - | ng | ng | N |
| Potassium (K) | 4,060 | ng | 2,180 | ng | ng | 6.17 | - | - | ng | ng | N |
| Selenium (Se) | **10.8** | 1 | 19.1 | ng | 5 | **0.00367** | **0.00512** | **0.00491** | 0.001 | ng | Y |
| Silver (Ag) | 5.00 | 20 | **2.30** | ng | 0.5 | **0.0240** | **0.000172** | **0.000186** | 0.0001 | 0.0001-0.003[3] | Y |
| Sodium (Na) | 4,650 | ng | 1,720 | ng | ng | 4.30 | - | - | ng | ng | N |
| Strontium (Sr) | 270 | ng | 152 | ng | ng | 0.396 | - | - | ng | ng | N |
| Thallium (Tl) | 0.50 | 1 | 0.612 | ng | ng | 0.000266 | 0.000102 | 0.000107 | 0.0008 | ng | N |
| Tin (Sn) | **21.3** | 5 | 2.50 | ng | ng | 0.0700 | - | - | ng | ng | Y |
| Titanium (Ti) | 6,760 | ng | 1,620 | ng | ng | 1.60 | - | - | ng | ng | N |
| Vanadium (V) | **351** | 130 | 157 | ng | ng | 0.0928 | 0.0309 | 0.0333 | ng | ng | Y |
| Zinc (Zn) | **236** | 200 | **1,460** | 123 | 123 | **0.395** | **0.0914** | **0.0986** | 0.03 | 0.033-0.130[3] | Y |
| WAD-Cyanide (WAD-CN) | nd | - | nd | - | - | 0.00120 | 0.000669 | 0.000717 | ng | 0.01 | N |
| Fluoride (F) | nd | - | nd | - | - | **0.157** | 0.0881 | 0.0837 | 0.12 | 0.8-1.67[3] | Y |
| Nitrate ($NO_3$) | nd | - | nd | - | - | 0.446 | 1.64 | 0.172 | 2.94 | 32.8 | N |
| Sulphate ($SO_4$) | nd | - | nd | - | - | **153** | **158** | **156** | ng | 100 | N |

**Highlighted and bolded values are higher than guideline**
**ng = no guideline**
**nd = not determined**
**[1] SC3, UR0, ECM7, ECM8, CC1, UR1A, UR1, UR2**
**[2] Maximum of modelled monthly predictions using the mean water quality data as source term and assuming normal flow; UR1, UR2, SC2, and SC3 were averaged**
**[3] Guideline is hardness-dependent and applicable range is provided**

Cadmium is known to damage the kidneys and the lungs, and can cause a weakening of bones at low concentrations (Godt et al. 2006). The US EPA has classified cadmium as a Group B1 or "probable" human carcinogen. Because cadmium is bioaccumulative, concentrations in the liver and kidneys of adult animals may be higher than in plants.

Hexavalent chromium (Cr VI) compounds are more toxic than trivalent chromium (Cr III) compounds. Ingestion of hexavalent chromium can cause irritation and ulcers in the stomach and intestine, and changes to the male reproductive system (ATSDR 2011a). Hexavalent chromium is considered a human carcinogen.

Cobalt has both beneficial (as a component of vitamin $B_{12}$) and harmful effects on human health (ATSDR 2011b). Cobalt is a possible human carcinogen. Exposure to high concentrations of cobalt through inhalation can cause breathing difficulties and asthma. Ingestion of high concentrations of cobalt can cause nausea, vomiting, and effects on the heart.

Copper is an essential micronutrient and is ubiquitous in the environment, food, and drinking water. Generally, there is no systemic toxicity associated with copper. In high doses, free (unbound) copper in the blood can cause toxicity via the generation of reactive oxygen species, which can damage proteins, lipids, and DNA.

Lead is toxic to a variety of organ systems at very low doses, and there is no demonstrable threshold dose for the manifestation of lead's toxicity. No nutritional value, positive biological effect, or nutrient deficiency has been associated with lead. The International Agency for Research on Cancer (IARC) has determined that the evidence for carcinogenicity of inorganic lead compounds to humans is inadequate and has classified these compounds as possibly carcinogenic to humans (Group 2B).

Mercury occurs as metallic mercury, inorganic mercury salts, and organic mercury (ATSDR 2011c). Methylmercury is of particular concern because it can build up in certain edible freshwater and saltwater fish and marine mammals to levels that are many times greater than levels in the surrounding water, and is the form of mercury most readily absorbed into the human body. It readily enters the brain and remains there for a long time, causing neurotoxic effects.

Molybdenum is an essential nutrient and component of many enzymes. Acute toxicity has not been seen in humans, and the toxicity depends strongly on the chemical state. Animal studies show that high levels of molybdenum uptake can cause diarrhea, growth retardation, infertility, low birth weight, and gout; it can also affect the lungs, kidneys, and liver. High levels of molybdenum can interfere with the body's uptake of copper, producing copper deficiency.

The most common harmful health effect of nickel in humans is an allergic reaction through inhalation (bronchitis and asthma), ingestion, or dermal contact (skin rash and eczema; ATSDR 2011d). People who are not sensitive to nickel must eat very large amounts of nickel to suffer harmful health effects (increased red blood cells and increased protein in urine). The IARC has determined that some nickel compounds are carcinogenic to humans and that metallic nickel may possibly be carcinogenic to humans (through the inhalation route).

Selenium is an essential trace element in the human diet, but selenium has a narrow margin between beneficial and harmful effects. Food is the main source of intake of selenium. Harmful effects are described as selenosis, which include jaundice, chloasma (facial pigmentation), dermatitis, nail changes, gastrointestinal disease, and other symptoms. Selenium compounds that can dissolve in water are sometimes very mobile. Thus, there is an increased chance of exposure to these compounds from bioconcentration in the food chain (ATSDR 2011e). Most of the selenium that enters the body quickly leaves the body, usually within 24 hours. However, selenium can build up in the body if exposure levels are very high and exposure occurs over a long time.

Silver can cause argyria, a permanent blue-gray discoloration of the skin and other tissues, upon repeated ingestion of high levels of silver (ATSDR 2011f). However, the condition is thought to be only a cosmetic problem and not a serious health effect. Exposure to dust containing relatively high levels of silver compounds may cause breathing problems, lung and throat irritation, and stomach pain.

Tin is present in the air, water, soil, and sediments and is a normal part in tissues of many plants and animals that live on land and in water (ATSDR 2011g). There is no evidence that tin is an essential element for humans. Most ingested or inhaled tin is efficiently excreted by the body and does not enter the blood stream. However, humans who swallowed large amounts of inorganic tin in research studies suffered stomach aches, anemia, and liver and kidney problems (ATSDR 2011g). Tin is not a carcinogen.

Vanadium is predominately taken up into the human body by ingestion of food (ATSDR 2011h). Nausea, mild diarrhea, and stomach cramps have been reported in people taking sodium metavanadate or vanadyl sulphate for the experimental treatment of diabetes. The IARC has determined that vanadium is possibly carcinogenic to humans through the inhalation route.

Zinc is an essential micronutrient. Zinc is relatively non-toxic if taken orally, and instances of acute poisoning due to zinc exposure from environmental sources are extremely rare (ATSDR 2011i). The acute effects of zinc are usually the result of short-term, high-dose exposure, and are reversible after cessation of zinc intake. Ingestion of zinc and zinc-containing compounds can result in a variety of chronic effects in the gastrointestinal, haematological, and respiratory systems. Zinc has not been shown to be a human mutagen or carcinogen (Nriagu 2011).

Mining operations can alter the natural metal concentration in environmental media within and surrounding the mine footprint. Metals in fugitive dust will be deposited at a distance from mine operations onto plants, soils, and surface water. Mine Site effluent may lead to an increase in some metal concentrations in the receiving aquatic environment (Chapter 14). Plants can take up dissolved metals from soils and water, and wildlife can be exposed to elevated concentrations of metals through ingestion of contaminated water, soil, vegetation, and prey; dermal absorption of metals through skin into the blood stream; and inhalation of metal-bound particulates in the air. For highly bioaccumulative metals (e.g., mercury), human exposure via the food chain can result in increases in metal concentrations, as these contaminants biomagnify at each trophic level (Pyatt et al. 2005).

In addition to naturally occurring metals, chemicals used in mine development and operation may be toxic to human health. Petroleum products such as fuel and hydraulic oil will be stored in above-ground storage tanks throughout the Mine Site. In addition, flocculants and chemical reagents such as ammonium nitrate and lime (CaO) will be used and stored at the site. Hazardous wastes will be produced in both the construction and operation phases of the KSM Project. They include materials such as fuel, oil and waste oil, hydraulic fluid, explosives, cyanide, selenium, ferric sulphate, sulphuric acid, chlorine, laboratory chemicals and solvents, lead acid batteries, and oil filters. Safe handling and storage of hazardous materials is governed by the Dangerous Goods and Hazardous Materials Management Plan (Section 26.7) and therefore does not pose a risk to human health. Accidental releases of these chemicals will be responded to efficiently and safely as described in the Spill Prevention and Emergency Response Plan (Section 26.10). Therefore, effects to human health from the exposure to process chemicals and hazardous wastes are considered negligible and will not be considered further.

To determine the potential effects to country foods, predicted changes in the concentration of COPC in the environmental media were reviewed. The following presents a summary of the predicted effects to the environmental media.

Predicted Effects to Water

An effects assessment for water quality is presented in Chapter 14. The overall residual effect for water quality identified in Chapter 14 was classified as not significant (moderate) after mitigation. Therefore, SLRAs for human health were conducted (Appendices 25-C and 25-D).

During operation and approximately five years into closure, the TMF is predicted to contain metals at concentrations that are higher than baseline concentrations (arsenic, chromium, cobalt, copper, mercury, selenium, and vanadium; Appendix 14-H). Although no vegetation will be permitted to grow in the TMF during operation, country foods wildlife species (e.g., moose, snowshoe hare, and grouse) may incidentally ingest the water. During closure and post-closure, the TMF will be capped and re-planted with vegetation (sedges, grasses, bushes, and trees along wildlife corridors), and increased habitat use may subsequently result in degradation in the quality of the wildlife.

Treated water discharged from the Water Treatment and Energy Recovery Area will generally improve water quality compared to baseline water quality. However, some metals and ions will remain at concentrations above water quality guidelines, and also above background, during operation and closure (chromium and selenium). Animals such as moose, mountain goats, marmots, grizzly bears, and waterfowl will potentially have access to pit lakes, the WSF, and creeks and rivers downstream of the Mine Site, which may subsequently result in degradation of the quality of the wildlife hunted for human consumption. Fish and bird populations in Sulphurets Creek and the Unuk River will be exposed to selenium concentrations that are predicted to be higher than baseline levels, and this may affect their fecundity, abundance, and tissue metal loads, and therefore their quality as a human country food.

Predicted Effects to Soil

Minor spills of fuel oils will be remediated as per the Spill Prevention and Emergency Response Plan (Section 26.10) as described above and therefore will not affect soil quality and the quality of country foods (i.e., vegetation or wildlife) during all Project phases.

During transmission line operation, vegetation will be mechanically managed (i.e., slash methods) rather than managed chemically. There will be no herbicides used along the transmission line corridor or along roads, except for control of an invasive species outbreak and where mechanical methods do not work. Application would be directly to the individual plant in very small quantities. No effects to the quality of soil or country foods (i.e., vegetation) are predicted along the transmission line or roads during its operation.

During operation, soil quality is predicted to be affected at the TMF, OPC, and RSF. Edible vegetation will not be permitted or will not be able to grow in these areas during operation. Furthermore, people will not be permitted to use these areas for vegetation harvesting purposes or for hunting or trapping. Thus, there are no predicted effects to vegetation used for consumptive purposes due to changes in soil quality during operation. However, there is the possibility that country foods wildlife species may incidentally ingest developing vegetation at the TMF during closure and thus the quality of the wildlife country foods (i.e., moose and grouse) may decrease. Animals may also ingest affected soils at the TMF during operation and closure. Therefore, soil was included in the SLRAs.

Airborne deposition of contaminants in dust from the PTMA and Mine Site is predicted to occur in a highly localized manner during construction and operation (Chapter 7). Receptor locations for wildlife (mountain goats, grizzly bears, and moose) have been modelled for dust deposition (Chapter 7). During construction, elevated dust levels are likely to occur at the Mitchell-Treaty Saddle Area and northwest of the Mine Site. During mine operation, dust levels further increase northwest of the Mine Site. Dust can contain metals due to the metal content in the rock media. However, wildlife receptors most frequently of concern to human health (moose) will unlikely be affected, because their habitat is outside of the dust deposition zone and dust deposition rates are relatively low.

Based on similar assessments (Intrinsik Environmental 2010), it is not expected that country foods at the PTMA and near the Mine Site will have elevated metal concentrations due to dusting. Vegetation in these areas may bioaccumulate metals from the soil. However, the bioavailability of metals from dust is unknown at this time, and future soil metal concentrations are predicted to be below agricultural soil quality guidelines (CCME 1999), and therefore are unlikely to present a significant risk to animals.

The Soil Salvage and Handling Plan (Section 26.13.2) indicates that, upon closure, the soils and overburden will be reapplied in a manner that preserves their value. Soils and till will be applied to a depth of 50 cm, except the submerged sediment along the tailing dams in the TMF and at the RSF above 1,100 m. However, wildlife may incidentally ingest the affected sediments in the TMF not covered by till, and thus the quality of the wildlife country foods (i.e., moose and grouse) may decrease, and was therefore modelled in the SLRA.

Predicted Effects to Vegetation

The quality of edible vegetation may be affected in areas of elevated metal concentrations (TMF after closure, RSF), as considered above for soil effects. The general public will not be permitted to harvest vegetation from the Mine Site, TMF, and access roads during all phases of the Project, but may continue to harvest in adjacent areas. During transmission line operation, vegetation will be mechanically managed (i.e., slash methods) rather than managed chemically (except in isolated and unlikely circumstances, as described above). At closure, the reclamation plan will ensure that the pathway for edible vegetation to uptake metals or other possible contaminants is limited to the extent possible by providing sufficient reclaimed soil cover on the TMF and RSF (Chapter 27, Closure and Reclamation).

In post-closure, the TMF wetland vegetation is expected to establish along the shores of each dam and on top of each dam, down to 2 m below the water surface. Wetland vegetation could uptake metals from the submerged tailing at these locations. If the wetlands take up the metals, this would result in a valid exposure pathway of metals to wildlife that ingest wetland vegetation (i.e., moose, snowshoe hare, grouse, and other herbivores). This may subsequently reduce the quality of country food wildlife species, and was therefore included in the SLRA.

Summary of Predicted Effects

Table 25.7-14 summarizes the potential residual effects to human health due to changes in country foods quality. A review of the potential Project-related changes to water, soil, and vegetation quality found that the potential sources of contaminant uptake into country foods during operation would be from the predicted elevated metals in sediment and water at the TMF, and from the water downstream of the Mine Site at Sulphurets Creek and the Unuk River. "Dusting" may affect soils and vegetation at distant locations, but is likely of small magnitude relative to changes in water metal concentrations. At closure, the potential sources of contaminant uptake into country foods would be from the predicted elevated metals in the submerged sediments along the TMF dam shores, from the water and establishing wetlands vegetation and aquatic invertebrates at the TMF, and from water downstream of the Mine Site, including Sulphurets Creek and the Unuk River.

The operation phase is expected to have the greatest effect on country foods quality and human health, and effects may be reduced during closure and post-closure. The country foods that may take up metals from environmental media would be wildlife species, bird species, and fish. The country foods baseline (Appendix 25-A) has identified moose and grouse as being the two relevant country foods that may uptake the metals. The quality of edible fish (Appendices 25-B and 25-C) may change due to metal concentration in water. Vegetation is not predicted to be significantly affected by Project activities.

#### 25.7.3.1 Mitigation for Changes in Country Foods Quality

Mitigation to reduce effects to human health from the consumption of country foods relies on mitigation measures that reduce effects to water quality, air quality, soil quality, wildlife, and vegetation. In addition, access management to the Project area will mitigate some of the effects to human health (Section 26.25, Traffic and Access Management Plan). Fugitive dust will be mitigated and managed according to the Air Quality Management Plan (Section 26.11). This plan ensures that the ambient air quality meets the Canada Wide Standards (Environment Canada 1999) and BC Ambient Air Quality and Pollution Control Objectives (BC MOE 2009). In addition, monitoring activities in soils, water, and vegetation in these areas will be included during construction, operation, closure, and post-closure phases of the Project. The Environmental Effects Monitoring and Follow-up Program for the KSM Project (Chapter 38) includes monitoring of surface water quality, and of levels of metals and other COPC in mine-disturbed soils. The Terrestrial Ecosystems Management and Monitoring Plan (Section 26.20) includes terrestrial plant tissue metal concentrations monitoring. If the concentrations of metals or other COPCs are shown to increase over time in water, soils, or vegetation due to mine activities, the requirement for further country foods risk assessments will be investigated. Adaptive management practices will be implemented if monitoring and modelling indicate an unacceptable level of risk to human health.

#### 25.7.3.2 Potential for Residual Effects

To assess the potential for residual human health effects from the consumption of country foods, SLRA for the PTMA and the Mine Site were conducted, as required by the AIR. The SLRA estimated risks to people consuming moose (*Alces alces*), snowshoe hare (*Lepus americanus*), grouse (*Phasianidae* sp.), a mixture of berries (*Viburnum edule, Vaccinium* spp., and *Rubus* ssp.), and Dolly Varden (*Salvelinus malma malma*) during baseline, operation, and closure. The development of the access road offers the potential for enhanced access to the area, even if the road has strict access control. The Traffic and Access Management Plan (Section 26.25) ensures that subsistence users can plan their activities in relation to Project activities with the goal to eliminate negative interactions.

<u>Results of the Screening Level Risk Assessment for the Processing and Tailing Management Area and Mine Site</u>

To determine the potential for residual effects to country foods, SLRAs were performed. Due to the size of the Project, the different types of Project activities, and the high variability in the concentrations of COPC in environmental media between the two components of the Project, two separate SLRAs were carried out: one for the PTMA and one for the Mine Site.

For the SLRAs, predicted changes in the concentration of metals in the environmental media were reviewed. It was assumed that potential effects would be greatest during Project operation and closure, and that if no effects were detected during these phases, construction and post-closure phases would also have no effects on human health. Assumptions, problem formulation, methods, detailed results, and a discussion of uncertainties in the assessment can be found in Appendices 25-C and 25-D. A summary of the results is presented in the following paragraphs.

The SLRAs integrated the results of the environmental media baseline studies and modelled predictions, human receptor characteristics, and regulatory-based TRVs during baseline, operation, and closure of the KSM Project. The potential for residual human health effects caused by the consumption of five country foods (moose, snowshoe hare, grouse, berries, and Dolly Varden) were assessed. The country foods SLRA methodology was based on Health Canada's guidelines for assessing country foods (Health Canada 2010b).

## Table 25.7-14. Potential Residual Effects on Human Health from Changes in Country Foods Quality

| VC | Timing Start | Project Area(s) | Component(s) | Description of Effect due to Component(s) | Type of Project Mitigation | Project Mitigation Description | Potential Residual Effect | Description of Residuals |
|---|---|---|---|---|---|---|---|---|
| Health of adults and toddlers consuming country foods | Operation, Closure, Post-closure | PTMA | Water and sediment quality in TMF and creeks immediately down-stream | Negative acute and chronic health effects due to metal toxicity from the consumption of exposed country foods | Project Design, Management Practices, Monitoring and Adaptive Management | There will be no unauthorized access along the Project right-of-ways and to the TMF.<br>A no hunting and no fishing policy will be implemented and enforced for employees and contractors.<br>Conduct ecological and human health risk assessment should metals exceed guidelines in environmental media during operation, closure and post-closure.<br>Safe transportation and storage of process chemicals, fuels, and oils as described in the Project Description.<br>Effective management of spills and emergencies according to the Spill Management Plan.<br>Effects of metals on water quality will be mitigated through Project design.<br>"Dusting" on soil and vegetation quality will be minimized according to the Fugitive Dust and Air Quality Management Plans.<br>Mitigation applicable to water, air, and soil quality will result in mitigation of potential effects to country food. | Yes | Residual health effects to public and First Nations consuming country foods near the TMF due to changes in water and sediment quality (metals), and bioaccumulation of metals in the food chain. |
| Health of adults and toddlers consuming country foods | Operation, Closure, Post-closure | Mine Site | Water quality in WSF and downstream of Mine Site, soil quality at RSF and Mine Site | Negative acute and chronic health effects due to metal toxicity from the consumption of exposed country foods | Project Design, Management Practices, Monitoring and Adaptive Management | There will be no unauthorized access along the Project right-of-ways and to the Mine Site.<br>A no hunting and no fishing policy will be implemented and enforced for employees and contractors.<br>Conduct ecological and human health risk assessment should metals exceed guidelines in environmental media during operation, closure and post-closure.<br>Safe transportation and storage of process chemicals, fuels, and oils as described in the Project Description.<br>Effective management of spills and emergencies according to the Spill Management Plan.<br>Effects of metals on water quality will be mitigated through Project design.<br>"Dusting" on soil and vegetation quality will be minimized according to the Fugitive Dust and Air Quality Management Plans.<br>Mitigation applicable to water, air, and soil quality will result in mitigation of potential effects to country food. | Yes | Residual health effects to public and First Nations consuming country foods downstream of Mine Site due to changes in water quality (metals) and bioaccumulation of metals in the food chain |

The country foods SLRAs compared the estimated daily intakes (EDIs) of metals by country food harvesters with applicable tolerable daily intakes to determine the ER. The ER is the assessment endpoint used to determine the potential for human health risks from non-carcinogenic metals. For metals considered carcinogenic via the ingestion pathway (e.g., arsenic), the ILCR was calculated. In addition, the recommended maximum weekly intakes (RMWIs) for moose, snowshoe hare, grouse, Dolly Varden, and berries were also calculated. The baseline ER, ILCR, and RMWI were compared to the predicted operation and closure phase results to assess potential changes in the quality of foods from mine development. The following sections present the results of the PTMA and Mine Site country foods SLRAs. The entire country foods SLRAs are presented in Appendices 25-C and 25-D.

Exposure Ratios

Tables 25.7-15 and 25.7-16 present the ERs for toddlers and adults consuming moose, snowshoe hare, grouse, Dolly Varden, and berries under the baseline, operation, and closure scenarios obtained at the TMF and downstream of the Mine Site.

For non-carcinogenic COPC, an ER of less than 0.2 represents exposure that does not pose a significant health risk to human receptors (Health Canada 2004b). Health Canada considers an ER of 0.2 appropriate because only one exposure pathway is evaluated, and it is assumed that people are exposed to COPC from multiple sources, such as other food groups, soil, air, water, cigarettes, and cigarette second-hand smoke.

ER values greater than 0.2 do not necessarily indicate that adverse health effects will occur because of the conservatism employed in their estimation (e.g., the tolerable daily intakes are conservative and protect human health based on the application of uncertainty factors in their derivation). ER values are not measures of risk, but are rather measures of levels of concern (Tannenbaum, Johnson, and Bazar 2003). Thus, an ER value of greater than 0.2 is not conclusive evidence that a human health risk exists. However, it does suggest a potential that may require a more detailed evaluation.

The assessment for the TMF showed that all ERs were at or below 0.2 for the baseline, operation, and closure scenarios for consuming snowshoe hare, berries, and Dolly Varden (Table 25.7-15). There is no concern related to the use of these country foods sources for human health. ERs for both moose and grouse were above 0.2 for aluminum (toddlers only), and for arsenic, chromium, and cobalt (for toddlers and adults). However, ER values were at or below 1, were elevated above 0.2 during baseline, and did not increase significantly during operation and closure. Therefore, the values reflect the naturally high concentrations of these metals at the TMF under baseline conditions and do not indicate a concern for human health.

The assessment for the Mine Site showed that all ERs were below 0.2 for the baseline, operation, and closure scenarios for consuming snowshoe hare and berries (Table 25.7-16). ERs for both moose and grouse were above 0.2 for aluminum (toddlers only), and for arsenic, chromium, and cobalt (for toddlers and adults). However, ER values were at or below 1, were elevated above 0.2 during baseline, and did not increase significantly during operation and closure. The values reflect the naturally high concentrations of these metals at the Mine Site under baseline conditions and do not indicate a concern for human health.

Incremental Lifetime Cancer Risks

Tables 25.7-17 and 25.7-18 present the ILCR due to ingestion of arsenic for adults consuming country foods at the PTMA and Mine Site under baseline, operation, and closure scenarios.

In BC, an ILCR estimate that is less than $1 \times 10^{-5}$ is considered acceptable. The ILCR for berries and snowshoe hare was less than $1 \times 10^{-5}$ at the PTMA and Mine Site during baseline, and predicted to be less than $1 \times 10^{-5}$ during operation and closure. Therefore, these country foods can be considered safe for consumption at the current assumed local consumption rates. The ILCR for moose and for grouse at the TMF and downstream of the Mine Site during baseline, operation, and closure, and for Dolly Varden at the TMF (fish were not assessed downstream of the Mine Site, because fishing in that area occurs rarely or not at all) was at or below $6 \times 10^{-4}$ and therefore higher than the accepted BC level. However, the ILCR was higher than $1 \times 10^{-5}$ during baseline and did not substantially increase during operation and closure, but may even decrease in some cases during closure.

Many agencies and provinces, including the US EPA, identify a range of increased cancer incidence risks; generally, from 1 in 10,000 (or $1 \times 10^{-4}$) to 1 in 1,000,000 (or $1 \times 10^{-6}$) is considered an acceptable risk range, depending on the situation and circumstances of exposure (Health Canada 2010a). Grouse was identified as the country food with the highest ILCR due to arsenic, because the soils in the Project area are naturally high in arsenic (Chapter 8) and the transfer factor for arsenic for chicken, used to model grouse arsenic tissue concentrations, is relatively high (Staven et al. 2003). These elevated arsenic concentrations may require further consideration independent of Project development due to potential health concerns for humans who consume these species frequently. In summary, the ILCR does not increase substantially from baseline due to Project activities and therefore reflects the naturally high concentrations of arsenic at the Project sites under baseline conditions.

Recommended Maximum Weekly Intakes

Tables 25.7-19 and 25.7-20 present the RMWI for country foods for adults and toddlers at the TMF and downstream of the Mine Site. The RMWI was calculated as described by Health Canada's guidance (2010d), using the following equation:

$$RMWI = \frac{TRV \times BW \times 7}{C_{food}}$$

where:

$RMWI$ = recommended maximum weekly intake of food (g/week);
$TRV$ = toxicological reference value (µg/kg BW/day);
$BW$ = receptor body weight (kg);
$7$ = days per week; and
$C_{food}$ = maximum metal concentration in food (µg/g).

## Table 25.7-15. Exposure Ratios for Human Receptors at the Processing and Tailing Management Area

| | Exposure Ratio for Adult Receptor | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | | | | | Operation | | | | | Closure | | | | |
| **COPC** | **Moose** | **Grouse** | **Hare** | **Berries** | **Dolly Varden** | **Moose** | **Grouse** | **Hare** | **Berries** | **Dolly Varden** | **Moose** | **Grouse** | **Hare** | **Berries** | **Dolly Varden** |
| Aluminum | 2.18E-02 | 1.17E-01 | 6.74E-06 | 1.72E-03 | 7.80E-03 | 3.07E-02 | 1.25E-01 | 6.74E-06 | 1.72E-03 | 8.78E-03 | 3.06E-02 | 1.25E-01 | 7.62E-06 | 1.72E-03 | 8.90E-03 |
| Arsenic | 2.00E-01 | **8.87E-01** | 6.39E-05 | 2.93E-03 | 2.52E-02 | 1.47E-01 | **8.47E-01** | 6.39E-05 | 2.93E-03 | 1.05E-01 | 1.46E-01 | **8.47E-01** | 5.82E-05 | 2.93E-03 | 1.05E-01 |
| Barium | 3.29E-04 | 9.01E-05 | 7.14E-08 | 1.62E-03 | 8.40E-04 | 5.56E-04 | 1.12E-04 | 7.14E-08 | 1.62E-03 | 6.70E-04 | 7.52E-04 | 1.13E-04 | 1.03E-07 | 1.62E-03 | 7.13E-04 |
| Beryllium | 9.42E-04 | 1.95E-03 | 2.14E-07 | 2.85E-03 | 1.89E-03 | 8.71E-04 | 1.90E-03 | 2.14E-07 | 2.85E-03 | 2.54E-03 | 7.16E-04 | 1.90E-03 | 2.00E-07 | 2.85E-03 | 2.68E-03 |
| Cadmium | 2.19E-04 | 4.41E-04 | 3.93E-08 | 5.22E-04 | 9.31E-03 | 2.11E-04 | 4.28E-04 | 3.93E-08 | 5.22E-04 | 3.96E-03 | 1.77E-04 | 4.27E-04 | 3.69E-08 | 5.22E-04 | 3.98E-03 |
| Chromium | **3.01E-01** | 1.08E-01 | 9.22E-05 | 1.27E-02 | 8.02E-02 | **2.36E-01** | 1.05E-01 | 9.22E-05 | 1.27E-02 | 1.10E-01 | **2.35E-01** | 1.05E-01 | 8.57E-05 | 1.27E-02 | 1.11E-01 |
| Cobalt | **2.24E-01** | **4.10E-01** | 6.58E-05 | 2.22E-03 | 1.93E-02 | 1.85E-01 | **3.97E-01** | 6.58E-05 | 2.22E-03 | 3.21E-02 | 1.83E-01 | **3.97E-01** | 6.17E-05 | 2.22E-03 | 3.32E-02 |
| Copper | 1.22E-02 | 6.23E-03 | 3.60E-06 | 8.86E-04 | 5.96E-04 | 1.25E-02 | 6.25E-03 | 3.60E-06 | 8.86E-04 | 1.04E-03 | 6.99E-02 | 6.35E-03 | 6.19E-06 | 8.86E-04 | 1.07E-03 |
| Mercury | 1.33E-02 | 3.70E-04 | 3.94E-06 | 2.28E-04 | 4.83E-03 | 1.01E-02 | 3.53E-04 | 3.94E-06 | 2.28E-04 | nd | 1.64E-02 | 3.54E-04 | 3.89E-06 | 2.28E-04 | nd |
| Molybdenum | 7.57E-07 | 1.36E-06 | 2.33E-10 | 4.05E-07 | 1.00E-07 | 7.63E-07 | 1.30E-06 | 2.33E-10 | 4.05E-07 | 1.27E-07 | 7.69E-07 | 1.31E-06 | 2.22E-10 | 4.05E-07 | 2.32E-07 |
| Nickel | 2.37E-02 | 2.61E-05 | 5.95E-06 | 2.70E-03 | 2.13E-04 | 5.05E-02 | 3.35E-05 | 5.95E-06 | 2.70E-03 | 4.29E-03 | 6.39E-02 | 3.36E-05 | 9.22E-06 | 2.70E-03 | 4.33E-03 |
| Selenium | 1.83E-03 | 3.97E-03 | 3.91E-07 | 2.35E-03 | 7.30E-03 | 2.11E-03 | 4.04E-03 | 3.91E-07 | 2.35E-03 | nd | 2.21E-03 | 4.04E-03 | 4.08E-07 | 2.35E-03 | nd |
| Silver | 6.71E-04 | 4.83E-03 | 2.16E-07 | nd | 4.01E-02 | 5.29E-04 | 4.67E-03 | 2.16E-07 | nd | nd | 5.29E-04 | 4.67E-03 | 2.01E-07 | nd | nd |
| Vanadium | 2.26E-02 | 2.86E-05 | 7.16E-06 | 7.45E-04 | 2.10E-04 | 2.28E-02 | 2.87E-05 | 7.16E-06 | 7.45E-04 | 3.21E-03 | 7.02E-02 | 2.88E-05 | 9.31E-06 | 7.45E-04 | 3.21E-03 |
| Zinc | 4.51E-05 | 1.03E-05 | 8.13E-09 | 3.75E-04 | 4.91E-05 | 4.50E-05 | 1.02E-05 | 8.13E-09 | 3.75E-04 | 7.62E-03 | 1.95E-04 | 1.07E-05 | 1.48E-08 | 3.75E-04 | 7.88E-03 |
| Fluoride | 3.71E-03 | 2.24E-08 | 2.59E-07 | nd | 2.85E-02 | **2.10E-01** | 2.16E-07 | 2.59E-07 | nd | nd | 7.25E-02 | 8.68E-08 | 1.75E-06 | nd | nd |

| | Exposure Ratio for Toddler Receptor | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | | | | | Operation | | | | | Closure | | | | |
| **COPC** | **Moose** | **Grouse** | **Hare** | **Berries** | **Dolly Varden** | **Moose** | **Grouse** | **Hare** | **Berries** | **Dolly Varden** | **Moose** | **Grouse** | **Hare** | **Berries** | **Dolly Varden** |
| Aluminum | 4.01E-02 | **2.16E-01** | 1.24E-05 | 3.18E-03 | 1.44E-02 | 5.66E-02 | **2.31E-01** | 1.24E-05 | 3.18E-03 | 1.62E-02 | 5.65E-02 | **2.31E-01** | 1.40E-05 | 3.18E-03 | 1.64E-02 |
| Arsenic | **3.68E-01** | **1.63E+00** | 1.18E-04 | 5.39E-03 | 4.65E-02 | **2.70E-01** | **1.56E+00** | 1.18E-04 | 5.39E-03 | 1.94E-01 | **2.69E-01** | **1.56E+00** | 1.07E-04 | 5.39E-03 | 1.94E-01 |
| Barium | 6.05E-04 | 1.66E-04 | 1.31E-07 | 2.99E-03 | 1.55E-03 | 1.02E-03 | 2.07E-04 | 1.31E-07 | 2.99E-03 | 1.23E-03 | 1.39E-03 | 2.08E-04 | 1.89E-07 | 2.99E-03 | 1.31E-03 |
| Beryllium | 1.74E-03 | 3.59E-03 | 3.94E-07 | 5.26E-03 | 3.49E-03 | 1.61E-03 | 3.50E-03 | 3.94E-07 | 5.26E-03 | 4.68E-03 | 1.32E-03 | 3.50E-03 | 3.68E-07 | 5.26E-03 | 4.93E-03 |
| Cadmium | 4.04E-04 | 8.12E-04 | 7.23E-08 | 9.62E-04 | 1.72E-02 | 3.89E-04 | 7.89E-04 | 7.23E-08 | 9.62E-04 | 7.29E-03 | 3.27E-04 | 7.88E-04 | 6.80E-08 | 9.62E-04 | 7.34E-03 |
| Chromium | **5.54E-01** | 2.00E-01 | 1.70E-04 | 2.34E-02 | 1.48E-01 | **4.35E-01** | 1.93E-01 | 1.70E-04 | 2.34E-02 | **2.03E-01** | **4.33E-01** | 1.93E-01 | 1.58E-04 | 2.34E-02 | **2.04E-01** |
| Cobalt | **4.13E-01** | **7.56E-01** | 1.21E-04 | 4.09E-03 | 3.56E-02 | **3.41E-01** | **7.31E-01** | 1.21E-04 | 4.09E-03 | 5.91E-02 | **3.36E-01** | **7.31E-01** | 1.14E-04 | 4.09E-03 | 6.12E-02 |
| Copper | 3.50E-02 | 1.78E-02 | 1.03E-05 | 2.53E-03 | 1.70E-03 | 3.57E-02 | 1.79E-02 | 1.03E-05 | 2.53E-03 | 2.97E-03 | 2.00E-01 | 1.81E-02 | 1.77E-05 | 2.53E-03 | 3.05E-03 |
| Mercury | 2.46E-02 | 6.82E-04 | 7.25E-06 | 4.21E-04 | 1.82E-02 | 1.86E-02 | 6.51E-04 | 7.25E-06 | 4.21E-04 | nd | 3.02E-02 | 6.52E-04 | 7.16E-06 | 4.21E-04 | nd |
| Molybdenum | 1.70E-06 | 3.05E-06 | 5.22E-10 | 9.09E-07 | 2.24E-07 | 1.71E-06 | 2.93E-06 | 5.22E-10 | 9.09E-07 | 2.85E-07 | 1.73E-06 | 2.93E-06 | 4.97E-10 | 9.09E-07 | 5.21E-07 |
| Nickel | 4.36E-02 | 4.81E-05 | 1.10E-05 | 4.98E-03 | 3.93E-04 | 9.31E-02 | 6.18E-05 | 1.10E-05 | 4.98E-03 | 7.91E-03 | 1.18E-01 | 6.20E-05 | 1.70E-05 | 4.98E-03 | 7.98E-03 |
| Selenium | 3.11E-03 | 6.72E-03 | 6.62E-07 | 3.98E-03 | 1.24E-02 | 3.58E-03 | 6.84E-03 | 6.62E-07 | 3.98E-03 | nd | 3.75E-03 | 6.84E-03 | 6.90E-07 | 3.98E-03 | nd |
| Silver | 1.24E-03 | 8.90E-03 | 3.97E-07 | nd | 7.39E-02 | 9.75E-04 | 8.61E-03 | 3.97E-07 | nd | nd | 9.75E-04 | 8.61E-03 | 3.71E-07 | nd | nd |
| Vanadium | 4.16E-02 | 5.27E-05 | 1.32E-05 | 1.37E-03 | 3.87E-04 | 4.21E-02 | 5.28E-05 | 1.32E-05 | 1.37E-03 | 5.91E-03 | 1.29E-01 | 5.31E-05 | 1.71E-05 | 1.37E-03 | 5.91E-03 |
| Zinc | 9.86E-05 | 2.25E-05 | 1.78E-08 | 8.20E-04 | 1.08E-04 | 9.84E-05 | 2.24E-05 | 1.78E-08 | 8.20E-04 | 1.67E-02 | 4.27E-04 | 2.34E-05 | 3.25E-08 | 8.20E-04 | 1.72E-02 |
| Fluoride | 6.83E-03 | 4.13E-08 | 4.77E-07 | nd | 5.26E-02 | **3.87E-01** | 3.97E-07 | 4.77E-07 | nd | nd | 1.34E-01 | 1.60E-07 | 3.22E-06 | nd | nd |

**nd = not determined**

**Highlighted and bolded numbers denote country food with an exposure ratio larger than 0.2 for a particular COPC**

## Table 25.7-16. Exposure Ratios for Human Receptors Downstream of the Mine Site

| | Exposure Ratio for Adult Receptor | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | | | | Operation | | | | Closure | | | |
| COPC | Moose | Grouse | Hare | Berries | Moose | Grouse | Hare | Berries | Moose | Grouse | Hare | Berries |
| Aluminum | 2.15E-02 | 1.17E-01 | 6.66E-06 | 5.20E-04 | 2.20E-02 | 1.17E-01 | 6.67E-06 | 5.20E-04 | 2.21E-02 | 1.17E-01 | 6.67E-06 | 5.20E-04 |
| Arsenic | **2.02E-01** | **8.87E-01** | 6.39E-05 | 1.87E-03 | **2.06E-01** | **8.87E-01** | 6.40E-05 | 1.87E-03 | **2.07E-01** | **8.87E-01** | 6.40E-05 | 1.87E-03 |
| Barium | 4.42E-04 | 9.14E-05 | 8.73E-08 | 1.50E-03 | 4.47E-04 | 9.14E-05 | 8.74E-08 | 1.50E-03 | 4.47E-04 | 9.14E-05 | 8.74E-08 | 1.50E-03 |
| Beryllium | 1.03E-03 | 1.96E-03 | 2.27E-07 | 1.68E-03 | 1.06E-03 | 1.96E-03 | 2.27E-07 | 1.68E-03 | 1.06E-03 | 1.96E-03 | 2.27E-07 | 1.68E-03 |
| Cadmium | 8.70E-04 | 5.55E-04 | 1.33E-07 | 3.37E-04 | 8.80E-04 | 5.55E-04 | 1.33E-07 | 3.37E-04 | 8.80E-04 | 5.55E-04 | 1.33E-07 | 3.37E-04 |
| Chromium | **2.95E-01** | 1.08E-01 | 9.12E-05 | 5.62E-03 | **2.97E-01** | 1.08E-01 | 9.12E-05 | 5.62E-03 | **2.98E-01** | 1.08E-01 | 9.12E-05 | 5.62E-03 |
| Cobalt | **2.28E-01** | **4.10E-01** | 6.62E-05 | 1.12E-03 | **2.30E-01** | **4.10E-01** | 6.62E-05 | 1.12E-03 | **2.31E-01** | **4.10E-01** | 6.62E-05 | 1.12E-03 |
| Copper | 1.30E-02 | 6.24E-03 | 3.68E-06 | 1.05E-03 | 1.33E-02 | 6.24E-03 | 3.68E-06 | 1.05E-03 | 1.34E-02 | 6.24E-03 | 3.68E-06 | 1.05E-03 |
| Mercury | 1.55E-02 | 3.71E-04 | 4.25E-06 | 9.14E-05 | 1.55E-02 | 3.71E-04 | 4.25E-06 | 9.14E-05 | 1.55E-02 | 3.71E-04 | 4.25E-06 | 9.14E-05 |
| Molybdenum | 8.71E-07 | 1.36E-06 | 2.48E-10 | 1.10E-06 | 8.74E-07 | 1.36E-06 | 2.48E-10 | 1.10E-06 | 8.73E-07 | 1.36E-06 | 2.48E-10 | 1.10E-06 |
| Nickel | 2.05E-02 | 2.60E-05 | 5.48E-06 | 8.18E-04 | 2.08E-02 | 2.60E-05 | 5.48E-06 | 8.18E-04 | 2.08E-02 | 2.60E-05 | 5.48E-06 | 8.18E-04 |
| Selenium | 2.03E-03 | 3.99E-03 | 4.17E-07 | 1.97E-03 | 2.15E-03 | 3.99E-03 | 4.18E-07 | 1.97E-03 | 2.15E-03 | 3.99E-03 | 4.18E-07 | 1.97E-03 |
| Silver | 6.71E-04 | 4.83E-03 | 2.16E-07 | nd | 6.79E-04 | 4.83E-03 | 2.16E-07 | nd | 6.79E-04 | 4.83E-03 | 2.16E-07 | nd |
| Tin | 6.12E-04 | 5.46E-05 | 1.76E-07 | 1.07E-05 | 6.12E-04 | 5.46E-05 | 1.76E-07 | 1.07E-05 | 6.12E-04 | 5.46E-05 | 1.76E-07 | 1.07E-05 |
| Vanadium | 2.54E-02 | 2.86E-05 | 7.19E-06 | 6.24E-04 | 2.32E-02 | 2.86E-05 | 7.17E-06 | 6.24E-04 | 2.33E-02 | 2.86E-05 | 7.17E-06 | 6.24E-04 |
| Zinc | 6.86E-05 | 1.07E-05 | 1.15E-08 | 4.05E-04 | 6.97E-05 | 1.07E-05 | 1.15E-08 | 4.05E-04 | 6.97E-05 | 1.07E-05 | 1.15E-08 | 4.05E-04 |

| | Exposure Ratio for Toddler Receptor | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Baseline | | | | Operation | | | | Closure | | | |
| COPC | Moose | Grouse | Hare | Berries | Moose | Grouse | Hare | Berries | Moose | Grouse | Hare | Berries |
| Aluminum | 3.96E-02 | **2.16E-01** | 1.23E-05 | 9.58E-04 | 4.06E-02 | **2.16E-01** | 1.23E-05 | 9.58E-04 | 4.07E-02 | **2.16E-01** | 1.23E-05 | 9.58E-04 |
| Arsenic | **3.73E-01** | **1.64E+00** | 1.18E-04 | 3.45E-03 | **3.80E-01** | **1.64E+00** | 1.18E-04 | 3.45E-03 | **3.81E-01** | **1.64E+00** | 1.18E-04 | 3.45E-03 |
| Barium | 8.14E-04 | 1.68E-04 | 1.61E-07 | 2.76E-03 | 8.23E-04 | 1.68E-04 | 1.61E-07 | 2.76E-03 | 8.25E-04 | 1.68E-04 | 1.61E-07 | 2.76E-03 |
| Beryllium | 1.91E-03 | 3.60E-03 | 4.17E-07 | 3.10E-03 | 1.95E-03 | 3.60E-03 | 4.18E-07 | 3.10E-03 | 1.95E-03 | 3.60E-03 | 4.18E-07 | 3.10E-03 |
| Cadmium | 1.60E-03 | 1.02E-03 | 2.46E-07 | 6.21E-04 | 1.62E-03 | 1.02E-03 | 2.46E-07 | 6.21E-04 | 1.62E-03 | 1.02E-03 | 2.46E-07 | 6.21E-04 |
| Chromium | **5.43E-01** | 2.00E-01 | 1.68E-04 | 1.03E-02 | **5.48E-01** | 2.00E-01 | 1.68E-04 | 1.03E-02 | **5.49E-01** | 2.00E-01 | 1.68E-04 | 1.03E-02 |
| Cobalt | **4.20E-01** | **7.56E-01** | 1.22E-04 | 2.07E-03 | **4.25E-01** | **7.56E-01** | 1.22E-04 | 2.07E-03 | **4.25E-01** | **7.56E-01** | 1.22E-04 | 2.07E-03 |
| Copper | 3.71E-02 | 1.78E-02 | 1.05E-05 | 3.00E-03 | 3.80E-02 | 1.78E-02 | 1.05E-05 | 3.00E-03 | 3.82E-02 | 1.78E-02 | 1.05E-05 | 3.00E-03 |
| Mercury | 2.85E-02 | 6.84E-04 | 7.82E-06 | 1.68E-04 | 2.86E-02 | 6.84E-04 | 7.83E-06 | 1.68E-04 | 2.86E-02 | 6.84E-04 | 7.83E-06 | 1.68E-04 |
| Molybdenum | 1.95E-06 | 3.06E-06 | 5.57E-10 | 2.47E-06 | 1.96E-06 | 3.06E-06 | 5.57E-10 | 2.47E-06 | 1.96E-06 | 3.06E-06 | 5.57E-10 | 2.47E-06 |
| Nickel | 3.78E-02 | 4.79E-05 | 1.01E-05 | 1.51E-03 | 3.83E-02 | 4.79E-05 | 1.01E-05 | 1.51E-03 | 3.83E-02 | 4.79E-05 | 1.01E-05 | 1.51E-03 |
| Selenium | 3.43E-03 | 6.75E-03 | 7.06E-07 | 3.34E-03 | 3.65E-03 | 6.76E-03 | 7.07E-07 | 3.34E-03 | 3.64E-03 | 6.76E-03 | 7.07E-07 | 3.34E-03 |
| Silver | 1.24E-03 | 8.90E-03 | 3.97E-07 | nd | 1.25E-03 | 8.90E-03 | 3.97E-07 | nd | 1.25E-03 | 8.90E-03 | 3.97E-07 | nd |
| Tin | 1.13E-03 | 1.01E-04 | 3.25E-07 | 1.96E-05 | 1.13E-03 | 1.01E-04 | 3.25E-07 | 1.96E-05 | 1.13E-03 | 1.01E-04 | 3.25E-07 | 1.96E-05 |
| Vanadium | 4.69E-02 | 5.28E-05 | 1.32E-05 | 1.15E-03 | 4.28E-02 | 5.28E-05 | 1.32E-05 | 1.15E-03 | 4.29E-02 | 5.28E-05 | 1.32E-05 | 1.15E-03 |
| Zinc | 1.50E-04 | 2.35E-05 | 2.52E-08 | 8.87E-04 | 1.52E-04 | 2.35E-05 | 2.52E-08 | 8.87E-04 | 1.53E-04 | 2.35E-05 | 2.52E-08 | 8.87E-04 |

**nd = not determined**

**Highlighted and bolded numbers denote country food with an exposure ration larger than 0.2 for a particular COPC**

## Table 25.7-17. Estimated Daily Lifetime Exposure and Incremental Lifetime Cancer Risk for Human Receptors Exposed to Arsenic in Country Foods from the Processing and Tailing Management Area

| | Baseline | | Operation | | Closure | |
|---|---|---|---|---|---|---|
| **Country Food** | **ELDE (mg/kg/day)** | **ILCR** | **ELDE (mg/kg/day)** | **ILCR** | **ELDE (mg/kg/day)** | **ILCR** |
| Moose | 5.99E-05 | **1.08E-04** | 2.59E-05 | **4.66E-05** | 2.73E-06 | 4.92E-06 |
| Grouse | 2.66E-04 | **4.79E-04** | 1.49E-04 | **2.69E-04** | 1.59E-05 | **2.86E-05** |
| Snowshoe hare | 1.92E-08 | 3.45E-08 | 1.08E-08 | 1.94E-08 | 1.09E-09 | 1.97E-09 |
| Berries | 8.78E-07 | 1.58E-06 | 5.16E-07 | 9.29E-07 | 5.49E-08 | 9.88E-08 |
| Dolly Varden | 7.57E-06 | **1.36E-05** | 1.85E-05 | **3.33E-05** | 3.84E-05 | **6.90E-05** |

**Highlighted and bolded numbers indicate elevated ICLR.**
**ELDE = Estimated Daily Lifetime Exposure**
**ILCR = Incremental Lifetime Cancer Risk (unitless)**

## Table 25.7-18. Estimated Daily Lifetime Exposure and Incremental Lifetime Cancer Risk for Human Receptors Exposed to Arsenic in Country Foods downstream of the Mine Site

| | Baseline | | Operation | | Closure | |
|---|---|---|---|---|---|---|
| **Country Food** | **ELDE mg/kg/day** | **ILCR** | **ELDE mg/kg/day** | **ILCR** | **ELDE mg/kg/day** | **ILCR** |
| Moose | 6.07E-05 | **1.09E-04** | 7.51E-05 | **1.35E-04** | 7.52E-05 | **1.35E-04** |
| Grouse | 2.66E-04 | **4.79E-04** | 3.23E-04 | **5.82E-04** | 3.23E-04 | **5.82E-04** |
| Hare | 1.92E-08 | 3.45E-08 | 2.33E-08 | 4.19E-08 | 2.33E-08 | 4.19E-08 |
| Berries | 5.62E-07 | 1.01E-06 | 6.82E-07 | 1.23E-06 | 6.82E-07 | 1.23E-06 |

**Highlighted and bolded numbers indicate elevated ICLR.**
**ELDE = Estimated Daily Lifetime Exposure**
**ILCR = Incremental Lifetime Cancer Risk (unitless)**

## Table 25.7-19. Recommended Maximum Weekly Number of Servings of Country Food at the Processing and Tailing Management Area

| Human Receptor | Country Food | Scenario | RMWI (kg/week) | Serving Size (kg) | RMW # of Servings | Current Weekly # of Servings[1] |
|---|---|---|---|---|---|---|
| Adult | Moose | Baseline | 4.94 | 0.213 | 23.2 | 7.0 |
| | | Operation | 6.29 | 0.213 | 29.5 | 7.0 |
| | | Closure | 6.32 | 0.213 | 29.7 | 7.0 |
| | Grouse | Baseline | 0.04 | 0.299 | 0.1 | 0.1 |
| | | Operation | 0.04 | 0.299 | 0.1 | 0.1 |
| | | Closure | 0.04 | 0.299 | 0.1 | 0.1 |
| | Snowshoe Hare | Baseline | 217 | 0.348 | 624 | 0.1 |
| | | Operation | 217 | 0.348 | 624 | 0.1 |
| | | Closure | 234 | 0.348 | 671 | 0.1 |

**(continued)**

## Table 25.7-19. Recommended Maximum Weekly Number of Servings of Country Food at the Processing and Tailing Management Area (completed)

| Human Receptor | Country Food | Scenario | RMWI (kg/week) | Serving Size (kg) | RMW # of Servings | Current Weekly # of Servings[1] |
|---|---|---|---|---|---|---|
| Adult *(cont'd)* | Berries | Baseline | 5.08 | 0.280 | 18.1 | 0.2 |
| | | Operation | 5.08 | 0.280 | 18.1 | 0.2 |
| | | Closure | 5.08 | 0.280 | 18.1 | 0.2 |
| | Dolly Varden | Baseline | 0.47 | 0.280 | 1.7 | 0.1 |
| | | Operation | 0.34 | 0.280 | 1.2 | 0.1 |
| | | Closure | 0.34 | 0.280 | 1.2 | 0.1 |
| Toddler | Moose | Baseline | 1.15 | 0.090 | 12.6 | 7.0 |
| | | Operation | 1.47 | 0.090 | 16.0 | 7.0 |
| | | Closure | 1.48 | 0.090 | 16.1 | 7.0 |
| | Grouse | Baseline | 0.01 | 0.130 | 0.1 | 0.1 |
| | | Operation | 0.01 | 0.130 | 0.1 | 0.1 |
| | | Closure | 0.01 | 0.130 | 0.1 | 0.1 |
| | Snowshoe Hare | Baseline | 50.7 | 0.150 | 339 | 0.1 |
| | | Operation | 50.7 | 0.150 | 339 | 0.1 |
| | | Closure | 54.5 | 0.150 | 364 | 0.1 |
| | Berries | Baseline | 1.19 | 0.120 | 9.8 | 0.2 |
| | | Operation | 1.19 | 0.120 | 9.8 | 0.2 |
| | | Closure | 1.84 | 0.120 | 15.3 | 0.2 |
| | Dolly Varden | Baseline | 0.11 | 0.120 | 0.9 | 0.1 |
| | | Operation | 0.08 | 0.120 | 0.7 | 0.1 |
| | | Closure | 0.08 | 0.120 | 0.7 | 0.1 |

**RMW = Recommended Maximum Weekly**
**[1] Based on annual averages**

## Table 25.7-20. Recommended Maximum Weekly Servings of Country Foods Downstream of the Mine Site

| Human Receptor | Country Food | Scenario | RMWI (kg/week) | Serving Size (kg) | RMW # of Servings | Current Weekly # of Servings[1] |
|---|---|---|---|---|---|---|
| Adult | Moose | Baseline | 5.05 | 0.213 | 23.7 | 7.0 |
| | | Operation | 5.00 | 0.213 | 23.5 | 7.0 |
| | | Closure | 4.99 | 0.213 | 23.4 | 7.0 |
| | Grouse | Baseline | 0.04 | 0.299 | 0.13 | 0.12 |
| | | Operation | 0.04 | 0.299 | 0.13 | 0.12 |
| | | Closure | 0.04 | 0.299 | 0.13 | 0.12 |
| | Hare | Baseline | 219.6 | 0.348 | 631.1 | 0.1 |
| | | Operation | 219.6 | 0.348 | 631.0 | 0.1 |
| | | Closure | 219.6 | 0.348 | 631.0 | 0.1 |

**(continued)**

## Table 25.7-20. Recommended Maximum Weekly Servings of Country Foods Downstream of the Mine Site (completed)

| Human Receptor | Country Food | Scenario | RMWI (kg/week) | Serving Size (kg) | RMW # of Servings | Current Weekly # of Servings[1] |
|---|---|---|---|---|---|---|
| Adult | Berries | Baseline | 11.47 | 0.28 | 41.0 | 0.2 |
| *(cont'd)* | | Operation | 11.47 | 0.28 | 41.0 | 0.2 |
| | | Closure | 11.47 | 0.28 | 41.0 | 0.2 |
| Toddler | Moose | Baseline | 1.18 | 0.0916 | 12.9 | 7.0 |
| | | Operation | 1.17 | 0.0916 | 12.7 | 7.0 |
| | | Closure | 1.17 | 0.0916 | 12.7 | 7.0 |
| | Grouse | Baseline | 0.01 | 0.1286 | 0.07 | 0.12 |
| | | Operation | 0.01 | 0.1286 | 0.07 | 0.12 |
| | | Closure | 0.01 | 0.1496 | 0.06 | 0.06 |
| | Hare | Baseline | 51.3 | 0.1496 | 342.6 | 0.1 |
| | | Operation | 51.2 | 0.1496 | 342.6 | 0.1 |
| | | Closure | 51.2 | 0.1496 | 342.6 | 0.1 |
| | Berries | Baseline | 2.68 | 0.1204 | 22.2 | 0.2 |
| | | Operation | 2.68 | 0.1204 | 22.2 | 0.2 |
| | | Closure | 2.68 | 0.1204 | 22.2 | 0.2 |

**RMW = Recommended Maximum Weekly**
**[1] Based on annual averages**

This equation was applied to each metal for both receptors (toddler and adult) and each Project phase (baseline, operation, and closure). The metal that had the lowest RMWI for each receptor was selected as the overall RMWI because the lowest metal-specific RMWI is the driver of potential risk. The RMWI was converted to the recommended maximum number of servings per week by applying the estimated serving size or consumption rates.

The RMWI and recommended number of servings for the operation and closure scenarios are similar to those of the baseline scenario. For the PTMA, this is largely because of the limited time that moose and grouse are expected to spend in the TMF, compared with more favourable habitat and forage in the surrounding area. For the Mine Site, this is mainly due to water quality largely improving downstream and because dust is not expected to affect low elevation habitat along the Unuk River. This area has been assessed because it is preferred wildlife habitat and people are more likely to hunt along the Unuk River below Sulphurets Creek than closer to the Mine Site. Under all scenarios, the RMWI is greater than the current ingestion rate of the country foods reported by the country food harvesters, except for grouse (due to arsenic). Thus, upon mine development and operation the country foods harvesters can continue to consume moose and grouse at rates and frequencies to which they are accustomed.

<ins>Summary</ins>

The SLRA for the PTMA, in particular the TMF, predicted no unacceptable or increased risks to people from consuming moose, snowshoe hare, grouse*,* a mixture of berries, or Dolly Varden during operation and closure. Fish are not expected to reside inside the TMF, but may be harvested immediately downstream of the TMF. Based on the measured baseline conditions and the modelled operation and closure conditions, country food quality is not expected to change substantially. The ER, ILCR, and RMWI of the assessed country foods did not change substantially from baseline to operation and closure scenarios. This means that country food harvesters can continue to consume moose, snowshoe hare, grouse, berries, and Dolly Varden at baseline rates and frequencies, and that the magnitude of health effects due to the TMF is considered negligible.

The SLRA for the area downstream of the Mine Site predicted no unacceptable risks to people from consuming moose, snowshoe hare, grouse, and a mixture of berries during operation and closure. Human health risks from the consumption of fish were not assessed, because there was no evidence of fishing downstream of the Mine Site. Based on the measured baseline conditions and the modelled operation and closure conditions, country food quality is not expected to change substantially. The ER and RMWI of the assessed country foods did not change substantially from baseline to operation and closure scenarios. This means that country food harvesters can continue to consume moose, snowshoe hare, grouse, and berries at baseline rates and frequencies, and that the magnitude of health effects due to the Mine Site is considered negligible.

Upon closure and during post-closure, the TMF will be reclaimed such that the only remaining potential source of metals exposure to wildlife country foods will be from predicted elevated metals in the TMF water, submerged sediments along the TMF dam shores, and potential wetlands and invertebrates that could establish themselves in the TMF and subsequently accumulate metals from the water and sediments. A country foods SLRA could not be conducted for the post-closure scenario because of the uncertainty regarding what wetland species might establish along the dam shores, and because of the inability to predict metals accumulation in wetland invertebrate and other species with any accuracy. The degree of bioaccumulation cannot be determined with any accuracy because it is based on various physical/chemical/biological conditions in the environment (i.e., water pH, hardness, and plant species). Thus, at post-closure the primary environmental media that are of potential concern with respect to metals uptake are wetland species and invertebrates. These media may accumulate metals from the water and sediment; wildlife may consume these species. The magnitude of bioaccumulation in wetland species and invertebrates would affect the levels of metals that moose would be exposed to following closure and post-closure. Notwithstanding, the country foods SLRA for the operation scenario showed that ER, ILCR, and RMWI were very similar to baseline risk estimates, and that changes to the soil and water in the TMF would not result in substantial changes to the quality of country foods. Upon mine closure, the metal concentrations in the TMF water are predicted to somewhat improve, indicating that post-closure risks are likely further decreasing.

A monitoring and adaptive management plan is proposed to ensure that the wetlands and aquatic invertebrates in the TMF do not accumulate metals to levels that may result in accumulation in wildlife species that consume them. The monitoring and adaptive management plans for wetlands and aquatic life are presented in Section 26.19, Wetland Management Plan. The monitoring and adaptive management plans propose to monitor selected wetland species and invertebrates, should they establish in the TMF during post-closure. If during monitoring, metals are found to accumulate, a country foods SLRA should be conducted, and adaptive management applied if the SLRA indicates the potential for unacceptable risks. There would be high certainty in conducting a country foods SLRA after closure, because the actual time spent by animals in the TMF would be known, as would the levels of any metals in the environmental media. If potential unacceptable risks were identified, adaptive management measures such as removing the vegetation could be considered. Notwithstanding, it is unlikely that metals levels in country foods caused by exposure of the environmental media in the TMF post-closure will result in unacceptable risks to human health.

### 25.7.4 Changes in Health due to Noise

The purpose of the noise effects assessment was to evaluate the potential for Project activities to affect human health from the exposure to increased noise. The rationale for this evaluation was that people use the area near the PTMA and, less frequently, the area downstream of the Mine Site for hunting, trapping, berry picking, and recreation, and may be exposed to noise. In addition, off-duty workers living at Project camps are included as residential receptors for the noise assessment. Traffic-related noise along Highway 37 is assessed separately in Appendix 22-C.

Noise is defined as any undesirable sound that may irritate people, disturb rest or sleep, cause loss of hearing, or otherwise affect the quality of life of affected individuals (PWC Consulting 2002). People encounter noise in their living and working environments daily. Noise is measured in a non-linear scale known as decibels (dB); however, these measurements are filtered or weighted (A-weighted) to account for noise frequencies that are audible to humans. Measured noise levels that are A-weighted are reported as dBA. Table 25.7-21 presents a table of typical noise levels in terms of dBA.

**Table 25.7-21. Typical Sound Levels**

| Sound Range (dBA) | Source |
|---|---|
| 0 | Human hearing threshold |
| 10 | Rustling of leaves |
| 20 to 40 | Quiet room |
| 40 | Living room or humming refrigerator |
| 40 to 60 | Typical conversation |
| 60 to 80 | Passenger car, 10 m away |
| 80 to 90 | Busy road, 10 m away |
| 100 | Jackhammer, 1 m away |
| 110 to130 | Take-off of a jet, 100 m away |
| 130 | Human pain threshold |
| Up to 140 | Firecrackers and small firearms |

The human health effects due to noise can include disturbance of rest and sleep, interference with speech communication, high annoyance resulting in complaints, and noise-induced hearing loss (NIHL). There is also a potential for psychological and physiological effects (e.g., stress and mental health; WHO 1999). The following paragraphs detail the first four potential noise effects. Quotes from the Health Canada (2011b) guideline have been included to explain the potential effects. The fifth potential noise effect, NIHL, will also be discussed, but has not been included in the assessment.

Sleep Disturbance

From the Health Canada guideline: "Sleep disturbance includes the following effects of noise: difficulty falling asleep, awakenings, curtailed sleep duration, alterations of sleep stages or depth, and increased body movements during sleep" (2011b).

Health Canada advises that the recommendations and guidelines of the WHO (1999) regarding sleep disturbance be taken into consideration in the EA. In quiet rural areas and in susceptible populations (such as those in hospitals, or in convalescent or senior homes), Health Canada suggests that the WHO guideline levels not be exceeded. The WHO's *Guidelines for Community Noise* (1999) reports a threshold for sleep disturbance of an indoor nighttime sound level ($L_n$) of no more than 30 dBA for continuous noise.

Health Canada also quotes the WHO for individual noise events: "For a good sleep, it is believed that indoor sound pressure levels should not exceed approximately 45 dBA $L_{AFmax}$ more than 10 to 15 times per night." $L_{AFmax}$ is the maximum A-weighted, fast time constant sound level.

Sound is attenuated as it is transmitted indoors, and the amount of reduction mostly depends on whether windows are open. Health Canada suggests to assume an outdoor-to-indoor noise reduction of 15 dBA if windows are open and 27 dBA if windows are closed. The actual reduction depends on construction materials, geometry, and other factors of the room and building.

Normally, noise effects are only assessed at human receptors not employed by the Project outside of the Project boundaries. However, Health Canada recommends the assessment of sleep disturbance at on-site mine camps as well (2011b).

Interference with Speech Communication

If continuous noise indoors or outdoors is high enough, the Project could interfere with speech communication, such that speakers will need to increase their vocal effort or move closer to each other. Health Canada advises that an indoor level of 40 dBA or an outdoor level of 55 dBA is required for good speech comprehension (2011b).

Complaints

Health Canada suggests that "the likelihood of a complaint is directly linked to the ability or willingness of an individual to make a complaint and his or her expectation that the complaint will result in noise reduction" (2011b). Therefore, there is not always a strong link between the disturbance and the complaint. However, Health Canada suggests that "widespread complaints" become more likely above a day-night sound level ($L_{dn}$) of 62 dBA and that "several threats of legal action or strong appeals to authorities to stop noise" should be expected if the project $L_{dn}$ is greater than 75 dBA.

High Annoyance

The response to noise is subjective and is affected by many factors, such as the:

- difference between the "specific sound" (sound from the Projects) and the "residual sound" (noise in the absence of the specific sound);

- characteristics of the sound (e.g., if it contains tones or impulses);
- absolute level of sound;
- time of day;
- local attitudes to the Project; and
- expectations for quiet.

Health Canada (2010a) suggests that the Percent Highly Annoyed (%HA) metric, which is calculated using the adjusted $L_{dn}$ (or rating level) pre- and post-Project, is "an appropriate indicator of noise-induced human health effects for project operational noise and for long-term construction noise exposure."

Health Canada (2011b) suggests that adjustments should be made to account for more annoying sound characteristics; specifically, if the sound at the receiver location can be characterized as having tones, impulses, or strong low-frequency content. Table 25.7-22 summarizes the adjustments used in the Project.

## Table 25.7-22. Adjustments Applied to Sources

| Source | Penalty | Adjustment Type |
|---|---|---|
| Air traffic (helicopter) | +5 dBA | Sound source adjustment |
| Dump truck tipping load | +5 dBA | Regular impulsive |
| Backup beeper | +5 dBA | Tonal |
| Blasting | Calculated (Chapter 19) as per standard ANSI S12.9-2005 part 4 (ANSI 2005) | High energy impulsive |
| Baseline noise | +10 dBA | Rural area adjustment |
| Total continuous Project noise | +10 dBA | Rural area adjustment |

Health Canada (2010a) also advises that "noise mitigation measures be considered when a change in the calculated %HA at any given receptor exceeds 6.5%" or if the Project $L_{dn}$ exceeds 75 dBA.

Noise Induced Hearing Loss

Health Canada advises: "When the human ear is exposed to excessive sound levels over long periods of time, permanent damage may occur (WHO 1999). There is no known risk of hearing loss associated with sound levels below 70 dBA regardless of the exposure duration. However, as sound levels increase, the duration of daily exposure becomes an important risk factor for hearing loss."

NIHL concerns are normally most efficiently addressed in the Project's detailed design phase due to the high variation in actual occupational noise exposures depending on design details. Therefore, assessing the potential for NIHL has not been included in this assessment.

Human Receptors

Human receptors were identified both on-site and off-site, as shown in Table 25.7-23. The closest off-site human receptor is 14 km from the centre of the Mine Site. Major noise sources included in this summary are identified as fixed equipment (indoors and outdoors), mobile equipment, road traffic, helicopter flight paths, and blasting.

### Table 25.7-23. Summary of Human Receptors for Noise

| Receiver Type | Off-site | On-site | Shortest Distance to Major Noise Source |
|---|---|---|---|
| Cabins | 4 | 0 | Trapline cabin 2 – helicopter flight path (980 m) |
| Camps | 0 | 14 | All camps are close to mine noise sources and helicopter flight paths |
| Municipality | 2 | 0 | Municipality 2 – helicopter flight path (120 m) |

Mine employees (on shift) were not selected as VCs because worker health will be addressed in the Health and Safety Management Plan that will be developed during the permitting process. However, off-shift workers residing in construction and operation camps will be included in the assessment.

The sub-populations that are more susceptible to health effects from exposure to noise are those who are less able to cope (WHO 1999). This includes people with decreased personal abilities (e.g., ill or depressed people), people with medical problems, people dealing with cognitive tasks (e.g., reading acquisition), people with mental disorders, people who are blind or who have hearing impairment, fetuses, babies and young children, the elderly, shift workers, and individuals who have sleeping disorders. The human VCs that will be assessed with respect to noise effects will be individuals that may have problems coping with noise (e.g., sensitive receptors), and therefore the assessment is conservative in nature and may over-estimate risks. The EA approach used to assess the effects from Project-related noise on human health is similar to that described for the Project (Chapter 5). The potential for noise to cause human health effects was assessed to identify the need for monitoring and mitigation, and to develop adaptive mitigation strategies if required. The health effects related to noise were assessed using the results of the noise model presented in Chapter 19, Noise; Appendix 19-A; and comparisons to the appropriate human health noise guidelines and standards, which included Health Canada's *Guidance for Evaluating Human Health Impacts in Environmental Assessment: Noise* (2011b). The worst case for blasting and helicopter noise was used for human receptors to assess effects during construction (Year –1) and operation (Year +4). During the construction phase, all Project components under construction and helicopter traffic will contribute to noise. During the operation phase, day-to-day activities (e.g., blasting, large trucks, and equipment) at the Mine Site, the OPC, and along access roads will contribute to noise.

Predicted Noise

**Total continuous noise:** This is all Project-related activity, excluding helicopter and blasting noise, to approximate the continuous sound level at the receptors. No penalties or adjustments are included. Baseline noise levels of 35 dB (day) and 25 dB (night) were used.

**Adjusted total noise:** This is the adjusted $L_{dn}$ metric calculated according to Appendix D of the Health Canada guideline (2011b). This includes all penalties and adjustments to source noise as well as baseline noise levels with associated adjustments as detailed in Appendix 19-A (BKL 2012).

Total Continuous Noise

It can be seen from Table 25.7-24 that off-site human receptors (cabins and municipalities) are not affected by Project noise. These receivers are expected to experience levels that are equivalent to the assumed baseline noise levels ($L_d$: 35 dBA and $L_n$: 25 dBA, Section 25.1.6).

## Table 25.7-24. Total Continuous Project Noise Level Summary

| Receiver Type | Construction | | Operation | |
|---|---|---|---|---|
| | $L_d$ (dBA) | $L_n$ (dBA) | $L_d$ (dBA) | $L_n$ (dBA) |
| Cabins | 0 | 0 | 0 | 0 |
| Camps | 67 | 62 | 63 | 62 |
| Municipality | 0 | 0 | 0 | 0 |

The noise levels at the loudest receivers are noted below for each phase of the Project. Both receivers are on the Project site and in close proximity to the modelled noise sources.

*Construction Phase*

During the construction phase, Camp 5: Treaty Plant Camp has the highest predicted noise level of the Project with:

- $L_{dn}$ = 70 dBA;
- $L_d$ = 67 dBA; and
- $L_n$ = 62 dBA.

*Operation Phase*

The Treaty operating camp has the highest predicted noise level for the operation phase of the Project with:

- $L_{dn}$ = 67 dBA;
- $L_d$ = 63 dBA; and
- $L_n$ = 60 dBA.

Adjusted Total Noise

Using all applicable adjustments (as detailed in Table 25.7-22), Table 25.7-25 summarizes the highest adjusted noise level, or "rated" noise level, at each human receiver type.

## Table 25.7-25. Highest Adjusted Noise Levels (All Sources) Summary

| Human Receiver Type | Adjusted $L_{dn}$ (dBA) | |
|---|---|---|
| | Construction | Operation |
| Cabins | 47 | 49 |
| Camps | 80 | 78 |
| Municipality | 52 | 52 |

The effect of individual events (such as blasting) on human receptors is accounted for as part of the %HA calculation below.

Effects Assessment for Human Receptors

Sound levels at a number of human receptors were higher than sound levels recommended by Health Canada (2011b). Table 25.7-26 lists the number of affected receivers, all of which are located on-site. The noise impact regarding each of the assessment criteria is explained in the following sub-sections.

## Table 25.7-26. Count of Receptors with Sound Levels Higher than Levels Recommended by Health Canada

| Criteria | Impact | Approximate Number of Receivers Higher than Recommended Level | |
|---|---|---|---|
| | | Year –1 | Year +4 |
| $L_d$ > 55 dBA | Interference with speech* | 0 | 0 |
| $L_n$ > 45 dBA | Sleep disturbance at off-site human receptors | 0 | 0 |
| $L_n$ > 57 dBA | Sleep disturbance at on-site human receptors | 1 | 2 |
| $L_{dn}$ > 62 dBA | Widespread complaints* | 0 | 0 |
| $L_{dn}$ > 75 dBA | Potential legal action* | 0 | 0 |
| ∆ %HA > 6.5% | Percentage highly annoyed* | 0 | 0 |
| $L_{LF}$ > 70 dB | Low frequency noise-induced rattles* | 0 | 0 |

* Only applicable to off-site human receptors.
**Criteria are based on Health Canada (2011b); $L_{LF}$ = sum of sound levels in the 16-Hz, 31.5-Hz, and 63-Hz octave bands**

*Daytime Noise Level $L_d$ > 55 dBA*

The $L_d$ level presented herein accounts for total continuous Project noise, and excludes helicopter and blasting contributions. The predicted human receivers that are above the $L_d$ 55 dBA level are on-site camps. Some degree of outdoor speech interference is expected to occur at the following camps (Table 25.7-27):

## Table 25.7-27. Receivers with Daytime Sound Levels $L_d$ > 55 dBA

| Receiver | $L_d$ (dBA) | Phase |
|---|---|---|
| Camp 5: Treaty Plant Camp | 67 | Construction |
| Camp 6: Treaty Saddle Camp | 62 | Construction |
| Camp 4: Mitchell North Camp | 58 | Construction |
| Camp 9: Mitchell Initial Camp | 56 | Construction |
| Camp 5: Treaty Plant Camp | 58 | Operation |
| Camp 6: Treaty Saddle Camp | 62 | Operation |
| Treaty Operating Camp | 63 | Operation |

*Nighttime Noise Level $L_n$ > 45 dBA at off-site human receptors*

The $L_n$ levels presented herein account for total continuous Project noise. No helicopter and blasting events are expected to occur at night. It is predicted that no off-site human receivers will be above the $L_n$ 45 dBA level in either the construction or operation phase. No increases above baseline are anticipated.

*Nighttime Noise Level $L_n$ > 57 dBA at on-site human receptors*

The $L_n$ levels presented herein (Table 25.7-28) account for total continuous Project noise. No helicopter and blasting events are expected to occur at night. There are three on-site camps that are above the $L_n$ 57 dBA level for sleep disturbance. Health Canada mentions that noise experienced by off-duty workers who reside on or near the Project site needs to be considered (Health Canada 2011b).

## Table 25.7-28. Receivers with Nighttime Sound Levels $L_n$ > 57 dBA

| Receiver | $L_n$ (dBA) | Phase |
|---|---|---|
| Camp 5: Treaty Plant Camp | 67 | Construction |
| Camp 6: Treaty Saddle Camp | 62 | Operation |
| Treaty Operating Camp | 63 | Operation |

*Daytime and Nighttime Noise Level $L_{dn}$ > 62 dBA*

The $L_{dn}$ levels presented herein account for total continuous Project noise, and exclude helicopter and blasting contributions. Only on-site camps are predicted to experience $L_{dn}$ > 62 dBA, which is unlikely to cause complaints as these camps are part of the Project. The levels experienced at these locations are shown in Table 25.7-29.

## Table 25.7-29. Receivers with Daytime/Nighttime Sound Levels $L_{dn}$ > 62 dBA

| Receiver | Adjusted $L_{dn}$ with Baseline (dBA) | Phase |
|---|---|---|
| Camp 5: Treaty Plant Camp | 80 | Construction |
| Camp 6: Treaty Saddle Camp | 71 | Construction |
| Camp 10: Mitchell Secondary Camp | 65 | Construction |
| Camp 4: Mitchell North Camp | 69 | Construction |
| Camp 9: Mitchell Initial Camp | 66 | Construction |
| Camp 5: Treaty Plant Camp | 72 | Operation |
| Camp 6: Treaty Saddle Camp | 78 | Operation |
| Camp 4: Mitchell North Camp | 62 | Operation |
| Camp 2: Ted Morris Camp | 68 | Operation |

*Daytime and Nighttime Noise Level $L_{dn}$ > 75 dBA*

The $L_{dn}$ levels used in this calculation account for total continuous Project noise, and excludes helicopter and blasting contributions. It is predicted that no off-site receivers will be above the $L_{dn}$ 75 dBA level in either the construction or operation phase. The highest predicted adjusted $L_{dn}$ is 48 dBA.

*Change in Percent Highly Annoyed %HA > 6.5%*

The change in %HA levels presented herein account for total continuous Project noise, helicopter and blasting contributions, and baseline noise levels. The Health Canada guideline does not include on-site camps as part of the affected receivers in the %HA calculation. None of the off-site receivers in this study exceeded this limit. The average off-site human receptors' %HA increase was predicted to be less than 1%. This is due to the large distance between these receivers and the Mine Site.

*Low-frequency Noise $L_{LF}$ > 70 dB*

The $L_{LF}$ levels used in this calculation account for total continuous Project noise, and exclude helicopter and blasting contributions. None of the receivers are predicted to be exposed to low-frequency noise above the "rattle criterion" of 70 dB.

In summary, predictions using detailed noise modelling have shown that the total continuous Project noise is contained largely within the Project boundary, with the most affected receivers being worker camps on-site. Health Canada exempts these receptors from noise level criteria meant to prevent human health effects, with the exception of sleep disturbance.

Event noise levels associated with blasting and helicopter flybys were not shown to significantly increase the noise levels when combined with the total continuous Project noise to the extent that off-site human receptors are likely to become annoyed or complain.

#### 25.7.4.1 Mitigation for Changes in Noise Levels

Mitigation to reduce effects to human health from noise relies on mitigation measures that reduce noise at the origin and at the receiver. Sleep disturbance at on-site camps is the only potential adverse effect identified. To mitigate this potential effect, the following should be considered during the detailed design phase:

- maximize distances between major noise sources and sleeping quarters to minimize noise; and
- calculate the appropriate level of building insulation required to meet predicted equivalent sound levels ($L_{eq}$) of 30 dBA or less.

In addition, the Noise Management Plan (Section 26.22) will ensure that noise levels during all phases of the Project are acceptably low for human receptors on-site and in the vicinity of the Project. Procedures under the Noise Management Plan include that:

- noise specifications will be considered when selecting equipment to purchase;
- vehicles will be maintained regularly;
- speed limits will be imposed;
- mufflers will be installed on vehicles and maintained;
- relevant site workers will be trained in noise reduction methods and proper machinery use;
- noise dampening measures will be applied to stacks where possible; and
- equipment will be maintained to original equipment manufacturers' standards.

Noise will be monitored periodically at various receptor locations, results will be reported, and, if required, mitigation strategies will be adjusted accordingly. Noise monitoring locations will be chosen to enable confirmation of noise modelling and effects assessment. Additional mitigation will be used, if necessary, to reduce the potential health impact of noise at accommodation complexes and other sites where humans require quiet conditions.

#### 25.7.4.2 Potential for Residual Effects

Table 25.7-30 summarizes the potential residual effects to human health from changes in noise levels. Residual effects may occur if mitigation does not satisfy the noise attenuation requirements on all on-site worker camps..

## 25.8 Significance of Residual Effects for Human Health

There is potential for residual effects from the Project on the health of human receptors who reside on-site while off shift, who are temporary land users, and who are residents in municipalities in the vicinity of the Project. For instance, should land users have access to the TMF during Project operation, residual human health risks may exist from accidentally drinking the water. Small changes in air quality-related human health endpoints are expected from Project activities that generate emissions and dust. Human health effects from the ingestion of country foods from near Project sites are expected to be very minor. Noise at Project camp locations may increase sufficiently to cause some level of sleep disturbance. The following sections describe the residual effects to human health due to changes in the quality of water, air, country foods, and noise.

### 25.8.1 Residual Effect Descriptors for Human Health

The significance of residual effects following the application of mitigation measures is assessed based on nine descriptors (timing, magnitude, geographic extent, duration, frequency, reversibility, context, probability, and confidence) as defined in Tables 25.8-1 and 25.8-2. The definitions for the residual effects descriptors depend on the type of effect described. For example, effects due to changes in the quality of water, air, and country foods are toxicological in nature (Table 25.8-1), while effects due to noise are physical in nature (Table 25.8-2). The significance of the residual effects for human health was determined using the definition and logic in the tables; however, professional judgment was also used in determining significance.

The magnitude for toxicological effects (drinking and recreational water quality, air quality, and country foods) ranges from negligible (no detectable change from baseline health conditions) to low (differs from baseline, but is below threshold levels), medium (effects are higher than threshold levels to a small extent), and high (effects are higher than threshold levels to a large extent). Human health relies on the socio-economic descriptors for geographic extents that range from an individual/household, community, regional/Aboriginal peoples, to a regional extent and beyond. The duration of human health effects ranges from short term (one hour or less) to medium term (one hour to two weeks), long term (two weeks to one year), and far future (effects will last the lifetime of a person). The frequency of effects describes whether, after an exposure has occurred, the health effect will occur once, rarely and sporadically, regularly, or continuously. A health effect may be reversible over a short term or a long term (with or without medical intervention) or be irreversible (e.g., chronic health effects or terminal cancer in extreme cases). The context assesses the unique value of the VC and ranges from low to medium to high. The probability assesses whether the effect is likely to occur. The confidence in the assessment considers literature data, confidence in the models, and the data used to derive quantitative assessment results, as well as unknowns, potential errors, and the assumptions that were included in the analyses of effects.

The definitions for residual effects descriptors for noise effects, shown in Table 25.8-2, are the same as those used in the Noise chapter (Chapter 19, Section 19.8, Table 19.8-1).

## 25.8.2 Residual Effects Assessment for Human Health

Table 25.8-3 summarizes the derivation of significance of residual effects to human health from changes in water quality, air quality, quality of country foods, and noise. The assessments of residual effects are described in the following four sections.

### 25.8.2.1 Changes in Health due to Drinking and Recreational Water Quality

The purpose of the drinking water effects assessment was to evaluate the potential for Project activities to affect human health from the ingestion of water. After mitigation, the magnitude of residual effects has been assessed as negligible during operation and closure. The assessment of negligible effects during operation and closure is based on mitigation, which eliminates public access to the TMF and Mine Site. The increase in magnitude to low during post-closure is due to the increased likelihood that people will have access to the TMF after the closure of the mine, and is not due to deterioration in water quality. Water quality is predicted to improve after mine operation ceases. Water quality meets BC drinking water guidelines (BC MOE 2006) downstream of the TMF and the Mine Site, and health effects are likely negligible. However, uncertainties in the assessment of the post-closure phase increase.

The extent of changes to human health will be at an individual/household level, because health may only be affected in individuals who temporarily access the PTMA and the area downstream of the Mine Site (hunters, trappers, and recreationists). Any potential health effects would be short in duration and sporadic, because the use of the areas is temporary and seasonal, and concentrations of contaminants in the TMF, Teigen, Treaty, and Sulphurets creeks, and in the Unuk River will not be high enough to cause chronic effects. Therefore, if any changes to human health were observed, they would likely be reversible in the short term. Human health is highly valued by individuals and by society (i.e., health care costs); therefore, the context was assessed as high. The probability that health effects will occur during operation, closure, and post-closure is assessed as low based on predicted potential contaminant concentrations, seasonal and temporal use, and mitigation for public access. The probability that health effects will be low during post-closure, while operation and closure phases are assessed as medium, due to the uncertainty in long-term water quality predictions. Confidence in the assessment is medium to low, as it relies on modelled water quality and risks, which have a high level of uncertainty (Chapter 14, Surface Water Quality). Overall, the level of significance of this effect is considered **not significant (minor).**

## Table 25.7-30. Potential Residual Effects on Human Health from Changes in Noise Levels

| VC | Timing Start | Project Area(s) | Component(s) | Description of Effect due to Component(s) | Type of Project Mitigation | Project Mitigation Description | Potential Residual Effect | Description of Residuals |
|---|---|---|---|---|---|---|---|---|
| Health of adults (off-duty workers, visitors to Project area, Aboriginal and non-aboriginal people at trapping cabins in the vicinity of the Project) | Construction | Mine Site, Processing and Tailings Management Area, Access Roads | All components under construction, Mine Site, TMF, access (road and air) | Complaints about noise due to increase in daytime and night time noise at off-site locations, interference with speech comprehension on site, sleep disturbance on site | Management Practices, Monitoring and Adaptive Management | Noise mitigation measures will be applied as outlined in the Noise Management Plan.<br>Noise will be monitored periodically at human and wildlife receptor locations, results will be reported and if required, mitigation strategies will be adjusted accordingly.<br>Additional mitigation (e.g. berms or insulation) will be used, if necessary, to reduce potential health impact of noise at accommodation complexes and other sites where humans require quiet conditions.<br>Minimize vegetation clearing surrounding Project footprint where possible to provide noise buffer.<br>All site vehicles to comply with noise limits, impose speed limits.<br>All vehicles and mining equipment to undergo regular maintenance. | Yes | Potential for sleep disturbance. |
| Health of adults (off-duty workers, visitors to Project area, Aboriginal and non-aboriginal people at trapping cabins in the vicinity of the Project) | Operation | Mine Site, Processing and Tailings Management Area, Access Roads | TMF, Mine Site, access (road and air) | Complaints about noise due to increase in daytime and night time noise at off-site locations, interference with speech comprehension on site, sleep disturbance on site | Management Practices, Monitoring and Adaptive Management | Noise mitigation measures will be applied as outlined in the Noise Management Plan.<br>Noise will be monitored periodically at human and wildlife receptor locations, results will be reported and if required, mitigation strategies will be adjusted accordingly.<br>Additional mitigation (e.g. berms or insulation) will be used, if necessary, to reduce potential health impact of noise at accommodation complexes and other sites where humans require quiet conditions.<br>Minimize vegetation clearing surrounding Project footprint where possible to provide noise buffer.<br>All site vehicles to comply with noise limits, impose speed limits.<br>All vehicles and mining equipment to undergo regular maintenance. | Yes | Potential for sleep disturbance. |

## Table 25.8-1. Definitions of Significance Criteria for Human Health Residual Effects (Air Quality, Drinking Water, Country Foods)

| **Timing** *What phase of the Project is the effect associated with?* | **Magnitude** *(negligible, low, medium, high)* | **Geographic Extent** *(local, landscape, regional, beyond regional)* | **Duration** *(short-term, medium-term, long-term, far future)* | **Frequency** *(once, intermittent, regular, continuous)* | **Reversibility** *(reversible short-term, reversible long-term, or irreversible)* | **Context** *(ecological resilience and/or unique attributes) (low, neutral, high)* | **Probability** *(low, medium, high)* | **Confidence** *(low, medium, high)* | **Significance** *(Not Significant: minor, moderate; Significant: major)* | **Follow-Up Monitoring** *(Not required, Required)* |
|---|---|---|---|---|---|---|---|---|---|---|
| **Construction** | **Negligible.** There is no detectable change from baseline health conditions. | **Individual/household.** The effect is limited to a few individuals, families or households. | **Short-term:** effect lasts approximately 1 hour or less. | **Once.** The effect occurs once during any phase of the project. | **Reversible short-term:** An effect that can be reversed relatively quickly. | **Low**. The valued component is considered to have little to no unique value to people living in potentially affected communities in the region. | **Low.** An effect is unlikely but could occur. | **Low** (< 50% confidence). The cause-effect relationship between the project and its interaction with the environment is poorly understood; data for the project area may be incomplete; uncertainty associated with synergistic and/or additive interactions between environmental effects may exist. High degree of uncertainty. | **Not Significant (minor).** Residual effects have no or low magnitude, local geographical extent, short or medium-term duration, and occur intermittently, if at all. There is a high level of confidence in the conclusions. The effects on the VC (at a population or species level) are indistinguishable from background conditions (i.e., occur within the range of natural variation as influenced by physical, chemical, and biological processes). Land use management objectives will be met. Follow-up monitoring is not required. | **Not Required** |
| **Operation** | **Low:** The magnitude of effect differs from the average value for baseline conditions, but is below the threshold value (i.e., ER<0.2, ILCR,$10^{-5}$) or below a guideline. | **Community.** The effect extents to a community level. | **Medium-term:** effect lasts from 1 hour to 2 weeks. | **Sporadic.** The effect occurs at sporadic, intermittent, intervals during any phase of the project. | **Reversible long-term:** An effect that can be reversed after many years. | **Neutral.** The valued component is considered to be valuable by people living in potentially affected communities in the region. | **Medium.** An effect is likely but may not occur. | **Medium. (**50 – 80% confidence): The cause-effect relationship between the project and its interaction with the environment is not fully understood, or data for the project area is incomplete: moderate degree of uncertainty. | **Not Significant (moderate).** Residual effects have medium magnitude, local, landscape or regional geographic extent, are short-term to chronic (i.e., may persist into the far future), and occur at all frequencies. Residual effects on VCs are distinguishable at the population, community, and/or ecosystem level. Ability of meeting land use management objectives may be impaired. Confidence in the conclusions is medium or low. The probability of the effect occurring is low or medium. Follow-up monitoring of these effects may be required. | **Required** |
| **Closure** | **Medium:** The magnitude of effect differs from the average value for baseline conditions, and exceeds the threshold value (i.e., ER between 0.2 and 10, ILCR between $10^{-5}$ and $10^{-4}$) or a guideline | **Regional/Aboriginal.** Effect extends across the broader regional community , or across one or more First Nations group(s). | **Long-term:** effect lasts between 2 weeks and 1 year. | **Regular.** The effect occurs on a regular basis during, any phase of the project. | **Irreversible.** The effect cannot be reversed. | **High.** The valued component is highly valued by people living in potentially affected communities or the region. | **High**. An effect is highly likely to occur. | **High**. There is greater than 80% confidence in understanding the cause-effect relationship between the project and its interaction with the environment, and all necessary data is available for the project area. There is a low degree of uncertainty. | **Significant (Major).** Residual effects have high magnitude, regional or beyond regional geographic extent, are chronic (i.e., persist into the far future), and occur at all frequencies. Residual effects on VCs are consequential (i.e., structural and functional changes in populations, communities and ecosystems are predicted). Ability to meet land use management objectives is impaired. Probability of the effect occurring is medium or high. Confidence in the conclusions can be high, medium, or low. Follow-up monitoring is required. | |
| **Post-closure** | **High.** The magnitude of effect is predicted to differ from baseline conditions and exceed guideline or threshold values so that there will be a detectable change beyond the range of natural variation (i.e., ER>10, ILCR>$10^{-4}$). | **Beyond Regional**: The effect extends possibly across or beyond the province. | **Far Future:** effect lasts a lifetime. | **Continuous.** An effect occurring constantly during, and potentially beyond, the project life. | | | | | | |

**Table 25.8-2. Definitions of Significance Criteria for Human Health Residual Effects (Noise)**

| **Timing** *What phase of the Project is the effect associated with?* | **Magnitude** *(negligible, low, medium, high)* | **Geographic Extent** *(local, landscape, regional, beyond regional)* | **Duration** *(short-term, medium-term, long-term, far future)* | **Frequency** *(once, intermittent, regular, continuous)* | **Reversibility** *(reversible short-term, reversible long-term, or irreversible)* | **Context** *(ecological resilience and/or unique attributes) (low, neutral, high)* | **Probability** *(low, medium, high)* | **Confidence** *(low, medium, high)* | **Significance** *(Not Significant: minor, moderate; Significant: major)* | **Follow-Up Monitoring** *(Not required, Required)* |
|---|---|---|---|---|---|---|---|---|---|---|
| **Construction** | **Negligible:** Noise level experience is more than 5 dB below the criteria or equivalent to baseline noise levels. | **Local.** The effect is limited to a small portion of the project footprint. | **Short term**. The effect lasts approximately 1 year or less. | **Once.** The effect occurs once during any phase of the project. | **Reversible short-term:** An effect that can be reversed relatively quickly. | **Low**. The valued component is considered to have little to no unique attributes and/or there is high resilience to imposed stresses. | **Low.** An effect is unlikely but could occur. | **Low** (< 50% confidence). The cause-effect relationship between the project and its interaction with the environment is poorly understood; data for the project area may be incomplete; uncertainty associated with synergistic and/or additive interactions between environmental effects may exist. High degree of uncertainty. | **Not Significant (minor).** Residual effects have no or low magnitude, local geographical extent, short or medium-term duration, and occur intermittently, if at all. There is a high level of confidence in the conclusions. The effects on the VC below all applicabel standards. Land use management objectives will be met. Follow-up monitoring is optional. | **Not Required** |
| **Operations** | **Low:** differs from the average value for baseline conditions to a small degree. Noise levels are < 5 dB below the criteria | **Landscape.** An effect covers the project footprint. | **Medium term.** The effect lasts from 1 – 11 years. | **Sporadic.** The effect occurs at sporadic or intermittent, intervals during any phase of the project. | **Reversible long-term:** An effect that can be reversed after many years. | **Neutral.** The valued component is considered to have some unique attributes, and/or there is neutral (moderate) resilience to imposed stresses. | **Medium.** An effect is likely but may not occur. | **Medium. (**50 – 80% confidence): The cause-effect relationship between the project and its interaction with the environment is not fully understood, or data for the project area is incomplete: moderate degree of uncertainty. | **Not Significant (moderate).** Residual effects have medium magnitude, local, landscape or regional geographic extent, are short-term to chronic (i.e., may persist into the far future), and occur at all frequencies. The effects on teh VC approaching or slightly above applicable standards. Ability of meeting land use management objectives may be impaired. Confidence in the conclusions is medium or low. Follow-up monitoring of these effects may be required. | **Required** |
| **Closure** | **Medium:** differs substantially from the average value for baseline conditions and is 0 – 5dB above limits set forth in acceptable criteria. | **Regional.** An effect extends beyond the project footprint to a broader regional area. | **Long term.** The effect lasts between 12 and 70 years. | **Regular.** The effect occurs on a regular basis during, any phase of the project. | **Irreversible.** The effect cannot be reversed. | **High.** The valued component is considered to be unique, and/or there is low resilience to imposed stresses. | **High**. An effect is highly likely to occur. | **High**. There is greater than 80% confidence in understanding the cause-effect relationship between the project and its interaction with the environment, and all necessary data is available for the project area. There is a low degree of uncertainty. | **Significant (Major).** Residual effects have high magnitude, regional or beyond regional geographic extent, are chronic (i.e., persist into the far future), and occur at all frequencies. Residual effects on VCs are consequential (i.e., standards will be exceeded frequently and over a large area). Ability to meet land use management objectives is impaired. Probability of the effect occurring is medium or high. Confidence in the conclusions can be high, medium, or low. Follow-up monitoring is required. | |
| **Post-Closure** | **High**: differs substantially from baseline conditions and is > 5dB above criteria. | **Beyond Regional**: The effect extends possibly across or beyond the province. | **Far Future: The** effect lasts more than 70 years. | **Continuous.** An effect occurs constantly during any phase of the Project. | | | | | | |

## Table 25.8-3. Summary of Residual Effects on Human Health

| Description of Residual Effect | Project component(s) | Timing of Effect | Magnitude | Extent | Duration | Frequency | Reversibility | Context | Likelihood of Effects: Probability | Likelihood of Effects: Confidence Level | Significance Determination | Follow-up Monitoring |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Human health effects due to ingestion of metals from untreated **surface water** from the TMF and downstream of Mine site | TMF, Mine site | Operation | Negligible | Individual/Household | Short | Sporadic | Reversible short-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| | TMF, Mine site | Closure | Negligible | Individual/Household | Short | Sporadic | Reversible short-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| | TMF, Mine site | Post-closure | Low | Individual/Household | Short | Sporadic | Reversible short-term | High | Low | Low | Not Significant (Minor) | Not Required |
| Health effects from emissions of $NO_2$, $SO_2$, CO, TSP, $PM_{2.5}$, and $PM_{10}$ related to Project rising above background, but below guidelines | Mining machinery, equipment and traffic emissions | Construction | Low | Community | Far future | Regular | Reversible long-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| | Mining machinery, equipment and traffic emissions, blasting | Operation | Low | Community | Far future | Regular | Reversible long-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| Increase in HQ for Metal Inhalation | Mining machinery, equipment and traffic emissions | Construction | Low | Community | Far future | Regular | Reversible long-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| | Mining machinery, equipment and traffic emissions, blasting | Operation | Low | Community | Far future | Regular | Reversible long-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| Increase in ILCR due to an increase in concentration of metals and $PM_{2.5}$ | Mining machinery and equipment emitting combustion $PM_{2.5}$ | Construction | Low | Community | Far future | Regular | Reversible long-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| | Mining machinery and equipment emitting combustion $PM_{2.5}$, especially near Mitchell and Treaty Operating Camps | Operation | Low | Community | Far future | Regular | Reversible long-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| Increase in risk of excess mortality due to increase in concentrations of $PM_{2.5}$ | Air emissions from machinery, traffic, incinerators, blasting | Construction | Low | Community | Far future | Regular | Reversible long-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| | Air emissions from machinery, traffic, incinerators, blasting | Operation | Low | Community | Far future | Regular | Reversible long-term | High | Low | Medium | Not Significant (Minor) | Not Required |
| Human health effects due to metal toxicity from ingestion of country foods | Water and sediment quality in TMF and creeks immediately downstream of TMF; water quality downstream of Mine Site | Operation | Negligible | Regional/Aboriginal Peoples | Short | Sporadic | Reversible short-term | High | Low | High | Not Significant (Minor) | Not Required |
| | Water, vegetation and sediment quality in TMF and creeks immediately downstream of TMF; water quality downstream of Mine Site | Closure | Negligible | Regional/Aboriginal Peoples | Short | Sporadic | Reversible short-term | High | Low | High | Not Significant (Minor) | Not Required |
| | Water, vegetation and sediment quality in TMF and creeks immediately downstream of TMF; water quality downstream of Mine Site | Post-closure | Low | Regional/Aboriginal Peoples | Short | Sporadic | Reversible short-term | High | Low | Low | Not Significant (Minor) | Not Required |
| Human health effects due to Noise: Sleep disturbance on site | Camp 5 | Construction | High | Local | Medium | Regular | Reversible short-term | Neutral | Medium | Medium | Not Significant (Minor) | Not Required |
| | Camp 6 and Treaty Operating Camp | Operation | High | Local | Long | Regular | Reversible short-term | Neutral | Low | Medium | Not Significant (Moderate) | Not Required |
| Overall Residual Effect | All | Post-closure | Low | Regional/Aboriginal Peoples | Short | Sporadic | Reversible short-term | High | Low | Low | Not Significant (Minor) | Not Required |

**Note: CIA = Cumulative Impact Assessment**

Follow-up monitoring of water quality at compliance sites and at the TMF is required as described in Chapter 27, Closure and Reclamation, to ensure that effluent meets discharge permit limits. A human health risk assessment should be conducted if concentrations of metals of concern approach drinking water guideline criteria at the environmental monitoring stations. Should risks be determined to exist, a communications strategy should be put in place by the Proponent to communicate occasions when a health effect event has occurred as a result of the proposed Project.

#### 25.8.2.2 Changes in Health due to Air Quality

After mitigation, the magnitude of residual health effects from changes in air quality above background concentrations has been assessed as low. Four different effects were assessed: the relationship of predicted air quality parameters to specific air quality objectives and standards, excess mortality due to PM levels, changes in HQs for inhaled metals, and ILCR due to exposure to carcinogenic substances.

Because air quality can affect a larger area, the extent has been assessed at the community level. If health effects were observed, the duration could range from short term to far future, depending on the specific health effect. The frequency of effects was assessed as regular, based on the frequency of emissions (Chapter 7, Air Quality). Most potential health effects may be reversible short term (airway irritation), but in some cases, such as repeat exposures to highly sensitive human receptors, effects may range to reversible long-term or irreversible (asthma, lung cancer). The ILCR and an increase in excess mortality were assessed as risk endpoints following Health Canada guidance (Health Canada 2010a) and the AIR. As a result, the duration was assumed to be far-future and the effects reversible in the long term for the purpose of this assessment.

The probability that the assessed health effects will occur is low because the HQ and ILCR (except for non-fugitive $PM_{2.5}$) were smaller than the acceptable threshold levels. It should also be noted that the ILCR is a risk calculation that inherently incorporates the probability of the effect to occur in the population. In addition, the air quality model does not model indoor air quality and off-duty workers will reside indoors; therefore, the assessment overestimates residual effects to off-duty workers. It is also emphasized that air quality objectives were not exceeded at any of the assessed sensitive receptor locations, and that trappers, hunters, and recreationists are at these locations only temporarily and seasonally. The air quality objectives are limits on the acceptable presence of contaminants in the atmosphere, established by government agencies to protect human health and the environment.

The confidence level for this assessment is considered medium. The rationale for this classification is provided in the following paragraphs.

To generate the air quality model, several assumptions had to be made regarding input parameters (i.e., specific equipment that will be used and associated specifications). In addition, there are some uncertainties associated with the assumed baseline data. Uncertainties associated with the baseline assumptions and model predictions are presented in Chapter 7.

The uncertainties associated with Health Canada's guidance (1998, 1999) on estimating effects were presented previously. In summary, the methods were based on large populations and urban demographics, thus the risk predictions may have been underestimated. Notwithstanding, the methods used are those recommended by Health Canada for assessing health effects due to changes in air quality. These uncertainties reduce the confidence in effects predictions. In addition, although the significance of the effects was rated as **not significant (minor)**, there was some uncertainty when assessing non-threshold air quality parameters, such as $PM_{2.5}$.

It is emphasized that the results of the air quality model indicate that none of the CACs were higher than BC air quality objectives and standards (BC MOE 2009) for annual averages for construction, at sensitive receptor sites including Project camps, trapline and hunting cabins, and permanent residences at communities (Bell II and Bob Quinn Lake). Construction and operation were chosen as the phases with the highest emission of CACs, and therefore provide the most conservative estimate for human health effects. Consequently, based on air quality objectives and standards, the risks of residual effects to human health from the change in air quality are possible, but unlikely.

In summary, residual effects to human health, in particular to ILCR and excess mortality due to an increase in concentration of $PM_{2.5}$, are considered **not significant (minor)**. Follow-up monitoring of air quality parameters is required. Air quality monitoring will be carried out to establish the emissions and dustfall associated with the site activities during construction, operation, and closure of the Project (Section 26.11, Air Quality Management Plan). Should emissions and dust particulates reach levels that are greater than air quality guidelines and standards, effects to human health should be considered and mitigated.

#### 25.8.2.3 Changes in Health due to Country Foods Quality

Residual effects on human health from the consumption of country foods at the PTMA and the Mine Site due to Project activities are predicted to be negligible during operation and closure. Any potential effects identified during the SLRA for the PTMA and the Mine Site already exist under baseline conditions, and changes in ER, RMWI, or ILCR due to Project activities are minor.

Any changes to human health will occur in residents or Aboriginal peoples consuming country foods. Since changes to human health are considered negligible, the duration has been assessed as short, and any changes are sporadic and reversible over a short period of time. Human health is valued by individuals and by society, and therefore the context is high.

Evaluating human health risks from exposure to country foods involves multiple steps. Each step has inherent uncertainties that ultimately influence the final risk estimates. In this assessment, the two main uncertainties were the modelled water and sediment COPC concentrations during operation and closure and the food chain model assumptions. For these uncertainties, conservative assumptions were made where possible such that wildlife exposure to the TMF was overestimated rather than underestimated, while consumption frequencies of wildlife obtained from the Project area were also overestimated. Uncertainties associated with measured environmental media are presented in Appendix 25-A, and uncertainties with the modelled environmental media are presented in Appendices 25-C and 25-D. Uncertainties with the food chain model assumptions are presented in Appendices 25-A, 25-C, and 25-D. Overall, the likelihood of occurrence for adverse health effects is low. Because of the conservativeness employed throughout the country food SLRAs, risks were more likely to be overestimated; thus, confidence is high that adverse changes to human health from consuming country foods are unlikely during operation and closure. The confidence level for the post-closure phase is low, because long-term and far-future predictions of changes to human health were not possible due to the high uncertainties with predicting the quality of country foods.

The monitoring and adaptive management plan for the TMF and Mine Site upon closure is such that the likelihood of adverse health effects occurring because of degraded country foods quality at post-closure is low. However, it is not possible to predict the potential future changes in country foods quality with any certainty. While water and sediment quality are predicted to improve during post-closure, wildlife may increasingly access the TMF and other Project areas because disturbances will decrease and habitat values and vegetation cover will increase. The water quality in the TMF (except in the CIL) is expected to be below guidelines in the sixth year after the closure of the mine. The TMF will be capped with till, but some metals may be taken up by the roots of the trees and shrubs that will establish after closure, to which moose and other animals have access (Murray, Thompson, and Macfie 2009; Chapters 18 and 27).

Because of these uncertainties, the residual effects assessment for post-closure relies on best professional judgement. It is recommended that a detailed risk assessment be conducted when sustained increases in metal concentrations in vegetation, soils, and water are detected during monitoring in the operation, closure, and post-closure phases.

The significance of the human health effects due to the consumption of country foods at the TMF and downstream of the Mine Site has been assessed as **not significant (minor).**

#### 25.8.2.4 Changes in Health due to Noise

Short-term construction noise effects are unavoidable during major construction projects, but should be minimized to the extent possible by adhering to best management practices. During construction, the predicted noise levels remain below guideline levels at all assessed receiver locations, except potential sleep disturbance at on-site worker camps (Camp 5: Treaty Plant Camp, Camp 6: Treaty Saddle Camp, and Treaty operating camp; Table 25.7-26).

The magnitude of noise effects is considered high during construction if mitigation measures are taken; however additional mitigation measures could be incorporated during the Project detailed design phase that could reduce the potential magnitude of effects to low. The spatial extent is local (effect is limited to a small portion of the Project footprint), as noise levels will change in the immediate vicinity of the Project and effects will be limited to the possibility of sleep disturbance at the onsite worker camps closest to noise sources. The duration is considered medium term, because effects may last for between 1 to 11 years (i.e., throughout the duration of the construction phase). The frequency of the effect is related to Project scheduling and is considered regular, as many noise sources are mobile and, while transient, will be a regular occurrence at a given location. Noise, and the predicted influence on human health (sleep disturbance), is reversible in the short term. Although proper sleep is important for the safe construction and operation of the mine, given the wide variability in people's tolerance for noise the context is considered to be neutral. The probability that sleep disturbance will occur at the worker camps is medium. Based on these criteria, the residual effect is considered **not significant (minor)** at on-site locations and follow-up monitoring is not required beyond what is outlined in the proposed Noise Management Plan (Section 26.22).

Similarly for operation, the noise modelling results predicted no significant effect, except potential sleep disturbance at on-site worker camps. The magnitude of this effect is considered high; however additional mitigation measures could be incorporated during the Project detailed design phase that could reduce the potential magnitude of effects to low. The spatial extent is local, because noise levels will change in the immediate vicinity of some portions of the Project footprint and the potential for effects has been predicted to decrease with distance from the noise sources. Given the timeframe for operation and the 24-hour work schedule, the duration of noise effects is considered long term (i.e., throughout the duration of the operation phase of the Project). The frequency will be related to Project scheduling and it is expected to be regular. Noise and the predicted effect on human health (sleep disturbance) is a reversible effect in the short term. Although proper sleep is important for the safe operation of the mine, given the wide variability in people's tolerance for noise the context is considered to be neutral.. The probability that sleep disturbance will occur at the workers camps is low. Based on these criteria, with mitigation the effect is considered **not significant (moderate)** at on-site locations and follow-up monitoring is not required beyond what is outlined in the proposed Noise Management Plan (Section 26.22).

There are no residual human health effects to off-site human receptors from noise.

#### 25.8.2.5 Overall Effects on Human Health

Effects to human health from changes in quality of water, air, and country food are assessed as **not significant (minor)**. This affects land users that hunt, trap, collect berries, or recreate near the Project area, either downstream of the PTMA or the Mine Site. While potential effects from changes in water and country food quality only apply to land users, effects from changes in air quality apply to land users and off-shift workers.

The overall effect to human health of off-shift workers is assessed as **not significant (moderate)**, which is based on the assessment of potential human health effects from noise during the operation phase.. Sleep disturbance is the only potential residual effect that may occur at worker camps during operation. Noise is unlikely to affect land users near the Project, because noise levels will change only in the immediate vicinity of the Project and are not close to the land users.

## 25.9 Potential Cumulative Effects for Human Health

### 25.9.1 Scoping of Cumulative Effects

Residual effects on human health from the Project resulted from increased noise levels (not significant, moderate), changes in air quality (not significant, minor), drinking water quality (not significant, minor), and altered quality of country foods (not significant, minor).

Any historical, current, and future activities near the Project area have the potential to induce additive or synergistic interactions with Project-specific effects on human health. In particular, the long-term persistence of water quality effects may result in interactions over a long-term temporal scale.

The cumulative effects assessments for each human health pathway (air quality, drinking water, country foods, and noise) considered the spatial and temporal linkages with other projects and activities, as appropriate, that have been identified for:

- air quality (Section 7.9);
- surface water quality (Section 14.9);
- fish and aquatic habitat (Section 15.9);
- terrestrial ecosystems (Section 17.9);
- wildlife and wildlife habitat (Section 18.9); and
- noise (Section 19.9).

#### 25.9.1.1 Spatial Linkages with other Projects and Human Actions

A list of projects from the past, present, and reasonably foreseeable future is presented in Table 25.9-1. Cumulative effects on water and air quality were included when considering cumulative effects to country foods.

Projects and human actions with a spatial overlap with the KSM Project's potential effect on country foods are shown in Figure 25.9-1. Potential noise effects from projects and human activities that may overlap with the KSM Project's potential effect on noise are shown on Figure 19.9-1 (Chapter 19, Noise).

Projects with potential cumulative effects on human health include:

- Past projects:
  - Eskay Creek Mine;
  - Granduc Mine; and
  - Sulphurets Project.
- Present projects:
  - Forrest Kerr Hydroelectric; and
  - Northwest Transmission Line (NTL).
- Reasonably foreseeable future projects:
  - Brucejack Mine;
  - Snowfield Project; and
  - Treaty Creek Hydroelectric.
- Land use activities:
  - roadway traffic.

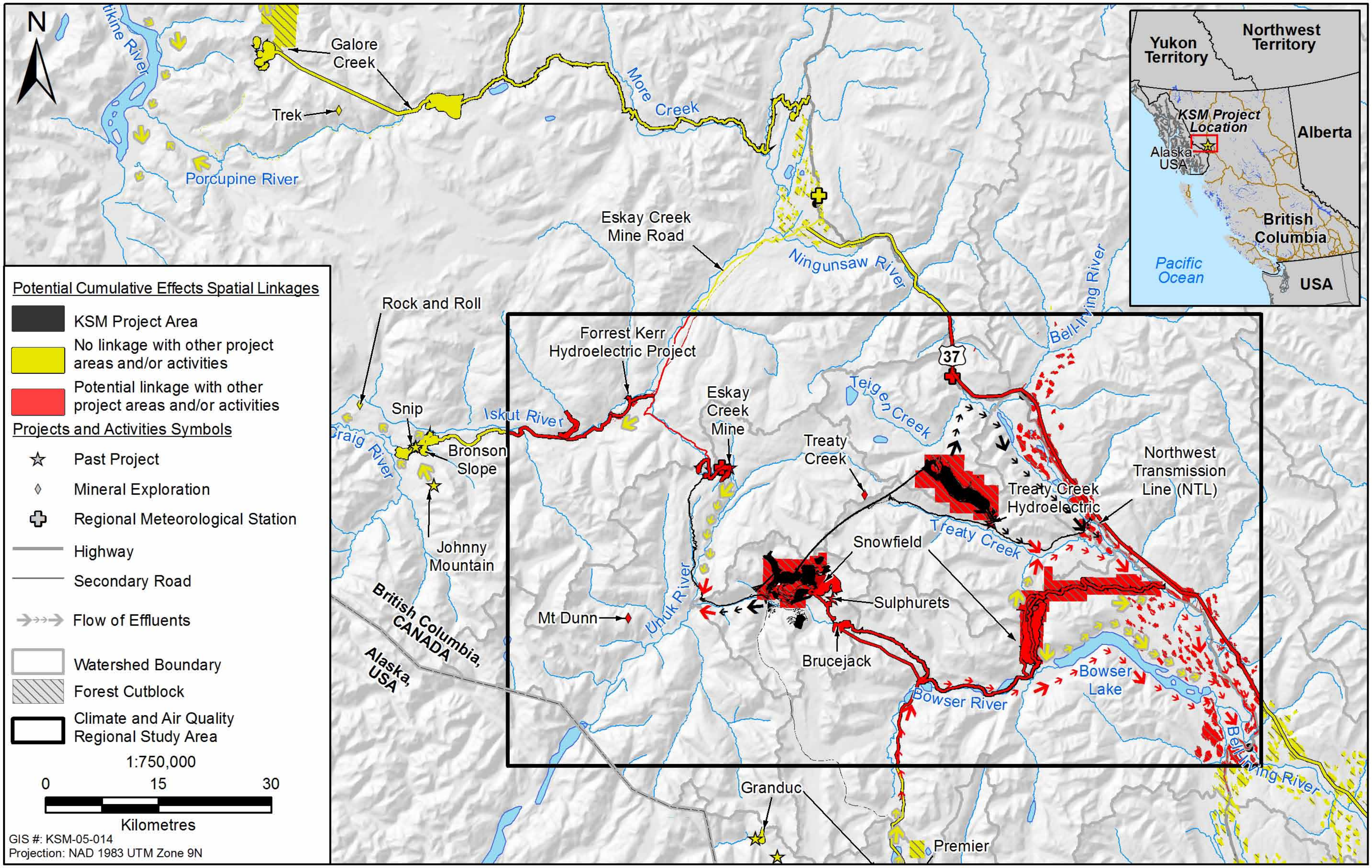


Figure 25.9-1

# KSM Cumulative Effects Issue Scoping: Potential Spatial Linkages for Country Food Quality

## Table 25.9-1. Summary of Potential Linkages between the KSM Project and other Human Actions in regard to Human Health

| Action/Project | | Past | Present | Future |
|---|---|---|---|---|
| Past Projects | Eskay Creek Mine | *X; tailing drain into Unuk River(water quality); dusting along the Eskay Creek Mine road (vegetation); exposure of wildlife; noise* | *X; maintenance vehicles (air quality)* | *NL* |
| | Granduc Mine | *X; tailing drain into Bowser River(water quality); exposure of wildlife* | *NL* | *NL* |
| | Johnny Mountain Mine | *NL* | *NL* | *NL* |
| | Kitsault Mine (closed) | *NL* | *NL* | *NL* |
| | Snip Mine | *NL* | *NL* | *NL* |
| | Sulphurets Project | *X; tailing drain into Sulphurets creek* | *NL* | *NL* |
| | Swamp Point Aggregate Mine | *NL* | *NL* | *NL* |
| Present Projects | Forrest Kerr Hydroelectric | *NL* | *X; noise if construction phase overlaps with construction of KSM Project; new access for land users* | *X; dusting (vegetation) for shared portion of Eskay Creek Mine road; access for land users* |
| | Long Lake Hydroelectric | *NL* | *NL* | *NL* |
| | NTL (Northwest Transmission Line) | *NL* | *X; noise if construction phase overlaps with construction of KSM Project; new access for land users, water quality effects* | *X; construction (air quality, dusting on vegetation, water quality, noise)* |
| | Red Chris Mine | *NL* | *NL* | *NL* |
| | Wolverine Mine | *NL* | *NL* | *NL* |
| Reasonably Foreseeable Future Projects | Arctos Anthracite Coal Mine | *NL* | *NL* | *NL* |
| | Bear River Gravel | *NL* | *NL* | *NL* |
| | Bronson Slope Mine | *NL* | *NL* | *NL* |
| | Brucejack Mine | *NL* | *NL* | *X; construction and operation (air quality, dusting on vegetation, water quality, noise, exposure of wildlife)* |
| | Galore Creek Mine | *NL* | *NL* | *NL* |
| | Granduc Copper Mine | *NL* | *NL* | *NL* |
| | Kitsault Mine | *NL* | *NL* | *NL* |
| | Kutcho Mine | *NL* | *NL* | *NL* |
| | McLymont Creek Hydroelectric | *NL* | *NL* | *NL* |

**(continued)**

# Table 25.9-1. Summary of Potential Linkages between the KSM Project and other Human Actions in regard to Human Health (completed)

| Action/Project | | Past | Present | Future |
|---|---|---|---|---|
| Reasonably Foreseeable Future Projects *(cont'd)* | Schaft Creek Mine | *NL* | *NL* | *NL* |
| | Snowfield Project | *NL* | *NL* | *X; construction and operation (air quality, dusting on vegetation, water quality, exposure of wildlife)* |
| | Storie Moly Mine | *NL* | *NL* | *NL* |
| | Turnagain Mine | *NL* | *NL* | *NL* |
| | Treaty Creek Hydroelectric | *NL* | *NL* | *X; construction (noise, air quality, dusting on vegetation, water quality)* |
| Land Use Activities | Agricultural Resources | *NL* | *NL* | *NL* |
| | Fishing | *NL* | *NL* | *NL* |
| | Guide Outfitting | *NL* | *NL* | *NL* |
| | Resident and Aboriginal Harvest | *NL* | *NL* | *NL* |
| | Mineral and Energy Resource Exploration | *NL* | *NL* | *NL* |
| | Recreation and Tourism | *NL* | *NL* | *NL* |
| | Timber Harvesting | *NL* | *NL* | *NL* |
| | Traffic and Roads | *X; traffic dust and exhaust (air quality), use of newly built access roads for increased harvesting* | *X; traffic dust and exhaust (air quality), use of newly built access roads for increased harvesting; noise* | *X; traffic dust and exhaust (air quality), use of newly built access roads for increased harvesting; noise* |

**NL = No Linkage (no spatial and temporal overlap, or potential effects do not act in combination).**
**X = Potential spatial and temporal linkage with project or action.**
**Note: Human Health table was created by compiling interactions from noise, air quality, surface water quality, fish, terrestrial ecosystems, wildlife, and land use, focusing on potential interactions via exposure to contaminated media, except for noise.**

### 25.9.1.2 Temporal Linkages with other Projects and Human Actions

The following periods are evaluated as part of the cumulative effects assessment:

1. **Past:** 1964 to 2008, coinciding with the development of the Granduc Copper-Gold Mine, which influenced the growth of the community of Stewart and other human activities in the area (StewartBC.com 2004):
   - past vehicle exhaust, particulates, and tailing drainage from Eskay Creek Mine, previous dusting along the Eskay Creek Mine road, and exposure of wildlife;
   - past tailing drainage into Bowser River from Granduc Mine;
   - past tailing drainage into Sulphurets Creek from the Sulphurets Project;

- past land use activities that have affected the quantity of country foods available for harvest and consumption (fishing, guide-outfitting, and resident and Aboriginal harvest); and
- past traffic dust and exhaust.

2. **Present:** 2008 to 2012, from the start of KSM Project baseline studies to the completion of the environmental effects assessment:
   - present air quality effects from maintenance vehicles at Eskay Creek Mine;
   - present air quality from the construction of Forrest Kerr Hydroelectric and the NTL, should construction overlap with construction of the Project;
   - noise from the construction of Forrest Kerr Hydroelectric and of the NTL if construction overlaps with construction of the Project;
   - current land use activities that can affect the quantity of country foods available for harvest and consumption (fishing, guide-outfitting, resident and Aboriginal harvest, and use of newly build access roads for increased harvesting); and
   - present traffic dust and exhaust.

3. **Future:** 2012 until water quality recovers to baseline conditions (taking into account natural cycles of ecosystem change):
   - dusting from the road construction and vehicles at the Bronson Slope Mine;
   - air quality, noise, and water quality effects from the construction and operation of Brucejack Mine, and exposure of wildlife;
   - air quality, noise, and water quality effects from the construction and operation of Snowfield Project, and exposure of wildlife;
   - noise, dusting, and water quality effects from the construction of Treaty Creek Hydroelectric;
   - future land use activities that will affect the quantity of country foods available for harvest and consumption (fishing, guide-outfitting, resident and Aboriginal harvest, and use of newly built access roads for increased harvesting); and
   - future traffic dust and exhaust.

## 25.9.2 Cumulative Effects Assessment for Human Health

Possible interactions between projects due to spatial and temporal linkages are summarized in Table 25.9-2.

### 25.9.2.1 Project-specific Residual Effects on Human Health that are Not Likely to Result in Cumulative Effects

All Project-specific residual effects on human health were carried forward into the assessment for cumulative effects. The following sections discuss the projects with spatial and temporal linkage to the KSM Project and the extent of potential cumulative effects.

#### 25.9.2.2 Cumulative Effect on Drinking Water

The residual effect to human health from drinking water was based on assessing temporal linkages and on an assessment of watershed boundaries and potential project effects. For instance, if watersheds of other projects did not overlap with the watersheds downstream of the KSM Project (Sulphurets, Unuk, Teigen, Treaty, Bell-Irving), human health effects due to cumulative effects on drinking water are not likely to occur.

Eskay Creek Mine

Since the Eskay Creek Mine has ceased operation, effects to water quality have been assessed as part of the baseline water quality for the Project (2008 to 2013). Therefore, a cumulative effect between Eskay Creek Mine and the KSM Project is not expected.

Granduc Mine

Since the Granduc Mine has ceased operation, effects to water quality have been assessed as part of the baseline water quality for the Project (2008 to 2013). Granduc Mine discharges into Bowser River, which flows into the Bell-Irving River. No residual effects are expected from the KSM Project at the confluence of the Bowser River into the Bell-Irving River. Therefore, a cumulative effect between Granduc Mine and the KSM Project is not expected.

Sulphurets Project

Since the Sulphurets Project has ceased operation, effects to water quality have been assessed as part of the baseline water quality for the Project (2008 to 2013). Therefore, a cumulative effect between Sulphurets Project and the KSM Project is not expected.

Northwest Transmission Line

There are no residual water quality effects from the KSM Project in the Bell-Irving River. Additionally, successful implementation of sedimentation and erosion control best management practices during construction of the NTL will minimize water quality effects (siltation) to the Bell-Irving River. No cumulative effects on human health from drinking water are expected.

Brucejack Mine

Water quality effects will be local in nature due to the underground design of the project and back-up water treatment options (Section 14.9). Therefore, cumulative effects to drinking water between Brucejack Mine and the KSM Project are not expected.

Snowfield Project

The Snowfield Project is located upstream of the proposed water management structures for the KSM Project, including the WSF and WTP. At present, there are no plans for further exploration of the property or activities to define how the project could be developed (Chapter 5). Therefore, cumulative effects to water quality-related human health were not assessed.

Treaty Creek Hydroelectric Project

No information is currently available on potential effects to water quality from the construction of Treaty Creek Hydroelectric. No toxicological effects to drinking water and human health are expected from the construction of Treaty Creek Hydroelectric Project.

## Table 25.9-2. Summary of Projects and Activities with Potential to Interact Cumulatively with expected Project-specific Residual Effects on Human Health

| Description of KSM Residual Effect | Potential for Cumulative Effect: Relevant Projects and Activities | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Eskay Creek Mine** | **Granduc Mine** | **Johnny Mountain Mine** | **Snip Mine** | **Sulphurets Project** | **Forrest Kerr Hydroelectric Project** | **NTL (Northwest Transmission Line)** | **Bronson Slope Mine** | **Brucejack Mine** | **Snowfield Project** | **Treaty Creek Hydroelectric Project** | **Fishing** | **Guide-outfitting** | **Resident and Aboriginal Harvest** | **Traffic and Roads** |
| Human health effects due to ingestion of metals from untreated **surface water** downstream of the Project | Possible Interaction | Possible Interaction | No Interaction | No Interaction | Possible Interaction | No Interaction | Possible Interaction | No Interaction | Possible Interaction | Possible Interaction | Possible Interaction | No Interaction | No Interaction | No Interaction | No Interaction |
| Health effects from emissions of $NO_2$, $SO_2$, CO, TSP, $PM_{2.5}$, and $PM_{10}$ related to Project rising above background, but below guidelines | Possible Interaction | No Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction | Possible Interaction | No Interaction | Possible Interaction | Possible Interaction | Possible Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction |
| Increase in HQ for Metal Inhalation | Possible Interaction | No Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction | Possible Interaction | No Interaction | Possible Interaction | Possible Interaction | Possible Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction |
| Increase in ILCR due to an increase in concentration of metals and $PM_{2.5}$ | Possible Interaction | No Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction | Possible Interaction | No Interaction | Possible Interaction | Possible Interaction | Possible Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction |
| Increase in risk of excess mortality due to increase in concentrations of $PM_{2.5}$ | Possible Interaction | No Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction | Possible Interaction | No Interaction | Possible Interaction | Possible Interaction | Possible Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction |
| Human health effects due to metal toxicity from ingestion of country foods | Possible Interaction | Possible Interaction | No Interaction | No Interaction | Possible Interaction | Possible Interaction | Possible Interaction | No Interaction | Possible Interaction | Possible Interaction | Possible Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction |
| Sleep Disturbance at Camps | Possible Interaction | No Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction | Possible Interaction | No Interaction | Possible Interaction | Possible Interaction | Possible Interaction | No Interaction | No Interaction | No Interaction | Possible Interaction |

##### *25.9.2.2.1 Project-specific Cumulative Effects Mitigations for Drinking Water*

No cumulative effects to human health from drinking water have been identified with respect to the Project; therefore, it is not necessary to identify further mitigation, monitoring, and management strategies. The Project has been designed with the goal to minimize adverse effects on water quality downstream of the Project area. Mitigation measures that are additional to those outlined in other sections of the Application/EIS are not anticipated to be required.

##### *25.9.2.2.2 Other Project/Activity Mitigations to Address Drinking Water*

No cumulative effects to human health from drinking water have been identified with respect to the Project; therefore, it is not necessary to identify further mitigation, monitoring, and management strategies. However, requirements for other projects to monitor water quality and provide wastewater treatment if necessary will prevent cumulative effects to human health from surface drinking water, provided that the water is boiled as recommended by Health Canada (2011c).

No potential for residual cumulative human health effects and significance was identified for drinking water (Table 25.9-3).

### 25.9.2.3 Cumulative Effect of Air Quality

Each of the projects with potential cumulative effects to air quality with spatial or temporal linkage with the KSM Project are discussed in Chapter 7 and reviewed in regard to human health effects below.

The residual effects to human health from changes in air quality were not determined to have an interaction with effects from the closed Granduc Mine, Johnny Mountain Mine, Snip Mine, Bronson Slope Mine, and the Sulphurets Project. The four mines are located outside the air quality boundary.

<u>Eskay Creek Mine</u>

Because the Eskay Creek Mine ceased operation in 2008, there is no temporal linkage, except the maintenance vehicles that still operate on-site and the ongoing care and maintenance. However, the activity level is expected to be negligible compared to the level of activity during the KSM Project construction and operation phases. A cumulative effect to human health between Eskay Creek Mine and the KSM Project is not expected.

<u>Forrest Kerr Hydroelectric Power Project</u>

The construction phase of the Forrest Kerr Hydroelectric Project will end before construction of the KSM Project begins; therefore, there is no temporal linkage to cumulative effects. During operation of the hydroelectric power facility, expected activities include some vehicle travel for inspection, maintenance, and employee travel. Provided that the activity level for the Forrest Kerr Project is low during operation, there will be no cumulative effect to human health due to air quality.

Northwest Transmission Line

The construction phase of the NTL will end before construction of the KSM Project begins; therefore, there is no temporal linkage to cumulative air quality and human health effects.

Snowfield Project

The Snowfield property is located within the Sulphurets District immediately adjacent to the KSM Project, and partially inside the KSM Project fenceline. The proponent of the project has indicated that the exploration and development of the Snowfield deposit has stopped (Chapter 5). Therefore, there is no temporal overlap with the KSM Project and cumulative effects are not expected.

Brucejack Mine

Temporal and spatial linkages between the Brucejack Mine and the KSM Project exist, and potentially have cumulative effects on air quality and human health. Emissions from the Brucejack underground mining operation are expected to be low and controlled. Project design will minimize fugitive dust emissions (Rescan 2012). Due to Brucejack's relatively small size compared to the KSM Project, the effect on air quality from Brucejack Mine is expected to be much less than that from the KSM Project. The KSM Project residual air quality effect is likely to be similar to the cumulative effect from the two projects combined. Although the cumulative effect in air quality between Brucejack Mine and the KSM Project is likely, the magnitude increase of the residual effect to human health is expected to be minor.

Treaty Creek Hydroelectric Project

This Project is in the very early planning stages and it is assumed for the purposes of the cumulative effects assessment that this project would not be constructed until 2017. Therefore, the construction of this small run-of-the-river project would overlap with the construction of the KSM Project. At this time, it is not possible to provide a cumulative effect assessment for human health. Given the small size of the project and provided that the maintenance activity level for the operation of the Treaty Creek Hydroelectric Project is low, any potential increase to residual effects to human health due to changes in air quality is expected to be minor.

Traffic and Roads

The exhaust from vehicles used to continue monitoring at the Eskay Creek Mine and construct and monitor other projects is considered negligible compared to traffic from the KSM Project.

##### *25.9.2.3.1 Project-specific Cumulative Effects Mitigations for Air Quality*

Project-specific mitigation and monitoring measures are described in Section 7.8.1. Monitoring and adaptive mitigation for air quality effects, as described in Section 26.11, Air Quality Management Plan, and summarized in Section 25.7.2, will be implemented by the Proponent. These will include emissions and dust monitoring, and best management practices for vehicle maintenance, road maintenance, incineration, emissions control equipment, and transport and storage of tailing and concentrate. Any mitigation that results in an improvement to air quality will also reduce effects to human health.

## Table 25.9-3. Summary of Residual Cumulative Effects on Human Health

| Description of KSM Residual Effect | Other Project(s)/ Activity(ies) | Timing of Effect | Magnitude | Magnitude Adjusted for CE | Extent | Extent Adjusted for CE | Duration | Duration Adjusted for CE | Frequency | Frequency Adjusted for CE | Reversibility | Reversibility Adjusted for CE | Context | Context Adjusted for CE | Likelihood of Effects | | | | Significance Determination | Significance Determination Adjusted for CE | Follow-up Monitoring | Follow-up Monitoring Adjusted for CE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | Probability | Probability Adjusted for CE | Confidence Level | Conf. Level Adjusted for CE | | | | |
| Human health effects due to ingestion of metals from untreated surface water from the TMF and downstream of Mine site | NTL, Brucejack Mine, Snowfields Project, Treaty Creek Hydroelectric Project | Operation | Negligible | N/A | Individual/ Household | N/A | Short | N/A | Sporadic | N/A | Reversible short-term | N/A | High | N/A | Low | N/A | Medium | N/A | Not Significant (minor) | N/A | Not Required | N/A |
| | NTL, Brucejack Mine, Snowfields Project, Treaty Creek Hydroelectric Project | Closure | Negligible | N/A | Individual/ Household | N/A | Short | N/A | Sporadic | N/A | Reversible short-term | N/A | High | N/A | Low | N/A | Medium | N/A | Not Significant (minor) | N/A | Not Required | N/A |
| | NTL, Brucejack Mine, Snowfields Project, Treaty Creek Hydroelectric Project | Post-closure | Low | N/A | Individual/ Household | N/A | Short | N/A | Sporadic | N/A | Reversible short-term | N/A | High | N/A | Low | N/A | Low | N/A | Not Significant (minor) | N/A | Not Required | N/A |
| Health effects from emissions of $NO_2$, $SO_2$, CO, TSP, $PM_{2.5}$, and $PM_{10}$ related to Project rising above background, but below guidelines | Brucejack Mine, Treaty Creek Hydroelectric Project | Operation | Low | Low | Community | Landscape | Far future | Far future | Regular | Regular | Reversible long-term | Reversible long-term | High | High | Low | Low | Medium | Low | Not Significant (Minor) | Not Significant (Minor) | Not Required | Not Required |
| Increase in HQ for Metal Inhalation | Brucejack Mine, Treaty Creek Hydroelectric Project | Operation | Low | Low | Community | Landscape | Far future | Far future | Regular | Regular | Reversible long-term | Reversible long-term | High | High | Low | Low | Medium | Low | Not Significant (Minor) | Not Significant (Minor) | Not Required | Not Required |
| Increase in ILCR due to an increase in concentration of metals and $PM_{2.5}$ | Brucejack Mine, Treaty Creek Hydroelectric Project | Construction | Low | Medium | Community | Landscape | Far future | Far future | Regular | Regular | Reversible long-term | Reversible long-term | High | High | Low | Low | Medium | Low | Not Significant (Minor) | Not Significant (Moderate) | Not Required | Not Required |
| | Brucejack Mine, Treaty Creek Hydroelectric Project | Operation | Low | Medium | Community | Landscape | Far future | Far future | Regular | Regular | Reversible long-term | Reversible long-term | High | High | Low | Low | Medium | Low | Not Significant (Minor) | Not Significant (Moderate) | Not Required | Not Required |
| Human health effects due to metal toxicity from ingestion of country foods | NTL, Brucejack Mine, Snowfields Project, Treaty Creek Hydroelectric Project | Operation | Negligible | N/A | Regional/ Aboriginal Peoples | N/A | Short | N/A | Sporadic | N/A | Reversible short-term | N/A | High | High | Low | N/A | High | N/A | Not Significant (minor) | N/A | Not Required | N/A |
| | NTL, Brucejack Mine, Snowfields Project, Treaty Creek Hydroelectric Project | Closure | Negligible | N/A | Regional/ Aboriginal Peoples | N/A | Short | N/A | Sporadic | N/A | Reversible short-term | N/A | High | High | Low | N/A | High | N/A | Not Significant (minor) | N/A | Not Required | N/A |
| | NTL, Brucejack Mine, Snowfields Project, Treaty Creek Hydroelectric Project | Post-closure | Low | N/A | Regional/ Aboriginal Peoples | N/A | Short | N/A | Sporadic | N/A | Reversible short-term | N/A | High | High | Low | N/A | Low | N/A | Not Significant (Minor) | N/A | Not Required | N/A |
| Human health effects due to Noise: Sleep disturbance on site | Eskay Creek Mine, Brucejack Mine, NTL, Forest Kerr Hydroelectric Project, Traffic and Roads | Construction | High | N/A | Local | N/A | Medium | N/A | Regular | N/A | Reversible short-term | N/A | Neutral | N/A | Medium | N/A | Medium | N/A | Not Significant (Minor) | N/A | Not Required | N/A |
| | Eskay Creek Mine, Brucejack Mine, Forest Kerr Hydroelectric Project, Traffic and Roads | Operation | High | N/A | Local | N/A | Long | N/A | Regular | N/A | Reversible short-term | N/A | Neutral | N/A | Low | N/A | Medium | N/A | Not Significant (Moderate) | N/A | Not Required | N/A |
| Overall Effect | All | Post-closure | Low | N/A | Regional/ Aboriginal Peoples | N/A | Short | N/A | Sporadic | N/A | Reversible short-term | N/A | High | N/A | Low | N/A | Low | N/A | Not Significant (Minor) | N/A | Not Required | N/A |

**Note: CE = Cumulative Effect**

#### 25.9.2.3.2 *Other Project/Activity Mitigations to Address Air Quality*

It is expected that the Brucejack Mine Project will implement similar monitoring and adaptive management plans as the KSM Project to minimize potential cumulative effects on human health. Provided that mitigation for air quality at other projects is comparable to mitigation at the KSM Project, increases in residual effects to human health are expected to be minor. Air quality monitoring during construction of the projects will indicate whether BC air quality guidelines are met, and whether further mitigation and monitoring will be required.

#### 25.9.2.3.3 *Determination of Potential for Residual Cumulative Effect and Significance*

The only projects that can have the potential for cumulative health effects with the KSM Project based on air quality in the foreseeable future are the Brucejack Mine Project and the construction of the Treaty Creek Hydroelectric Project (Table 25.9-3). The residual effect on air quality from Brucejack Mine is expected to be much lower than that from the KSM Project. Since the increase in residual cumulative air quality effect from the Project residual air quality effect is expected to be minor, the magnitude adjusted for cumulative effect for human health related to increases of $NO_2$, $SO_2$, CO, TSP, $PM_{10}$, and $PM_{2.5}$ above baseline, but below guideline, is low. The cumulative magnitude of the HQ for metal inhalation also likely remains low. Therefore, these potential cumulative effects have been rated as **not significant (minor)**.

Since there is no threshold for health effects from small particulates, the minor cumulative increase in $PM_{2.5}$ may lead to a medium cumulative magnitude for ILCR and excess death endpoints. The extent for cumulative human health effects becomes landscape-wide. Qualifiers for human health effects due to degradation of air quality from both projects are considered similar to qualifiers for health effects from the KSM Project alone, because health outcomes are similar: far-future duration, regular frequency, and reversible long term (Section 25.7.2). Health is highly valued by people. Due to the smaller sizes and designs of other Projects compared to the KSM Project, the probability of a cumulative effect actually occurring is low. Since an emission inventory has not yet been developed, and dispersion and risk models have not been conducted for the Brucejack Mine, the adjusted confidence level for cumulative effect is low. The cumulative effect on ILCR and excess death due to potential cumulative increases in $PM_{2.5}$ is considered **not significant (moderate)**.

### 25.9.2.4 Cumulative Effect of Country Foods

The residual effect to human health from changes in the quality of country food was not expected to have an interaction with Johnny Mountain Mine, Snip Mine, and Bronson Slope Mine. Potential country foods effects at these mines are unlikely to have spatial linkage with the KSM Project due to a lack of overlap for effects to air quality and water quality.

Cumulative effects on human health from country foods were assessed by considering the following components:

- the potential for cumulative effects on water quality;
- the potential for cumulative increases in dust and metals deposition onto plants and soils; and
- cumulative effects on wildlife quality.

A summary of projects and activities with a potential to interact cumulatively with the KSM Project is provided in Table 25.9-2.

Potential for Cumulative Effects on Water Quality

Relevant projects and activities with a potential for cumulative effects on water quality were assessed in Section 25.9.2.2. Cumulative effects from past projects (Eskay Creek Mine, Granduc Mine, and Sulphurets Project) are included in the baseline assessment for country foods, and no additional future cumulative effects are expected. No interactions are expected for Brucejack Mine, since water quality effects will be local. Currently, there is no information available on other projects in the foreseeable future (Snowfield Project and Treaty Creek Hydroelectric). Therefore, cumulative effects on country foods quality due to changes in water quality are not expected.

Potential for Cumulative Dusting and Metal Deposition

Relevant projects and activities with a potential for cumulative effects on air quality were assessed in Section 25.9.2.3. Brucejack Mine and the construction of Treaty Creek Hydroelectric Project are the only projects in the reasonably foreseeable future that will have cumulative effects on air quality. There is no information available currently for the Snowfield Project. Since the increase in the maximum 30-day dust deposition rate due to the KSM Project is only 0.07% from background, dust deposition is highly localized. Since Brucejack Mine will use an underground mining and milling process with minimal dust, it is expected that there will be no cumulative effects from dust deposition on soils and vegetation in areas suitable for human harvest or for wildlife consumption.

Potential for Cumulative effects on Wildlife Quality

Wildlife with large home ranges or migratory wildlife may be exposed to effects from chemical hazards from several projects even if there is no spatial linkage for water and air quality effects, as long as these projects are located within the animals' home range. Commonly harvested wildlife that were assessed for Project residual effects included moose, snowshoe hare, grouse, and non-migratory Dolly Varden. Except for moose, none of the assessed animals are migratory and home ranges are smaller than the Project footprint. Therefore, snowshoe hare, grouse, and non-migratory Dolly Varden are not expected to be exposed to cumulative effects from other projects. Most moose are not migratory and remain within one watershed in low elevation forested habitat. Any cumulative toxicological effects on moose from the KSM Project and from the Eskay Creek Mine have been included in the baseline country foods assessment and will not contribute to future cumulative effects. Because there are no cumulative effects on water quality or air quality (dust) in moose habitat (Section 18.9), no cumulative toxicological effects are expected for moose.

Based on an assessment of cumulative effects to water quality, air quality, and wildlife, no cumulative effects to human health from the consumption of country foods were identified (Table 25.9-3).

###### *25.9.2.4.1 Project-specific Cumulative Effects Mitigations for Country Foods*

No cumulative effects to human health from country foods have been identified; therefore, it is not necessary to identify further Project mitigation, monitoring, and management strategies.

A monitoring and adaptive management plan is proposed to ensure that the wetlands and aquatic invertebrates in the TMF do not accumulate metals to levels that may result in accumulation in wildlife species that consume them, and therefore may lead to human health effects.

##### *25.9.2.4.2 Other Project/Activity Mitigations to Address Country Foods*

No cumulative effects to human health from country foods have been identified; therefore, it is not necessary to identify further mitigation, monitoring, and management strategies.

#### 25.9.2.5 Cumulative Effect of Noise

The residual effect to human health from elevated noise levels were not determined to have an interaction with either past projects or projects that are at a distance from the KSM Project. Noise effects generally diminish with distance from a source. Since most human-generated noise has been found to be undetectable within 5 km for a large industrial source, a 10-km range from Project activities is expected to conservatively encompass all potential acoustic effects of the proposed Project. Land use activities (fishing, guide-outfitting, resident and aboriginal harvest) are not expected to generate cumulative noise effects. Acoustic effects may lead to human health effects at residential receptors (construction and mining camps). Table 25.9-2 lists the potential interactions between each of the projects and activities identified in the previous section as potentially having a cumulative effect with the KSM Project.

A detailed description of cumulative human health effects from noise is provided in Section 19.9.2.1. Briefly, none of the other projects or activities are anticipated to have any interaction with the KSM Project. According to the model results presented in Appendix 19-A, all sources of noise, except blasting, reach background levels a distance away from other potential sources of noise. Additionally, each of these sources of noise are, or will be, significantly smaller than those from the KSM Project. The potential for non-significant cumulative effects relating to noise are limited to those receivers within approximately 1 km of the area where the KSM Project and Snowfield Project/Brucejack Mine are immediately adjacent to each other.

Assuming the Snowfield Project/Brucejack Mine produces an equivalent amount of noise to the KSM Project (which is a very conservative assumption given the relative size of the two planned projects), receivers in this vicinity will experience a maximum 3 dB cumulative effect. Noise, at exploration Camp 1, the current closest receiver, will still be below the limit and therefore no significant cumulative effects to human health are anticipated from the Snowfield Project/Brucejack Mine.

Cumulative effects from traffic-related noise at the closest residential receivers along the sections of highways 37 and 37A that are used by the KSM Project, Forest Kerr Hydroelectric Project, and Snowfield Project/Brucejack Mine are assessed in Chapter 22, Appendix 22-C.

##### *25.9.2.5.1 Project-specific Cumulative Effects Mitigations for Noise*

No significant cumulative effects were identified for human health from noise at the PTMA and Mine Site. Therefore, it is not necessary to identify further mitigation, monitoring, and management strategies.

#### 25.9.2.5.2 Other Project/Activity Mitigations to Address Noise

Assuming that other projects will apply the same mitigation strategies as the KSM Project, no significant cumulative effects to human health from noise are expected.

#### 25.9.2.5.3 Determination of Potential for Residual Cumulative Effect and Significance

No significant cumulative effects are expected for human health from noise at the Project sites (Table 25.9-3).

### 25.9.2.6 Overall Cumulative Effect on Human Health

Overall cumulative effects for human health in post-closure are not expected (Table 25.9-3). No cumulative human health effects are expected for the other phases of the Project (construction, operation, and closure), except for cumulative effects from air quality. During operation, cumulative human health effects have been rated as **not significant (moderate)** for ILCR and the risk of increased mortality.

## 25.10 Summary of Assessment of Potential Environmental Effects on Human Health

A summary of the assessment of effects to human health is presented in Table 25.10-1.

## 25.11 Human Health Conclusions

Human health is a highly valued component for each individual and for society. The assessment included several different pathways through which health can be affected: the ingestion of water, the inhalation of air, the ingestion of country foods, and the effects of noise. It is recognized that health is more than just physical well-being. For instance, social, cultural, nutritional, and economic factors also play a role in a person's overall health status. These health indices have been assessed in other sections of the Application/EIS. Chapter 25 follows a science-based approach recommended by Health Canada to protect people from adverse health effects caused by exposure to contaminants of potential concern in water, air, or country food, and exposure to noise.

The Project area is remote and therefore the assessment focused on temporary and seasonal land users, Nisga'a Nation, First Nations, and resident hunters, trappers, berry pickers, recreationists, guide-outfitters, and trapline holders. While workers' health is covered under Occupational Health and Safety Plans, as required by law, the health of off-duty workers was included in the assessment, as required by Health Canada.

The human health assessment relied on data measured during baseline studies and future modelled water quality, air quality, country foods quality, and noise predictions. These predicted data were used to model and assess potential effects of the proposed Project to human health. There are high uncertainties associated with the models, and therefore highly conservative assumptions were made. This resulted in an overestimation of human health risks.

## Table 25.10-1. Summary of Assessment of Potential Environmental Effects: Human Health

| Description of KSM Residual Effect | Phase of Project | Potential Effect | Key Mitigation Measures | Significance Analysis of Project Residual Effects | Significance Analysis of Cumulative Residual Effects |
|---|---|---|---|---|---|
| Drinking Water Quality | Operation | Human health effects due to ingestion of metals from untreated surface water from downstream of the TMF and Mine site | Project Design, water treatment, water quality monitoring | Not significant (minor) | N/A |
| | Closure | | | Not significant (minor) | N/A |
| | Post-closure | | | Not significant (minor) | N/A |
| Air Quality | Operation | Health effects from emissions of $NO_2$, $SO_2$, CO, TSP, $PM_{2.5}$, and $PM_{10}$ related to Project rising above background, but below guidelines | Project design, emission control systems, vehicle and equipment mainenance, dust management, monitoring | Not significant (minor) | Not significant (minor) |
| | Operation | Increase in HQ for Metal Inhalation | | Not significant (minor) | Not significant (minor) |
| | Operation | Increase in ILCR due to an increase in concentration of metals and $PM_{2.5}$ | | Not significant (minor) | Not Significant (moderate) |
| | Operation | Increase in risk of excess mortality due to increase in concentrations of $PM_{2.5}$ | | Not significant (minor) | Not Significant (moderate) |
| Country Foods Quality | Operation | Human health effects due to metal toxicity from ingestion of country foods | Project design, dust management, water treatment, water and air quality monitoring, adaptive management | Not Significant (Minor) | N/A |
| | Closure | | | Not Significant (Minor) | N/A |
| | Post-closure | | | Not Significant (Minor) | N/A |
| Noise | Construction | Human health effects due to Noise: Sleep disturbance on site | Monitoring, adaptive management, regular maintenance of vehicles and machinery, speed control | Not Signficant (Minor) | N/A |
| | Operation | | | Not Significant (Moderate) | N/A |

The following paragraphs summarize the results for the assessment of the four different exposure pathways:

Drinking Water

The assessment concluded that risks to human health from the ingestion of surface water are **not significant (minor)**. BC's ambient water quality guidelines (BC MOE 2006) for drinking water were not predicted to be exceeded during the operation, closure, and post-closure phases of the Project.

Air Quality

The Project is likely to have residual effects on human health from changes in air quality during the construction and operation phases. However, these effects have been assessed as **not significant (minor)**, because BC air quality objectives and standards, which are protective of public health, were not exceeded. Human health effects were based on calculations that showed minor increases in non-threshold parameters and endpoints commonly used for air quality health assessments.

Quality of Country Foods

Human health effects from the ingestion of country foods have been assessed for the operation, closure, and post-closure phases. Effects were found to be negligible and have been rated as **not significant (minor)**. During post-closure, upon cessation of Project activities, access by country food harvesters to the area may increase. Predicting the quality of country foods during post-closure has very high uncertainty associated with it. Therefore, if the concentrations of metals or other COPCs are shown to increase over time in water, soils, or vegetation due to Project activities, the requirement for further country foods risk assessments will be investigated. Adaptive management practices will be implemented if monitoring and modelling indicate an unacceptable level of risk to human health.

Noise

Noise effects only occur during Project activities in the construction, operation, and closure phases. Noise effects are only expected for off-duty workers at Project camp locations (Camp 5, Camp 6, and Treaty operating camp) and will not affect temporary and seasonal land users near the Project. There may be some sleep disturbance for off-duty workers, and therefore the effect has been characterized as **non-significant (moderate)** during operations phase.

The overall residual effect from the Project to human health in post-closure is therefore **not significant (minor).**

Cumulative effects to human health from other current and reasonably foreseeable projects in the area are unlikely (i.e., not applicable or not significant (mnor) for most potential cumulative effects). Because air quality may decrease due to other projects (Brucejack Mine, Treaty Creek Hydroelectric Project), human health from inhalation exposure was rated as **not significant (minor to moderate)**.

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