21. Assessment of Potential Health Effects

21.1 INTRODUCTION

This section examines potential effects of the Brucejack Gold Mine Project (the Project) on human health from contaminants and from noise. The establishment of a mine and associated activities, including blasting; road and camp construction; mine operation; and the transport and management of chemicals, waste rock, and tailings have the potential to generate noise; release pollutants in the dust, soil, and water; and lead to the uptake of chemicals by vegetation and country foods, potentially affecting the health of humans using the area. In other words, Project Construction, Operation, Closure, and Post-closure phases may affect human health via environmental media, such as noise levels, air quality, drinking water, and the quality of country foods.

Human health was identified as a receptor Valued Component (VC) in this Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS). Noise, air quality, drinking water quality, and country foods quality were identified as the main exposure pathways through which effects to human health may occur, and were considered as sub-components of human health.

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

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

The human health effects assessment does not address occupational exposures. Health and safety of employees while working is addressed by various legislation and codes in British Columbia (BC) such as the Occupational Health and Safety Regulation (BC Reg. 296/97) and associated policies and guidelines administered by WorkSafeBC and the Health, Safety, and Reclamation Code (BC MEMPR 2008) administered by the Ministry of Energy and Mines. Since the proponent must adhere to these occupational health and safety requirements to ensure provision of a safe working environment, there is no additional need to consider on-duty worker health and safety in the Application/EIS. Safety and human health concerns for on-shift workers would be addressed separately in site- and/or activity-specific Health and Safety Plans that would be developed before Construction.

However, off-duty workers that reside at worker camps should be considered as potential human receptors (Health Canada 2010e). In addition, this human health assessment applies to humans who could enter the Project and surrounding areas on an occasional and temporary basis (e.g., campers, hunters).

It is recognized that health is more than just physical health, i.e., social, nutritional, and economic factors, as well as customs and cultural practices also play a role in a person's overall health and feeling of well-being. However, potential effects on the non-physical health and quality of life of the people residing near the Project were evaluated in Appendix 20-A of Chapter 20, Assessment of Potential Social Effects, and are not considered here.

21.2 REGULATORY AND POLICY FRAMEWORK

The inclusion of human health assessment in the environmental assessment (EA) process in Canada has been recognized by the federal government and by the Province of BC under various legislation and policy requirements (Health Canada 1999a, 2010e).

Under BC's *Environmental Assessment Act* (2002), an environmental assessment certificate is required and the proponent may not proceed with the project without an assessment of whether the project has "a significant adverse environmental, economic, social, heritage or health effect."

Under the *Canadian Environmental Assessment Act, 2012* (2012), the definition of an "environmental effect" includes any changes in health or socio-economic conditions that are caused by the project's environmental effects. The Act requires that the environment be protected from significant adverse environmental effects caused by a designated project.

The province of BC (Environmental Assessment Office) typically relies on Health Canada to assess the adequacy of the human health effects assessment component of the environmental assessment. Health Canada provides some guidance on the type of information required to be included in the effects assessment for human health, including noise levels, air quality, drinking water, and country foods quality (Health Canada 2010e).

21.2.1 Noise

There is currently no federal or provincial legislation that stipulates noise levels for mine development projects. The Project lies within the Cassiar Iskut-Stikine Land and Resource Management Plan (CIS LRMP; BC ILMB 2000). The CIS LRMP does not have any direct restriction or management plan regarding noise in the area (BC ILMB 2000). Thus, recommended noise levels from other jurisdictions will be used to provide a reference or benchmark for the purposes of this assessment. Health Canada considers a variety of internationally recognized standards for noise, including the United States Environmental Protection Agency (US EPA; 1974), the World Health Organization (WHO; 1999), and other publications regarding indicators of noise-induced human health effects (Michaud 2008).

The US EPA (1974) recommends a background noise level of 55 dBA for areas where people may spend limited amounts of time. The WHO (1999) have published guidelines on recommended noise levels to minimize sleep disturbance in humans:

- "if negative effects on sleep are to be avoided, the equivalent sound pressure level should not exceed 30 decibels (dBA) indoors for continuous noise;" and
- "for a good sleep, it is believed that indoor sound pressure levels should not exceed approximately 45 dB L_{max} more than 10 – 15 times per night."

Michaud et al. (2008) suggests the calculation of the percent highly annoyed (%HA) metric as a measure of potential health effects from noise. A %HA of equal to or greater than 6.5% is recommended as an indicator of noise-induced human health effects for long-term project noise (Michaud 2008) when noise duration is expected to exceed one year.

The most commonly used noise metrics are L_{Aeq}, L_{A90}, L_{Cpeak}, L_{Amax}, L_{Amin}, L_d, L_n, and L_{dn} and they are defined in Table 8.1 in Chapter 8, Noise Predictive Study, which is reproduced here for convenience as Table 21.2-1.

Table 21.2-1. Common Noise Metrics

Noise Matrix	Definition
L_{Aeq}	Continuous equivalent sound level over a time period in A-weighting.
L_{A90}	Sound level exceeded for 90% of the measurement period in A-weighting.
L_{Cpeak}	The maximum sound level in C-weighting
L_{Amax}	Maximum sound level in A-weighting during a measurement period.
L_{Amin}	Minimum sound level in A-weighting during a measurement period.
L_d	Equivalent day time sound level in A-weighting equivalent during the day time (7:00 to 20:00)
L_n	Equivalent nighttime sound level in A-weighting during the night (20:00 to 7:00)
L_{dn}	Day-night equivalent sound level in A-weighting over 24 hour period, with 10 dB penalty added to the nighttime sound level.

Sound levels are often presented as continuous equivalent sound level over a time period (L_{eq}). The L_{eq} includes all noise from all sources, including anthropogenic sources such as helicopters and aircraft. Therefore, L_{eq} does not typically reflect the natural noise level conditions in the area. An alternative metric is L_{90}, the ninetieth percentile level, or the sound pressure level which is exceeded 90% of the time during the measurement period. The L_{90} provides a better indication of the natural noise levels in an area, since discrete events generated by anthropogenic sources are usually excluded from the measurement metric.

21.2.2 Air Quality

Managing air quality is a partnership between multiple government jurisdictions and stakeholders including federal, provincial, regional, and municipal governments, along with international joint organizations.

The *Canadian Environmental Protection Act* (CEPA; 1999), which came into force on March 31, 2000, is an important part of Canada's federal environmental legislation aimed at preventing pollution and protecting the environment and human health. The CEPA also regulates emission sources that lie beyond provincial authorities such as motor vehicles and fuel, marine vessels, railways, and off-road engines (BC Air Quality 2013).

The *Environmental Management Act* (EMA; 2003) and Waste Discharge Regulation (WDR; BC Reg. 320/2004) are the most important pieces of legislation for air quality in BC. The EMA provides a flexible authorization framework, increases enforcement options, and uses modern environmental management tools (BC MOE 2013c). The WDR, under the EMA, stipulates that it is applicable to mining and mining activities such as clearing and burning and incineration (BC Reg. 320/2004). Many codes of practice and regulations are also in development and review under the EMA, which include the Hazardous Waste Regulation (BC Reg. 63/88), the Open Burning Smoke Control Regulation (BC Reg. 145/93), and the Small Electrical Power Generating Facility Code of Practice (BC MOE 2011).

Ambient air quality objectives are non-statutory limits that provincial or federal governments place on the level of contaminants in the atmosphere in order to guide decisions to protect human health and the environment. Discharge limits of fugitive dust and air contaminants, as well as ambient air quality objectives (in particular for dustfall), may also be explicitly written into a waste discharge air permit.

The federal and provincial ambient air quality criteria are summarized in Table 21.2-2. The national ambient air quality objectives (NAAQOs) have been the benchmark for Canadian impact assessment of anthropogenic activities on air quality (Environment Canada 2010) which has been updated since 1998

(Health Canada 1998). The first NAAQOs developed in the mid-1970s consisted of a three-tiered approach (maximum desirable, acceptable, and tolerable levels). The NAAQOs framework, introduced in the National Air Pollution Surveillance (NAPS) data report for the year 2000 (Environment Canada 2013), specified two levels developed through extensive scientific assessment:

- a reference level, which is the level above which there are demonstrated effects on human health, and/or the environment; and
- an Air Quality Objective, which reflects a specific level of protection for the general population and environment and also considers aspects of technical feasibility (Environment Canada 2013).

Table 21.2-2. Federal and Provincial Ambient Air Quality Criteria

		Concentrations (μg/m^3)					
		Canada			BC Objective		
Pollutant	Averaging Time	Maximum Desirable	Maximum Acceptable	Maximum Tolerable	Level A	Level B	Level C
SO_2	1-hour	450	900	-	450	900	900-1,300
	24-hour	150	300	800	160	260	260
	Annual	30	60	-	25	50	80
NO_2	1-hour	-	400	1,000	-	-	-
	24-hour	-	200	300	-	-	-
	Annual	60	100	-	-	-	-
CO	1-hour	15,000	35,000		14,300	28,000	35,000
	8-hour	6,000	15,000	20,000	5,500	11,000	14,300
TSP	24-hour	-	120	400	150	200	260
	Annual	60	70	-	60	70	75
PM_{10}	24-hour	-	-	-	-	50	-
$PM_{2.5}$	24-hour	-	30[a]	-	-	25[b]	-
	Annual	-	-	-	-	8[c]	-

Notes: (-) dash indicates not applicable
[a] *Annual 98th percentile value, averaged over three consecutive years. Canada-wide standard published by CCME (1999b).*
[b] *Based on annual 98th percentile value.*
[c] *BC objective of 8 μg/m^3 and planning goal of 6 μg/m^3 was established in 2009.*
Shaded cells indicate the guidelines used in this assessment.

The original objectives have not been formally revised to the new two-level system. In the interim, sulphur dioxide (SO_2), oxides of nitrogen (NO_2), carbon monoxide (CO), and ozone (O_3) are typically compared with the existing desirable and acceptable NAAQOs.

The province also has the authority to develop air quality standards and guidelines, regulate point and area sources, and require the preparation of airshed management plans (BC MOE 2013c). The BC air quality objectives are generally similar to those from NAAQOs; however, some pollutants are only regulated by either the federal or the provincial government.

The Canadian Council of Ministers of the Environment (CCME) developed Canada-wide Standards (CWS) for $PM_{2.5}$ and O_3 in 2000 (CCME 2012a). Since BC is a member of the CCME, a 24-hour $PM_{2.5}$ CWS of 30 μg/m^3 (based on the annual 98th percentile averaged over three consecutive years), is being implemented in BC (CCME 2012a). In 2009, new ambient air quality criteria for $PM_{2.5}$ were developed in BC (BC MOE 2013b). The 24-hour $PM_{2.5}$ objective of 25 µg/m^3, based on an annual 98th percentile, is more stringent than the CWS for $PM_{2.5}$. BC also established an annual average objective of 8 µg/m^3 for $PM_{2.5}$ and a planning goal of 6 µg/m^3.

Regional and municipal governments can also develop bylaws to control emissions such as open burning and vehicle idling. However, in the Regional District of Kitimat-Stikine, where the Project is located, there are currently no anti-idling or open-burning bylaws.

The Pollution Control Objectives for the Mining, Smelting, and Related Industries of British Columbia (BC MOE 1979) developed dustfall objectives ranging from 1.7 to 2.9 mg/dm^2/day, averaged over 30 days. The dustfall objective depends on whether the receiving environment is considered to be sensitive (lower value) or not (higher value). The most conservative available criteria were used in this assessment (shaded cells in Table 21.2-2).

21.2.3 Drinking Water

The BC *Drinking Water Protection Act* (2001) and Drinking Water Protection Regulation (B.C. Reg. 200/2003) are the key pieces of legislation supporting the provision of potable drinking water in BC. This legislation applies to all water systems, other than those that supply single family homes or other specifically excluded systems. The *Drinking Water Protection Act* and Drinking Water Protection Regulation require that all water systems meet minimum water treatment standards, monitoring type and frequency, and specific water quality standards.

Provincial and federal drinking water quality guidelines (DWQGs) are available to ensure potability of water and protection of human health (Table 21.2-3). Drinking water quality must comply with the BC DWQGs (BC MOE 2006a) under the BC *Drinking Water Protection Act* (2001) and BC Drinking Water Protection Regulation (B.C. Reg. 200/2003).

Table 21.2-3. Provincial and Federal Drinking Water Quality Guidelines

Parameter	BC Drinking Water Quality Guidelines (mg/L)[2]	Canadian Drinking Water Quality Guidelines (mg/L)[1]
Antimony	-	0.006
Arsenic	0.025	0.010
Barium	-	1
Beryllium	0.004	-
Boron	5	5
Cadmium	-	0.005
Chromium	-	0.05
Copper	0.5	1
SAD-Cyanide and Thiocyanate (CN)	0.2	0.2
Fluoride	1	1.5
Lead	0.05	0.010
Mercury	0.001	0.05
Molybdenum	0.25	-
Nitrate (as N)	10	10
Nitrite (as N)	1	1

(continued)

Table 21.2-3. Provincial and Federal Drinking Water Quality Guidelines (completed)

Parameter	BC Drinking Water Quality Guidelines (mg/L)[2]	Canadian Drinking Water Quality Guidelines (mg/L)[1]
Selenium	0.01	0.01
Strontium	-	0.01
Thallium	0.002	-
Uranium	-	0.02
Zinc	5	5

[1] *Guidelines for Canadian Drinking Water Quality Summary Table, (Health Canada 2012b).*
[2] *BC Drinking Water Quality Guidelines, (BC MOE 2013d).*

Although not legally enforceable, the Guidelines for Canadian Drinking Water Quality (referred to throughout this chapter as the Canadian DWQGs; Health Canada 2012b) and Guidelines for Canadian Recreational Water Quality (Health Canada 1992, 2012b) may be used as guidelines for parameters where BC DWQGs are lacking.

21.2.4 Country Foods

Country foods are an important component of human health impact assessment and the inclusion of human health impact assessment in the EA process in Canada has been recognized by the federal government and by the Province of BC under various legislative and regulatory requirements (Health Canada 1999a, 2010e).

For assessing the potential for contamination of country foods under baseline and Project conditions, Health Canada indicates that the human health risk assessment should “consider adequate baseline data and/or modelling of contaminants of potential concern (COPCs) in country foods prior to any project activities” (Health Canada 2010e). A country foods baseline assessment report was completed to fulfill this requirement and an equivalent approach will be used to assess the potential for Project-related effects on country food quality as part of the effects assessment.

21.3 BASELINE CHARACTERIZATION

21.3.1 Regional Overview

21.3.1.1 Noise

Noise, generally defined as undesirable sound, is characterized in terms of the pressure of the sound wave. It has intrinsic importance to employees, local residents, and temporary land users, and noise can directly affect the health of humans and wildlife. Noise may result in psychological and physiological effects in humans, such as irritation, interference with speech comprehension, sleep disturbance, and hearing loss.

Due to the localized and short-lived nature of noise, noise levels are not monitored regionally; however, noise levels monitored by other projects in the region can help define the background noise level in the area. For example, background noise monitoring conducted for the proposed Schaft Creek Project (Schaft) in June and July 2007 (Rescan RTEC 2008) found that noise levels were comparable to baseline levels for rural areas suggested in the Alberta Energy and Utilities Board Directive 038 (Alberta EUB 2007).

21.3.1.2 Air Quality

Air quality is an important environmental factor in ensuring the conservation of local vegetation, wildlife, and human health values. The air quality in the area proposed for the Project and elsewhere in northwestern BC is predominantly not affected by anthropogenic sources, reflecting the region's remoteness and the relatively low amount of local sources of anthropogenic air emissions sources. The Project lies within the CIS LRMP (BC ILMB 2000) and Nass South Sustainable Resource Management Plan (SRMP; BC MFLNRO 2012). Neither of these two management plans specifies objectives or goals to regulate ambient air quality. However, the CIS LRMP states that clean air is one of its competitive advantages; as such, it is understood that clean air in the area is valued.

21.3.1.3 Drinking Water

Water quality is an essential component of the ecosystem and is linked to human health directly via drinking or indirectly through the food web (e.g., vegetation, fish, and wildlife). Drinking water may be obtained from either surface or groundwater sources, although in undeveloped areas surface water sources are more commonly used since they are more readily accessible. Human health can be affected by chemical (e.g., ions, metals) and bacteriological constituents that may be present in untreated, naturally occurring surface waters.

Surface water may be used by water licence holders, trappers, hunters, country food gatherers, and recreational users who consume surface water during backcountry trips. It may also be used by local people and First Nations; for example, it has been indicated that surface water at the junction of the Bowser River and Surveyor's Creek may be used as a source of drinking water by First Nations as it rarely freezes in winter (Appendix 25-B of Chapter 25, Assessment of Potential Effects to Current Use of Lands and Resources for Traditional Purposes). Similarly, clients participating in commercial recreation (guided mountaineering or heli-skiing; Appendix 24-A of Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects) may consume surface water and use water for recreational purposes. It should be emphasized that no surface water can be considered safe for human consumption without treatment (Health Canada 2008).

21.3.1.4 Country Foods

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. The quality of country foods is directly related to the quality of the surrounding environmental media (e.g., soil, water, and vegetation). Human health may be affected by consumption of country foods that contain contaminants that occur naturally or as a result of anthropogenic activities.

Hunting, trapping, fishing, plant collection, cultural events, and recreational activities are common activities among Nisga'a and First Nations, residents, and guide/outfitting operators (Appendix 24-A of Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects). The Project is within Skii km Lax Ha traditional territory. Nisga'a Lands and the Nass Wildlife Area are to the southeast of the Project while the Brucejack Access Road, Brucejack Transmission Line, Knipple Transfer Area, and Bowser Aerodrome are all within the Nass Area as defined by the *Nisga'a Final Agreement* (NLG, Province of BC, and Government of Canada 2000). The Project is also in close proximity to the southern part of the Tahltan territory; approximately 9 km of the Brucejack Access Road falls within the Tahltan traditional territory (Appendix 21-A, Country Foods Baseline Assessment). For more information on Nisga'a and First Nations Traditional Territories in relation to the Project, see Section 21.3.4.4.

Wildlife such as black bear, grizzly bear, moose, mountain goat, hoary marmot, wolverine, wolf, marten, squirrel, beaver, lynx, weasel, mink, and hare may be hunted or trapped by people from nearby communities, First Nation hunters, or non-resident hunters through guide outfitting activities (Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects, and Chapter 25, Assessment of Potential Effects to Current Use of Lands and Resources for Traditional Purposes, respectively). Fishing and berry/plant harvesting were historically, and continue to be, important activities among Nisg̲a'a and First Nations in the area (Chapter 25, Assessment of Potential Effects to Current Use of Lands and Resources for Traditional Purposes).

21.3.2 Historical Activities

Several historic and current human activities are within close proximity to the proposed Project Area. These include mining exploration and production, hydroelectric power generation, forestry, and road construction and use.

The Granduc Mine was a copper mine located approximately 25 km south of the Project which operated from 1970 to 1978 and 1980 to 1984. The mine included underground workings and a mill site near Summit Lake, connected by an 17-km tunnel. In addition, a 52-km all-weather access road was built from the communities of Stewart, BC and Hyder, Alaska to the former mill site near Summit Lake. The area of the former mill site near Summit Lake is currently used as staging for several mineral exploration projects in the region. The terminus of the Granduc Access Road is 25 km south of the proposed Brucejack Mine Site and is currently used by mineral exploration traffic and tourists accessing the Salmon Glacier viewpoint.

The Sulphurets Project was an advanced underground exploration project of Newhawk Gold Mines located at the currently proposed Brucejack Mine Site. Underground workings were excavated between 1986 and 1990 as part of an advanced exploration and bulk sampling program. Reclamation efforts following the Newhawk advanced exploration work included deposition of waste rock and ore within Brucejack Lake.

The exploration phase of the proposed Brucejack Gold Mine Project commenced in 2011 and has included a drilling program, bulk sample program, construction of an exploration access road from Highway 37 to the west end of Bowser Lake, and rehabilitation of an existing access road from the west end of Bowser Lake to the Brucejack Mine Site.

In 2010, construction began on the Long Lake Hydroelectric Project which is located approximately 42 km south of the Project. It includes redevelopment of a 20-m-high rockfill dam located at the head of Long Lake, and a new 10-km-long 138-kilovolt transmission line.

Historical forestry activities occurred within the immediate Project area between Highway 37 and Bowser Lake, south of the Wildfire Creek and Bell-Irving River confluence. Additional details regarding historic and current human activities nearby the Project are included in Section 6.9, Cumulative Effects Assessment.

All of the above historical or current activities have the potential to affect environmental quality (i.e., noise levels or air, water, soil, and vegetation quality), which can in turn affect human health. The legacy contribution of these historical and current activities to environmental quality has been captured during baseline studies undertaken for the proposed Project.

21.3.3 Baseline Studies

This section presents the outcomes of the baseline studies related to human health, structured according to the four human health VC sub-components of noise, air quality, drinking water, and country foods. Each sub-component is addressed in terms of the data sources accessed, and the methods applied to each, the latter including definitions of the particular baseline study areas.

21.3.3.1 Noise

The objective of the noise baseline study was to collect information on baseline noise conditions in the vicinity of the proposed Project before Project commencement. During the 2012 noise baseline monitoring program, primary locations of anticipated Project-related noise sources were identified, field measurements during snow-free and snow-cover periods were collected, and periods of background noise from recorded data were identified (Appendix 8-A of Chapter 8, Noise Predictive Study). The noise baseline study followed methods as described in the Application Information Requirements (AIR; BC EAO 2014) and EIS Guidelines (CEA Agency 2013b).

Data Sources

Background noise monitoring was conducted for the proposed Schaft Creek and Kitsault Projects in 2007 and 2009, respectively (McKendry 2006; Rescan RTEC 2008; AMEC 2011). Noise levels at these two projects are comparable to estimated baseline levels for rural areas as given in the Alberta Energy and Utilities Board Directive 038, which considers a rural area with nighttime L_{eq} sound levels to be 35 dBA (Alberta EUB 2007). Daytime ambient sound levels are commonly 10 dBA higher than nighttime levels (WHO 1999); therefore, daytime sound level values are considered to be approximately 45 dBA.

Methods

Baseline Study Area

A baseline LSA for noise was adopted from wildlife characterization and wildlife baseline programs (Chapter 18, Appendices 18-A and 18-B) since wildlife could be potentially affected by noise. The LSA extends approximately 1 km along the exploration access road and the proposed transmission line. Around Brucejack Lake, the LSA extends approximately 1 km to the northeast to approximately 9 km to the southwest (Figure 21.3-1).

Sampling/Monitoring/Assessment

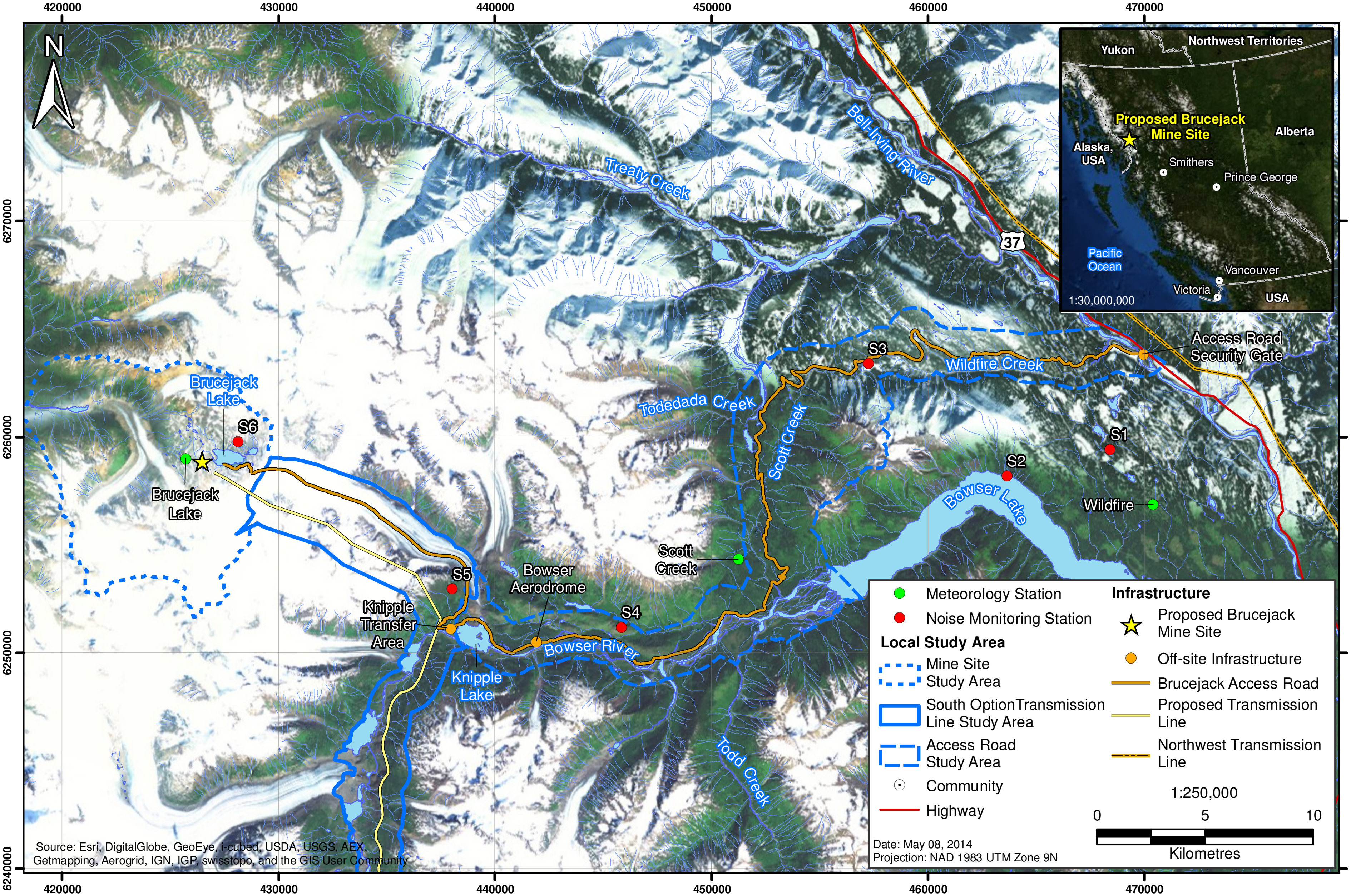
Methods employed for the baseline noise sampling program are detailed in Chapter 8, Noise Predictive Study, and Appendix 8-A, Brucejack Gold Mine Project: 2012 Noise Baseline Report.

21.3.3.2 Air Quality

The objective of the air quality baseline program was to collect information on the existing ambient air quality conditions prior to Project commencement. Following AIR (BC EAO 2014) and EIS (CEA Agency 2013b) Guidelines, the air quality baseline program included assessment of a group of pollutants referred to as criteria air contaminants (CACs), which included:

- sulphur dioxide (SO_2);
- nitrogen dioxide (NO_2);
- carbon monoxide (CO);
- volatile organic compounds (VOCs);
- total suspended particulates (TSP);
- suspended particulates with diameter less than 10 µg (PM_{10});
- suspended particulates with diameter less than 2.5 µg ($PM_{2.5}$); and
- ozone (O_3).

Figure 21.3-1
Noise Baseline Local Study Area and Monitoring Locations



Other than the CACs, dustfall levels, which are the amounts of dust that are deposited on a given area, were also monitored.

Data Sources

The background concentration of CACs collected at other monitoring sites or projects in the area are summarized in Table 21.3-1. The best available estimates of ambient background concentrations are published by the Canadian Air and Precipitation Monitoring Network (CAPMoN). CAPMoN is a non-urban air quality monitoring network, with siting criteria designed to ensure that the measurement locations are regionally representative (i.e., not affected by local sources of air pollution). The closest CAPMoN site to the Project is the Saturna station, off the southern tip of Vancouver Island in the middle of the Strait of Georgia. Although the station is almost 1,000 km southeast of the Project, it provides the best estimate of background concentration available for BC. Daily measurements of SO_2 concentrations are available from the Saturna monitoring station from 1996 to 2002 (1997 missing). The average annual SO_2 concentration for that period was reported as 2.3 μg/m^3. However, ambient NO_2 concentrations were not measured at the Saturna station.

Table 21.3-1. Summary of Ambient Criteria Air Contaminant Concentrations from Other Sources

		Concentration (μg/m^3)			
Pollutant	**Averaging Period**	**Saturna**	**Diavik**	**Galore**	**Kitsault**
SO_2	1-hour	-	4.0	-	-
	24-hour	-	4.0	-	-
	Annual	2.3	2.0	-	-
NO_2	1-hour	-	21	-	-
	24-hour	-	21	-	-
	Annual	-	5.0	-	-
CO	1-hour	-	100	-	-
	8-hour	-	100	-	-
TSP	24-hour	-	10	-	3.5
	Annual	-	10	-	-
PM_{10}	24-hour	-	10	3.4	2.5
$PM_{2.5}$	24-hour	-	-	1.3	2.3
	Annual	-	-	-	-

The Diavik Diamond Mine (Diavik) is in the Northwest Territories, located about 300 km northeast of Yellowknife. In the Diavik Diamond Mine Environmental Assessment (Cirrus 1998) ambient background concentrations of CACs were estimated based on surveys and assumptions. These ambient concentrations have been considered to be typical background concentrations for remote areas with limited anthropogenic sources of CACs.

Background dust deposition monitoring has been conducted in the region for the proposed KSM Project (Rescan 2013c), Galore Creek (Rescan 2006), Kitsault (AMEC 2011), and Schaft Creek (RTEC 2010; Table 21.3-2).

A technical document about background concentrations of ozone (McKendry 2006) indicated background ozone concentration to be in the range of 40 to 80 μg/m^3 (20 to 40 parts per billion) in BC.

Table 21.3-2. Summary of Dustfall Deposition Rates from Other Sources

		Deposition Rate (mg/dm²/day)			
	Averaging Period	KSM Project	Galore Creek	Kitsault	Schaft Creek
Dust Deposition	30-day	0.12 to 1.22	0.09 to 0.96	0.46	0.13 to 0.93

Methods

The following sections describe the rationale for the selection of the baseline study areas and methodology used under baseline conditions.

Baseline Study Area

No baseline LSA was defined for the air quality baseline assessment.

Sampling/Monitoring/Assessment

Methods employed for the baseline ambient air quality and dustfall monitoring programs are detailed in Chapter 7, Air Quality Predictive Study, and Appendix 7-A, Brucejack Gold Mine Project: 2012 Meteorology Baseline Report. Figure 21.3-2 presents the baseline dustfall and Passive Air Sampling System (PASS) monitoring stations.

21.3.3.3 Drinking Water

Drinking water quality was not the subject of a baseline report. However, following the AIR (BC EAO 2014) and EIS Guidelines (CEA Agency 2013b), a comprehensive surface water quality baseline monitoring program was conducted between 2007 and 2013. The objective of the water quality baseline program was to collect water quality data from selected stream/river and lake sites in the Project area. Water chemistry data from the baseline monitoring program were compiled in Appendix 13-A of Chapter 13, Assessment of Potential Surface Water Quality Effects, and these data were then used to assess the potential for human health risk from the drinking of surface water.

Data Sources

The proposed KSM Project recently submitted an Application/EIS, which included extensive surface water quality baseline data collected from 2007 to 2012. Surface water quality at the KSM Project is included in an ongoing baseline monitoring program, and data from the KSM Project relevant to the Brucejack Gold Mine Project were included in the baseline drinking water quality assessment.

A drinking water quality baseline assessment was conducted as a part of the human health chapter of the KSM Project Application/EIS (Rescan 2013c); however, many of the sites assessed for drinking water quality are not relevant to the Brucejack Gold Mine Project since they are too distant from the Project site.

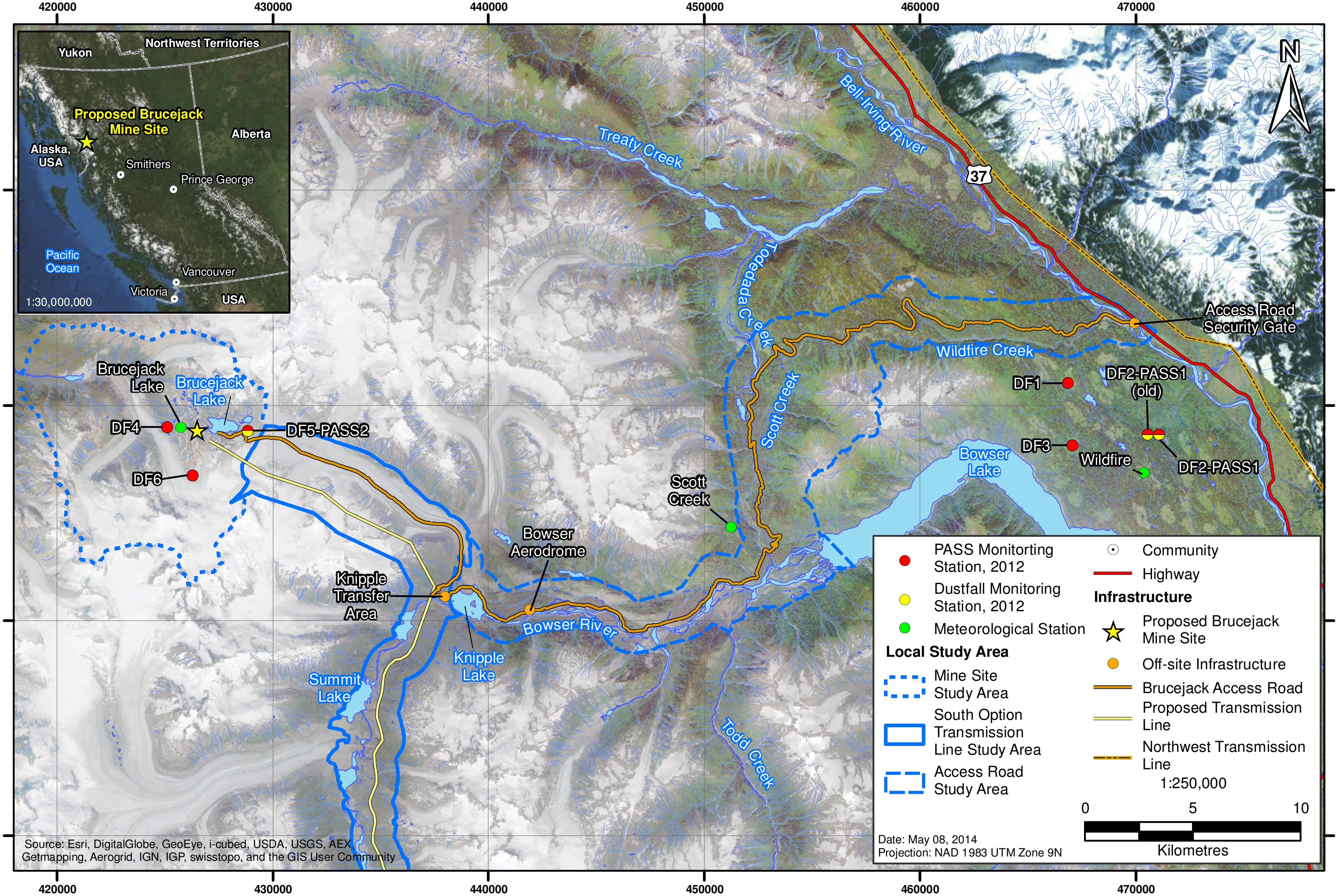
Methods

The following sections describe the rationale for the selection of the baseline study areas and methodology used under baseline conditions.

Baseline Study Area

The drinking water baseline LSA encompasses the proposed Project footprint (all physical structures and activities that comprise the Project) and watersheds that could be potentially indirectly or directly affected by mine development and operation (Figure 21.3-3).

Figure 21.3-2
Baseline Dustfall and PASS Monitoring Stations



The drinking water baseline LSA is depicted in Figure 21.3-3 and consists of three main areas:

- Brucejack Watershed (mine site area);
- Knipple Lake / Bowser River Watershed (ancillary Project infrastructure, access corridor); and
- Wildfire Creek/Scott/Todedada Watersheds (access corridor).

For further details on the boundaries and main areas of the drinking water LSA, refer to Chapter 13, Assessment of Potential Surface Water Quality Effects, Section 13.3.3.2, Methods.

The drinking water baseline RSA, shown in Figure 21.3-3, extends beyond the LSA and includes the portion of watersheds downstream of the Project with a potential for both direct and indirect effects on surface water quality. The boundaries of the drinking water baseline RSA include watersheds upstream of those with a potential for direct effects.

The drinking water RSA includes the following watersheds:

- Unuk River;
- Lower Bowser River (downstream of Knipple Lake), Scott Creek, Todedada Creek, and Wildfire Creek; and
- Salmon River and Upper Bowser River (upstream of Knipple Lake).

For further details on the drinking water baseline RSA, refer to Section 13.3.3.2.

<u>Sampling/Monitoring/Assessment</u>

Drinking Water Receptor Locations and Baseline Assessment

Following the AIR (BC EAO 2014) and EIS Guidelines (CEA Agency 2013b), potential drinking water sources in the LSA and RSA were identified (Figure 21.3-4). The drinking water quality LSA was divided into three sub-areas for assessment of baseline drinking water quality. These areas were Brucejack Lake within the Brucejack watershed, Knipple Lake / Bowser River watershed, and Wildfire Creek/ Scott/Todedada watersheds. The water quality sampling sites included within each of these sub-areas are listed in Tables 4.3-1 and 4.3-2 of Appendix 13-A of Chapter 13, Assessment of Potential Surface Water Quality Effects. Figure 21.3-3 shows the location of the sampling sites within the drinking water quality LSA and RSA.

Historical mining and mineral exploration activities have affected lake and stream water quality within the mine site area (Brucejack Watershed). No pre-disturbance baseline water quality data are available for Brucejack Lake, Brucejack Creek, or Camp Creek. Monitoring began in 1987 to support a Stage 1 Impact Assessment for the Sulphurets Project proposed by Newhawk Gold Mines Ltd., whereas underground development began in autumn 1986; from that time onward watercourses within the Brucejack watershed were affected by drainage from areas disturbed through surface activities, active (dewatering) or passive drainage from the adit, as well as reclamation activities (Newhawk Gold Mines Ltd. 1989; Price 2005). Newhawk Gold Mine Ltd.'s active mining and exploration ceased in 1990. Historical surface water quality data (1987 to 2001; Newhawk Gold Mines Ltd. 1989; Price 2005) are thus incorporated into the current environmental setting and assessment to more accurately constrain effects of previous mining and explorations from the proposed Project-related activities. For further information on the inclusion of the historical data into this assessment, refer to Section 13.3.2, Historical Activities.

Figure 21.3-3

Drinking Water Baseline Local and Regional Study Areas and Surface Water Quality Sampling Locations

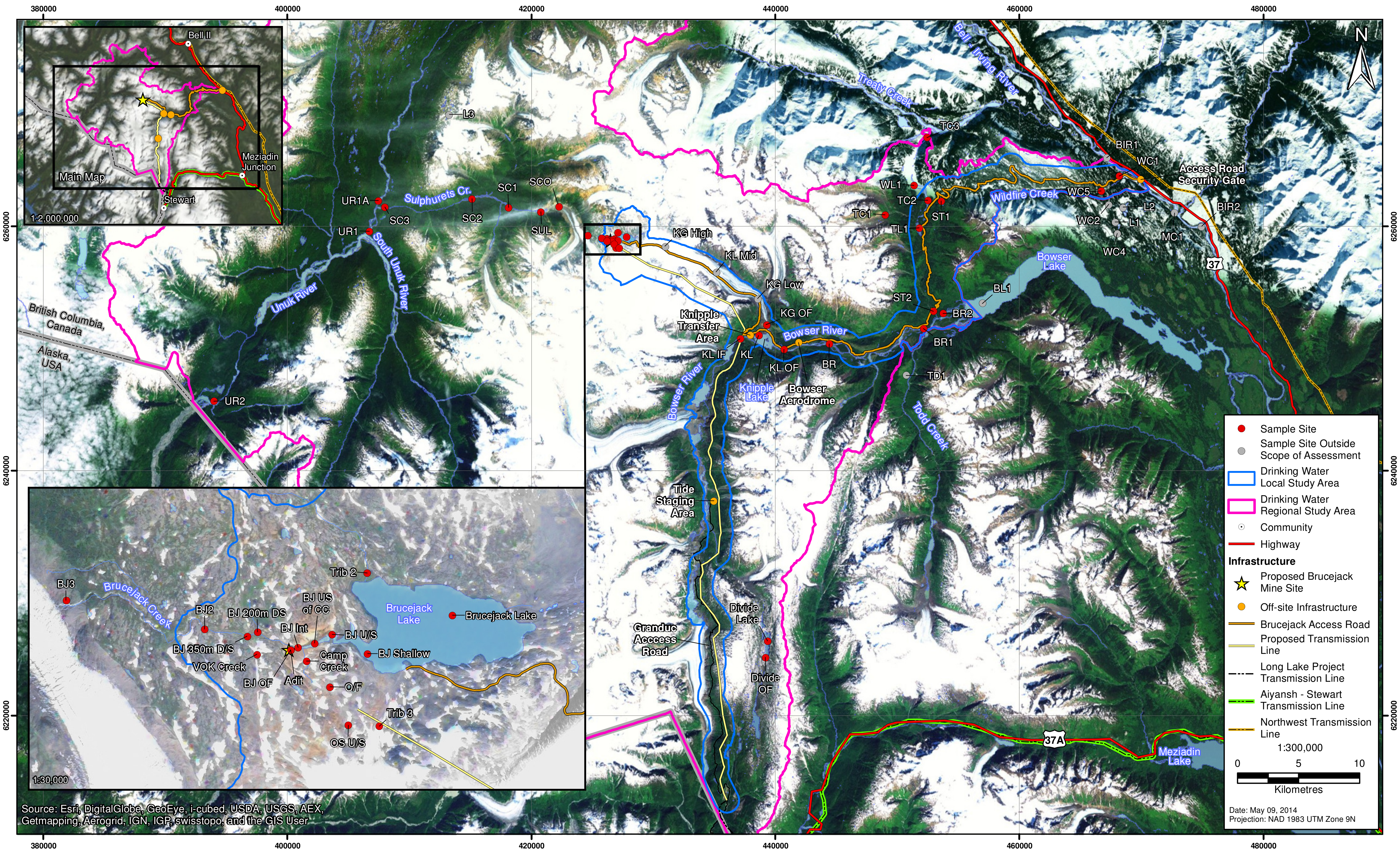
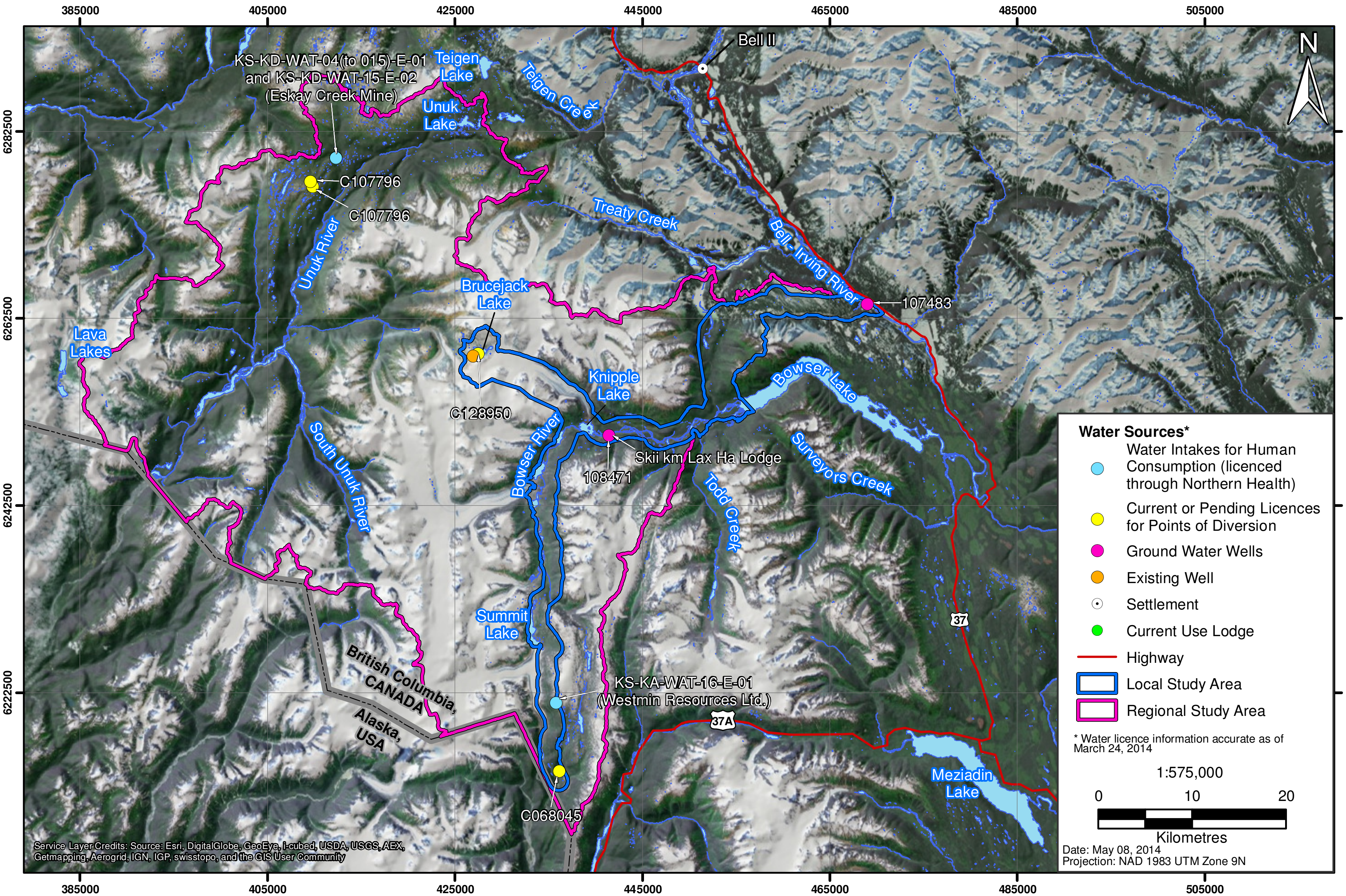


Figure 21.3-4

Water Licence Points of Diversion and Groundwater Wells near the Brucejack Project (as of March 2014) and Current Use Lodges



Post-mining water quality data conducted from 1991 to 1998, as well as 2000/2001 and 2009/2010, are believed to be a close approximation of pre-disturbance baseline conditions for the Brucejack watershed. This assertion is based on assessment of adit loadings during this period combined with no documented site presence/disturbance, and observed minima in incidence of guideline exceedances (Section 13.3.2, Historical Activities.

Based on the non-traditional land use baseline (Appendix 24-A) and Skii km Lax Ha Traditional Knowledge/Traditional Use (TK/TU) Report (Appendix 25-B) and the country foods baseline assessment (Appendix 21-A), it is possible that individuals may occasionally obtain drinking water from a variety of surface water sources while engaging in activities within those areas (e.g., hunting, trapping, camping, hiking, etc.). However, the likelihood of people drinking surface water from different areas of the drinking water baseline LSA varies depending on the type of land use and accessibility of the area. The following sections provide potential use of surface water within the drinking water LSA.

Neither the Brucejack Mine Site nor the Brucejack Transmission Line is within Tahltan traditional territory (Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects, Section 24.3, Baseline Characterization). Surface water may be used as drinking water during hunting, trapping, fishing, or gathering activities by First Nations.

Drinking Water Use of Brucejack Lake

It is very unlikely that people would drink surface water from Brucejack watershed. This is due to the climate; inaccessibility; below freezing temperatures during the winter months; absence of country foods such as fish, moose, or grouse in this area; and general low use of the Brucejack watershed (including Brucejack Lake and Creek) by individuals from First Nations groups or the general public (Appendix 21-A, Country Foods Baseline Assessment). The Brucejack Mine Site does not intersect Nisg̲a'a traplines (Section 25.3.4, Aboriginal Land and Resource Use Setting) and is not within Tahltan traditional territory (Section 25.3.4). There is no indication of Skii km Lax Ha or other First Nations obtaining drinking water from the mine site area, which includes Brucejack Lake, Brucejack Creek, and Camp Creek. Pretium Resources Inc. (Pretivm) holds a water licence on Brucejack Lake for the exploration work camps. The Pretivm water licence on Brucejack Lake (C128950) is used to supply water for domestic use to workers residing in the camp. In addition, there is an existing groundwater well near the camp at the mine site area, but the well water is not currently used for drinking water purposes (Figure 21.3-4). Therefore, Brucejack Lake was included in the drinking water settings. Brucejack Lake has remained largely uninfluenced by site activities within the Project area, exhibiting generally consistent physicochemistry as well as concentrations of nutrients, anions, and total metals and dissolved metals, regardless of sampling period. All parameters are below the Health Canada guidelines for Canadian DWQGs (Health Canada 2012b) and BC DWQGs (BC MOE 2006a). Table 21.3-3 provides the summary statistics for baseline water quality parameters within Brucejack Lake.

Drinking Water Use in the Knipple Lake / Bowser River Watershed (Ancillary Project Infrastructure, Access Corridor) and Wildfire Creek/Scott/Todedada Watersheds (Access Corridor)

The Knipple Lake / Bowser River watershed and Wildfire Creek/Scott/Todedada watersheds contain a number of lakes, creeks, and rivers where members of First Nations and recreational users that engage in backcountry trips may potentially obtain their drinking water. Potential human receptors include Skii km Lax Ha, Nisg̲a'a Nation, Tahltan Nation, and local hunters and guide outfitting companies. It is possible that hikers, climbers, Nisg̲a'a Nation, or First Nations collect water from lower elevation water bodies including Wildfire Creek, Scott Creek, the Bell-Irving River, Todedada Creek, and Todedada Lake. Although the Brucejack Mine Site is not within the Nass Area of the *Nisg̲a'a Final Agreement* (NLG, Province of BC, and Government of Canada 2000), the Brucejack Transmission Line and Brucejack Access Road areas are within the Nass Area. The Brucejack Access Road and Brucejack Transmission Line do not intersect Nisg̲a'a traplines, most of which are located further south near

Nisga’a Lands (Section 25.3.4, Aboriginal Land and Resource Use Setting). However, there has been no indication of drinking water use by Nisga’a within the drinking water LSA. The eastern most segment of the Brucejack Access Road, approximately the first 9 km of the road branching of the west of Highway 37, is within Tahltan territory (Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects, Section 24.3, Baseline Characterization). Available information identifies the majority of fishing, hunting, trapping, and gathering activity as occurs in other more northern areas of the Tahltan territory, for example, near the confluence of Tahltan and Stikine rivers (Section 24.8, Summary of Residual Effects and Significance for Commercial Land Use). There are no indications of drinking water use of surface waters by Tahltan within the drinking water LSA. Skii km Lax Ha’s traditional territory encompasses the drinking water LSA and therefore, Skii km Lax Ha would be the most relevant group among other First Nations and Nisga’a Nation for assessing the human health effects due to consuming water within the drinking water LSA.

Currently, Skii km Lax Ha have a lodge, close to the existing Bowser camp facilities along the Brucejack Access Road, which is the only permanent residence within the drinking water LSA. Filtered and treated well water (licence # 108471) that meet the Canadian and BC DWQG is the source of drinking water for the residents of the Skii km Lax Ha Lodge. However, Skii km Lax Ha, other First Nations, hunters and trappers, or occasional recreational users within the area may occasionally use the streams and lakes within the Knipple Lake / Bowser River watershed, and Wildfire Creek/Scott/Todedada watersheds within the drinking water LSA for drinking water. Current Skii km Lax Ha sites closest to Project infrastructure include a cranberry picking area along the Bowser River West of Bowser Lake (near the Brucejack Access Road), a hunting and trapping area on the north side of Mount Anderson (used for harvesting moose, grizzly bear, mountain goat, and martens), and a travel corridor along the Salmon River close to the Brucejack Transmission Line (Chapter 25, Assessment of Potential Effects to Current Use of Lands and Resources for Traditional Purposes). Surface water within the Knipple Lake / Bowser River watershed, and Wildfire Creek/Scott/Todedada watersheds may be used as drinking water source during the hunting, trapping, and gathering of country foods or travelling within these areas.

Apart from Skii km Lax Ha Lodge which is within the drinking water LSA near Knipple Lake, two additional lodges (Mouth of Bell Creek Lodge and Mouth of Bowser Lake Lodge) are within the drinking water RSA (Figure 21.3-4).

In addition, there are two surface water licences within the LSA, including a water licence (C068045) belonging to Boliden Ltd. on the Cascade River for land improvement purposes in the southern portion of the proposed transmission line route (Figure 21.3-10; BC MOE 2013e). Westmin Resources Ltd has a water intake for a drinking water system (KS-KA-WAT-16-E-01) in the southern portion of the drinking water LSA along the Brucejack Transmission Line, on an unnamed stream flowing south-west from Mount Dilworth, approximately 2.5 km east of Long Lake (Figure 21.3-4).

In addition to surface water licences, Pretivm holds a well water licence for domestic use (108471) that is currently the source of drinking water for the Skii km Lax Ha Lodge. The water is filtered and treated to BC and Canadian DWQG standards before use for drinking water. Pretivm also owns a water well for the purpose of domestic water supply at the Wildfire Creek confluence with the Bell-Irving River (107483).

There are a few additional surface water licences within the drinking water regional study area (RSA). Barrick Gold Inc. has two water licences (C107796), one on Eskay Creek and one on Cranberry Creek for camps to the west of Unuk River. In addition, Eskay Creek Mine has a water intake for a drinking water system (KS-Kd-WAT-04 [20 015]-E01 and KS-KD-WAT-15-E02) to the northwest of Unuk River (Figure 21.3-4).

Table 21.3-3. Baseline Water Quality of Brucejack Lake, Brucejack Gold Mine Project

Project Area		Drinking Water Quality Guidelines		Brucejack Lake									
				Under Ice (n=8)					Open Water (n=22)				
Parameter[1]	Units	BC	Canadian	Min.	Max.	Median	Mean	95th P	Min.	Max.	Median	Mean	95th P
Antimony	mg/L	-	0.006	0.000050	0.000280	0.000250	0.000218	0.000276	0.000230	0.00030	0.000250	0.000252	0.000291
Arsenic (As)	mg/L	0.025	0.01	0.00020	0.00200	0.000610	0.000918	0.00193	0.00050	0.00240	0.00097	0.00114	0.00230
Barium (Ba)[2]	mg/L	-	1	0.0177	0.0339	0.0326	0.0301	0.0339	0.0325	0.0363	0.0347	0.0344	0.0359
Beryllium (Be)[2]	mg/L	0.004	-	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000250	0.000250	0.000170	0.000250
Boron (B)	mg/L	5	5	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Cadmium (Cd)[2]	mg/L	-	0.005	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.00010	0.0000050	0.0000321	0.00010
Chromium (Cr)	mg/L	-	0.05	0.000050	0.000110	0.000050	0.0000620	0.0000980	0.00010	0.000250	0.000120	0.000133	0.000205
Copper (Cu)	mg/L	0.5	1	0.000250	0.0010	0.000250	0.000406	0.000825	0.000140	0.00050	0.000250	0.000342	0.00050
Cyanide, Total	mg/L	0.2*	0.2*	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050
Cyanide, WAD	mg/L	0.2*	0.2*	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050
Fluoride (F)	mg/L	1	1.5	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100	0.0100
Lead (Pb)	mg/L	0.05	0.01	0.0000250	0.00050	0.000040	0.000207	0.00050	0.0000250	0.0010	0.000250	0.000329	0.000982
Mercury (Hg)	mg/L	0.001	0.05	0.0000050	0.000250	0.0000050	0.0000429	0.000183	0.0000050	0.00120	0.0000050	0.0000832	0.000210
Molybdenum (Mo)	mg/L	0.25	-	0.0000050	0.00050	0.000362	0.000323	0.00050	0.000337	0.0060	0.00050	0.00070	0.00050
Nitrate (as N)	mg/L	10	10	0.00250	0.0198	0.00650	0.00786	0.0174	0.00250	0.00250	0.00250	0.00250	0.00250
Nitrite (as N)	mg/L	1	1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Selenium (Se)	mg/L	0.01	0.01	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000130	0.00010	0.0000830	0.000117
Strontium (Sr)	mg/L	-	0.01	0.0226	0.0577	0.0535	0.0486	0.0573	0.0525	0.0575	0.0558	0.0555	0.0572
Thallium (Tl)	mg/L	0.002	-	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.000050	0.000050	0.0000320	0.000050
Uranium (U)	mg/L	-	0.02	0.0000050	0.0000250	0.0000230	0.0000198	0.0000248	0.0000250	0.0000370	0.0000315	0.0000307	0.0000352
Zinc (Zn)	mg/L	5	5	0.00150	0.0110	0.00150	0.00325	0.00890	0.000250	0.170	0.00250	0.0111	0.0241

Notes:

- Parameter not reported.

As hydrological regime is an important determinant of surface water quality in the Project Area, concentrations (predicted and baseline) were assessed for both high flow (June to October) and low flow (November to May) periods.

Orange values exceed health-based drinking water quality guidelines (both Canadian and BC guidelines applied).

[1] *All metals among the parameter list are total metal concentrations except from aluminum concentrations that are in dissolved form.*

[2] *Working guideline.*

** Cyanide guidelines are based on SAD-Ccyaide and thiocyanate (CN).*

Therefore, the drinking water quality within the Knipple Lake / Bowser River watershed and Wildfire Creek/Scott/Todedada watersheds was assessed. Data from current Brucejack Gold Mine Project and KSM Project water quality sampling sites were included in the determination of baseline drinking water quality of surface water for this area (Figure 21.3-3).

Drinking Water Assessment Methodology

Summary statistics for surface water quality in the three assessment sub-areas were generated and compared with the Canadian DWQGs (Health Canada 2012b) and BC DWQGs (BC MOE 2006a), which were summarized in Tables 21.3-3, 21.3-4, and 21.3-5. BC DWQGs were given precedence even if Canadian DWQG were also available for a parameter. Since aesthetic and operational objectives are not based on potential human health effects (Health Canada 2012b), only health-based drinking water quality guidelines were included in the drinking water assessment. In cases where BC DWQGs were absent for a parameter, the Canadian DWQGs were used if available.

Summary statistics tables were generated to present minimum, mean, median, 95th percentile, and maximum water quality data parameters against the Canadian or BC DWQGs.

21.3.3.4 Country Foods

The main objective of the country foods baseline assessment was to determine what, if any, risk there is to human consumers of country foods collected from within the country foods baseline study area. The country foods baseline methodology and approach followed the AIR (BC EAO 2014), EIS Guidelines (CEA Agency 2013b), and Health Canada guidance (Health Canada 2010f, 2010d, 2010c). The country foods baseline assessment identified which country foods harvesters were potentially the highest users of the area (and therefore would experience the highest potential risk from country foods consumption) and which country foods were consumed (Appendix 21-A, Country Foods Baseline Assessment). The concentrations of COPCs in selected country foods were measured or modelled and a human health risk assessment was completed to determine the potential for human health effects from consumption of selected country food items under baseline conditions.

Data Sources

The human health effects due to quality of country foods harvested from the proposed KSM Project, adjacent to the Project, were assessed under baseline conditions (Rescan 2010). In addition, the predicted human health effects due to quality of these country foods were assessed as a part of the human health chapter for the proposed KSM Project Application/EIS. However, the quality of country foods harvested from the proposed KSM Project LSA was not considered relevant to the Project and was not used in this Application/EIS. This is because the quality of country foods is related to the quality of the local environmental media, which can vary substantially from place to place and over time.

Methods

The following sections describe the rationale for the selection of the baseline study areas and methodology used under baseline conditions.

Baseline Study Area

A country foods baseline LSA was chosen based on the outer limits of the proposed infrastructure, development, physical barriers, and watershed boundaries (Section 5 of Appendix 21-A, Country Foods Baseline Assessment). The country foods baseline LSA was also adopted as the country foods effects assessment LSA.

The country foods baseline RSA is 374,400 ha in size, and is the same RSA utilized in the wildlife baseline report (Figure 21.3-5; Appendix 18-A, Brucejack Gold Mine Project Wildlife Characterization Baseline Report). Boundaries of the RSA took into account the area that provides habitat for wildlife species that may come into contact with proposed Project infrastructure during a season or a lifetime. Other ecological factors, such as height of land, were also considered when delineating boundaries. It was thought to be unlikely that potential Project activities would result in an increase of contaminants in soil, water, or vegetation beyond the country foods LSA. Therefore, the effects of the Project on the human health due to the quality of country foods in the country foods RSA, beyond country foods LSA, were not assessed.

The country foods baseline LSA was further broken down into three separate areas because of the variety of landforms and vegetation types present, the different types of effects that may result from the various infrastructure components, and the relatively large geographical separation among some of the infrastructure components. These three areas included the Brucejack Mine Site, the Brucejack Access Road, and the Brucejack Transmission Line areas. The access road area has a climate which transitions from coastal at the western edge to continental at the eastern edge. The mine site area is situated above the tree line in alpine and parkland ecosystems. The transmission line area extends from around the Premier mine site to the Project Mine Site.

The country foods baseline LSA is within Skii km Lax Ha traditional territory (Figures 21.3-6); their traditional knowledge and site use is shown in Figure 21.3-6.

Nisga'a Lands and the Nass Wildlife Area are to the southeast of the Project while the Brucejack Access Road, Brucejack Transmission Line, Knipple Transfer Area, and Bowser Aerodrome are all within the Nass Area as defined by the *Nisga'a Final Agreement* (NLG, Province of BC, and Government of Canada 2000; Figure 21.3-7). The Project is also in close proximity to the southern part of the Tahltan territory; approximately 9 km of the Brucejack Access Road falls within the Tahltan traditional territory (Figure 21.3-8).

Sampling/Monitoring/Assessment

The approach for the country foods baseline study (Appendix 21-A, Country Foods Baseline Assessment) was based on Health Canada's guidelines for assessing food issues in environmental impact assessments (Health Canada 2010c, 2010f). As such, this study was divided into the following five stages:

1. Problem Formulation: The conceptual model for conducting the country foods study was developed in the problem formulation stage. This stage identified the COPCs and human receptor characteristics.
2. Exposure Assessment: The measured or predicted metal concentrations in country foods were integrated with human consumption characteristics to calculate the estimated daily intake (EDI) of COPCs.
3. Toxicity Assessment: The Toxicity Reference Values (TRVs; levels of daily exposure that can be taken into the body without appreciable health risk) were identified.
4. Risk Characterization: The exposure and effects assessments were integrated by comparing the EDIs with TRVs to produce quantitative risk estimates (exposure ratios, ERs). In addition, the Recommended Maximum Weekly Intake (RMWI) of each country food was calculated.
5. Uncertainty Analysis and Data Gaps: The assumptions made throughout the study and their effects on the conclusions were evaluated.

Table 21.3-4. Baseline Water Quality of Knipple Lake/Bowser River Watershed Sampling Sites, Brucejack Gold Mine Project

Project Area		Drinking Water Quality Guidelines		Knipple Lake/ Bowser River Watershed (Ancillary Project Infrastructure, Access Corridor)																
Site				Knipple Lake Inflow/Outflow (2 sites)										Knipple Lake (KL)		Knipple Glacier Outflow (KG OF)				
				Low Flow (n=2)					High Flow (n=4)					Open Water		High Flow (n=2)				
Parameter	Units	BC	Canadian	Min.	Max.	Median	Mean	95th P	Min.	Max.	Median	Mean	95th P	Shallow (1 m)	Deep (30 m)	Min.	Max.	Median	Mean	95th P
Antimony (Sb)	mg/L	-	0.006	0.000510	0.000580	-	0.000545	-	0.00117	0.00181	0.00149	0.00149	0.00176	0.00137	0.00131	0.000290	0.00116	-	0.000725	-
Arsenic (As)	mg/L	0.025	0.01	0.000650	0.000810	-	0.000730	-	0.00847	0.0126	0.0109	0.0107	0.0124	0.00968	0.00948	0.000660	0.0127	-	0.00668	-
Barium (Ba)[1]	mg/L	-	1	0.0341	0.0351	-	0.0346	-	0.179	0.200	0.190	0.190	0.199	0.215	0.204	0.0903	0.518	-	0.304	-
Beryllium (Be)[1]	mg/L	0.004	-	0.000050	0.000050	-	0.000050	-	0.000190	0.000230	0.000210	0.000210	0.000227	0.00020	0.00020	0.000050	0.000530	-	0.000290	-
Boron (B)	mg/L	5	5	0.0050	0.0050	-	0.0050	-	0.0050	0.0110	0.0050	0.00650	0.0101	0.0050	0.0050	0.0050	0.0130	-	0.0090	-
Cadmium (Cd)[1]	mg/L	-	0.005	0.0000150	0.0000160	-	0.0000155	-	0.000224	0.000368	0.000295	0.000296	0.000358	0.000243	0.000244	0.0000160	0.000314	-	0.000165	-
Chromium (Cr)	mg/L	-	0.05	0.000270	0.000380	-	0.000325	-	0.0104	0.0161	0.0138	0.0135	0.0158	0.0124	0.0118	0.000770	0.0120	-	0.00639	-
Copper (Cu)	mg/L	0.5	1	0.000650	0.000790	-	0.000720	-	0.0206	0.0285	0.0256	0.0251	0.0285	0.0221	0.0218	0.000560	0.0229	-	0.0117	-
Cyanide, Total[2]	mg/L	0.2*	0.2*	0.00050	0.00050	-	0.00050	-	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	-	0.00050	-
Cyanide, WAD	mg/L	0.2*	0.2*	0.00050	0.00050	-	0.00050	-	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	-	0.00050	-
Fluoride (F)	mg/L	1	1.5	0.023	0.037	-	0.030	-	0.010	0.021	0.010	0.013	0.019	0.0100	0.0100	0.0360	0.0520	-	0.0440	-
Lead (Pb)	mg/L	0.05	0.01	0.000121	0.000149	-	0.000135	-	0.00697	0.00955	0.00841	0.00833	0.00941	0.00798	0.00785	0.000311	0.0128	-	0.00656	-
Mercury (Hg)	mg/L	0.001	0.05	0.0000050	0.0000050	-	0.0000050	-	0.0000250	0.0000470	0.0000285	0.0000323	0.0000443	0.0000290	0.0000260	0.0000050	0.0000250	-	0.0000150	-
Molybdenum (Mo)	mg/L	0.25	-	0.00153	0.00159	-	0.00156	-	0.000810	0.00140	0.00114	0.00112	0.00139	0.00101	0.000968	0.00197	0.00201	-	0.00199	-
Nitrate (as N)	mg/L	10	10	0.036	0.056	-	0.046	-	0.0025	0.0251	0.0158	0.0148	0.0250	0.00660	0.00610	0.0148	0.0187	-	0.0168	-
Nitrite (as N)	mg/L	1	1	0.001	0.001	-	0.001	-	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	-	0.000500	-
Selenium (Se)	mg/L	0.01	0.01	0.00050	0.000550	-	0.000525	-	0.000440	0.000690	0.000580	0.000573	0.000683	0.000450	0.000450	0.000410	0.000740	-	0.000575	-
Strontium (Sr)	mg/L	-	0.01	0.149	0.161	-	0.155	-	0.0630	0.0982	0.0805	0.0806	0.0981	0.0686	0.0706	0.189	0.253	-	0.221	-
Thallium (Tl)	mg/L	0.002	-	0.0000050	0.0000050	-	0.0000050	-	0.000070	0.00009900	0.0000820	0.0000833	0.0000980	0.0000980	0.0000920	0.0000190	0.000211	-	0.000115	-
Uranium (U)	mg/L	-	0.02	0.000115	0.000120	-	0.000118	-	0.000171	0.000268	0.000222	0.000221	0.000265	0.000216	0.000213	0.000198	0.000492	-	0.000345	-
Zinc (Zn)	mg/L	5	5	0.00150	0.00150	-	0.00150	-	0.0443	0.0548	0.0526	0.0511	0.0547	0.0504	0.0495	0.00150	0.0772	-	0.0394	-

(continued)

Table 21.3-4. Baseline Water Quality of Knipple Lake/Bowser River Watershed Sampling Sites, Brucejack Gold Mine Project (completed)

Project Area		Knipple Lake/ Bowser River Watershed (Ancillary Project Infrastructure, Access Corridor; *cont'd*)											
Site		Bowser River (3 sites)										Bowser Lake (BL1)	
		Low Flow (n=13)					High Flow (n=18)					Open Water	
Parameter	**Units**	**Min.**	**Max.**	**Median**	**Mean**	**95th P**	**Min.**	**Max.**	**Median**	**Mean**	**95th P**	**Shallow (1 m)**	**Deep (30 m)**
Antimony (Sb)	mg/L	0.000160	0.000670	0.000390	0.000395	0.000640	0.000130	0.00140	0.000550	0.000671	0.00137	0.000410	0.000410
Arsenic (As)	mg/L	0.000280	0.00216	0.000510	0.000826	0.00209	0.000320	0.0101	0.00282	0.00360	0.00846	0.00126	0.00125
Barium (Ba)[1]	mg/L	0.0365	0.101	0.0475	0.0560	0.0954	0.0309	0.248	0.106	0.114	0.211	0.0683	0.0667
Beryllium (Be)[1]	mg/L	0.000050	0.000250	0.000250	0.000235	0.000250	0.000190	0.000280	0.000250	0.000248	0.000255	0.000250	0.000250
Boron (B)	mg/L	0.0050	0.0120	0.00500	0.00777	0.0120	0.0050	0.0130	0.0050	0.00678	0.0122	0.0110	0.0110
Cadmium (Cd)[1]	mg/L	0.000010	0.000351	0.0000230	0.0000596	0.000200	0.0000280	0.000302	0.000161	0.000148	0.000268	0.0000570	0.0000510
Chromium (Cr)	mg/L	0.000160	0.00434	0.000400	0.00112	0.00420	0.000370	0.0158	0.00318	0.00570	0.0141	0.00234	0.00236
Copper (Cu)	mg/L	0.000250	0.00573	0.000920	0.00178	0.00563	0.00080	0.0212	0.00421	0.00819	0.0201	0.00316	0.00306
Cyanide, Total[2]	mg/L	0.00050	0.00250	0.00050	0.00070	0.00155	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050
Cyanide, WAD	mg/L	0.00050	0.00210	0.00050	0.000685	0.00162	0.00050	0.00290	0.00110	0.00118	0.00290	0.00050	0.00050
Fluoride (F)	mg/L	0.0290	0.0490	0.0350	0.0371	0.0484	0.0100	0.0270	0.0100	0.0160	0.0262	0.0100	0.0100
Lead (Pb)	mg/L	0.0000250	0.00180	0.000306	0.000487	0.00162	0.0000760	0.00811	0.00207	0.00292	0.00680	0.00098	0.00112
Mercury (Hg)	mg/L	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000370	0.0000115	0.0000132	0.0000277	0.0000050	0.0000050
Molybdenum (Mo)	mg/L	0.000408	0.00167	0.00134	0.00123	0.00156	0.000445	0.00147	0.000806	0.000911	0.00145	0.000746	0.000793
Nitrate (as N)	mg/L	0.0388	0.666	0.0845	0.145	0.408	0.0067	0.379	0.0480	0.0894	0.376	0.0415	0.0454
Nitrite (as N)	mg/L	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500
Selenium (Se)	mg/L	0.00010	0.000670	0.000550	0.000525	0.000652	0.00010	0.000660	0.000380	0.000378	0.000635	0.000360	0.000280
Strontium (Sr)	mg/L	0.155	0.320	0.206	0.211	0.301	0.0572	0.200	0.132	0.131	0.199	0.0935	0.0944
Thallium (Tl)	mg/L	0.0000050	0.000050	0.000050	0.0000465	0.000050	0.000050	0.000128	0.000050	0.0000555	0.0000795	0.000050	0.000050
Uranium (U)	mg/L	0.0000460	0.000161	0.000121	0.000111	0.000145	0.0000260	0.000324	0.000136	0.000137	0.000225	0.0000810	0.0000930
Zinc (Zn)	mg/L	0.00150	0.0119	0.00480	0.00502	0.0116	0.00150	0.0514	0.0174	0.0200	0.0432	0.00800	0.00830

Notes:

As hydrological regime is an important determinant of surface water quality in the Project Area, concentrations (predicted and baseline) were assessed for both high flow (June to October) and low flow (November to May) periods.

- Parameter not reported.

Orange values exceed health-based drinking water quality guidelines (both Canadian and provincial guidelines applied).

[1] Working guideline.

[2] Samples where n≤3, median and 95th percentile summary statistics were not calculated.

** Cyanide guidelines are based on SAD-Ccyaide and thiocyanate (CN).*

Table 21.3-5. Baseline Water Quality of Wildfire Creek/Scott/Todedada Watersheds Sampling Sites, Brucejack Gold Mine Project

Project Area		Drinking Water Quality Guidelines		Wildfire Creek/Scott/Todedada Watersheds (Access Corridor)														
				Scott Creek (2 sites)										Todedada Creek (3 sites)				
Site				Low Flow (n=11)					High Flow (n=9)					Low Flow (n=10)				
Parameter	**Units**	**BC**	**Canadian**	**Min.**	**Max.**	**Median**	**Mean**	**95th P**	**Min.**	**Max.**	**Median**	**Mean**	**95th P**	**Min.**	**Max.**	**Median**	**Mean**	**95th P**
Antimony (Sb)	mg/L	-	0.006	0.000050	0.000180	0.000050	0.000104	0.000180	0.000050	0.00115	0.000140	0.000308	0.000930	0.000120	0.00146	0.000270	0.000498	0.00144
Arsenic (As)	mg/L	0.025	0.01	0.000130	0.000500	0.000310	0.000318	0.000465	0.000120	0.00728	0.000320	0.00172	0.00577	0.000230	0.00627	0.00112	0.00213	0.00620
Barium (Ba)[1]	mg/L	-	1	0.0196	0.0446	0.0285	0.0313	0.0435	0.0149	0.160	0.0291	0.0587	0.141	0.0350	0.141	0.0497	0.0661	0.137
Beryllium (Be)[1]	mg/L	0.004	-	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250	0.000250
Boron (B)	mg/L	5	5	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050
Cadmium (Cd)[1]	mg/L	-	0.005	0.0000050	0.000112	0.0000170	0.0000249	0.0000685	0.0000050	0.000665	0.0000360	0.000112	0.000456	0.000070	0.00109	0.0000975	0.000319	0.00107
Chromium (Cr)	mg/L	-	0.05	0.000120	0.000500	0.000240	0.000272	0.000495	0.000170	0.00670	0.000590	0.00160	0.00520	0.000050	0.00558	0.000260	0.00151	0.00537
Copper (Cu)	mg/L	0.5	1	0.000250	0.00209	0.000520	0.000629	0.00158	0.000250	0.0109	0.00123	0.00241	0.00814	0.000250	0.00854	0.000380	0.00233	0.00840
Cyanide, Total[2]	mg/L	0.2*	0.2*	0.00050	0.00250	0.000500	0.00115	0.00250	0.00050	0.00100	0.00050	0.000563	0.000825	0.00050	0.00250	0.00050	0.000914	0.00217
Cyanide, WAD	mg/L	0.2*	0.2*	0.00050	0.00220	0.00130	0.00126	0.00190	0.00050	0.00380	0.00110	0.00148	0.00344	0.00050	0.00250	0.00115	0.00119	0.00223
Lead (Pb)	mg/L	1	1.5	0.0000250	0.000188	0.0000730	0.0000903	0.000187	0.0000250	0.00465	0.0000860	0.00101	0.00375	0.0000250	0.00292	0.0000725	0.000734	0.00287
Mercury (Hg)	mg/L	0.05	0.01	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000440	0.0000050	0.0000101	0.0000312	0.0000050	0.0000360	0.0000050	0.00000960	0.0000288
Molybdenum (Mo)	mg/L	0.001	0.05	0.000185	0.000805	0.000328	0.000480	0.000788	0.000309	0.00124	0.000765	0.000733	0.00111	0.000834	0.00196	0.00119	0.00130	0.00196
Nitrate (as N)	mg/L	0.25	-	0.00550	0.327	0.0586	0.135	0.288	0.00250	0.392	0.0355	0.0708	0.258	0.0089	0.245	0.0555	0.0670	0.176
Nitrite (as N)	mg/L	10	10	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.00100	0.000500	0.000556	0.000800	0.000500	0.000500	0.000500	0.000500	0.000500
Nickel (Ni)	mg/L	1	1	0.000250	0.00189	0.00172	0.00115	0.00189	0.000250	0.00833	0.00154	0.00211	0.00619	0.000250	0.0105	0.000855	0.00308	0.0104
Selenium (Se)	mg/L	0.01	0.01	0.000270	0.00100	0.000480	0.000574	0.000920	0.00010	0.000730	0.000400	0.000403	0.000678	0.000660	0.00208	0.00115	0.00123	0.00204
Strontium (Sr)	mg/L	-	0.01	0.108	0.334	0.204	0.221	0.329	0.0984	0.198	0.144	0.155	0.196	0.190	0.359	0.292	0.286	0.357
Thallium (Tl)	mg/L	0.002	-	0.000050	0.000050	0.000050	0.000050	0.000050	0.000050	0.000200	0.000050	0.0000667	0.000140	0.000050	0.000240	0.000050	0.0000930	0.000236
Uranium (U)	mg/L	-	0.02	0.0000050	0.0000570	0.0000050	0.0000257	0.0000560	0.0000050	0.000180	0.0000250	0.0000556	0.000154	0.0000440	0.000203	0.0000970	0.000104	0.000202
Zinc (Zn)	mg/L	5	5	0.00150	0.00350	0.00150	0.00168	0.00250	0.00050	0.0542	0.00320	0.0105	0.0390	0.00150	0.0868	0.00405	0.0231	0.0845

(continued)

Table 21.3-5. Baseline Water Quality of Wildfire Creek/Scott/Todedada Watersheds Sampling Sites, Brucejack Gold Mine Project (completed)

Project Area		Wildfire Creek/Scott/Todedada Watersheds (Access Corridor; *cont'd*)														
		Todedada Creek (3 sites; *cont'd*)					Wildfire Area Creeks (2 sites)									
Site		High Flow (n=10)					Low Flow (n=13)					High Flow (n=28)				
Parameter	Units	Min.	Max.	Median	Mean	95th P	Min.	Max.	Median	Mean	95th P	Min.	Max.	Median	Mean	95th P
Antimony (Sb)	mg/L	0.000150	0.00153	0.000475	0.000641	0.00152	0.000050	0.000050	0.000050	0.000050	0.0000500	0.000050	0.000360	0.000050	0.0000639	0.000102
Arsenic (As)	mg/L	0.000380	0.00753	0.00250	0.00302	0.00745	0.000050	0.000200	0.000100	0.0000915	0.000158	0.000050	0.000630	0.000205	0.000219	0.000476
Barium (Ba)[1]	mg/L	0.0257	0.126	0.0636	0.0702	0.119	0.0090	0.0205	0.0122	0.0126	0.0180	0.00970	0.0241	0.0150	0.0158	0.0222
Beryllium (Be)[1]	mg/L	0.000250	0.000250	0.000250	0.000250	0.000250	0.000050	0.000250	0.000050	0.0000808	0.000250	0.000050	0.000250	0.000050	0.0000643	0.000180
Boron (B)	mg/L	0.0050	0.0110	0.0050	0.00543	0.00710	0.0050	0.0050	0.0050	0.0050	0.0050	0.0050	0.0110	0.0050	0.00521	0.0050
Cadmium (Cd)[1]	mg/L	0.0000720	0.00123	0.000166	0.000373	0.00120	0.0000050	0.0000170	0.0000050	0.00000612	0.0000113	0.0000050	0.0000270	0.0000050	0.00000882	0.0000212
Chromium (Cr)	mg/L	0.000240	0.00533	0.000910	0.00185	0.00506	0.00020	0.00146	0.000410	0.000520	0.00109	0.00030	0.00415	0.00140	0.00162	0.00323
Copper (Cu)	mg/L	0.000250	0.00944	0.00215	0.00337	0.00943	0.000860	0.00295	0.00114	0.00128	0.00215	0.0010	0.00358	0.00151	0.00173	0.00296
Cyanide, Total[2]	mg/L	0.00050	0.00050	0.00050	0.00050	0.00050	0.00050	0.000550	0.00050	0.000504	0.000520	0.00050	0.00170	0.00050	0.000571	0.00102
Cyanide, WAD	mg/L	0.00050	0.00370	0.00050	0.00100	0.002465	0.00050	0.00760	0.00050	0.00187	0.00664	0.00050	0.0050	0.00050	0.00123	0.00353
Lead (Pb)	mg/L	0.000112	0.00382	0.00128	0.00148	0.00379	0.0000250	0.000159	0.0000250	0.0000415	0.000112	0.0000250	0.000553	0.000143	0.000170	0.000415
Mercury (Hg)	mg/L	0.0000050	0.0000610	0.00000850	0.0000200	0.0000545	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050
Molybdenum (Mo)	mg/L	0.000599	0.00224	0.00130	0.00135	0.00215	0.0000250	0.000307	0.0000950	0.000113	0.000287	0.0000530	0.000410	0.000138	0.000193	0.000393
Nitrate (as N)	mg/L	0.0025	0.138	0.0025	0.0164	0.0689	0.089	0.501	0.272	0.260	0.469	0.0025	0.300	0.0355	0.0557	0.151
Nitrite (as N)	mg/L	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500	0.000500
Nickel (Ni)	mg/L	0.000580	0.00968	0.00114	0.00304	0.00938	0.000650	0.00225	0.000990	0.00110	0.00177	0.000850	0.00563	0.00187	0.00220	0.00432
Selenium (Se)	mg/L	0.00010	0.00145	0.000740	0.000789	0.00137	0.000050	0.000400	0.000160	0.000171	0.000394	0.000050	0.000430	0.000170	0.000195	0.000340
Strontium (Sr)	mg/L	0.0913	0.249	0.133	0.154	0.234	0.0282	0.129	0.0493	0.0596	0.114	0.0278	0.0962	0.0402	0.0506	0.0896
Thallium (Tl)	mg/L	0.000050	0.000270	0.000050	0.000111	0.000270	0.0000050	0.0000500	0.0000050	0.0000119	0.000050	0.0000050	0.0000500	0.0000050	0.0000105	0.0000472
Uranium (U)	mg/L	0.0000270	0.000241	0.000108	0.000126	0.000240	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000050	0.0000180	0.0000050	0.00000846	0.0000167
Zinc (Zn)	mg/L	0.00320	0.0838	0.0119	0.0255	0.0832	0.00150	0.00370	0.00150	0.00207	0.00358	0.00150	0.0102	0.00395	0.00408	0.00816

Notes:

As hydrological regime is an important determinant of surface water quality in the Project Area, concentrations (predicted and baseline) were assessed for both high flow (June to October) and low flow (November to May) periods.

- Parameter not reported.

Orange values exceed health-based drinking water quality guidelines (both Canadian and provincial guidelines applied).

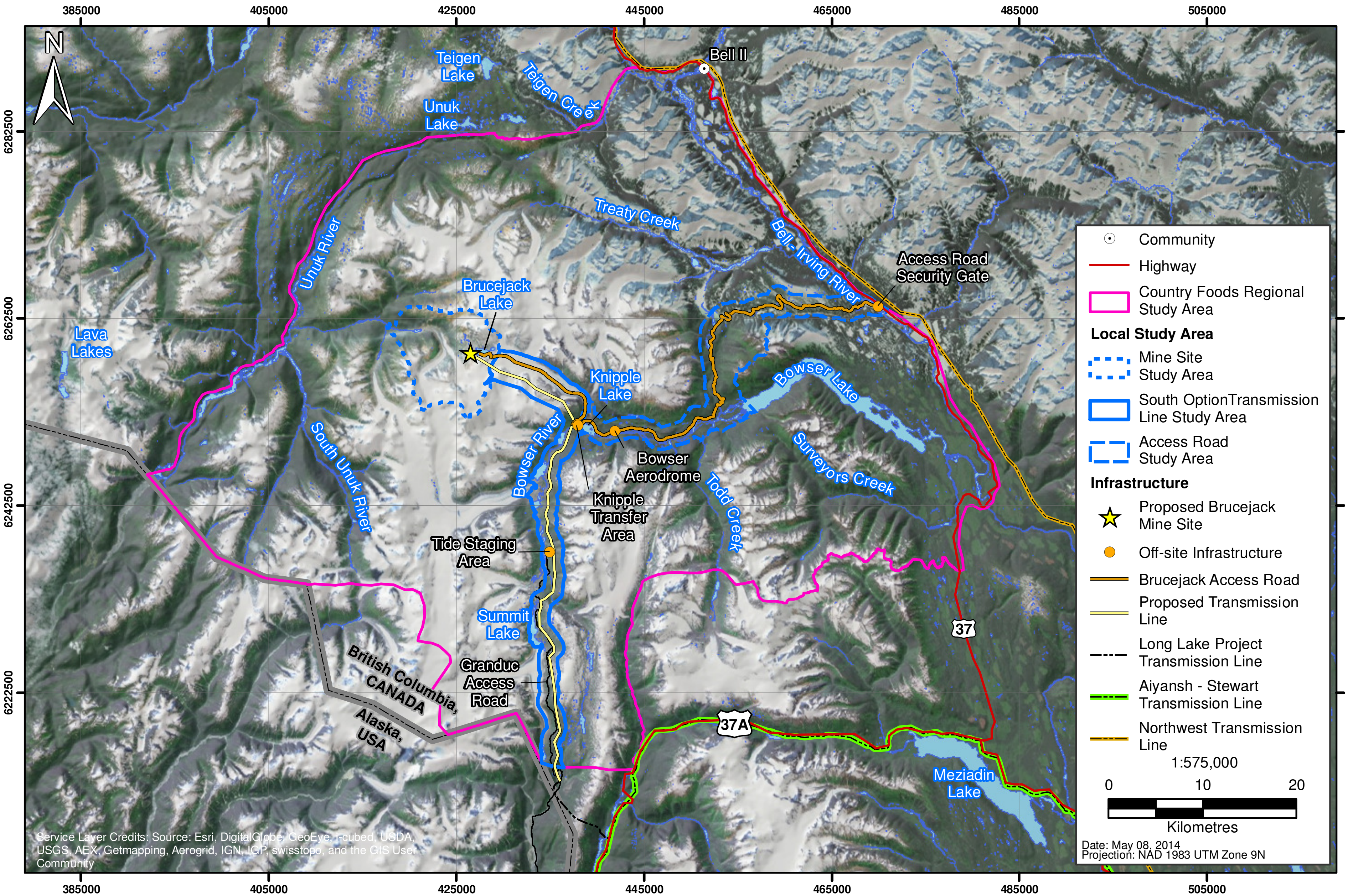
[1] Working guideline.

[2] Samples where n≤3, median and 95th percentile summary statistics were not calculated.

** Cyanide guidelines are based on SAD-Ccyaide and thiocyanate (CN).*

Figure 21.3-5

Country Foods Baseline Local and Regional Study Areas



Environmental quality data (metal chemistry data) were compiled from the baseline monitoring programs for water, sediment, soil, and vegetation (Appendix 21-A, Country Foods Baseline Assessment). Specific metals were selected as COPCs if they met at least one of the following four screening criteria:

1. The maximum metal concentration in soil samples exceeded its CCME soil quality guideline for agricultural land (CCME 2012c).
2. The maximum total metal concentration in surface water samples exceeded its BC (maximum water criteria) or CCME water quality guideline for the protection of aquatic life, whichever guideline was lower (BC MOE 2006a; CCME 2012d).
3. The maximum metal concentration in sediment samples exceeded its CCME sediment quality guideline for the protection of aquatic life (CCME 2012b) or CCME and BC interim sediment quality guidelines (ISQGs). If ISQGs were not available, screening level concentrations (SLC) were used (BC MOE 2006b).
4. The metal has a potential to bioaccumulate in organisms or biomagnify in food webs, such that there could be significant transfer of the metal from soil to plants and subsequently into higher trophic levels. Information on the bioaccumulation/biomagnification potential of each metal was obtained from a review of relevant documents from the Joint FAO/WHO Expert Committee on Food Additives (JECFA) and the US EPA (JECFA 1972, 1982; US EPA 1997; JECFA 2000; US EPA 2000; JECFA 2005, 2007, 2011).

Surface metal concentrations from streams and lakes during Project baseline studies between 2010 and 2012 were included in the assessment (Appendix 13-A of Chapter 13, Assessment of Potential Surface Water Quality Effects), in the project formulation (screening of COPCs), and in the exposure assessment (modelling of tissue metals in country foods). The water sampling locations and data included in the country foods assessment included Wildfire Creek and Bell Irving River watershed sampling locations (WC1 and WC5); Scott, Todedada, and Todd Creeks sampling locations (STI1, ST2, TL1, and TC2); and Bowser watershed sampling locations (BR1 and BR2).

Fish, vegetation, and berry metal concentrations were measured within the country foods LSA during baseline studies (Appendix 15-A, Brucejack Project: 2012 Fish and Fish Habitat Baseline Report; Appendix 11-A, Brucejack Terrain Geohazards). No terrestrial wildlife was sacrificed to obtain tissue samples. Instead, tissue metal residues for moose, snowshoe hare, and grouse were predicted using measured surface water, soil, and vegetation metal concentrations from the country foods LSA in a food chain model (Golder and Associates 2005). For further information on the terrestrial food chain model, refer to Appendix C in Appendix 21-A.

Since Skii km Lax Ha's traditional territory encompasses all the country foods (Figures 21.3-6), country foods consumption data from Skii km Lax Ha would be the most relevant and informative data and were therefore used for assessing the potential risk posed by country foods harvested from the country foods LSA. Figure 21.3-7 provides Skii km Lax Ha traditional use and use of sites within the country foods LSA and RSA. The Tahltan traditional territory also overlaps with the country foods LSA, covering the eastern portion of the access road. Since country foods consumption information was also available for this group (Jin 2006), Tahltan Nation consumption data were also included in this assessment. For additional information on the human receptors used in the baseline assessment, refer to Section 7.4 of Appendix 21-A, Country Foods Baseline Assessment.

Figure 21.3-6

Skii km Lax Ha Traditional Territory and Traditional Knowledge and Use Sites in relation to the Country Foods Local and Regional Study Areas

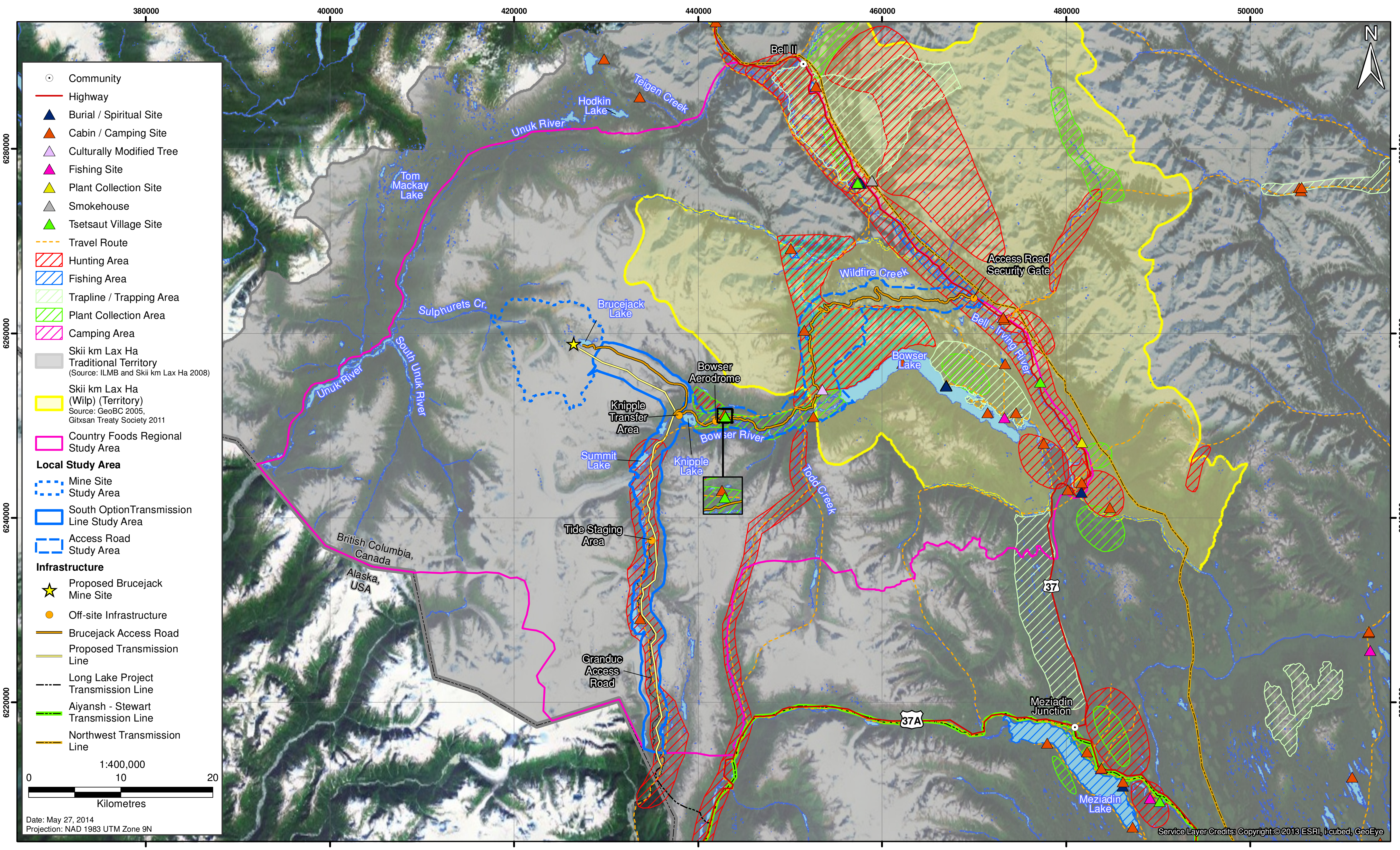


Figure 21.3-7
Areas Defined under the *Nisga'a Final Agreement* in relation to the Country Foods Local and Regional Study Areas

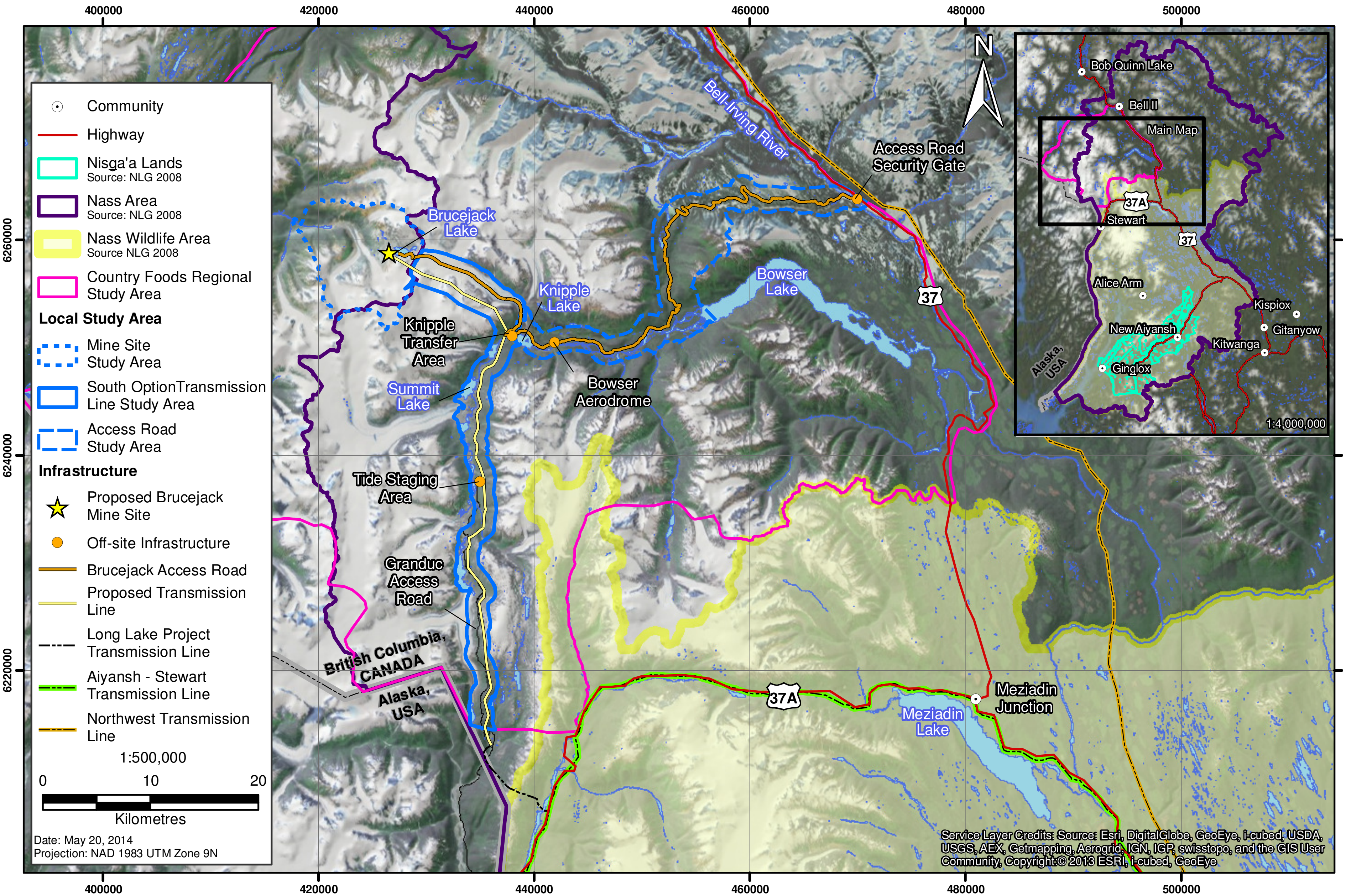
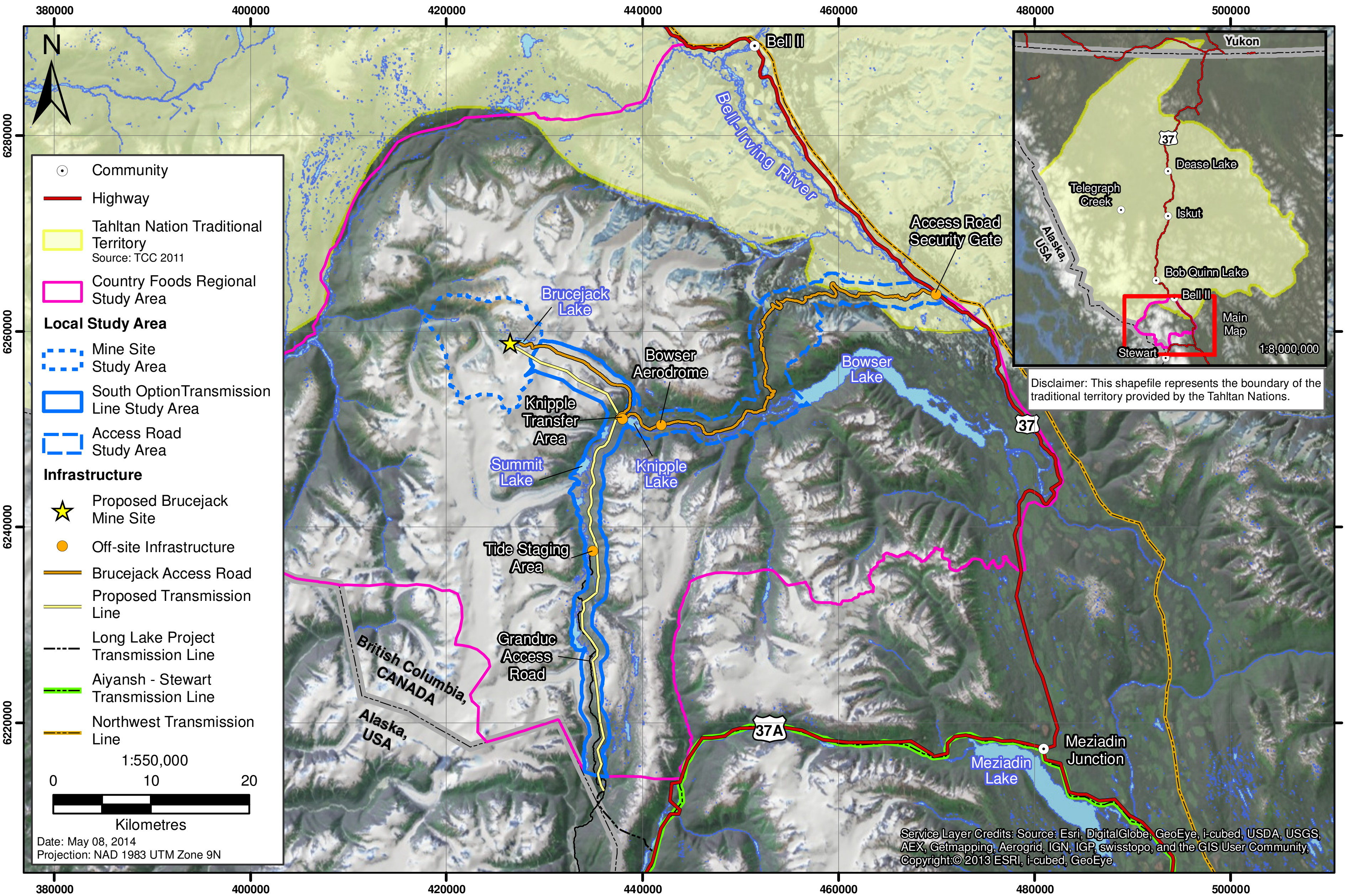


Figure 21.3-8
Tahltan Nation Traditional Territory in relation to the Country Foods Local and Regional Study Areas

ERM



21.3.4 Characterization of Human Health Baseline Conditions

21.3.4.1 Noise

Results from the noise monitoring program captured both the noise levels and the sources of the noise. Natural background noise sources included birds, mammals, waves, and wind, while anthropogenic sources included helicopters, airplanes, vehicles, and machinery. The summer monitoring periods had higher noise levels than the winter monitoring period. This is due to the combination of ground cover conditions as well as increased wind and rain. Only one station, S6, located near the existing Brucejack Exploration Camp, observed anthropogenic sounds other than aircraft.

Depending on the noise monitoring station location and season, the mean L_{eq} noise levels ranged from 32.5 to 64.7 dBA while minimum and maximum noise levels during the 24-hour sampling period were 15.7 to 37.3 dBA and 67.6 to 121.9 dBA, respectively. Anthropogenic noise sources were generally louder than natural background noise levels. L_{90}, the ninetieth percentile level, provides a better indication of the natural noise levels since discrete events that occur from anthropogenic sources are typically not present during 90% of the measurement time period. The average L_{90} levels that were measured ranged from 16.1 to 43.8 dBA. The day time equivalent noise (L_d), defined as from 7 a.m. to 10 p.m., ranged from 26 dBA to 50.3 dBA while the nighttime equivalent noise (L_n), defined as from 10 p.m. to 7 a.m., ranged from 16.4 dBA to 47.4 dBA.

The L_{eq} values recorded in 2012 were similar to studies done in other remote and undeveloped areas in BC, where L_{eq} values have been observed to range from 40 to 48 dBA (Rescan RTEC 2008). The higher values measured at the Project are predominantly due to the high number of aircraft passing over the area and the occurrence of high winds. The L_{90} results are similar to measurements taken at other proposed mine sites (e.g., Kitsault and Schaft) and are below the estimated baseline level at rural areas (WHO 1999; Alberta EUB 2007).

21.3.4.2 Air Quality

From July to September 2012 at the six dustfall monitoring locations, the average dustfall deposition rates ranged from 0.2 to 0.7 mg/dm^2/day, with the exception of DF1 where the average dustfall deposition rate was 1.53 mg/dm^2/day. *The Pollution Control Objectives for the Mining, Smelting, and Related Industries of British Columbia*'s dustfall objective (BC MOE 1979) is between 1.7 to 2.9 mg/dm^2/day, depending on the sensitivity of the receiving environment. The highest dustfall rate of 2.67 mg/dm^2/day measured during baseline studies is within the range of BC's pollution control objective. Mean dustfall deposition rates observed during the 2012 studies were consistent with baseline dustfall deposition rates recorded for other mineral development projects in the region including the proposed KSM Project (from below detection limit to 3.75 mg/dm2/day; Rescan 2013c), the proposed Schaft Creek Mine Project (from below detection limit to 2.5 mg/dm2/day; Rescan RTEC 2008), and the proposed Kitsault Mine Project (0.46 mg/dm^2/day; AMEC 2011). Most of the metal deposition levels analyses were below detection limits. The reported metal deposition rates are the result of natural sources in the area.

The results from ambient air quality monitoring showed that NO_2 and SO_2 concentrations in the Wildfire Creek area (at PASS1) and SO_2 concentration in the Brucejack Lake area (at PASS2) were below detection limits during the entire sampling period. The NO_2 results from the Brucejack Lake area averaged approximately 4 µg/m^3. There is currently no 30-day average criterion for NO_2 in Canada or BC, but the 30-day average of 4 µg/m^3 is much lower than the Canadian annual maximum desirable standard of 60 µg/m^3.

The average O_3 concentration at PASS1 was 20 μg/m^3, while the O_3 concentration at PASS2 was 57 μg/m^3. Health Canada states that the monthly 1-hour O_3 averages between May and September should be in the range of 49 to 78 μg/m^3 (25 to 40 parts per billion) when the source is away from anthropogenic influence (Health Canada 1999b). Ambient O_3 concentrations measured at PASS1 and PASS2 are approximately within this range.

21.3.4.3 Drinking Water

The Canadian DWQGs (Health Canada 2012b) for total aluminum, copper, iron, manganese, and zinc are based on aesthetic considerations (taste, colour, odour, staining of laundry and plumbing fixtures, and interference with disinfection); therefore, exceedances of these guidelines are unlikely to result in any human toxicological health effects and are excluded from the following discussion.

Mercury was the only parameter where the measured water concentration was greater than drinking water guidelines in samples collected from Brucejack Lake. The maximum mercury concentration exceeded the BC maximum DWQGs, while minimum, mean, median, and 95th percentile concentrations were lower than the guidelines (BC MOE 2006a; Tables 21.2-3 and 21.3-3). Exceedance of the mercury DWQGin Brucejack Lake is associated with samples from August of 1988. A total of ten samples from August of 1988 exceeded the BC maximum DWQG; however, the exceedance was due to high mercury detection limits for nine out of ten samples. For those nine samples, where detection limits are greater than the guideline, no conclusions can be made about whether the concentration of mercury actually exceeds the DWQG.

All other water quality parameters at Brucejack Lake were lower than their BC or Canadian DWQGs (Table 21.3-3). The exploration camp drinking water is supplied from Brucejack Lake and water is treated to meet the necessary standards for the Health Canada and BC DWQGs. Since mercury concentrations are generally below guidelines (except for the maximum concentration, 95th percentile concentration is below the guidelines), no effects to human health from the consumption of drinking water from this source would be expected.

All measured water quality parameters at all stations within the Knipple Lake / Bowser River watershed and Wildfire Creek/Scott/Todedada watersheds were below the BC DWQGs (Tables 21.3-4 and 21.3-5). Most of other measured water quality parameters were below the Canadian DWQGs at all stations within these watersheds (Tables 21.3-4 and 21.3-5).Within this area, maximum water lead and arsenic concentration at Knipple Glacier outflow (high flow regime, n = 2), mean, median, 95th percentile, and maximum arsenic concentrations at Knipple Lake inflow/outflow (high flow regime, n = 4), and maximum arsenic concentration at Bowser River (high flow regime, n = 18) exceeded the Canadian DWQGs.

Since arsenic and lead concentrations occasionally exceeded the Canadian DWQGs in surface water from Knipple Glacier, Knipple Lake outflow, or Bowser River (even though the concentrations were below BC DWQGs), these metals were selected as COPCs for the baseline drinking water assessment. There are no water licences for these waterbodies and no known permanent drinking water users of these potential surface water sources. Drinking water consumption amounts and frequency of consumption by transient potential users (such as hunters, trappers, hikers, etc.) is not known, and it is possible that users may bring water with them from other sources outside of the LSA, particularly on day trips. Since the DWQGs are based on frequent and chronic consumption of drinking water, using the DWQGs for occasional consumption of surface water is very conservative. The marginal baseline exceedance of Health Canada DWQGs for lead and arsenic within the Knipple Lake / Bowser River watershed and Wildfire Creek/Scott/Todedada watersheds combined with low consumption frequency of surface water by potential users is unlikely to result in human health effects due to drinking water. In addition, Health Canada recommends that water collected from surface waterbodies always be treated before it is used for drinking water (Health Canada 2008).

21.3.4.4 Country Foods

Country foods include a wide range of animals, plants, and fungi species that are harvested for medicinal or nutritional purposes.

The selection of country foods for evaluation was based on findings presented in Appendix 25-B, Skii km Lax Ha Traditional Knowledge / Traditional Use Report, and the Skii km Lax Ha Country Foods Consumption Questionnaire (Appendix A of Appendix 21-A, Country Foods Baseline Assessment). Country foods identified for evaluation are presented in Table 21.3-6. For further details on the methodology used for selection of the country foods included in the assessment refer to Section 7.2 of Appendix 21-A, Country Foods Baseline Assessment.

Table 21.3-6. Country Foods Selected for Evaluation

Category	Country Food	Species Name
Large Mammal	Moose	*Alces alces*
Small Mammal	Snowshoe hare	*Lepus americanus*
Bird	Grouse	*Phasianidae* sp.
Fish	Dolly Varden/ Bull trout	*Salvelinus malma/S. confluentus*
Vegetation	Berries	Mixture of berries[1]

[1] Consisted of Alaska blueberry, thinleaf huckleberry, bog blueberry, and Canada Buffaloberry.

In addition to Nisga'a and other Aboriginal groups, the country foods LSA may also be used by local hunters and guide outfitting companies (Appendix 21-A, Country Foods Baseline Assessment); however, Nisga'a Nation and First Nations consumption of country foods is assumed to be higher than other resident and non-resident users (Health Canada 2010d).

The problem formulation stage of the risk assessment identified several metals as COPCs based on screening (relative to guidelines) of soil, sediment, and surface water baseline data collected from the country foods LSA. The COPCs selected for consideration in the country foods baseline assessment included aluminum, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, silver, thallium, tin, vanadium, and zinc.

The human receptors selected were toddlers (six months to four years of age) and adults (greater than 19 years of age; Health Canada 2010d, 2010f) and consumption rates of country foods were based on available data for Skii km Lax Ha and Tahltan Nations that may consume country foods from the country foods LSA (Appendix 21-A, Country Foods Baseline Assessment; Jin 2006). Tables 21.3-7 and 21.3-8 present summaries of the human receptor characteristics used in this assessment.

Table 21.3-7. Human Receptor Ingestion Rates

	Receptor Groups	
Receptor Characteristics	**Toddlers**	**Adults**
Body Weight (kg)[a]	**16.5**	**70.7**
Country Foods Serving Size (kg/serving)[b,c]		
Moose	0.0916	0.213
Snowshoe Hare	0.150	0.348
Grouse	0.129	0.299
Fish (Dolly Varden/Bull Trout)	0.12	0.279
Berries[d]	0.120	0.280

[a] Based on Health Canada guidelines (Health Canada 2010f).
[b] Based on First Nation traditional diet in the region (Jin 2006).
[c] Toddlers ingestion rates are assumed to be 43% of adult ingestion rates based on Richardson (1997).
[d] Includes Alaska blueberry, thinleaf huckleberry, bog blueberry, and Canada Buffaloberry.

Table 21.3-8. Human Receptor Consumption Frequencies

Receptors Characteristics	Consumption Frequency			
First Nation	**Skii km Lax Ha**		**Tahltan**	
Country Foods	**Number of Meals per Year[1]**	**Exposure Frequency (F)[1]**	**Number of Meals per Year[2]**	**Exposure Frequency (F)[2]**
Moose	156	0.427	364*	0.997*
Snowshoe Hare	12*	0.0329*	3	0.008
Grouse	12*	0.0329*	6	0.016
Fish (Dolly Varden/Bull Trout)	12*	0.0329*	12	0.019
Berries[3]	156*	0.427*	12	0.033

[1] *Based on Skii km Lax Ha Country Foods Questionnaire (see Appendix A of Appendix 21-A, Country Foods Baseline Assessment).*
[2] *Based on First Nation traditional diet in the region (Jin 2006).*
[3] *Includes Alaska blueberry, thinleaf huckleberry, bog blueberry, and Canada Buffaloberry.*
** Indicates the more conservative receptor characteristics that were used in this assessment.*

Brucejack Lake is located on a high plateau above the treeline at an elevation of 1,400 metres above sea level and is ice-bound for about eight months of the year (Appendix 11-A, Brucejack Terrain Geohazards). The lake currently has low potential for accessibility due to the lack of roads to the area. Little wildlife was observed at such elevations (Appendix 18-B, Brucejack Gold Mine Project Wildlife Habitat Suitability Report). Moose (Appendix 18-B) and grouse (Campbell et al. 1990; Williamson et al. 2008; BirdLife International 2012) are found to spend no time within the mine site area. Fish are not present in Brucejack Lake or the tributaries of the lake (Appendix 15-A, Brucejack Project: 2012 Fish and Fish Habitat Baseline Report). None of the First Nations or Nisga'a has identified country food collection, hunting sites, or cabins within the mine site area (Figure 21.3-6; see Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects, and Chapter 26, Assessment of Effects on Asserted or Established Aboriginal Rights and Interests, for further details). Therefore, people are unlikely to harvest foods from the mine site area within the country foods LSA. Metal concentrations from environmental media in the mine site area were excluded from the toxicity assessment and risk characterization calculations since they were not considered to be representative of the potential for exposure to and uptake of COPCs from within the country foods LSA.

Skii km Lax Ha hunt, trap, fish, and gather country foods within the Brucejack Access Road and Brucejack Transmission Line areas (Appendix 21-A, Country Foods Baseline Assessment, and Appendix 25-B, Skii km Lax Ha Traditional Knowledge / Traditional Use Report). Therefore, Skii km Lax Ha are identified as human receptors for country foods assessment.

Although the Brucejack Mine Site is not within the Nass Area of the *Nisg̲a'a Final Agreement* (NLG, Province of BC, and Government of Canada 2000), the Brucejack Transmission Line and Brucejack Access Road are within the Nass Area. The Brucejack Mine Site, Brucejack Access Road, and Brucejack Transmission Line do not intersect Nisg̲a'a traplines, most of which are located further south near Nisg̲a'a Lands (Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects, Section 24.3.4, Regional Land and Resource Management Plans). There has been no indication of hunting, trapping, fishing, or gathering of country foods by Nisg̲a'a within the country foods LSA. Neither the Brucejack Mine Site nor the Brucejack Transmission Line is within Tahltan traditional territory (Section 24.3, Baseline Characterization). The easternmost segment of the Brucejack Access Road, approximately the first 9 km of the road branching of the west of Highway 37, is within Tahltan territory (Section 24.3). Available information identifies the majority of fishing, hunting, trapping, and gathering activity as occurs in other more northern areas of the Tahltan territory, for example, near the confluence of Tahltan and Stikine rivers (Section 24.8, Summary of Residual Effects, Likelihood, Significance, and Confidence on Land Use). There are no indications of hunting, trapping, fishing, or gathering of country foods by Tahltan within the country foods LSA. Assessment of the potential country foods effects on the health of Skii km Lax Ha will be a conservative representation of Nisga'a Nation and other First Nations.

Using the measured and modelled concentrations of COPCs in country foods, the EDI of each COPC for toddlers and adult receptors were estimated and are provided in Section 8.5 of Appendix 21-A, Country Foods Baseline Assessment. It was assumed that 100% of the country foods consumed were harvested from the country foods LSA and that 100% of the COPCs present in the foods were bioavailable, i.e., capable of being absorbed. These assumptions result in a highly conservative estimate of potential risk to human health.

The TRV is defined as the amount of metal per unit body weight (BW) that can be taken into the body each day (e.g., mg/kg BW/day) with no risk of adverse health effects. Section 9 of Appendix 21-A, Country Foods Baseline Assessment, provides the TRV values used in this assessment for both carcinogenic (i.e., arsenic) and non-carcinogenic COPCs.

Using the results of the exposure assessment (EDI) and toxicity assessment (TRV), human health risks from the consumption of country foods were quantified using ERs; for non-carcinogenic COPCs, an ER of 0.2 or less is associated with an acceptable risk level. 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 second-hand cigarette smoke. The RMWI was then calculated for each COPC in each country food evaluated (Table 21.3-9). These RMWIs (using the lowest RMWI) were compared to current weekly consumption rates of the country foods. In addition, the incremental lifetime cancer risk (ILCR) was determined for arsenic in country foods (Table 21.3-10); for carcinogenic COPCs, an ILCR of less than 1×10^{-5} is associated with an acceptable level of risk. Calculation of the risk estimates were based on guidance provided by Health Canada (2010f).

Table 21.3-9. Recommended Maximum Weekly Intake and Number of Servings of Country Food

Human Receptor	Country Food	Exposure Ratio (unitless)	Lowest RMWI (kg/week)	Serving Size (kg/serving)	Recommended Number of Servings (servings/week)	Current Number of Servings (servings/week[1])
Adult	Moose[2]	0.255	3.39	0.213	12.9	6.98
	Grouse	0.189	0.403	0.299	1.25	0.230
	Hare	0.000233	229	0.348	477	0.230
	Dolly Varden/ Bull Trout	0.0344	1.87	0.279	6.69	0.230
	Berries	0.121	6.81	0.280	24.3	2.99
Toddler	Moose[2]	0.469	0.791	0.0916	6.99	6.98
	Grouse[3]	0.349	0.0941	0.129	0.681	0.230
	Hare	0.000430	53.4	0.150	259	0.230
	Dolly Varden/ Bull Trout	0.0634	0.436	0.120	3.63	0.230
	Berries[4]	0.223	1.59	0.120	13.2	2.99

RMWI = recommended maximum weekly intake, n/a = not applicable
[1] based on annual averages (Jin 2006)
[2] elevated adult and toddler exposure ratios due to moose consumption were due to thallium concentrations
[3] elevated toddler exposure ratios due to grouse consumption were due to aluminum concentrations
[4] elevated toddler exposure ratios due to berries consumption were due to thallium concentrations

Table 21.3-10. Estimated Lifetime Daily Exposure and Incremental Lifetime Cancer Risk for Adult Human Receptors Exposed to Arsenic in Country Foods

Country Food	ELDE (mg/kg/day)	ILCR (unitless)
Moose	2.58×10^{-7}	4.65×10^{-7}
Grouse	2.23×10^{-6}	4.02×10^{-6}
Snowshoe hare	2.77×10^{-10}	4.99×10^{-10}
Berries	4.06×10^{-6}	7.31×10^{-6}
Dolly Varden/bull trout	4.33×10^{-7}	7.79×10^{-7}

ILCR = incremental lifetime cancer risk
ELDE = estimated lifetime daily exposure
ILCR is calculated by dividing ELDE by the slope factor for arsenic of 1.8 (mg/kg BW/day)$^{-1}$
An ILCR estimate less than 1 x 10^{-5} is normally considered acceptable (Health Canada 2010a)

ERs for adults and toddlers consuming moose and toddlers consuming berries were above threshold of 0.2 due to thallium. In addition, in toddlers only, the ER for grouse consumption was above threshold of 0.2 due to aluminum. Since the mine site area was scoped out of the assessment, the baseline elevated ERs due to consumption of country foods were due to naturally elevated metal concentrations within the Brucejack Access Road and the Brucejack Transmission Line areas. Naturally elevated soil concentration of thallium combined with the high consumption rate of vegetation by moose result in elevated ERs for adult and toddler consumers. Naturally elevated concentration of aluminum in soil ingested by grouse result in the elevated ER for toddlers. In addition, naturally high concentration of thallium in berries ingested by toddlers also results in elevated ER for toddlers.

In a screening level risk assessment, it is common to make a number of very conservative assumptions during the assessment process which will tend to overestimate the actual risk to human health. If no unacceptable risks are identified using this conservative approach, then it is very unlikely that human health will be affected by consumption of country foods at the frequencies and quantities used in the assessment.

However, when risks are identified, such as the elevated ERs indicated in Table 21.3-9, a more detailed examination of risk, such as calculation of RMWIs, is warranted. This further assessment is important, since overestimation of risk as a result of applying conservative assumptions can lead to needless concern in human consumers of country foods. People may choose to avoid eating country foods due to concerns about potential health effects due to COPCs that may be present, which can have social, cultural, or economic impacts.

Further assessment of non-carcinogenic risk based on the calculated RMWIs indicated that there are no unacceptable risks to human receptors from the consumption of moose, snowshoe hare, grouse, berries, or Dolly Varden / bull trout at the current levels of consumption. Based on empirical and modelled concentrations of metals in these foods, the amounts currently consumed are less than the recommended maximum weekly intakes and have an acceptable risk in terms of the ILCR.

21.4 ESTABLISHING THE SCOPE OF THE ASSESSMENT FOR HUMAN HEALTH

This section includes a description of the scoping process used to identify potentially affected VCs, select assessment boundaries, and identify the potential effects of the Project that are likely to arise from the Project's interaction with an intermediate component or receptor VC. Scoping is fundamental to focusing the Application/EIS on those issues where there is the greatest potential to cause significant adverse effects. The scoping process for the assessment of human health consisted of the following four steps:

- *Step 1:* undertaking an issues scoping process to select components, sub-components, and indicators based on a consideration of the Project's potential to interact with human health;
- *Step 2:* consideration of feedback on the results of the scoping process from technical experts and the EA Working Group[1];
- *Step 3:* definition of assessment boundaries for human health, and/or sub-components; and
- *Step 4:* identification of key potential effects on human health and/or sub-components.

These steps are described in detail below.

21.4.1 Selecting Receptor Valued Components

Selecting receptor VCs for assessment is done to focus the Application/EIS on the issues of highest concern. Receptor VCs are specific attributes of the biophysical and socio-economic environments that have environmental, social, economic, heritage, or health significance. Receptor VCs also have the potential to be indirectly affected by changes in the baseline condition of other environmental components thereby acting as receptors of that change. Indirect effects may, in turn, also affect the baseline condition of the receptor VC. To be considered for assessment, a VC must be of recognized importance to society, the local community, or the environmental system, and there must be a perceived likelihood that the receptor VC will be affected by the proposed Project. Receptor VCs are scoped during consultation with key stakeholders, including Aboriginal communities and the EA Working Group. Consideration of certain receptor VCs may also be a legislated requirement, or known to be a concern because of previous project experience.

Canadian federal and provincial governments and health officials have accepted the WHO's definition of holistic health: "A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity (WHO 1948)."

This was expanded to include:

> *The extent to which an individual or group is able, on the one hand, to realize aspirations and to satisfy needs, and on the other, to change or cope with the environment. Health is therefore seen as a resource for everyday life, not the objective of living; it is seen as a positive concept emphasizing social and personal resources, as well as physical capabilities* (WHO 1948).

This definition indicates that all aspects of well-being should be considered when assessing human health, including physical, social, emotional, spiritual, and environmental impacts on health. There are many determinants of human health, such as the physical environment (including environmental contaminants), lifestyle (e.g., smoking, drinking, diet, exercise, and coping skills), occupation, education, and the social and economic environment in which a person lives (Health Canada 2000). The physical environment factors contributing to human health are considered as sub-components because they have the potential to affect the physical health of human receptors directly through chemical

[1] The EA Working Group is a forum for discussion and resolution of technical issues associated with the proposed Project, as well as providing technical advice to the BC EAO and CEA Agency, which remain ultimately responsible for determining significance. It comprises representatives of provincial, federal, and local government, and Aboriginal groups.

means (e.g., quality of air, water, and country foods) and noise. Physical health is assessed in this chapter, while other determinants of human health are included in Chapter 19, Assessment of Potential Economic Effects, and Chapter 20, Assessment of Potential Social Effects.

Following the EIS Guidelines, Health Canada's *Useful Information for Environmental Assessments* document (2010e) was used to scope relevant and appropriate receptor VCs and sub-components into the human health assessment. In addition, as described in Section 6.4.1.1, Scoping Potential Interactions between the Project and Candidate Components, a scoping exercise was conducted during the development of the draft AIR to explore potential Project interactions with candidate receptor VCs, and to identify the key potential adverse effects associated with that interaction. The results of the scoping exercise were circulated for review and approval by the EA Working Group, and feedback from that process was integrated into the Application/EIS.

Subject areas are classified as either an intermediate component or receptor VCs and are further refined into sub-components and indicators as described in Section 21.4.1.3. Human health was identified as a receptor VC as a result of the scoping process, and refined as follows:

- Sub-component 1: noise;
- Sub-component 2: air quality;
- Sub-component 3: drinking water; and
- Sub-component 4: country foods.

Predictive study effects assessment results from the following intermediate components will be used to support the effects assessment for human health:

- noise predictive study;
- air quality predictive study;
- water quality effects assessment; and
- country foods screening level risk assessment (SLRA), if warranted based on the potential for changes in environmental media quality.

Indicators used for the four sub-components are as follows:

- noise indicators;
  - percent highly annoyed;
  - sleep disturbance;
  - sleep interference;
  - interference with speech communication;
  - complaints;
- air quality indicators;
  - NO_2;
  - SO_2;
  - CO;
  - TSP;
  - PM_{10};

  - $PM_{2.5}$;
  - dustfall;
- drinking water indicators;
  - concentrations of total and dissolved metals, nutrients, turbidity, and total suspended solids (TSS);
- country food indicators; and
  - degradation of quality of country foods.

21.4.1.1 Potential Interactions between the Project and Human Health

Human receptors that may be affected by air quality and noise were identified as workers accommodation camps as well as cabins/camping locations. Drinking water and country foods human receptors were also identified. For additional information on noise, air quality, drinking water, and country foods human receptor locations refer to Section 21.4.2.1.

Dermal exposure to chemicals or contaminated water is considered under occupational health hazard (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. Therefore, health effects from dermal exposure are not included in this assessment.

There may be health effects from incidental soil ingestion. However, this is mainly a concern for children and since children are not considered receptors at the proposed mine, they would not be affected by mineralized dustfall on soil.

Table 21.4-1 provides an impact scoping matrix of the human receptor VC sub-components that have a possible or likely interaction with Project components and activities. A full impact scoping matrix for all intermediate and receptor VCs is provided in Table 6.4-1.

Interactions between the Project and the human receptor VCs were assigned a colour code as follows:

- not expected (white);
- possible (grey); and
- likely (black).

Interactions coded as not expected (white) are considered to have no potential for adverse effects on a receptor VC, and are not considered further. Potential Project interactions with human health due to noise, air quality, and drinking water are based on Tables 8.4-1, 7.4-1, and 13.4-1, respectively. Potential Project interactions with human health due to the quality of country foods are based on the worst case potential interactions among air quality and drinking water since the quality of country foods may potentially be affected by contaminants originating from the air and water pathways.

21.4.1.2 Consultation Feedback on Receptor Valued Components

The selection of potential VCs for the Project was based on a scoping process that involved public consultation with potentially affected communities, consultation with regulatory agencies, and regulatory considerations.

The following feedback and concerns were raised during the pre-application consultation process (see Chapter 3, Information Distribution and Consultation).

Table 21.4-1. Interaction of Project Components and Physical Activities with Human Health

Project Components and Physical Activities by Phase	Air Quality	Noise	Drinking Water	Country Foods
Construction Phase				
Activities at existing adit				
Air transport of personnel and goods				
Avalanche control				
Chemical and hazardous material storage, management and handling				
Construction of back-up diesel power plant				
Construction of Bowser Aerodrome				
Construction of detonator storage area				
Construction of electrical tie-in to the BC Hydro grid				
Construction of electrical substation at Brucejack Mine Site				
Construction of equipment laydown areas				
Construction of helicopter pad				
Construction of incinerators				
Construction of Knipple Transfer Area				
Construction of local site roads				
Construction of mill building (electrical induction furnace, backfill paste plant, warehouse, mill/ concentrator)				
Construction of mine portal and ventilation shafts				
Construction of Brucejack Operations Camp				
Construction of ore conveyer				
Construction of tailings pipeline				
Construction and decommissioning of Tide Staging Area construction camp				
Construction of truck shop				
Construction and use of sewage treatment plant and discharge				
Construction and use of surface water diversions				
Construction of water treatment plant				
Development of the underground portal and facilities				
Employment and labour				
Equipment maintenance/machinery and vehicle refuelling/fuel storage and handling				
Explosives storage and handling				
Grading of the mine site area				
Helicopter use				
Installation and use of Project lighting				
Installation of surface and underground crushers				
Installation of the transmission line and associated towers				
Machinery and vehicle emissions				
Potable water treatment and use				
Pre-production ore stockpile construction				

(continued)

Table 21.4-1. Interaction of Project Components and Physical Activities with Human Health (continued)

Project Components and Physical Activities by Phase	Air Quality	Noise	Drinking Water	Country Foods
Construction Phase (cont'd)				
Procurement of goods and services				
Quarry construction	■	■	▒	■
Solid waste management	■	■		■
Transportation of workers and materials	■	■		■
Underground water management			■	■
Upgrade and use of exploration access road	■	■	■	■
Use of Granduc Access Road	■	■	▒	■
Operation Phase				
Air transport of personnel and goods and use of aerodrome	■	■		■
Avalanche control	▒	▒		▒
Backfill paste plant				
Back-up diesel power plant	■	■		■
Bowser Aerodrome			▒	▒
Brucejack Access Road use and maintenance	■	■	▒	■
Brucejack Operations Camp				
Chemical and hazardous material storage, management, and handling				
Concentrate storage and handling	▒	▒		▒
Contact water management			■	■
Detonator storage				
Discharge from Brucejack Lake			■	■
Electrical induction furnace	■	■		■
Electrical substation				
Employment and labour				
Equipment laydown areas			▒	▒
Equipment maintenance/machine and vehicle refuelling/fuel storage and handling				
Explosives storage and handling				
Helicopter pad(s)				
Helicopter use	■	■		■
Knipple Transfer Area	■	■	▒	■
Machine and vehicle emissions	■	■		■
Mill building	■	■		■
Non-contact water management			▒	▒
Ore conveyer	▒	▒		▒
Potable water treatment and use				
Pre-production ore storage			▒	▒
Procurement of goods and services				

(continued)

Table 21.4-1. Interaction of Project Components and Physical Activities with Human Health (continued)

Project Components and Physical Activities by Phase	Air Quality	Noise	Drinking Water	Country Foods
Operation Phase (cont'd)				
Project lighting				
Quarry operation				
Sewage treatment and discharge				
Solid waste management/incinerators				
Subaqueous tailings disposal				
Subaqueous waste rock disposal				
Surface crushers				
Tailings pipeline				
Truck shop				
Transmission line operation and maintenance				
Underground backfill tailings storage				
Underground backfill waste rock storage				
Underground crushers				
Underground: drilling, blasting, excavation				
Underground explosives storage				
Underground mine ventilation				
Underground water management				
Use of mine site haul roads				
Use of portals				
Ventilation shafts				
Warehouse				
Waste rock transfer pad				
Water treatment plant				
Closure Phase				
Air transport of personnel and goods				
Avalanche control				
Chemical and hazardous material storage, management, and handling				
Closure of mine portals				
Closure of quarry				
Closure of subaqueous tailings and waste rock storage (Brucejack Lake)				
Decommissioning of Bowser Aerodrome				
Decommissioning of back-up diesel power plant				
Decommissioning of Brucejack Access Road				
Decommissioning of camps				
Decommissioning of diversion channels				

(continued)

Table 21.4-1. Interaction of Project Components and Physical Activities with Human Health (completed)

Project Components and Physical Activities by Phase	Air Quality	Noise	Drinking Water	Country Foods
Closure Phase (cont'd)				
Decommissioning of equipment laydown	Grey	Grey	Grey	Grey
Decommissioning of fuel storage tanks	Grey	Grey	Grey	Grey
Decommissioning of helicopter pad(s)	Grey	Grey	Grey	Grey
Decommissioning of incinerators	Grey	Grey	Grey	Grey
Decommissioning of local site roads	Grey	Grey	Grey	Grey
Decommissioning of mill building	Grey	Grey	Grey	Grey
Decommissioning of ore conveyer	Grey	Grey	Grey	Grey
Decommissioning of Project lighting	Grey	Grey		Grey
Decommissioning of sewage treatment plant and discharge	Grey	Grey	Grey	Grey
Decommissioning of surface crushers	Grey	Grey	Grey	Grey
Decommissioning of surface explosives storage	Grey	Grey	Grey	Grey
Decommissioning of tailings pipeline	Grey	Grey	Grey	Grey
Decommissioning of transmission line and ancillary structures	Grey	Grey	Grey	Grey
Decommissioning of underground crushers	Grey	Grey		Grey
Decommissioning of waste rock transfer pad	Grey	Grey	Black	Black
Decommissioning of water treatment plant	Grey	Grey	Grey	Grey
Employment and labour				
Helicopter use	Grey	Grey		Grey
Machine and vehicle emissions	Grey	Grey		Grey
Procurement of goods and services				
Removal or treatment of contaminated soils	Grey	Grey	Grey	Grey
Solid waste management	Grey	Grey		Grey
Transportation of workers and materials (Mine Site and access roads)	Grey	Grey		Grey
Post-closure Phase				
Discharge from Brucejack Lake			Black	Black
Employment and labour				
Environmental monitoring				
Procurement of goods and services				
Subaqueous tailings and waste rock storage			Black	Black
Underground mine			Grey	Grey

Notes:
White = interaction not expected between Project components/physical activities and a receptor VC
Grey = possible interaction between Project components/physical activities and a receptor VC
Black = likely interaction between Project components/physical activities and a receptor VC

No specific concerns were expressed regarding the potential for air quality changes as a result of Project activities and infrastructure.

Although concerns were expressed regarding surface water quality, no specific concerns about drinking water quality were raised. The Gitxsan Watershed Authorities were concerned that mine seepage may contaminate surrounding and downstream water (Appendix 3-D, Summary of Communications with Aboriginal Groups). NLG was concerned that the leaching of tailings may affect Bowser Lake (Appendix 3-D, Summary of Communications with Aboriginal Groups).

Skii km Lax Ha have indicated a preference for traditional animals and plants, medicinal plants, berries, fish, wildlife, and water as these are important for traditional knowledge (Rescan 2013b). The Gitanyow Nation have expressed the importance of medicinal plants, berries, fish, wildlife, and water to the First Nations' food security (Gitanyow Nation, Appendix 3-D, Summary of Communications with Aboriginal Groups). In addition, Nisga'a fish for spring salmon in Bowser Lake (Appendix 3-D), and sockeye spawning was indicated as vital to the Gitanyow Nation (Appendix 3-D).

21.4.1.3 Summary of Receptor Valued Components and Sub-components Included/Excluded in the Application/EIS

Human health was the only receptor VC considered for this assessment. The selection of sub-components for evaluation (noise, air quality, drinking water quality, and country foods quality) was based on Health Canada guidance, consultation with potentially-affected communities, consultation with regulatory agencies, and regulatory considerations. The rationale for their inclusion is presented in Table 21.4-2.

Table 21.4-2. Human Receptor Sub-components Included in the Application/EIS

	Identified by*				
Sub-components	**AG**	**G**	**P/S**	**IM**	**Rationale for Inclusion**
Noise		X		X	Noise can affect human health physically and emotionally (2010e). Included as human health VC sub-component because off-duty workers will reside in camps close to Project activities and may be affected. In addition, Skii km Lax Ha Lodge is in close proximity to the Bowser camp and may also be affected by noise due to Project activities
Air quality		X		X	May directly affect the respiratory health of off-duty workers or transient land users near sources of CACs. In addition, air quality can directly result in changes in soil and vegetation quality, and consequently the quality of country foods as indicated by Health Canada (2010e).
Drinking water quality	X	X		X	Selected as a sub-component of human health as contaminant levels in drinking water have the potential to directly affect human health (2010e). Although concerns were expressed regarding surface water quality, no specific concerns about drinking water quality were raised (Chapter 3, Information Distribution and Consultation).
Country foods	X	X		X	Contaminant levels in country foods have the potential to directly affect human health (2010e). Working group members expressed concerns regarding potential changes in quality of country foods including traditional animals (especially moose) and plants, medicinal plants, berries, fish, wildlife and water. Since the quality of country foods harvested and consumed is directly related to human health, country foods was selected as sub-component for the human health VC.

**AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder; IM = Impact Matrix*

Other potential sub-components that may contribute to the human health VC were considered, but were excluded from the assessment. For instance, Health Canada suggests providing information for radiological effects in the human health assessment within an environmental assessment. However since the Project is a metal mine, radiological effects are not expected to occur and therefore are not included as a sub-component.

Power lines can cause weak electric currents to flow through the human body. However, the magnitude of the currents in power lines, assuming there is no direct physical contact with active lines, is not associated with any known short- or long-term health risks. Therefore, health effects from electric and magnetic fields are not included in this assessment.

21.4.2 Assessment Boundaries for Human Health

Assessment boundaries define the maximum limit within which the effects assessment is conducted. They encompass the areas within, and times during, which the Project is expected to interact with the receptor VCs, as well as the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries), and limitations in predicting or measuring changes (technical boundaries). The definition of these assessment boundaries is an integral part of the assessment process of human health, and encompasses possible direct, indirect, and induced effects of the Project on human health, inclusive of Project effects on relevant intermediate components, as well as the trends in processes that may be relevant.

21.4.2.1 Spatial Boundaries

Noise

Local Study Area

An LSA was not defined for noise since the spatial boundaries for the effects assessment were based on the noise modelling domain, which is equivalent to the noise RSA (Section 8.4.2.1, Spatial Boundaries).

Regional Study Area

The noise RSA follows the noise model domain (Chapter 8, Figure 8.4-1) and includes the closest receptor locations (i.e., permanent or temporary locations identified in Appendix 24-A, Brucejack Gold Mine Project: Non-traditional Land Use Baseline; contemporary locations identified in Appendix 25-B, Skii km Lax Ha Traditional Knowledge / Traditional Use Report; Appendix 25-A, Ethnographic Overview Report; and receptor locations associated with the proposed mining activities (Figure 21.4-1).

Air Quality

Local Study Area

An LSA was not defined for air quality since the spatial boundaries for the effects assessment were based on the air quality modelling domain, which is equivalent to the air quality RSA (Section 7.4.2.1, Spatial Boundaries).

Regional Study Area

The air quality RSA follows the air quality domain (Chapter 7, Air Quality Predictive Study, Figure 7.4-1) and includes the closest receptor locations, i.e., permanent or temporary locations identified in Appendix 24-A, Brucejack Gold Mine Project: Non-traditional Land Use Baseline; contemporary locations identified in Appendix 25-B, Skii km Lax Ha Traditional Knowledge / Traditional Use Report; Appendix 25-A, Ethnographic Overview Report; and receptor locations associated with the proposed mining activities (Figure 21.4-2).

Figure 21.4-1
Noise Regional Study Area and Human Health Receptor Locations

ERM

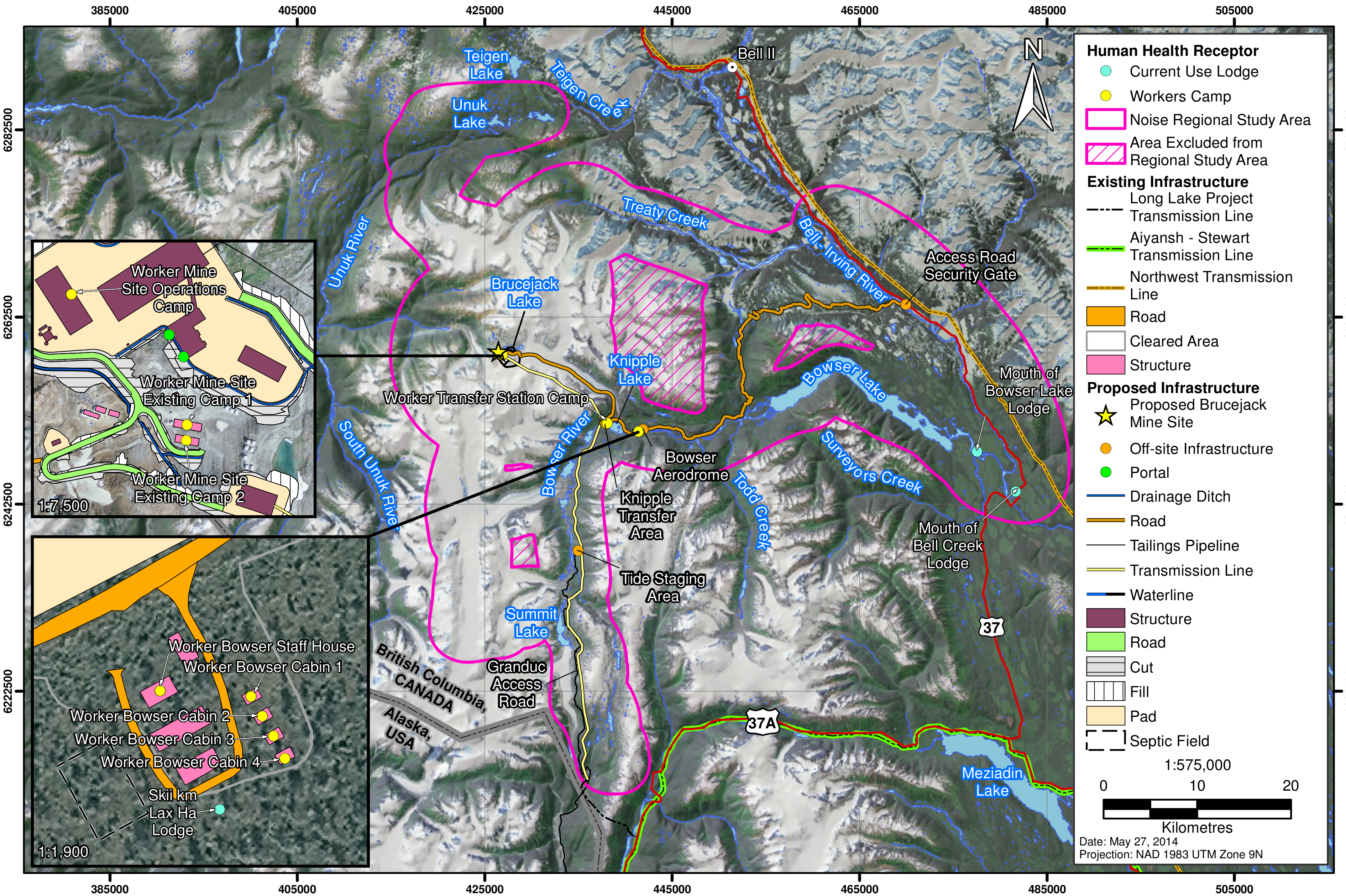
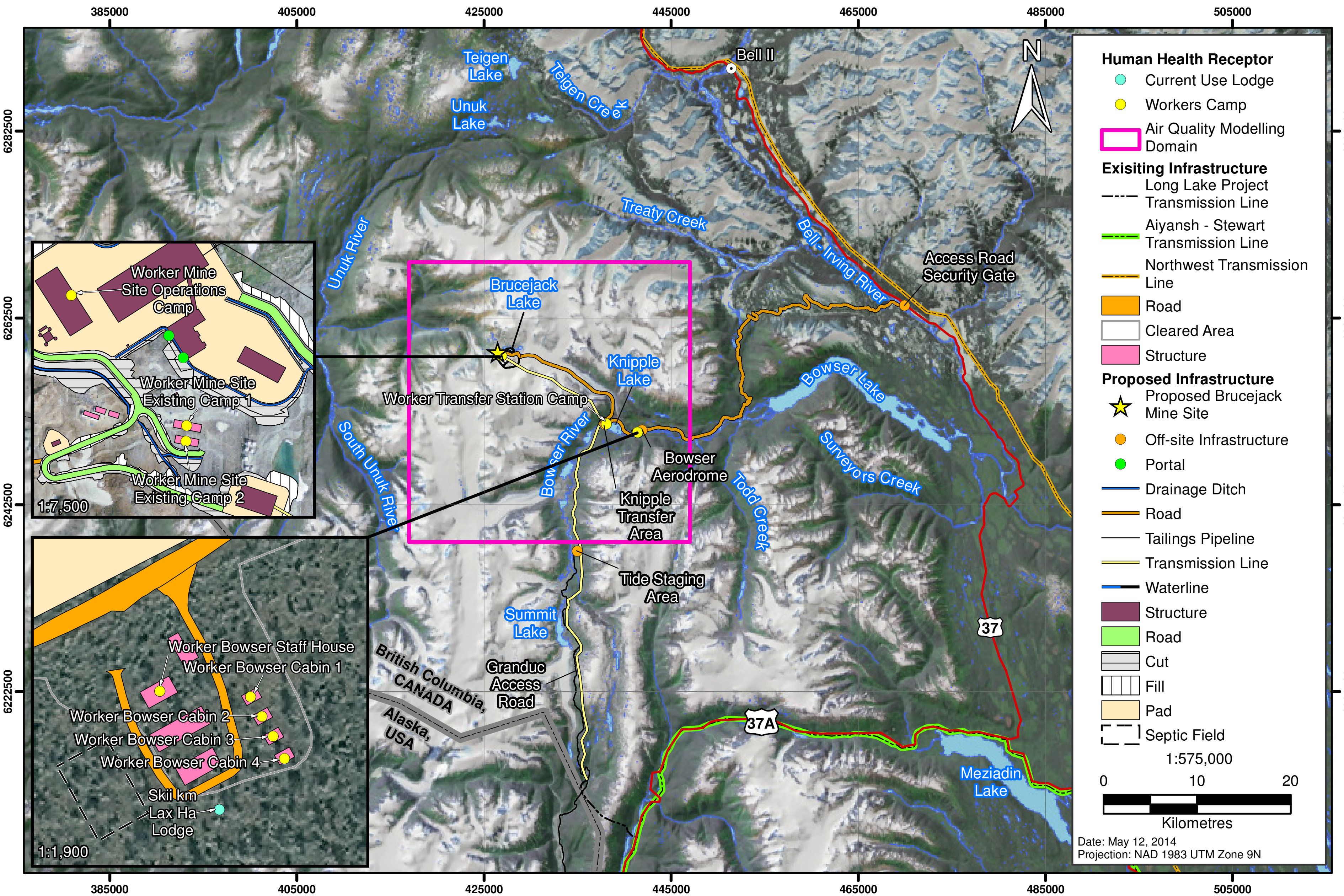


Figure 21.4-2

Air Quality Regional Study Area and Human Health Receptor Locations



Drinking Water

Local Study Area

The spatial boundary of the drinking water LSA is consistent with the surface water quality LSA (Figure 13.3-1 of Chapter 13, Assessment of Potential Surface Water Quality Effects). The drinking water LSA encompasses the proposed Project footprint (all physical structures and activities that comprise the Project) and watersheds that could be potentially indirectly or directly affected by mine development and operation (Figure 21.4-3). These include lakes and streams located within and downstream of the proposed tailings deposition area in Brucejack Lake, sewage treatment plant, rock storage facilities, and the quarry (mine site area), as well as ancillary infrastructure outside of the mine site area, including the proposed transmission line right-of-way, access corridor, Knipple Transfer Area, and the Bowser Aerodrome. For further details on the boundaries and main areas of the drinking water LSA, refer to Chapter 13.

The drinking water LSA used for the effects assessment is the same as what was used in the baseline drinking water assessment (see Section 21.3.3.2). The drinking water baseline LSA is depicted in Figure 21.4-3 and consists of three main areas:

- Brucejack watershed (mine site area);
- Knipple Lake / Bowser River watershed (ancillary project infrastructure, access corridor); and
- Wildfire Creek/Scott/Todedada watersheds (access corridor).

Regional Study Area

The drinking water RSA (Figure 21.4-3) adopted the surface water quality RSA (Figure 13.4-1 of Chapter 13, Assessment of Potential Surface Water Quality Effects). It encompasses the drinking water LSA and includes the Unuk River, Lower Bowser River, Scott Creek, Todedada Creek, Wildfire Creek, Salmon River, and Upper Bowser River upstream of Knipple Lake (See Section 13.4.1.5, Spatial Boundaries, for additional information). The RSA is expected to be the outer boundary of where indirect effects of the Project may occur.

Country Foods

Local Study Area

The spatial boundary for the country foods LSA (Figure 21.4-4) is consistent with the country foods baseline LSA (Figure 21.3-5 and Section 21.3.3.4). The country foods LSA is based on the outer limits of the proposed infrastructure, development, physical barriers, and watershed boundaries.

The country foods baseline LSA was further broken down into three separate areas because of the variety of landforms and vegetation types present, the different types of effects that may result from the various infrastructure components, and the relatively large geographical separation among some of the infrastructure components. These three areas were the Brucejack Mine Site, the Brucejack Access Road, and the Brucejack Transmission Line areas (Figure 21.4-4).

Regional Study Area

The country foods RSA is 374,400 ha in size, and is the same RSA utilized in the wildlife baseline report (Figure 21.4-4; Appendix 18-A, Brucejack Gold Mine Project Wildlife Characterization Baseline Report). Selection of the RSA boundaries took into account the area that provides habitat for wildlife species that may come into contact with proposed Project infrastructure during the course of a season or a lifetime. Other ecological factors, such as height of land, were also considered when delineating boundaries.

Figure 21.4-3
Drinking Water Local and Regional Study Areas

ERM

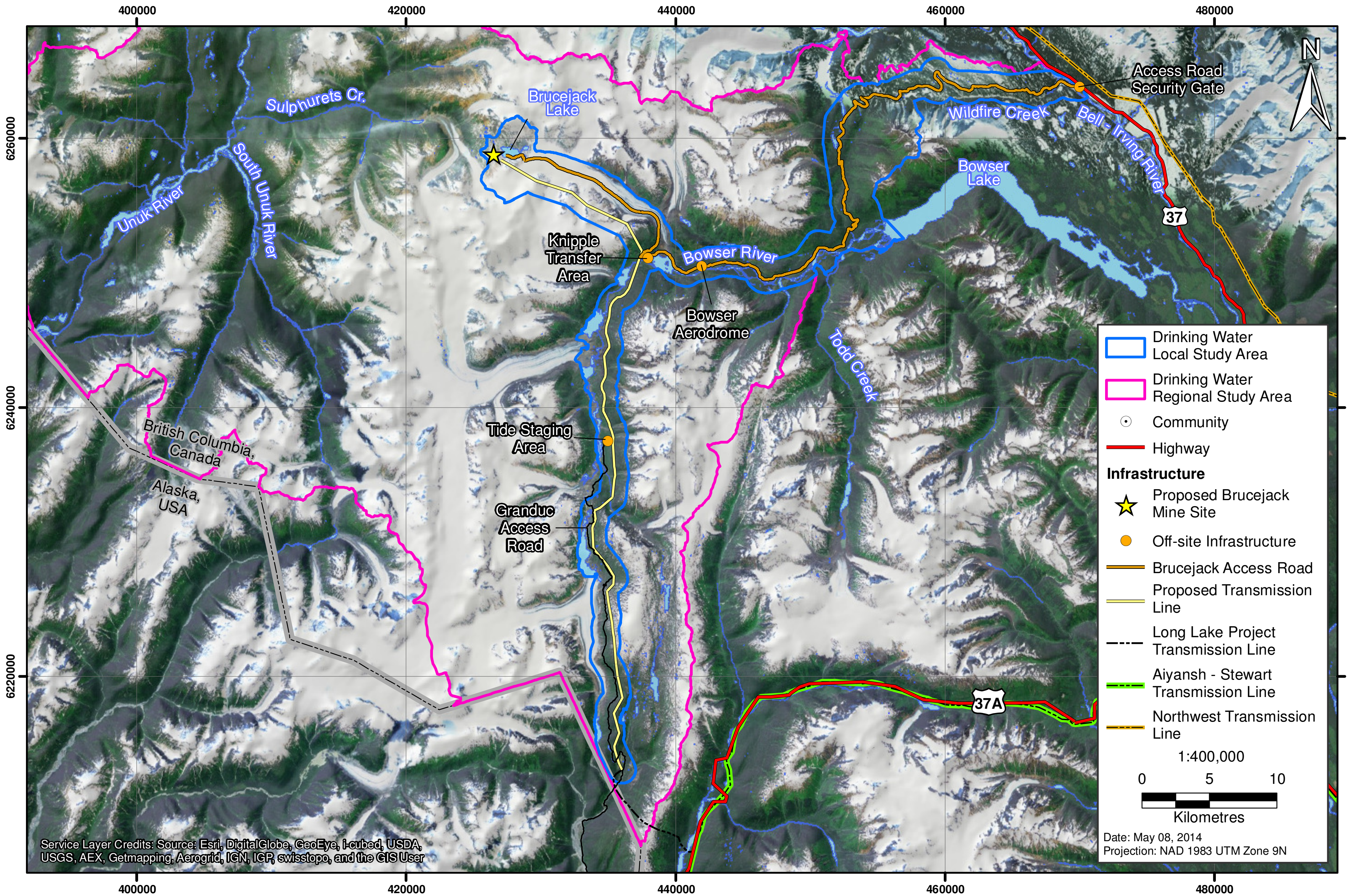
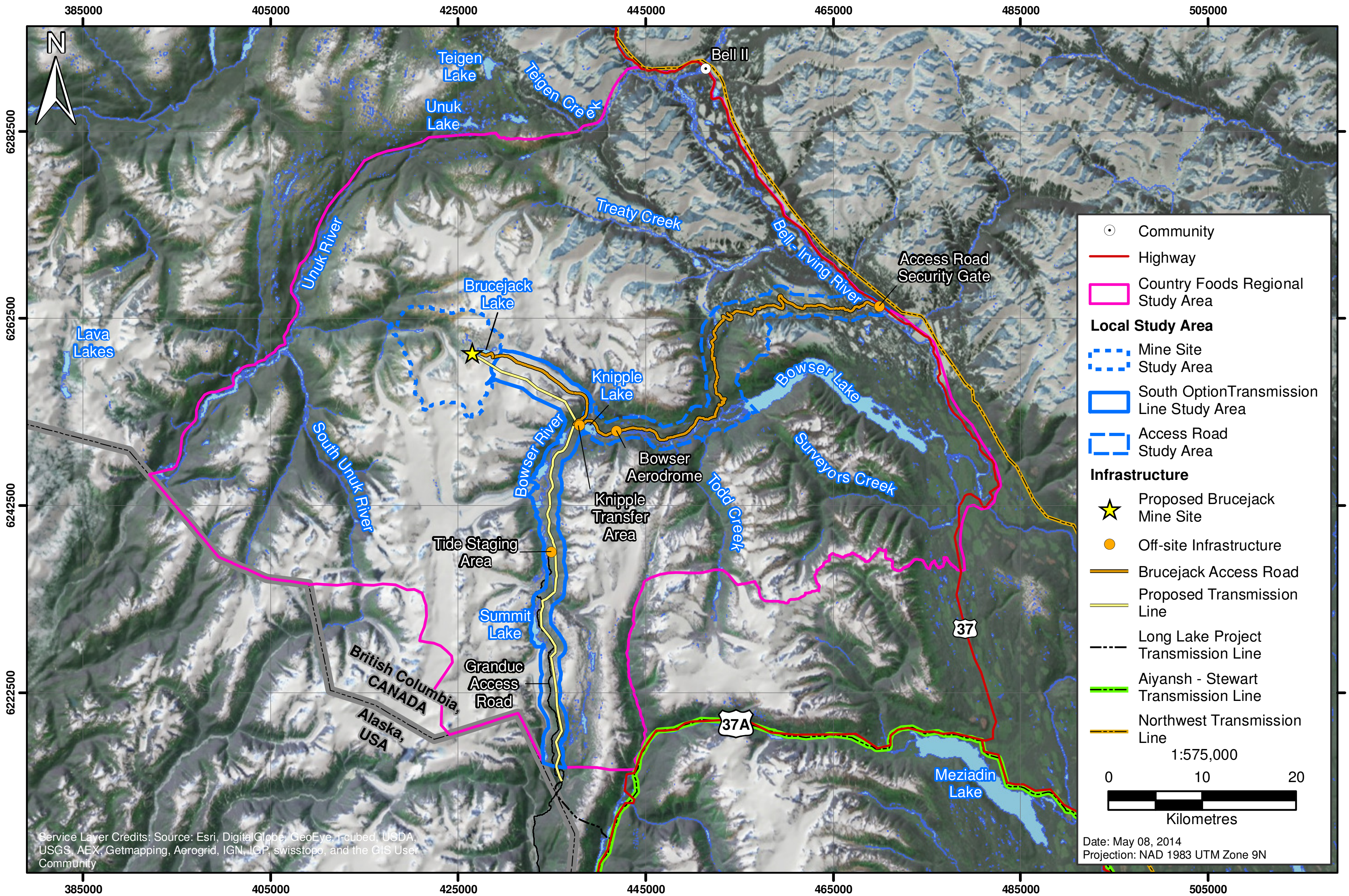


Figure 21.4-4
Country Foods Local and Regional Study Areas

ERM



21.4.2.2 Temporal Boundaries

Human health can potentially be affected throughout the life of the mine, encompassing the Construction, Operation, Closure, and Post-closure phases. The temporal boundaries of the Project include the following:

- Construction: 2 years;
- Operation: 22 years;
- Closure: 2 years (includes project decommissioning, abandonment and reclamation activities); and
- Post-closure: minimum of 3 years (includes ongoing reclamation activities and post-closure monitoring).

Temporal boundaries for each of the human health sub-components are further defined in the following sections.

Temporal Boundaries for the Noise Predictive Model

Noise modelling conducted to support the assessment considers the Construction and Operation phases of the Project (Section 8.4.2.2, Temporal Boundaries). Modelling years were chosen to be years in which the highest numbers of mobile and fixed equipment units are expected to be in use, as follows:

- the busiest year of the Construction phase; and
- the year in the Operation phase immediately following completion of construction.

Since noise is a transient effect, if the potential effects that occur during these years are found to be not significant on human health then the potential effect of the entirety of the Project would also be not significant (Section 8.4.2.2).

Temporal Boundaries for the Air Quality Predictive Model

The air quality assessment focuses on the Construction and Operation phases of the Project since the majority of emissions will occur during these two phases (Section 7.4.2.2, Temporal Boundaries). Project Closure and Post-closure activities may emit emissions intermittently; however, the effects are expected to be limited and substantially less than that during the Construction and Operation phases (Section 7.4.2.2).

Drinking Water Temporal Boundaries

Temporal boundaries for drinking water quality assessment are the same as those used for the assessment of surface water and include all four phases of Project activities.

Country Foods Temporal Boundaries

The country foods assessment focuses on the Construction and Operation phases because they are considered to have the greatest potential for effects to the health of consumers of country foods. This aligns with the air quality assessment, since these two phases have the greatest potential for air emissions that can affect the quality of country foods (i.e., deposition of fugitive dust). Project Closure and Post-closure activities may have air emissions intermittently; however, the effects are expected to be limited and less significant as that during the Construction and Operation phases (Section 7.4.2.2). Therefore, the Construction and Operation phases will be the focus of the quantitative assessment of risk to human health.

21.4.2.3 Other Boundaries – Human Receptor Locations and Other Considerations

Human receptor locations also influence the assessment boundaries for human health. This is because in order for there to be effects to human health, humans must be present and be exposed to the contaminant or noise (see Section 21.1). The following sections describe the locations of human receptors for the purposes of the effects assessment (in Section 21.5), and how the human receptor locations influence the scope or boundaries for the effects assessment.

Noise and Air Quality

Human receptor locations for noise and air quality are categorized in two groups; non-worker camps and workers' accommodation camps. The Mine Site's existing exploration camps include Worker camps include Worker Mine Site Existing Camp 1 and Worker Mine Site Existing Camp 2. Worker Mine Site Existing Camp 1 is a kitchen and Worker Mine Site Existing Camp 2 is a bunkhouse. Although it is unlikely that workers stay and sleep at the Worker Mine Site Existing Camp 1, this location is included as a receptor location for both noise and air quality assessments (Figures 21.4-1 and 21.4-2). Bowser camps include a staff house (Worker Bowser Staff House) and four cabins (Worker Bowser Cabin 1, Worker Bowser Cabin 2, Worker Bowser Cabin 3, and Worker Bowser Cabin 4; Figures 21.4-1 and 21.4-2). There is also a camp at the Knipple Transfer Area (Worker Transfer StationTransfer Area Camp; Figures 21.4-1 and 21.4-2). Bowser camps, existing exploration camps, as well as Knipple Transfer Area camp will be in use during the Construction phase of the Project. Operation phase camps include Worker Transfer Station Camp at Knipple Transfer Area and Worker Mine Site Operation Camp which is located at the Mine Site. Non-worker camps include the Skii km Lax Ha Lodge (Figures 21.4-1 and 21.4-2), Mouth of Bell Creek Lodge, and Mouth of Bowser Lake Lodge (Figure 21.4-1). Human receptors may be present at these camps during one or all phases of the Project, depending on when the camp is open and operating. The effects assessment will only consider a camp as a human receptor location if the camp is open and operating during the specific phase (i.e., a human receptor is present and could be exposed to Project-related noise and air emissions).

Drinking Water

Receptor locations and potential uses for drinking water during the life of the project are the same as for the baseline (see Section 21.3.3.3). One exception is the source of drinking water for the camps. Brucejack Lake is currently the source of drinking water for the existing worker camps (Worker Mine Site Existing Camp 1, Worker Mine Site Existing Camp 2), as Pretivm holds a water licence on Brucejack Lake (C128950; Figure 21.3-4). However, the drinking water source for the camps during the life of the Project will be from a well (to be installed). Drinking water for the worker camps will meet both BC and Canadian DWQG and standards before use for drinking water. Skii km Lax Ha Lodge residents currently use the same drinking water source as the Bowser worker camps. Therefore, Brucejack Lake is scoped out of the drinking water assessment during the life of the Project since it will no longer be a potential source of drinking water.

Country Foods

Receptor locations and potential users for the country foods assessment during the life of the Project are the same as the baseline (see Section 21.3.3.4 and Figure 21.3-6). Consistent with the country foods baseline study, the mine site area was excluded as a potential source of country foods. This is due to absence of country foods including moose and grouse in such a high alpine area and absence of fish in Brucejack Lake. In addition, there has been no indication of hunting, fishing, or gathering in the vicinity of the mine site area during the consultation phase (Chapter 3, Information Distribution and Consultation). Furthermore, the mine site area is highly inaccessible due to its elevation, climate, and absence of roads that connect with Highway 37, other than the recently completed exploration access road (Brucejack Access Road), which is fully controlled such that public access is not available (see Sections 7.3 and 10.3.1 of Appendix 21-A, Brucejack Gold Mine Project: Country Foods Baseline Assessment, for further details). Country food harvesting is not expected to occur at the mine site area as public access will be restricted along the Brucejack Access Road and a no hunting policy will be in place for workers on-site (Sections 29.16, Transportation and Access Management Plan, and 29.21, Wildlife Management and Monitoring Plan).

21.4.3 Identifying Potential Effects on Human Health

The purpose of this section is to describe the types of potential effects that can result from the interaction of the Project's components and activities with each sub-component by which human health can be affected (i.e., noise, air quality, drinking water quality, country foods quality). Effects to human health could potentially occur during all phases of the Project. Components and activities for each phase are discussed to describe the pathways that can lead from components/activities to effects on human health (Sections 21.4.3.1. to 21.4.3.4). Note that the potential for spills and accidents involving large quantities of petroleum products or other chemicals are not considered here since this is addressed in Section 29.14, Spill Prevention and Response Plan, and Chapter 31, Accidents and Malfunctions.

Table 21.4-1 illustrates all the potential linkages between the Project components and activities, and the noise, air quality, drinking water, and country foods sub-components of the human health VC, during all the Project phases.

21.4.3.1 Construction

<u>Noise</u>

Table 21.4-1 shows that the key effects of the Project on noise during the Construction phase are expected to be due to equipment and activities associated with the construction of the Brucejack Mine Site, quarry, Knipple Transfer Area, Bowser Aerodrome, diesel power generation, Brucejack Access Road activities, helicopter use, and blasting (Section 8.4.3, Identifying Key Potential Effects on Noise). Introduction of these noise sources during construction may increase noise levels at the identified human receptor locations. These noise sources were included in the noise predictive model (Chapter 8, Noise Predictive Study).

<u>Air Quality</u>

The main source of air emissions during the Construction phase is predicted to be through fuel combustion by equipment and machinery, vehicles, and helicopters used for the construction of the Project components (Section 7.4.3, Identifying Key Effects on Air Quality). Although blasting is predicted to create airborne particulates, the main sources of fugitive dust are from use of Brucejack Access Road (Section 7.4.3).

<u>Drinking Water</u>

Most of the activities of the Construction phase will involve the excavation, removal, and consecutive storage of large quantities of rock and soil, and are focused at the mine site area, which will be excluded from the effects assessment since the exposure pathway is not operable (see Section 21.5). More limited activities are expected to occur along the transmission line and access road corridors (Section 13.4, Establishing the Scope of the Effects Assessment for Surface Water Quality).

Erosion and sedimentation into streams and waterbodies may be caused by Brucejack Access Road upgrade activities and installation of the Brucejack Transmission Line and associated towers; this could introduce turbidity into drinking water sources and may increase the concentration of total metals in water (depending on the soil metal concentrations). There may be a potential change of water quality from metal leeching/acid rock drainage (ML/ARD) generated from surface disturbances and subsequent weathering of newly exposed rock (e.g., construction of camp at the Knipple Transfer Area and upgrades to the Brucejack Access Road; Section 13.4, Establishing the Scope of the Effects Assessment for Surface Water Quality). There are also potential changes of water quality through the release of nitrogen as nitrate, nitrite, and ammonia from blasting residues used in construction (e.g., local site roads; Section 13.4). Airborne contaminant loading from disturbing soils, air emission from generators, vehicle tailpipe emissions, and airborne particulates generated from road traffic may also contribute to the contaminant loading in the water.

There are potential changes of water quality through uncontained seepage from septic fields at the Knipple Transfer Area and Tide Staging Area (Section 13.4, Establishing the Scope of the Effects Assessment for Surface Water Quality). Accidental spills during the transport and storage of fuel, chemicals, and explosives may be of special importance to human health due to the potential contamination of drinking water (Section 13.4). Routine Project-related traffic have the potential for introducing oils and diesel fuels into the aquatic environment from spills or leaks, affecting fish (Chapter 15, Assessment of Potential Fish and Fish Habitat Effects), water quality (Chapter 13, Assessment of Potential Surface Water Quality Effects), and human health.

Country Foods

The quality of country foods could be affected by dust deposition on soils and plants, and by potential degradation of water quality from Construction activities and components.

The main sources of fugitive dust are from blasting, from traffic along the Brucejack Access Road, from cut and fill earthworks to create platforms, from quarries, and other disturbances from the handling of waste rock (Section 7.4.3, Identifying Key Effects on Air Quality). Contaminants from fugitive dust or construction activities may result in changes in soil, water, and vegetation metal concentrations and have the potential to alter the quality of country foods.

Construction activities and their potential effects to surface water quality have been described under Drinking Water in the previous section. These potential changes in water quality can also affect human health due to changes in the quality of country foods through the aquatic (fish) and terrestrial (wildlife) food chains.

21.4.3.2 Operation

The Operation phase consists of mining, ore processing, waste management, and transportation activities and will last for 22 years. It is expected to have the highest potential for effects on human health.

Noise

The key potential effects of the Project on noise during the Operation phase are expected to be due to the operation of the Mine Site, Knipple Transfer Area and Bowser Aerodrome, access and mine site area road activities, and aircraft (Section 8.4.3, Identifying Key Potential Effects on Noise). Introduction of these noise sources during Operation may increase noise levels at the identified human receptor locations. These noise sources were included in the noise predictive model (Section 8.5, Predictive Study Methods for Noise).

Air Quality

During the Operation phase, the main sources of air emissions are from fuel combustion by equipment and machinery, and vehicles used for the Operation of the Project. Exhaust gas from equipment tailpipes is also emitted through portals from the underground mine. Fugitive dust emissions from the roads and handling of the waste rock are the main sources of dust during the mining operation.

Drinking Water

Potential effects identified for the Operation phase are similar to those anticipated to occur during Construction. There is potential for degradation of water quality from continued generation of ML/ARD from surface disturbances and subsequent weathering of rock exposed during the construction phase (e.g., upgrades to the Brucejack Access Road; Section 13.4, Establishing the Scope of the Effects Assessment for Surface Water Quality). Airborne contaminant loading, generator and incinerator emissions, vehicle tailpipe emissions and airborne particulates generated from road traffic may also contribute to the contaminant loading in the water.

Potential effects associated with erosion and sedimentation may result predominantly from activities such as road use, upgrading, or maintenance. The transportation of chemicals and petroleum products could result in a spill into streams and waterbodies along the Brucejack Access Road. There are potential changes to water quality through un-captured seepage from septic fields at the Knipple Transfer Area and Tide Staging Area camps (Section 13.4, Establishing the Scope of the Effects Assessment for Surface Water Quality).

Country Foods

The main source of fugitive dust during the Operation phase is from traffic along the Brucejack Access Road (Section 7.4.3, Identifying Key Effects on Air Quality). Contaminants from fugitive dust or construction activities may result in changes in soil, water, and vegetation metal concentrations and alter the quality of country foods, including berries, fish, and wildlife which in turn could affect human health.

Operation activities and their potential effect to water quality have been described under Drinking Water in the previous section. These potential changes in water quality can also affect human health due to changes in the quality of country foods through the aquatic (fish) and terrestrial (wildlife) food chains.

21.4.3.3 Closure and Reclamation

During the Closure phase of the Project, most of the mine site area facilities will be decommissioned, equipment and infrastructure removed, and surfaces reclaimed within a two year period.

Noise

The potential noise effects of the Project during the Closure phase are expected to be due to the closure activities and decommissioning of Bowser Aerodrome, Brucejack Access Road, camps, and other Project infrastructure (Section 8.4.3, Identifying Key Potential Effects on Noise). Introduction of these noise sources during Closure may increase noise levels in comparison to the background noise levels at the identified human receptor locations although the generated noise during Closure is expected to be less than that generated during the Construction and Operation phases.

Air Quality

During the Closure phase, reclamation activities such as use of salvaged material to cover pad surfaces or decommissioning of components may create sources of fugitive dust emissions, while tailpipe emissions from equipment are the main non-fugitive sources. The emissions during the Closure phase are expected to be limited and intermittent compared to the Construction and Operation phases.

Drinking Water

Closure and reclamation activities involving the use of heavy equipment in or around water, for decommissioning of the Project infrastructure (e.g., roads and bridges), may create some potential for water quality effects from surface runoff, siltation, chemical spills, airborne dust, and emissions. This may result in erosion and sedimentation of waterbodies (e.g., sedimentation to streams from road decommissioning) and water quality degradation (e.g., petroleum product spills).

Country Foods

Closure and reclamation activities may create some potential for water quality effects from surface runoff, chemical spills, airborne dust, and emissions, subsequently resulting in changes in the quality of country foods. Fugitive dust containing metals may result in metal deposition on soils and water within the country foods LSA. The metals in soil can be taken up by vegetation and, in addition to metal deposited directly on the surface of vegetation, the metals can enter the food chain when consumed by organism that are collected or harvested as country foods.

21.4.3.4 Post-closure

Noise

No interactions between activities and components of the Project's Post-closure phase and noise were identified, because most activities will have ceased (Table 21.4-1), and therefore no further consideration of noise effects to human health are warranted.

Air Quality

During the Post-closure phase, no significant source of air emissions is expected. There may be minor helicopter emissions during the maintenance of environmental monitoring equipment during travel to monitoring locations; however, the emissions are considered negligible when compared to emissions during the Construction and Operation phases.

Drinking Water

After Closure, potential will remain for ML/ARD and the release of elevated metal concentrations into drinking water sources. These discharges are anticipated to be within legal discharge requirements but may have the potential to affect surface water quality.

Country Foods

After Closure, potential will remain for ML/ARD and the release of elevated metal concentrations into surface water. These metals in water can enter the food chain when consumed by organisms that are harvested as country foods.

21.5 EFFECTS ASSESSMENT AND MITIGATION FOR HUMAN HEALTH

Table 21.5-1 shows the potential key effects between individual Project components and activities and the four sub-components of human health. The goal of identifying potential key effects is to narrow the scope of the effects assessment to those Project interactions that have the greatest potential to cause effects to human health. All of the potential Project interactions identified in Table 24.4-1 are reconsidered in light of other factors such as the relative magnitude of potential effects (e.g., Operation phase potential effects are greater than during the Closure phase) and the location of human receptors (described in Section 24.4.1.3, Summary of Receptor Valued Components Included/Excluded in the Application/EIS).

Table 21.5-1. Ranking Potential Effects on Human Health by Sub-components

Project Components and Physical Activities by Phase	Noise	Air Quality	Drinking Water Quality	Country Foods
Construction Phase				
Activities at existing adit	🟢	🟢	○	○
Air transport of personnel and goods	🟡	🟡	○	🟡
Avalanche control	🟢	🟢	○	○
Chemical and hazardous material storage, management, and handling	○	○	○	○
Construction of back-up diesel power plant	🟡	🟡	🟢	🟡
Construction of Bowser Aerodrome	🟡	🟡	🟢	🟡
Construction of detonator storage area	🟡	🟡	○	🟡
Construction of electrical tie-in to the BC Hydro grid	🟢	🟢	🟢	🟢
Construction of electrical substation at Brucejack Mine Site	🟡	🟡	○	○
Construction of equipment laydown areas	🟡	🟡	🟡	🟡
Construction of helicopter pad	🟡	🟡	○	🟡
Construction of incinerators	🟡	🟡	○	○
Construction of Knipple Transfer Area	🟡	🟡	🟢	🟡
Construction of local site roads	🟡	🟡	○	🟡
Construction of mill building (electrical induction furnace, backfill paste plant, warehouse, mill/concentrator)	🟡	🟡	○	○
Construction of mine portal and ventilation shafts	🟡	🟡	○	○
Construction of Brucejack Operations Camp	🟡	🟡	○	○
Construction of ore conveyer	🟡	🟡	○	○
Construction of tailings pipeline	🟡	🟡	○	○
Construction and decommissioning of Tide Staging Area construction camp	🟡	🟡	🟢	🟡
Construction of truck shop	🟡	🟡	○	○
Construction and use of sewage treatment plant and discharge	🟡	🟡	○	🟡
Construction and use of surface water diversions	🟡	🟡	○	○
Construction of water treatment plant	🟡	🟡	○	○
Development of the underground portal and facilities	🟡	🟡	○	○
Employment and labour	○	○	○	○
Equipment maintenance/machinery and vehicle refuelling/fuel storage and handling	○	○	○	○
Explosives storage and handling	○	○	○	○
Grading of the mine site area	🟡	🟡	○	○
Helicopter use	🟡	🟡	○	🟡
Installation and use of Project lighting	🟢	🟢	○	🟢
Installation of surface and underground crushers	🟢	🟢	○	○
Installation of the transmission line and associated towers	🟢	🟢	🟢	🟢
Machinery and vehicle emissions	🟡	🟡	○	🟡
Potable water treatment and use	○	○	○	○
Pre-production ore stockpile construction	🟡	🟡	○	○

(continued)

Table 21.5-1. Ranking Potential Effects on Human Health by Sub-components (continued)

Project Components and Physical Activities by Phase	Noise	Air Quality	Drinking Water Quality	Country Foods
Construction Phase (cont'd)				
Procurement of goods and services	○	○	○	○
Quarry construction	● (yellow)	● (yellow)	○	○
Solid waste management	● (green)	● (green)	○	● (green)
Transportation of workers and materials	● (yellow)	● (yellow)	○	● (yellow)
Underground water management	○	○	○	○
Upgrade and use of exploration access road	● (yellow)	● (yellow)	● (yellow)	● (yellow)
Use of Granduc Access Road	● (yellow)	● (yellow)	● (green)	● (yellow)
Operation Phase				
Air transport of personnel and goods and use of aerodrome	● (yellow)	● (yellow)	○	● (yellow)
Avalanche control	● (green)	● (green)	○	○
Backfill paste plant	○	○	○	○
Back-up diesel power plant	● (green)	● (green)	○	● (green)
Bowser Aerodrome	○	○	● (green)	● (green)
Brucejack Access Road use and maintenance	● (yellow)	● (yellow)	● (green)	● (yellow)
Brucejack Operations Camp	○	○	○	○
Chemical and hazardous material storage, management, and handling	○	○	○	○
Concentrate storage and handling	● (yellow)	● (yellow)	○	● (yellow)
Contact water management	○	○	○	○
Detonator storage	○	○	○	○
Discharge from Brucejack Lake	○	○	○	○
Electrical induction furnace	● (yellow)	● (yellow)	○	● (yellow)
Electrical substation	○	○	○	○
Employment and labour	○	○	○	○
Equipment laydown areas	○	○	○	○
Equipment maintenance/machine and vehicle refuelling/fuel storage and handling	○	○	○	○
Explosives storage and handling	○	○	○	○
Helicopter pad(s)	○	○	○	○
Helicopter use	● (yellow)	● (yellow)	○	● (yellow)
Knipple Transfer Area	● (yellow)	● (yellow)	● (yellow)	● (yellow)
Machine and vehicle emissions	● (yellow)	● (yellow)	○	● (yellow)
Mill building	● (yellow)	● (yellow)	○	○
Non-contact water management	○	○	● (green)	● (green)
Ore conveyer	● (yellow)	● (yellow)	○	○
Potable water treatment and use	○	○	○	○
Pre-production ore storage	○	○	○	○
Procurement of goods and services	○	○	○	○

(continued)

Table 21.5-1. Ranking Potential Effects on Human Health by Sub-components (continued)

Project Components and Physical Activities by Phase	Noise	Air Quality	Drinking Water Quality	Country Foods
Operation Phase (cont'd)				
Project lighting	○	○	○	○
Quarry operation	● (green)	● (green)	○	○
Sewage treatment and discharge	○	○	○	○
Solid waste management/incinerators	● (green)	● (yellow)	○	● (yellow)
Subaqueous tailings disposal	○	○	○	○
Subaqueous waste rock disposal	○	○	○	○
Surface crushers	● (yellow)	● (yellow)	○	○
Tailings pipeline	○	○	○	○
Truck shop	○	○	○	○
Transmission line operation and maintenance	○	○	● (green)	● (green)
Underground backfill tailings storage	○	○	○	○
Underground backfill waste rock storage	○	○	○	○
Underground crushers	○	● (yellow)	○	○
Underground: drilling, blasting, excavation	● (green)	● (yellow)	○	○
Underground explosives storage	○	○	○	○
Underground mine ventilation	● (yellow)	● (yellow)	○	○
Underground water management	○	○	○	○
Use of mine site haul roads	● (yellow)	● (yellow)	● (green)	● (yellow)
Use of portals	● (green)	● (green)	○	○
Ventilation shafts	○	○	○	○
Warehouse	○	○	○	○
Waste rock transfer pad	○	○	○	○
Water treatment plant	○	○	○	○
Closure Phase				
Air transport of personnel and goods	● (green)	● (green)	○	● (green)
Avalanche control	● (green)	● (green)	○	○
Chemical and hazardous material storage, management, and handling	○	○	○	● (green)
Closure of mine portals	○	○	○	○
Closure of quarry	● (green)	● (green)	○	○
Closure of subaqueous tailings and waste rock storage (Brucejack Lake)	○	○	○	○
Decommissioning of Bowser Aerodrome	● (green)	● (green)	● (green)	● (green)
Decommissioning of back-up diesel power plant	● (green)	● (green)	○	● (green)
Decommissioning of Brucejack Access Road	● (green)	● (green)	● (yellow)	● (yellow)
Decommissioning of camps	● (green)	● (green)	● (green)	● (green)
Decommissioning of diversion channels	● (green)	● (green)	○	○
Decommissioning of equipment laydown	● (green)	● (green)	○	● (green)

(continued)

Table 21.5-1. Ranking Potential Effects on Human Health by Sub-components (completed)

Project Components and Physical Activities by Phase	Noise	Air Quality	Drinking Water Quality	Country Foods
Closure Phase (cont'd)				
Decommissioning of fuel storage tanks	🟢	🟢	🟢	🟢
Decommissioning of helicopter pad(s)	🟢	🟢	○	🟢
Decommissioning of incinerators	🟢	🟢	○	🟢
Decommissioning of local site roads	🟢	🟢	🟡	🟡
Decommissioning of mill building	🟢	🟢	○	○
Decommissioning of mill/concentrators	🟢	🟢	○	○
Decommissioning of ore conveyer	🟢	🟢	○	○
Decommissioning of Project lighting	🟢	🟢	○	🟢
Decommissioning of sewage treatment plant and discharge	🟢	🟢	○	🟢
Decommissioning of surface crushers	🟢	🟢	○	○
Decommissioning of surface explosives storage	🟢	🟢	○	○
Decommissioning of tailings pipeline	🟢	🟢	○	○
Decommissioning of transmission line and ancillary structures	🟢	🟢	🟢	🟢
Decommissioning of underground crushers	🟢	🟢	○	○
Decommissioning of waste rock transfer pad	🟢	🟢	○	○
Decommissioning of water diversion channels	🟢	🟢	○	○
Decommissioning of water treatment plant	🟢	🟢	○	○
Employment and labour	○	○	○	○
Helicopter use	🟢	🟢	○	🟢
Machine and vehicle emissions	🟢	🟢	🟢	🟢
Procurement of goods and services	○	○	○	○
Removal or treatment of contaminated soils	🟢	🟢	🟡	🟡
Solid waste management	🟢	🟢	○	🟢
Transportation of workers and materials (Mine Site and access roads)	🟢	🟢	○	🟢
Post-closure Phase				
Discharge from Brucejack Lake	○	○	○	○
Employment and labour	○	○	○	○
Environmental monitoring	○	○	○	○
Procurement of goods and services	○	○	○	○
Subaqueous tailings and waste rock storage	○	○	○	○
Underground mine	○	○	○	○

○ = *No interaction anticipated, no further consideration warranted.*
🟢 = *Negligible to minor adverse effect expected; implementation of best practices, standard mitigation and management measures; no monitoring required, no further consideration warranted.*
🟡 = *Potential moderate adverse effect requiring unique active management/monitoring/mitigation; warrants further consideration.*
🔴 = *Key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.*

Potential human health effects due to noise and air quality are adopted from Tables 8.5-1 and 7.5-1. All of the components or activities that have been ranked as having potentially moderate adverse effects (yellow) or as having key interactions resulting in potentially significant major adverse effects (red), i.e., corresponding with items that require further consideration, were included as inputs into the noise or air quality predictive models.

Potential human health effects due to drinking water are adopted from Table 13.5-1 of Chapter 13, Assessment of Potential Surface Water Quality Effects, based on the highest potential effects due to discharges, ML/ARD, nutrient loading from blasting residues, atmospheric deposition, groundwater interactions and seepage, and spills within the drinking water LSA. However, given that there are no human receptors for drinking water (from surface sources) in the mine site area during the four phases of the Project, the components or activities that could affect surface water quality in this area have been excluded from the drinking water effects assessment (see Section 21.4.2.3 for further details).

In Table 21.5-1, potential key effects to human health due to country foods are based on the ratings for air quality and drinking water quality. This is because country foods quality may be affected by contaminants from air (i.e., dust deposition) and water. The rating with the highest potential for effects from either air quality or water quality was used (i.e., red > yellow > green > no linkage) for activities or components outside of the Brucejack Mine Site. For components within the mine site area, the ratings for air quality were used since there is potential for fugitive dust to be transferred via the air from within the mine site area to areas outside of it.

The following sections describe the key adverse effects that human receptors may experience as a result of noise, changes in air quality, drinking water quality, and country foods quality in further detail. Mitigation measures to avoid, control, and mitigate these potential human health effects are also described.

21.5.1 Key Effects on Human Health due to Noise

21.5.1.1 Identifying Potential Key Health Effects due to Noise

Noise can directly affect human health through psychological and physiological effects. There are three main ways that noise can adversely affect humans: through increased annoyance, sleep disturbance, or activity interference such as a reduction in speech intelligibility. Sleep disturbance includes difficulty falling asleep, awakenings, curtailed sleep duration, alterations of sleep stages or depth, and increased body movements during sleep. The measures of the potential effects of noise covered in this human health assessment are those recommended by Health Canada (2010e).

Health Canada (2010e) recommends evaluating increases in predicted noise levels over baseline conditions for the daytime (L_d) and nighttime (L_n) equivalent noise levels, as well as a whole day equivalent noise level descriptor (L_{dn}). Impulsive and tonal characteristics of source noise can increase potential adverse effects and should also be accounted for. People are often exposed to sounds from more than one source and combinations of health effects are common, such as interference with speech in the day and sleep disturbance at night, thus the total adverse health load of noise must be considered over 24 hours (WHO 1999).

The Project components and activities that can affect human health due to noise were described in the previous sections for the Construction, Operation, Closure, and Post-closure phases (Section 21.4.3). The main sources of noise are from blasting during Construction, generators, equipment and machinery, and vehicles. Key Project activities and components that may emit noise are listed in Table 21.5-1. The human health effects assessment from noise focuses on the Construction and

Operation phases of the Project when noise will occur predominately. Project effects from noise during Closure and Post-closure are expected to be limited, intermittent, and less significant than those during Construction and Operation and will not be considered further in this effects assessment.

Noise is generally defined as undesirable sound. Therefore, it is intrinsically linked to receptors, which are the people who may experience the undesirable sound. Receptors for the human health VC are people who reside or spend time at or near the Project site, in particular off-shift employees; visitors at the hunting and trapping cabins; and transient land users who hunt, trap, fish, or collect berries and other plants in the LSA. Except from the residents of the Skii km Lax Ha Lodge, there are no permanent communities and residents near the Project site. On-shift employees were not selected as receptors because worker health will be addressed by health and safety policies that will be in place during Construction and Operation. Human receptor locations for noise are illustrated on Figure 21.4-1.

Chapter 8, Noise Predictive Study, predicts standard noise metrics that are used to evaluate the potential for human health effects from noise. Table 21.5-2 reproduces those metrics from Chapter 8 that are included for human health. All of these guidelines are for non-workers human receptor locations except for sleep disturbance, where worker camps have been assessed with the assumption that windows would be permanently closed.

Table 21.5-2. Project Noise Guidelines

Project Metric	Description	Limit
	Human Receptors (off site)	
L_d	Daytime noise level for assessing speech interference	55 dBA
L_n	Nighttime noise level for assessing sleep disturbance outside the Project boundary	30 dBA
	Noise level for assessing sleep disturbance inside the Project boundary (i.e., windows closed) [1]	57 dBA [2]
L_{AE}	Noise level for assessing sleep disturbance outside the Project boundary	90 dBA
	Noise levels for assessing sleep disturbance inside the Project boundary (i.e., windows closed)	120 dBA
L_{dn}	Assessing the likelihood of complaints	62 dBA
	Project noise mitigation required due to excessive annoyance	75 dBA
Δ %HA	Increase in % HA metric before and after Project initiation	6.5%
L_{peak}	Peak sound pressure level for assessing human sensitivity to impulsive blasting noise	120 dB
LAF_{max}	Sleep disturbance level not to be exceeded more than 10-15 times per night outside the Project boundary	45 dBA
	Sleep disturbance level not to be exceeded more than 10-15 times per night inside the Project boundary	72 dBA [2]

[1] Project construction and operations are assumed to occur 24 hours a day and therefore workers may be sleeping during the day. To account for this, sleep disturbance limits for Project worker's accommodation locations are also compared with daytime (Ld) noise levels.
[2] This is an external noise level and assumes that internal noise levels are in the order of 27 dBA lower with closed windows (which would be the expected normality in this climate). In addition, WHO (1999) recommends that internal sound levels should not exceed approximately 45 dBA more than 10-15 times per night.

Each metric and its relevance as a human health indicator is described in detail in Appendix 8-A, Brucejack Gold Mine Project: 2012 Noise Baseline Report.

Sleep Disturbance

Uninterrupted sleep is required for normal physiological and mental functioning; however, environmental noise commonly causes sleep disturbance (WHO 1999). The primary effects of sleep disturbance are: difficulty falling asleep; awakenings and alterations of sleep stages or depth; increased blood pressure, heart rate and finger pulse amplitude; vasoconstriction; changes in respiration; cardiac arrhythmia; and increased body movements (WHO 1999). There are also secondary/after-effects of sleep disturbance which occur the following morning or day(s) including: reduced perceived sleep quality; increased fatigue; depressed mood or well-being; and decreased performance (WHO 1999). A good night's sleep requires indoor nighttime equivalent sound levels (L_n, L_{Aeq}, 22:00 to 07:00 hours) of continuous background noise below 30 dBA and individual noise events exceeding 45 dBA (L_{AFmax}) should not occur more than 10 to 15 times per night (WHO 1999). Sensitivity to noise disturbance varies considerably between individuals, and this guideline is taken to apply to the whole population, so the vast majority of the population would not suffer sleep disturbance above guidelines. Studies around airports have shown that there is little effect on the general population sleeping in their homes from aircraft noise levels below approximately L_{AE} 90 dB (approximately L_{Amax} 80 dB). Vehicle pass-by can contribute to sleep disturbance and therefore was included as a source in the assessment.

As the Project is expected to operate 24-hours a day on two 12-hour shifts, off-duty workers may be expected to sleep during the day. As a conservative assumption, the nighttime noise (L_n) guideline for sleep disturbance was used for both nighttime and daytime for the worker camps with the assumption that windows would be permanently closed.

Sound is attenuated as it is transmitted indoors, and the amount of reduction is most dependent on whether windows are open or not. The US EPA (1974) suggests assuming an outdoor-to-indoor noise level reduction of 15 dBA if windows are slightly open and 27 dBA if windows are closed. The actual sound reduction depends on construction materials, geometry, and other design factors of the room and building.

Interference with Speech Communication

Speech interference occurs when noise levels are high enough that the ability to understand speech is impaired (WHO 1999). Normal speech has a sound pressure level of approximately 50 dBA, and indoor noise with sound levels of 40 dBA or more interferes with speech comprehension (US EPA 1974). Outdoors, background noise levels should be kept below 55 dBA for continuous noise (US EPA 1974). Vehicle pass-by can contribute to speech interference and therefore was included as a source in the assessment.

Complaints

A partial indication of a problem with noise can arise from noise complaints; however, the individual has to be willing and/or able to make a complaint and the complainant generally has some expectation that the complaint will cause a reduction in noise (Michaud 2008). When the normalized 24-hour A-weighted equivalent sound level (L_{dn}) reaches 62 dBA, complaints become widespread and complaints should be expected if the Project L_{dn} is greater than 75 dBA (US EPA 1974).

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

The %HA is a reliable and widely accepted indicator of human health effects due to environmental noise and is calculated using the adjusted L_{dn} (or Rating Level) pre- and post-Project (Michaud 2008; Health Canada 2010e). Much of the data available on the health and welfare effects of noise are expressed in terms of %HA, yet this is a description of a subjective human reaction to "noise interference" (US EPA 1974). While the %HA can be statistically quantified, it is not a legal concept and it is the actual interference with activity that is important (US EPA 1974). However, the change in %HA within an average community in reaction to sound levels has been reported as uniform (Michaud 2008). Health Canada (2010e) advises that when there is a change in the %HA at any given receptor greater than 6.5%, or if the Project L_{dn} exceeds 75 dBA, then noise mitigation measures should be considered.

Adjustments to sound levels are suggested to account for more annoying sound characteristics such as the presence of tonal or impulsive noise (US EPA 1974). The penalty for tones and regular impulsive sound is a +5 dBA adjustment to the predicted, calculated, or measured sound pressure level (US EPA 1974). The penalty for highly impulsive noise is a +12 dBA adjustment. The penalties for high-energy impulsive sound (e.g., blasting) and sound with strong low frequency content are variable and calculated according to the American National Standards Institute (ANSI) standard S12.9-2005/Part 4 (ANSI 2005). The penalty for sound with strong low frequency content should only be considered if the C-weighted sound pressure level is more than 10 dB higher than the A-weighted sound pressure level.

Summary

Based on the previous identification of potential effects, six guidelines have been chosen to rate potential effects (sleep disturbance, interference with speech communication, complaints, and high annoyance). These criteria are relevant for non-worker human receptor locations and were included in the effects assessment for non-workers. However, the Project is expected to operate 24-hours a day on two 12-hour shifts; therefore, off-duty workers are expected to sleep during the day. As a conservative assumption, the nighttime noise (L_n) guideline for sleep disturbance was used for both nighttime and daytime for the worker camps with the assumption that windows would be permanently closed. Human health effects are likely to occur if any of the noise metrics exceed the relevant guidelines indicated in Table 21.5-3 at the worker camps or non-worker receptor locations.

Table 21.5-3. Selected Noise Guidelines for Worker and Non-worker Receptor Locations

Project Metric	Worker Camps	Non-worker Receptor Location
L_d	57	55
L_n	57	45[1]
L_{dn}	75	75
L_{AFmax}	72	72
L_{peak}	120	120
Δ %HA	6.5	6.5

Ld: day time noise level for assessing speech interference.
Ln: nighttime noise level for assessing sleep disturbance.
Ldn: Assessing the likelihood of complaints.
Lmax: sleep disturbance level not to be exceeded more than 10-15 times per night inside the project boundary.
L_{peak}: peak sound pressure level for assessing human sensitivity to impulsive blasting noise.
%HA: increase in % HA metric before and after Project initiation.
[1] Ln for non-workers assumes that people sleeping indoors might have windows open. This indoor reduction was not applied for day time speech interference since people are not restricted to indoors.

No nighttime blasting or aircraft noise is expected; however, the maximum nighttime sound level (L_{AFmax}) has been included as off-duty workers are expected to sleep in the camps during the day.

21.5.1.2 Mitigation Measures for Noise

There are three main mitigation strategies for noise control: controlling noise at the source, controlling the noise pathway, and controlling noise at the receptor. These noise mitigation strategies should follow a hierarchy of control, with source control always the preferred option where reasonable and feasible, and control at the receptor the least favourable option.

A Noise Management Plan (Section 29.11) has been developed to provide measures to control the noise sources (i.e., to reduce the overall noise from the Project). Mitigation measures for noise are also described in Chapter 8, Noise Predictive Study.

The following mitigation methods will be implemented:

- considering noise rating when selecting equipment;
- adequately maintaining equipment to minimize noise, including lubrication and replacement of worn parts, especially exhaust systems;
- optimizing the operation of equipment to minimize noise, e.g., through use of natural screens such as buildings, locating doors away from noise sources and facing away from relevant receptors, minimizing the need for mobile equipment to use their backup alarms;
- optimizing site procedures to minimize noise impacts, e.g., keeping doors closed;
- conducting loud procedures indoors;
- turning off equipment when not in use and avoiding unnecessary idling of motors;
- fitting all diesel-powered vehicle with mufflers meeting manufacturers' recommendations for optimal attenuation, and maintaining these silences in effective working conditions;
- avoiding surface blasting configurations that could result in more than seven holes detonating simultaneously;
- ensuring that blast holes are stemmed to be at least 6 m;
- ensuring that all equipment located indoors does not exceed an interior reverberant level of 85 dBA, or a level specified by occupational noise limits; and
- developing and maintaining a complaint procedure and register.

In addition, monitoring will be conducted as per regulations and to address complaints should they occur (Section 8.7, Mitigation Measures for Noise).

Effects on human health due noise associated with Project activities are considered to be mitigated by the proposed management strategies summarized above. Despite active management and mitigation, potential residual effects on human health due to noise may occur. These are discussed in detail in Section 21.6.1.

21.5.2 Key Effects on Human Health due to Air Quality

21.5.2.1 Identifying Potential Key Health Effects due to Air Quality

This section describes the human receptors, exposure pathways, and potential key effects to human health from Project-related changes in air quality.

The key effects on human health due to 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 contaminant, the degree of exposure, 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 2004). Although everyone is at risk from the health effects of air contaminants, certain individuals are more susceptible. Sensitive individuals who are more susceptible to respiratory contaminants 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).

The Project components and activities that can affect human health through a deterioration of air quality were described in the previous sections for the Construction, Operation, Closure, and Post-closure phases (Section 21.4.3). The human health effects assessment from changes in air quality focuses on the Construction and Operation phases of the Project when the majority of emissions will occur. Project effects on air quality during the Closure and Post-closure phases are expected to be limited, intermittent, and less significant than those during the Construction and Operation phases. Thus, the Closure and Post-closure phases will not be considered further in this assessment.

Human receptors for the air quality human health assessment are people that reside in or temporarily occupy the LSA, such as off-duty workers; people visiting the hunting and trapping cabins; and transient or recreational land users who may fish, hunt, or collect berries and other plants in the Project area. With an exception of the Skii km Lax Ha Lodge residents, there are no permanent communities and residents near the Project site. On-duty employees were not selected as potential receptors because worker health will be addressed by health and safety policies that will be in place during Construction and Operation. Human receptor locations for air quality that were included in the assessment are illustrated on Figure 21.4-2.

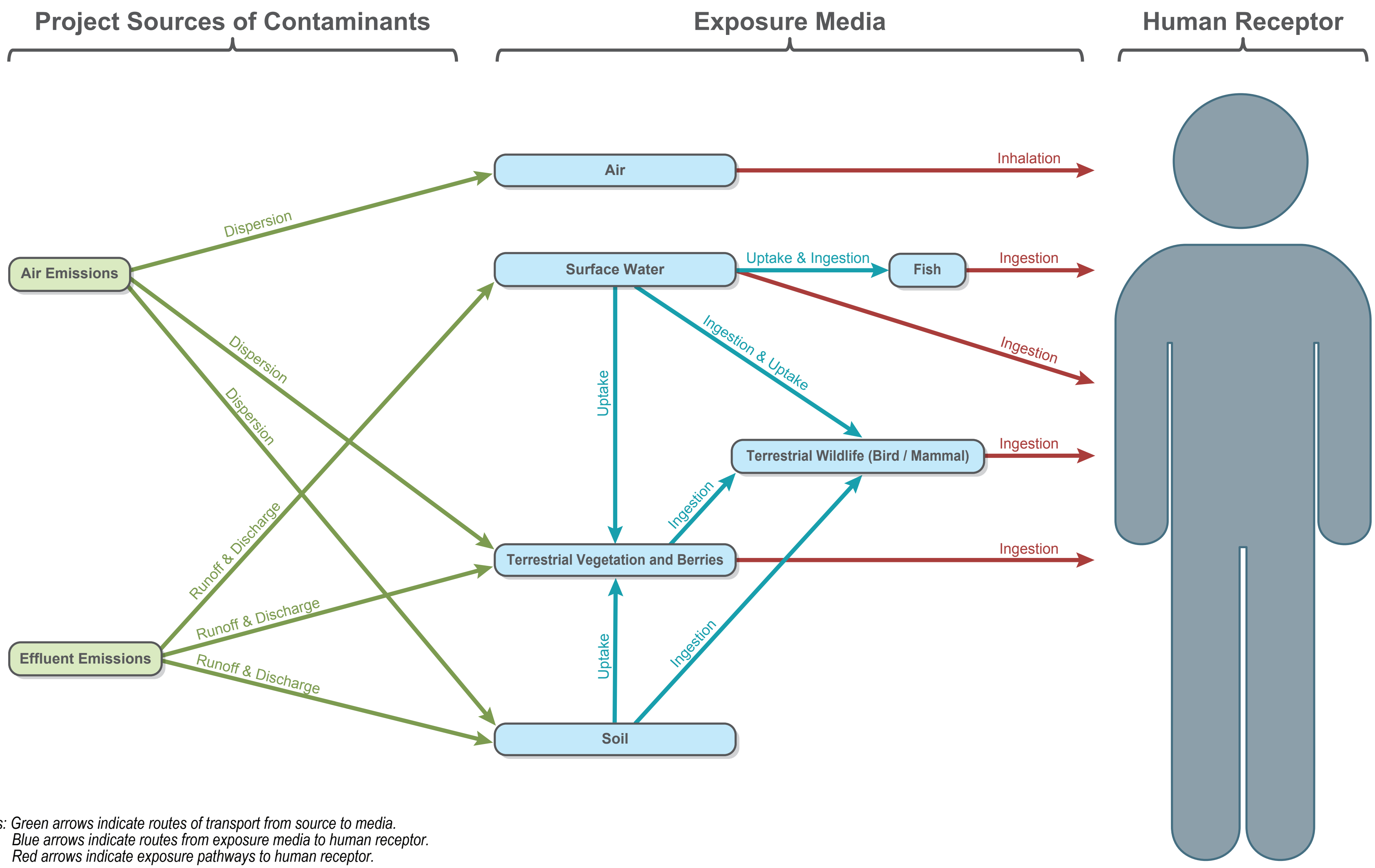
Since the Project is in a remote location, people most susceptible to air contaminants such as children and the elderly are unlikely to be in the vicinity of fugitive dust and other potential air emissions from the Project. Consequently, health effects from the exposure to air pollution will be assessed for individuals that are present near the Project sites during Construction and Operation, who are adults with the sensitivity to air pollution of an average, normal population.

Direct exposure pathways exist from the sources of air emissions (such as fuel combustion exhaust from generators, equipment and machinery, vehicles, and helicopters; dust from blasting and from disturbance of the access road; and other disturbances from ore and waste rock handling) to human receptors through the inhalation pathway (Figure 21.5.1).

Figure 21.5-1 is a simplified diagram of the pathways by which human receptors may potentially be exposed to Project-related emissions containing contaminants that may be released to the atmospheric, aquatic, and terrestrial environments. The conceptual model guides the remainder of the human health risk assessment (HHRA) where COPCs are selected, screened for potential to cause adverse effects in receptors, and the risk to human health is determined.

Figure 21.5-1

Conceptual Model for Potential Human Receptor Exposure to Contaminants for the Brucejack Gold Mine Project



Notes: Green arrows indicate routes of transport from source to media.
Blue arrows indicate routes from exposure media to human receptor.
Red arrows indicate exposure pathways to human receptor.

The following is a list of the air pollutants (also called criteria air contaminants, or CACs) that were identified in the AIR (BC EAO 2014) as indicators, which were modelled for the Construction and Operation phases of the Project (Chapter 7, Air Quality Predictive Study), and their potential human health effects at elevated concentrations:

- Nitrogen oxides (NO_x): NO_2 is usually formed near roadways and vehicles and constitutes a large portion of nitrogen oxides. Exposure to elevated levels can decrease lung function and lung function growth in children, irritate the respiratory system, and make breathing difficult, especially in people with pre-existing conditions such as asthma and bronchitis. Health Canada (2013) indicates that exposure to NO_2 may result in adverse health effects including "irritation of the lungs, decreased in lung function, and increase susceptibility to allergens for people with asthma;"
- 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 particulate matter: Particulate matter can be generated from burning of fossil fuels for heating, transportation, and the generation of electricity, motor vehicles travelling on unpaved site roads during the ice-free season, moving and crushing of rock and ore, and construction and blasting activities. Fine particles ($PM_{2.5}$ and PM_{10}) can affect human health as they can travel into and lodge themselves deeply in the lungs. They may cause coughing, breathing difficulties, reduced lung function, an increased use of asthma medication, irritation of the eyes and nose, and can cause lung cancer. While PM_{10} is produced primarily by mechanical processes (e.g., construction activities, blasting, road dust re-suspension, and wind), $PM_{2.5}$ originates primary from combustion sources. Epidemiological and toxicological studies have shown that 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). However, PM_{10} can travel into and lodge themselves deep in the lungs posing a health risk, particularly in susceptible and sensitive subpopulations. $PM_{2.5}$ and PM_{10} are generally thought to be of greater concern to human health than larger particles, such as total suspended particles (TSP). When these larger particles are inhaled, over 99% of them are either exhaled or trapped in the upper areas of the respiratory system and expelled. However, they can cause irritation of the bronchial system and lungs. $PM_{2.5}$ is recognized as the fraction of the PM with the greatest effects on human health. Potential effects associated with inhaling $PM_{2.5}$ include lung inflammation and increasing response to an inhaled allergen, acute respiratory illness in children, and lung cancer. 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 2012a); 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.

The potential health effects listed above represent the most common direct health effects of the CACs and are listed to provide a rationale for their inclusion in the health effects assessment. Indirect effects from air pollution generally include restricted activity days, lost work days, unscheduled hospital admissions, and an increase in mortality. These indirect effects can be a result of air pollution-related illnesses.

Other indirect exposure pathways for air emissions include the deposition of dust on water, soil, and plants, which can affect the quality of water and the quality of country foods. Animals and people may ingest water that is enriched with suspended particulates to which metals can attach.

Among the CACs, only $PM_{2.5}$ is recognized as a carcinogen. 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 exposure. The WHO (2013) also recognizes the carcinogenic properties of particulate matter. However, the US EPA's risk information system (IRIS) 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 epidemiologic studies. In the absence of an inhalation slope factor, calculation of ILCR is not possible; therefore only potential non-carcinogen effects of $PM_{2.5}$ were assessed.

21.5.2.2 Mitigation Measures for Air Quality

Mitigation measures for air quality are covered in Chapter 7, Air Quality Predictive Study, of the Application/EIS. Mitigation to reduce effects to human health from the inhalation of air contaminants relies on mitigation measures that reduce effects to air quality. The following provides a list of main mitigation measures for air quality:

- underground mining process;
- maintenance and regular inspection of equipment and vehicles used for the project;
- watering the unpaved access roads and achieving at least a 2% moisture ratio, resulting in reduction of fugitive dust by 75%;
- installation of two baghouses, one underground and one on surface, with multiple dust pickup points along the crushing circuit to reduce fugitive dust emissions;
- installation of a scrubber in the gold room to reduce SO_2, and particulate emissions;
- using add-ons as cabin heaters to reduce idling;
- optimizing driving speed to reduce fuel usage and fugitive road dust; and
- minimizing drop distance of material into the surge bin, stockpiles, or between conveyor belts.

An Air Quality Management Plan (Section 29.2) has been developed to detail mitigation and management measures.

Effects on human health due to air quality changes because of Project activities are considered to be mitigated by the proposed management strategies summarized above. Despite active management and mitigation, potential human health residual effects due to air quality may occur. These are discussed in detail in Section 21.6.2.

21.5.3 Key Effects on Human Health due to Drinking Water Quality

21.5.3.1 Identifying Potential Key Health Effects due to Drinking Water Quality

The purpose of the drinking water effects assessment is to evaluate the potential for Project activities to affect human health from the ingestion of water (Figure 21.5-1). The rationale for this evaluation is that First Nations, Nisga'a, and other public users may access the drinking water LSA for hunting, trapping, and gathering and may ingest untreated surface water during these activities. People may stay at the hunting and trapping cabins and camp site at or near the Bowser River, and at the Skii km Lax Ha Lodge near the proposed Bowser Aerodrome. Nisga'a have the right to reasonable access to and onto Crown lands that are outside Nisga'a lands, including streams and highways, to allow for the exercise of Nisga'a rights and interests.

Health Canada recommends that water collected from surface waterbodies always be treated before being used for drinking (Health Canada 2008), because surface water can contain naturally occurring bacteria, viruses, and protozoa. However, land users may have limited access to water purification systems and may consume un-treated water. Generally, personal water purification systems are not designed to treat metals or other chemicals. Consumption of water and any potential contaminants, such as total and dissolved metals may have potential negative effects to human health.

Metals occur naturally in surface waters due to local physical and geological processes, and their concentrations could potentially change as a result of Project activities due to deposition of dust containing metals, effluent discharge containing metals, or accidental spillage of concentrate. In addition to metals from dust deposition, there is the risk of spillage of process reagents and fuels during transport along the Brucejack Access Road including on the Knipple Glacier.

Drinking water may be affected during all phases of the Project from the release of metals or the accidental release of process chemicals and fuel. Below is a brief description of potential health effects to humans due to ingestion of metals, process chemicals, and fuel.

Toxicity can result in a variety of health effects depending on the individual contaminant, and effects may range from carcinogenic to non-carcinogenic (e.g., changes in physiological functions or systems). Many metals may lead to toxicity if high enough exposures are achieved. Even essential metals can have adverse effects if consumed in excess amounts. Metals can disturb biochemical processes and normal body functions and involve many body organ systems such as neurological, cardiovascular, immunological, hematological, gastrointestinal, and musculoskeletal systems.

Potential human health effects from the ingestion of surface water with elevated total and dissolved metal concentrations from dust deposition, leaching, or with contamination from accidentally spilled process reagents or fuels depend on a number of factors, such as:

- the concentration and toxicity of the contaminant;
- speciation of the metal;
- bioavailabilty;
- whether the body is able to efficiently eliminate the contaminant;
- whether the contaminant can bioaccumulate;
- the amount of water that is consumed (a function of both time and quantity), and
- the period of time that a land user spends in the area.

Ingestion of diluted process reagents and fuels downstream of accidental spills may cause irritation of the digestive system and suppression of the central nervous system (e.g., headache, dizziness, nausea). However, conditions that cause harmful effects are unlikely to be present. No carcinogenic effects are expected for any of the anticipated process reagents (Chapter 5, Project Description, and Section 21.4.3).

The level of disturbance with respect to exposing new rock will be low for the transmission line as no blasting is anticipated and BMPs will implemented to minimize land disturbance and preserve stream bank integrity (see Section 13.5.4, Mitigation Measures: Off-site Areas). Thus, the potential for ML/ARD effects along the transmission line is considered negligible during all Project phases and potential effects will not be considered further.

Infrastructure built with non-PAG rock is assumed to not contribute poor quality water to the freshwater environment. Samples taken from Bowser Aerodrome and the majority of samples from the access road are characterized as non-PAG and thus assumed to not contribute to poor quality water to the freshwater environment. Shale material poses the greatest risk to ARD as over half of the samples show some potential for ML/ARD. However, level of disturbance with respect to exposing new rock will be relatively low from the access road upgrades (Chapter 5, Project Description). Thus, potential effects of ML/ARD for the road is considered low for all during all Project phases although they may occur; these are further assessed in Section 13.6, Residual Effects on Surface Water Quality.

Potential Project-specific sources of sedimentation and erosion within the Bowser River watershed, Knipple Lake, and Wildfire Creek/Scott/Todedada watersheds includes construction and installation of Brucejack Transmission Line, rehabilitation of Bowser Aerodrome, construction of the Knipple Transfer Area, and upgrade of Brucejack Access Road. Recovery from sedimentation will be more rapid in high-velocity streams relative to wetlands or lakes. Many waterbodies within the LSA and RSA have naturally high sediment loads due to glacial origins, including Knipple Lake, the Bowser River and Bowser Lake (Chapter 13, Assessment of Potential Surface Water Quality Effects, Table 13.3-5). Further, watercourses in the LSA within Bowser River watershed, Knipple Lake, and Wildfire Creek/Scott/Todedada watersheds exhibit substantial seasonal variability (mean high flow: 44.8 mg/L to 318 mg/L; mean low flow: 1.5 mg/L to 40.0 mg/L) and sedimentation erosion events, should they occur, would not be expected to be outside this large natural range of variability.

Sewage treatment plant effluent can be a potential source for bacterial contamination, especially in conditions of high suspended solids (turbidity), and nutrients. Some bacteria can cause intestinal upsets, such as abdominal pain and diarrhea. Nutrients, such as ammonia and nitrate, can be harmful to infants at higher concentrations and prolonged ingestion; however, infants would not be expected to be present for long periods of time in the LSA or RSA. Conditions that could cause harmful effects are unlikely to be present, particularly if surface water is treated for microbiological contamination as recommended by Health Canada prior to drinking (Health Canada 2008).

21.5.3.2 Mitigation Measures for Drinking Water Quality

Mitigation to reduce effects to human health from 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. Mitigation measures for surface water quality were discussed in Sections 13.5.2, Mine Site Area, and 13.5.4, Off-site Areas, as well as Section 29.14, Spill Prevention and Response Plan, of this Application/EIS. Some of the proposed mitigation measures are:

- Erosion and sediment control Best Management Practices (BMPs) will be implemented. These practices include isolation of work areas from surface waters and proper use of control practices when required, such as sediment traps, geotextile cloth, sediment fences, gravel berms, and straw bales to mitigate and control erosion and sediment.
- Minimization of all clearing and grubbing dimensions during construction activities.
- Controlling and directing runoff from disturbed areas by grading slopes and ditching.
- Minimizing runoff energy by limiting the length and steepness of bare, exposed slopes and by applying appropriate surface drainage techniques (e.g., ditch blocks, ditch surface lining, rip-rap).
- Stabilizing water diversion channels and ditches and protecting channel banks with willow, rocks, gabions, or fibre mats, where appropriate.
- Protecting disturbed areas from water erosion, and collecting surface water from disturbed areas and treating it to meet discharge standards prior to release.

- Following earthworks, exposed slopes should be re-vegetated as soon as feasibly possible. Temporary cover may be used if re-vegetation is not immediately possible, if required.
- Re-establish vegetation cover during site restoration and reclamation, as detailed in Chapter 11, Terrain and Soils Predictive Study, and Chapter 30, Closure and Reclamation.
- Regular inspection and maintenance of all water management and sediment control structures. Maintenance procedures will include prompt attention to potential erosion sites, ditch or culvert failure, ditch or culvert blockage, or outside seepage as such problems could lead to structure failure and sediment transport. Maintenance will also include routine removal of accumulated sediment from ditches and retention structures.
- Along the full length of the transmission line, construction activities (i.e., equipment access, construction of transmission structures, and conductor stringing) will be conducted in a manner that minimizes riparian vegetation effects and maintains stream bank integrity.
- Cross-drain culverts will not discharge directly into streams. Unless they are in use as part of a stream crossing, culverts will discharge onto rock or another stable energy dissipater and then diffuse flow will be directed away from site.
- Catch basins will be excavated around the inlet of culverts to trap the coarse material that is transported in drainage ditches.
- Mitigation and management measures for ML/ARD will also include the re-establishment of vegetation cover during site restoration and reclamation.
- Explosives transportation, storage, and use will be consistent with the requirements of the federal *Explosives Act* (1985), *Transportation of Dangerous Goods Act* (1992), and the provincial *Health, Safety and Reclamation Code for Mines in British Columbia* (BC MEMPR 2008).
- The Hazardous Materials Management Plan, to be developed prior to Construction, will guide the safe transportation, storage, use and disposal of explosives at the site throughout the life of the Project.
- Project activities requiring the use of explosives in or near water bodies will adhere to the *Guidelines for Use of Explosives In or Near Canadian Fisheries* (Wright and Hopky 1998) to mitigate effects of blasting surface water quality.
- The Spill Prevention and Emergency Response Plan (Section 29.14) will implement documented operation procedures to avoid spills during explosives handling, which will minimize nitrogen loadings.
- Watering the unpaved access roads and achieving at least a 2% moisture ratio, resulting in reduction of fugitive dust by 75%.
- Sewage management for the Project will be consistent with the requirements of the *Environmental Management Act* (Staven et al. 2003) and its *Municipal Wastewater Regulation* (BC Reg. 87/2012).

There is generally minimal risk of effects to surface water quality due to the limited extent of Project activities in the Brucejack Access Road and transmission line areas. Best management practices, planned mitigation and management measures, combined with the small extent and duration of surface disturbances and blasting activities are predicted to fully avoid and mitigate potential effects to surface water quality.

However, to be conservative, potential effects to surface water quality cannot be completely ruled out with certainty; there is potential for a change in surface water quality due to an aggregated/combined effects of the pathways outlined above (e.g., sedimentation/erosion, ML/ARD, etc.). Therefore, residual effects to human health due to changes in drinking water quality are discussed in Section 21.6.3.

21.5.4 Key Effects on Human Health due to Country Foods Quality

21.5.4.1 Identifying Potential Key Health Effects due to Changes in 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 incidental consumption of contaminants in country foods. Since the proposed Project is a gold mine located in a highly mineralized area, the emphasis in the assessment is on metals since these are the most likely contaminants to be present in the aquatic or terrestrial environment at levels high enough to have the potential to affect human health (via country foods consumption) in the LSA or RSA. The rationale for this evaluation was that people could use the LSA for obtaining food from hunting, trapping, fishing, and berry picking. People may stay at the hunting and trapping cabins and camp site at or near Bowser River, and at the Skii km Lax Ha Lodge near the proposed Bowser Aerodrome.

The health of people obtaining country foods by hunting; trapping; collecting berries, mushrooms, and medicinal plants from the country foods LSA; and by fishing inside and downstream of the county foods LSA, can be affected by the quality of country foods they consume. There are no permanent residents living in the country foods LSA; however, limited seasonal and temporary use of the area does occur (described in Chapter 19, Assessment of Potential Economic Effects, Section 19.3, Baseline Characterization; Appendix A of Appendix 21-A; Chapter 22, Assessment of Potential Heritage Effects, Section 22.3.1, Regional Overview; Chapter 23, Assessment of Potential Navigation Effects, Section 23.3.1, Regional Overview; Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects, Section 24.3, Baseline Characterization; Section 25.3.4, Future Aboriginal Use of Lands and Resources; Section 26.2, Aboriginal Context and Overview; and Section 27.5, Summary of Nisga'a Consultation Activities). Aboriginal hunters, trappers, and gatherers are likely the most frequent users of the country foods LSA and are therefore the focus of the assessment (Health Canada 2010d).

An assessment of the quantity and accessibility of country foods is not provided, because the assessment focuses on country foods quality and potential impacts to human health due to incidental intake of contaminants present in the country foods. An assessment of potential loss and degradation of ecosystems is provided in Chapter 16, Assessment of Potential Terrestrial Ecology Effects. Loss of wildlife habitat is assessed in Chapter 18, Assessment of Potential Wildlife Effects.

Because country foods can take up metals from environmental media (i.e., water, soil, and vegetation), the quality of the foods is directly influenced by concentrations of contaminants in the media. To determine the potential effects to human health from consumption of country foods, predicted changes to metal concentrations in the environmental media were considered. If predicted metal concentrations in the environmental media were not significantly changed relative to baseline conditions due to Project activities, then there would be no predicted change in the quality of country food and, consequently, no human health effects due to country foods consumption would be expected. For Project components and phases where environmental media quality was predicted to change, a screening level risk assessment was done.

Even though country foods may be affected during the Closure and Post-closure phases of the Project, it is anticipated that the Construction and Operation phases of the Project have the highest potential for changes to the quality of country foods. Therefore, the assessment of Construction and Operation phases would be the most conservative, and if no potential residual effects were identified for these phases, then no residual effects in Closure and Post-closure would be expected.

The following sections provide a brief description of the potential for Project-related changes in the quality of country foods that may occur due air emissions or changes in freshwater quality, and the subsequent potential health effects to humans from the ingestion of metals in country foods.

Potential for Change in the Quality of Country Foods due to Contaminants in Air Emissions

A variety of Project components such as the mill, access road, quarry, underground mine workings, incinerators, waste rock and ore handling facilities, and the variety of equipment (e.g., generators) and transportation methods (e.g., vehicles and aircrafts) can result in emissions of airborne pollutants (e.g., particulate matter, combustion by-products) and fugitive dust. This may occur during all phases of the Project. Atmospheric Project emissions have the potential to enter the air and be transported some distance from the source. The contaminants in air emissions have the potential to affect country foods directly (e.g., through inhalation of contaminants by wildlife) or indirectly (e.g., through the food chain via consumption of soil and vegetation).

While it is possible that country foods (e.g., moose and other terrestrial organisms) could take up contaminants from inhalation of contaminants from the air, this pathway is considered to be a very minor source of contaminants compared to uptake through the diet (Sample et al. 1997; BC MOE 2013d). Therefore, exposure of country foods to contaminants via the inhalation route has been excluded from further consideration in wildlife harvested as country foods.

The main source of Project-related contaminant release to the terrestrial environment is through deposition of dust (Figure 21.5-1). Fugitive dust containing metals from a variety of sources could result in metal deposition to soils within the country foods LSA. The metals in soil can be taken up by wildlife through incidental intake of soil while eating vegetation. Metals in soil can also be taken up by vegetation through the roots, and fugitive dust containing metals may be deposited directly on the surface of vegetation. Metals in soil or vegetation can enter the human food chain when consumed by organisms (e.g., wildlife) that are collected or harvested as country foods. Berries, with fugitive dust present on their external surfaces, could be directly consumed by human receptors.

Potential for Change in the Quality of Country Foods due to Contaminants in Freshwater

Exposure to water containing suspended solids, total and dissolved metals, other contaminants (i.e., fuels, processing chemicals) and nutrients may have potential effects to the quality of terrestrial wildlife and fish, and subsequently to humans who consume these country foods (Figure 21.5-1).

There are several potential sources of contaminants to the freshwater environment. Water that has been in contact with Project infrastructure has the potential to contain contaminants such as metals, fuels, blasting residues, and nitrates (from sewage treatment plan effluent or fuel oils used in explosives), and could affect the quality of country foods if not appropriately managed.

During the Construction and Operation phases of the Project, activities and components such as blasting, excavation, grading/bulldozing, vehicle/road use, and road maintenance can introduce fugitive dust into water. Dust deposition into the freshwater environment could affect the surface water quality by introducing suspended material and associated metals and nutrients into surrounding waterbodies. Metals and other contaminants present in fugitive dust deposited into surface water can either remain in the water column or be deposited to sediments.The potential effects from dust deposition may occur during all phases of the Project.

Physical disturbance of the terrain during all Project phases has the potential to increase surface runoff and erosion, resulting in increased turbidity, TSS (which may have bound metals) and sedimentation in receiving waters (see Chapter 13, Assessment of Potential Surface Water Quality

Effects, Section 13.5.3, Identifying Key Effects: Off-site Areas, for further details). Recovery from sedimentation will be more rapid in high-velocity streams relative to wetlands or lakes. Many waterbodies within the LSA and RSA have naturally high sediment loads due to glacial origins, including Knipple Lake, the Bowser River and Bowser Lake (Chapter 13, Table 13.3-5). Further, watercourses in the LSA within the Bowser River watershed, Knipple Lake, and Wildfire Creek/Scott/Todedada watersheds exhibit substantial seasonal variability (mean high flow: 44.8 mg/L to 318 mg/L; mean low flow: 1.5 mg/L to 40.0 mg/L) and sedimentation erosion events, should they occur, would not be expected to be outside this large natural range of variability.

ML/ARD has the potential to occur as a result of surface disturbances during construction activities and subsequent weathering of newly exposed rock. Potential Project-specific sources of ML/ARD in off-site areas include the upgrade of the Brucejack Access Road, replacement of the exiting overgrown airstrip with the Bowser Aerodrome, and construction of the Brucejack Transmission Line.

Potential by-products of incineration, such as metals, polycyclic aromatic hydrocarbons (PAHs), dioxins, and furans, could be carried by air and subsequently be deposited on surface waters. These components could partition to water and sediment, where they may be available for uptake by aquatic organisms such as fish.

Fuels or other chemicals present in the country foods LSA could enter the aquatic environment through combustion by-products in exhausts or incidental contact between machinery and water or sediments during work conducted in and around waterways. Uptake by fish or other aquatic organisms from water or sediment could introduce these contaminants into the food chain.

There are no proposed discharge points (to water) outside of the Brucejack Mine Site (Chapter 5, Project Description). However, uncaptured seepage containing nitrogen compounds from the septic field (ground disposal of sewage) at the Knipple Transfer Area camp could potentially be introduced into the receiving environment during the Construction, Operation, and Closure phases. Limited blasting will be used during Brucejack Access Road upgrades. During Operation, additional small explosives and cap magazines will be required near the Knipple Transfer Area for ongoing avalanche control work (Section 5.12.11, Explosives Storage and Use), however, they will be waterproof and no nitrogen releases are expected. Unmitigated nitrogen loading to surface water has the potential to elevate nitrate concentrations. Exposure to elevated nitrate levels may lead to “blue baby syndrome” (methemoglobinemia), a condition that causes blue coloration of skin due to conversion of hemoglobin to methemoglobin, which results in decrease in oxygen delivery to tissues (US EPA 2006).

Potential Human Health Effects due to Country Foods Quality

Potential changes in the quality of country foods that could affect the health of human consumers are limited to the Brucejack Transmission Line and Brucejack Access Road areas (see Section 21.4.2.1 for further details).

Toxicity can result in a variety of health effects depending on the individual contaminant, and effects may range from carcinogenic effects to non-carcinogenic effects (e.g., changes in physiological functions or systems). Metals can disturb biochemical processes and normal body functions and involve many body organ systems such as neurological, cardiovascular, immunological, hematological, gastrointestinal, and musculoskeletal systems. However, toxicity in human consumers of country foods will only occur if sufficiently high concentrations of contaminants are taken in, such that toxicity thresholds are surpassed. The potential for effects to humans due to contaminants that may be present in country foods depends on a number of factors such as:

- the developmental stage of the human receptor (i.e., adult, toddler, women of childbearing age);
- the toxicity of the contaminant;
- the speciation of the metal;
- bioavailability;
- whether the body is able to efficiently eliminate the contaminant;
- whether the contaminant can bioaccumulate;
- the amount of country food that is consumed (dose and frequency of exposure); and
- the period of time that wildlife spends in the area.

It is noted that the toxicology of mixtures of contaminants in humans is poorly understood, although it is known that antagonistic, additive, synergistic, or potentiating effects are possible outcomes.

21.5.4.2 Mitigation Measures for Country Foods Quality

No additional mitigation measures were considered in the assessment beyond what was outlined in the previous chapters. Mitigation measures for air quality, such as mitigation to minimize fugitive dust emissions, were discussed in Chapter 7, Air Quality Predictive Study, and Section 29.2 (Air Quality Management Plan). Mitigation measures for surface water quality were discussed in Chapter 13, Assessment of Potential Surface Water Quality Effects, and Section 29.3, Aquatic Effects Monitoring Plan.

These mitigation and management measures include using relevant Best Management Practices, sediment and erosion control mitigation and management measures, contaminant loading mitigation and management measures, discharge mitigation and management measures, and routine inspection and monitoring. Monitoring these media during different phases of the Project will be essential to conducting future ecological and human health risk assessment and adaptive management, should media quality decrease.

Public access will be restricted along Project roads through the Transportation and Access Management Plan (Section 29.16) and the Wildlife Management and Monitoring Plan (Section 29.21). In addition, a no hunting and gathering policy for workers on-site will be implemented, which will reduce the potential for exposure to contaminants by minimizing the collection of country foods in areas closest to Project infrastructure (i.e., the areas in which there is the greatest potential for changes in the quality of country foods).

Effects on potential human health effects due to consumption of country foods from outside of the mine site area due potential changes to water, soil, and vegetation quality as a result of Project related atmospheric deposition, leaching of blasting residues, as well as surface water quality changes are considered to be fully mitigated by the proposed management strategies summarized above.

Despite active management and mitigation measures in place, potential residual effects on human health due to consumption of country foods may occur. These are discussed in detail in Section 21.6.4.

21.6 RESIDUAL EFFECTS ON HUMAN HEALTH

21.6.1 Residual Effects on Human Health due to Noise

21.6.1.1 Methodology and Assumptions

An Environmental Noise Modelling Study was conducted for the Brucejack Gold Mine Project by BKL Consultants in Acoustics (Appendix 8-B, Brucejack Gold Mine Project: Final Environmental Noise Modelling Study). The study provides details of the modelling undertaken to assess the environmental effects of noise associated with Construction and Operation activities at the proposed Project.

Currently, Health Canada has not established noise guidelines or enforceable noise thresholds or standards (Health Canada 2010e). However, it provides a general noise assessment approach. BC does not have ambient noise standards applicable to remote areas. Health Canada considers a variety of internationally recognized standards for noise, including US Environmental Protection Agency (EPA, 1974), the World Health Organization (WHO 1999), and other publications regarding indicators of noise-induced human health effects (Michaud 2008). Potential human health effects due to noise were assessed using the Health Canada noise assessment approach (2010e), guidelines from the WHO (1999), the US EPA (1974), and Michaud (2008).

Some of the noise guidelines, such as sleep disturbance, should be compared to indoor noise instead of outdoor noise. It was assumed that the outdoor-to-indoor noise transmission loss with doors closed and windows partially open is 15 dBA (US EPA 1974). Fully closed windows are assumed to reduce outdoor sound levels by approximately 27 dBA (US EPA 1974). For the workers' accommodations, it was assumed that the doors and windows will be permanently closed, providing a noise reduction of 27 dB. Note that the 27 dBA reduction from outdoor to indoor was based on the US EPA's *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety* in 1974 (US EPA 1974). It can also be assumed that the noise reduction with current building technology can exceed 27 dBA.

For the non-worker human receptor locations, it was assumed that the doors will be closed with windows slightly open, resulting in an outdoor-to-indoor noise reduction of 15 dB. It was also assumed that non-worker receptors would only be sleeping at night, so nighttime sound levels were compared to acceptable thresholds for nighttime noise. Daytime predicted noise levels were assessed for their potential to cause speech interference for non-worker receptors, which occurs at noise levels that exceed 55 dBA.

21.6.1.2 Human Receptors for Noise

The worker camps and Skii km Lax Ha Lodge are within the noise RSA and were included in this assessment. Figure 21.4-1 provides the location of the human receptor sites assessed for human health effects due to noise.

21.6.1.3 Exposure Assessment

This section presents the findings of the noise impact assessment. Calculated noise levels with respect to human receptors are presented in Tables 21.6-1 to 21.6-4. Apart from the worker camps and three non-worker receptor locations (the Skii km Lax Ha Lodge, Outlet of Bell Creek Lodge, and Outlet of Bowser Lake Lodge), there are no other currently used cabins or camp sites within the noise RSA. In line with current best practice, the noise assessment included evaluation of sleep disturbance at worker camps. In addition to sleep disturbance, other potential human health effects due to noise were assessed for non-worker receptor locations.

Table 21.6-1. Predicted Construction and Operation Noise Levels at the Worker Camp Receptor Locations

Human Receptor Location (Worker Camps)	Construction			Operation	
	Average Noise L_d dBA	Average Noise L_n dBA	Vehicle Pass-by Noise L_{max} dBA	Average Noise L_d dBA	Average Noise L_n dBA
Relevant Guideline	*57*	*57*	*72*	*57*	*57*
Worker Bowser Cabin 1	62	55	80	n/a	n/a
Worker Bowser Cabin 2	61	52	79	n/a	n/a
Worker Bowser Cabin 3	60	51	77	n/a	n/a
Worker Bowser Cabin 4	59	49	76	n/a	n/a
Worker Bowser Staff House	64	60	84	n/a	n/a
Worker Mine Site Existing Camp 1	58	54	67	n/a	n/a
Worker Mine Site Existing Camp 2	57	54	68	n/a	n/a
Worker Mine Site Operation Camp	n/a	n/a	n/a	55	55
Worker Transfer Station Camp	71	55	83	63	61

Notes:
Gray shading indicates human noise receptor locations with noise levels above relevant guideline.
Indoor speech interferences during the day and during the night are likely at all of the worker camps as the noise levels at these locations are above 40 dBA.
n/a indicates not applicable since camps not in use during specific phases of the Project (See Section 21.4.2.3 for further details).

Table 21.6-2. Predicted Construction Phase Noise Levels for the Non-worker Receptor Locations

Non-worker Receptor Location	Brucejack Mine Site Blasting L_{peak} dBZ	Quarry Blasting L_{peak} dBZ	Average Noise L_d dBA	Average Noise L_n dBA	Total L_{dn} dBA	%HA %	Δ%HA %
Relevant Guideline	*120*	*120*	*55*	*45*	*75*	-	*6.5*
Outlet of Bell Creek	63	63	14	11	45	1.1	0.0
Outlet of Bowser Lake	64	64	14	11	36	1.3	0.2
Skii km Lax Ha Lodge	74	75	59	45	58	11.1	10.0

Notes:
Gray shading indicates human noise receptor locations with noise levels above relevant guideline.

Table 21.6-3. Predicted Operation Phase Noise Levels for the Non-worker Receptor Locations

Receptor	Average Noise L_d dBA	Average Noise L_n dBA	Total L_{dn} dBA	%HA %	Δ%HA %
Relevant Guideline	*55*	*45*	*75*	-	*6.5*
Outlet of Bowser Lake	6	6	46	1.3	0.2
Outlet of Bell Creek	7	7	47	1.5	0.4
Skii km Lax Ha Lodge	53	51	64	12.4	11.3

Notes:
Gray shading indicates human noise receptor locations with noise levels above relevant guideline.

Table 21.6-4. Selection of Criteria Air Contaminants at Human Receptor Locations during the Construction Phase

Criteria Air Contaminant	Averaging Period	British Columbia Ambient Air Quality Objectives[1] ($\mu g/m^3$)	National Ambient Air Quality Objectives - Maximum Desirable[2] ($\mu g/m^3$)	Worker Mine Site Existing Camp 1							Worker Mine Site Existing Camp 2						
				Baseline Concentration ($\mu g/m^3$)	Predicted Air Concentration ($\mu g/m^3$)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?	Baseline Concentration ($\mu g/m^3$)	Predicted Air Concentration ($\mu g/m^3$)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	9.5	No	0.0211	n/a	n/a	No	4.0[4]	7.5	No	0.0167	n/a	n/a	No
	24-hour	160	-	4.0[4]	5.39	No	0.0337	n/a	n/a	No	4.0[4]	4.63	No	0.0289	n/a	n/a	No
	Annual	25	-	2.0[4]	2.39	No	0.0957	n/a	n/a	No	2.0[4]	2.12	No	0.0848	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	302	No	0.755	n/a	n/a	No	21[4]	199	No	0.497	n/a	n/a	No
	24-hour	200	-	21[4]	139.8	No	0.699	n/a	n/a	No	21[4]	107.1	No	0.536	n/a	n/a	No
	Annual	60	-	5.0[4]	81.5	Yes	1.359	Yes	16.30	Yes	5.0[4]	54.8	No	0.914	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	3841	No	0.2686	n/a	n/a	No	100[4]	2147	No	0.1502	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	2192	No	0.3986	n/a	n/a	No	100[4]	1041	No	0.1892	n/a	n/a	No
TSP	24-hour	120	-	10[4]	246	Yes	2.05	Yes	24.6	Yes	10[4]	146	Yes	1.22	Yes	14.6	Yes
	Annual	60	-	10[4]	91	Yes	1.52	Yes	9.1	Yes	10[4]	39.1	No	0.65			No
PM_{10}	24-hour	50	-	3.4[5]	160	Yes	3.21	Yes	47.1	Yes	3.4[5]	99	Yes	1.98	Yes	29.1	Yes
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	105.8	Yes	4.23	Yes	81.4	Yes	1.3[5]	54.0	Yes	2.16	Yes	41.5	Yes
	Annual	8	8.8[3]	1.3[5]	42.1	Yes	5.26	Yes	32.35	Yes	1.3[5]	16.29	Yes	2.04	Yes	12.53	Yes

Criteria Air Contaminant	Averaging Period	British Columbia Ambient Air Quality Objectives[1] ($\mu g/m^3$)	National Ambient Air Quality Objectives - Maximum Desirable[2] ($\mu g/m^3$)	Worker Bowser Cabin 1							Worker Bowser Cabin 2						
				Baseline Concentration ($\mu g/m^3$)	Predicted Air Concentration ($\mu g/m^3$)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?	Baseline Concentration ($\mu g/m^3$)	Predicted Air Concentration ($\mu g/m^3$)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	14.2	No	0.0315	n/a	n/a	No	4.0[4]	14.3	No	0.0317	n/a	n/a	No
	24-hour	160	-	4.0[4]	7.61	No	0.0476	n/a	n/a	No	4.0[4]	7.53	No	0.0471	n/a	n/a	No
	Annual	25	-	2.0[4]	2.90	No	0.116	n/a	n/a	No	2.0[4]	2.88	No	0.115	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	96	No	0.241	n/a	n/a	No	21[4]	97	No	0.242	n/a	n/a	No
	24-hour	200	-	21[4]	75.8	No	0.379	n/a	n/a	No	21[4]	75.2	No	0.376	n/a	n/a	No
	Annual	60	-	5.0[4]	21.5	No	0.359	n/a	n/a	No	5.0[4]	21.1	No	0.351	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	214	No	0.0150	n/a	n/a	No	100[4]	214	No	0.0150	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	177	No	0.0322	n/a	n/a	No	100[4]	174	No	0.0317	n/a	n/a	No
TSP	24-hour	120	-	10[4]	106	No	0.884	n/a	n/a	No	10[4]	104.1	No	0.867	n/a	n/a	No
	Annual	60	-	10[4]	53.8	No	0.896	n/a	n/a	No	10[4]	51.4	No	0.857	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	99.4	Yes	1.99	Yes	29.2	Yes	3.4[5]	97.5	Yes	1.95	Yes	28.7	Yes
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	32.9	Yes	1.317	Yes	25.34	Yes	1.3[5]	31.6	Yes	1.265	Yes	24.32	Yes
	Annual	8	8.8[3]	1.3[5]	13.23	Yes	1.654	Yes	10.18	Yes	1.3[5]	12.93	Yes	1.617	Yes	9.95	Yes

Criteria Air Contaminant	Averaging Period	British Columbia Ambient Air Quality Objectives[1] ($\mu g/m^3$)	National Ambient Air Quality Objectives - Maximum Desirable[2] ($\mu g/m^3$)	Worker Bowser Cabin 3							Worker Bowser Cabin 4						
				Baseline Concentration ($\mu g/m^3$)	Predicted Air Concentration ($\mu g/m^3$)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?	Baseline Concentration ($\mu g/m^3$)	Predicted Air Concentration ($\mu g/m^3$)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	14.4	No	0.0320	n/a	n/a	No	4.0[4]	14.6	No	0.0324	n/a	n/a	No
	24-hour	160	-	4.0[4]	7.40	No	0.0463	n/a	n/a	No	4.0[4]	7.28	No	0.0455	n/a	n/a	No
	Annual	25	-	2.0[4]	2.86	No	0.115	n/a	n/a	No	2.0[4]	2.83	No	0.113	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	97	No	0.244	n/a	n/a	No	21[4]	97	No	0.243	n/a	n/a	No
	24-hour	200	-	21[4]	75.6	No	0.378	n/a	n/a	No	21[4]	73.4	No	0.367	n/a	n/a	No
	Annual	60	-	5.0[4]	21.2	No	0.353	n/a	n/a	No	5.0[4]	20.3	No	0.339	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	216	No	0.0151	n/a	n/a	No	100[4]	216	No	0.0151	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	172	No	0.0312	n/a	n/a	No	100[4]	168	No	0.0306	n/a	n/a	No
TSP	24-hour	120	-	10[4]	113	No	0.943	n/a	n/a	No	10[4]	108.7	No	0.906	n/a	n/a	No
	Annual	60	-	10[4]	54.9	No	0.914	n/a	n/a	No	10[4]	51.8	No	0.863	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	106.6	Yes	2.13	Yes	31.3	Yes	3.4[5]	102.1	Yes	2.04	Yes	30.0	Yes
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	31.2	Yes	1.249	Yes	24.03	Yes	1.3[5]	30.21	Yes	1.208	Yes	23.24	Yes
	Annual	8	8.8[3]	1.3[5]	12.96	Yes	1.620	Yes	9.97	Yes	1.3[5]	12.54	Yes	1.567	Yes	9.64	Yes

(continued)

Table 21.6-4. Selection of Criteria Air Contaminants at Human Receptor Locations during the Construction Phase (completed)

				Worker Bowser Staff House							Worker Transfer Station Camp						
Criteria Air Contaminant	Averaging Period	British Columbia Ambient Air Quality Objectives[1] (μg/m³)	National Ambient Air Quality Objectives - Maximum Desirable[2] (μg/m³)	Baseline Concentration (μg/m³)	Predicted Air Concentration (μg/m³)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?	Baseline Concentration (μg/m³)	Predicted Air Concentration (μg/m³)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	14.5	No	0.0323	n/a	n/a	No	4.0[4]	4.50	No	0.0100	n/a	n/a	No
	24-hour	160	-	4.0[4]	7.37	No	0.0461	n/a	n/a	No	4.0[4]	4.16	No	0.0260	n/a	n/a	No
	Annual	25	-	2.0[4]	2.84	No	0.114	n/a	n/a	No	2.0[4]	2.03	No	0.0814	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	96	No	0.240	n/a	n/a	No	21[4]	92.2	No	0.231	n/a	n/a	No
	24-hour	200	-	21[4]	69.4	No	0.347	n/a	n/a	No	21[4]	51.2	No	0.256	n/a	n/a	No
	Annual	60	-	5.0[4]	20.7	No	0.344	n/a	n/a	No	5.0[4]	13.9	No	0.231	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	230	No	0.0161	n/a	n/a	No	100[4]	159	No	0.0111	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	181	No	0.0329	n/a	n/a	No	100[4]	127	No	0.0230	n/a	n/a	No
TSP	24-hour	120	-	10[4]	116	No	0.97	n/a	n/a	No	10[4]	161.4	Yes	1.345	Yes	16.14	Yes
	Annual	60	-	10[4]	64.3	Yes	1.07	Yes	6.43	Yes	10[4]	23.2	No	0.387	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	109.9	Yes	2.20	Yes	32.3	Yes	3.4[5]	88.0	Yes	1.759	Yes	25.9	Yes
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	31.0	Yes	1.238	Yes	23.82	Yes	1.3[5]	7.58	No	0.303	n/a	n/a	No
	Annual	8	8.8[3]	1.3[5]	13.07	Yes	1.634	Yes	10.05	Yes	1.3[5]	2.88	No	0.360	n/a	n/a	No

				Skii km Lax Ha Lodge						
Criteria Air Contaminant	Averaging Period	British Columbia Ambient Air Quality Objectives[1] (μg/m³)	National Ambient Air Quality Objectives - Maximum Desirable[2] (μg/m³)	Baseline Concentration (μg/m³)	Predicted Air Concentration (μg/m³)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	14.2	No	0.0315	n/a	n/a	No
	24-hour	160	-	4.0[4]	7.05	No	0.0441	n/a	n/a	No
	Annual	25	-	2.0[4]	2.72	No	0.109	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	97	No	0.242	n/a	n/a	No
	24-hour	200	-	21[4]	63.8	No	0.319	n/a	n/a	No
	Annual	60	-	5.0[4]	18.3	No	0.305	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	211	No	0.0148	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	167	No	0.0303	n/a	n/a	No
TSP	24-hour	120	-	10[4]	114.6	No	0.955	n/a	n/a	No
	Annual	60	-	10[4]	54.5	No	0.908	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	108.0	Yes	2.16	Yes	31.8	Yes
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	28.3	Yes	1.131	Yes	21.74	Yes
	Annual	8	8.8[3]	1.3[5]	11.59	Yes	1.449	Yes	8.91	Yes

Notes:

[1] Government of British Columbia (2013).

[2] Environment Canada (1999).

[3] CCME (2012).

[4] Baseline concentrations of SO2, NO2, CO, and TSP are based on surveys conducted at the Diavic Diamond Mine (Diavic) in the Northwest Territories, 300 km northeast of Yellowknife and are considered to be typical background concentrations for remote areas with few anthropogenic sources.

[5] $PM_{2.5}$ and PM_{10} baseline concentrations are the annual averages used for the Galore Creek Copper-Gold-Silver Project (Galore) located 100 km northwest of the Project.

COPC = contaminant of potential concern.

CO = carbon monoxide.

NO_2 = nitrogen dioxide.

SO_2 = sulphur dioxide.

TSP = total suspended particles.

$PM_{2.5}$ = particulate matter up to 2.5 μm in size.

PM_{10} = particulate matter up to 10 μm in size.

Concentration used for calculating chronic exposure dose is the predicted maximum concentration for 24-hour averaging.

Shaded cells indicate that a CAC was selected for further assessment as a COPC.

n/a = not applicable. These CACs were not compared against baseline concentrations since they were below guideline.

Worker Camps (Off-duty Worker Receptor Locations)

Since some off-duty workers may sleep during the day, the nighttime noise guideline for sleep disturbance was used for comparison with both L_n and L_d for the worker accommodations. All worker camps meet the nighttime noise guideline of 57 dBA, except for Worker Bowser Staff House where the nighttime noise levels are predicted to be 60 dBA. Workers are not expected to sleep at the Worker Bowser Staff House during the day except on rare occasions. At the Worker Mine Site Existing Camp 2, daytime noise levels are predicted to be 57 dBA, equivalent to the guideline for nighttime noise. For most worker camps, the maximum predicted daytime noise is slightly (1 to 5 dBA) above the guideline for sleep disturbance. However, the maximum predicted daytime noise exceedance is 7 dBA above the acceptable noise level at the Worker Bowser Staff House and is 14 dBA above the acceptable noise level at the Worker Transfer Station Camp. In addition, workers are not expected to use the Worker Mine Site Existing Camp 1 (Kitchen) for sleeping purposes. The Worker Transfer Station Camp (Knipple Transfer Area) will be built early during the Construction phase and will be in use during both Construction and Operation phases of the Project. Workers are not expected to sleep at the Worker Transfer Station Camp during the day except on rare occasions.

For the vehicle pass-by noise presented in Table 21.6-1, the applicable noise guideline was exceeded at all of the worker camp locations except the Worker Mine Site Existing Camps 1 and 2. However, the vehicle pass-by noise will not be continuous and is only experienced when a vehicle passes. Moreover, the prediction was based on the loudest vehicle; therefore, this assessment is conservative and may over-estimate the potential for sleep disturbance to off-duty workers due to vehicles passing by.

Non-worker Receptor Locations

For non-workers during the Construction phase, none of the predicted noise levels for blasting exceed the applicable guideline (Table 21.6-2). Noise predictions at Skii km Lax Ha Lodge during the Construction phase indicate noise levels may exceed an L_d of 55 dBA for speech interference (Table 21.6-2). Nighttime noise levels during the Operation phase exceed the acceptable L_n of 45 dBA by 6 dBA (Table 21.6-3). In addition, the increase in %HA was predicted to be more than 6.5% during Construction and Operation phases of the Project. This suggests that there is likelihood of annoyance of the human receptors and therefore possibility of complaints from inhabitants of the Skii km Lax Ha Lodge. The predicted exceedances of relevant noise guideline levels during the Construction and Operation phases are due to the short distance between the Skii km Lax Ha Lodge and the Bowser Aerodrome and the Brucejack Access Road.

The Skii km Lax Ha Lodge was built with triple-paned windows and two-inch by six-inch insulated walls with two-inch foam insulation (G. Simpson, pers. comm.). The noise attenuation from outdoor to indoor is likely to be higher than what was conservatively used in this assessment (i.e., 15 dBA). The residents of the Skii km Lax Ha Lodge have built the lodge to be close to the Bowser Aerodrome camp facilities and in close proximity to the Project. Some of the Skii km Lax Ha Lodge residents are hired as third party contractors to work at the Project. Therefore, Skii km Lax Ha Lodge residents are very unlikely to express annoyance due to noise levels from the Project. Residents of the Skii km Lax Ha Lodge have indicated that if predicted noise levels actually occur and exceed the noise guidelines, Skii km Lax Ha Lodge residents are willing to accept additional mitigation measures offered to reduce the noise levels or relocate if necessary (G. Simpson, pers. comm.).

21.6.1.4 Summary of Residual Effects due to Noise

Human health residual effects due to noise were identified, including potential for sleep disturbance at worker camps and speech interference; sleep disturbance; and increase in complaints from non-workers, including the residents of the Skii km Lax Ha Lodge.

21.6.2 Residual Effects due to Air Quality

21.6.2.1 Methodology and Assumptions

In order for there to be a potential for effects to human health due to air quality within the air quality LSA, the following criteria must be met:

- contaminants must be present in the air inhaled within the air quality LSA at concentrations high enough that effects in humans may occur;
- human receptors must be present and within the air quality LSA; and
- humans must take in contaminants via inhalation of air (i.e., there must be an exposure route).

Therefore, in considering the potential for adverse effects to health due to changes in air quality, human receptor locations were considered.

To assess residual effects to human health from changes in air quality due to Project activities, future Project-related air quality was modeled. The methodology and assumptions used in the air quality dispersion model and the results are described in Appendix 7-A, Brucejack Gold Mine Project: 2012 Meteorology Baseline Report. A screening process was used to select contaminants of potential concern for human health due to predicted air quality changes. Predicted Construction and Operation concentrations of CACs (NO_2, SO_2, CO, TSP, PM_{10}, and $PM_{2.5}$) at the human receptor locations were compared to the British Columbia Ambient Air Quality Objectives (BC AAQO) concentrations (BC MOE 2013a).

Hazard quotients (HQs) were calculated by dividing the predicted concentrations of CACs by guideline limits at each human receptor location. CACs with an HQ less than 1.0 for a particular receptor point were screened out of the HHRA for that specific receptor location, since these contaminants would not be expected to cause adverse health effects due to air in that receptor location.

CACs with an HQ greater than 1.0 relative to the guideline limit at a particular receptor location were retained for a second screening step for that receptor location. In the second screening step, the predicted criteria air pollutants were compared to the baseline concentrations (determined as the mean concentration plus the coefficient of variation, CV). This step was done to ensure that all CACs identified and carried through the HHRA process for each receptor location were only those with concentrations that were predicted to have a measureable increase beyond baseline levels due to Project-related activities. This process eliminates CACs for receptor locations which already exceeded guidelines during the baseline studies (which is not a Project-related effect).

If a predicted CAC was greater than both the baseline concentration and the guideline limit, then it was identified as a COPC and was carried forward in the HHRA for further evaluation at that particular receptor point. The screening process for criteria air pollutants is shown in the flowchart presented in Figure 21.6-1.

21.6.2.2 Risk Assessment for Human Health Due to Air Quality

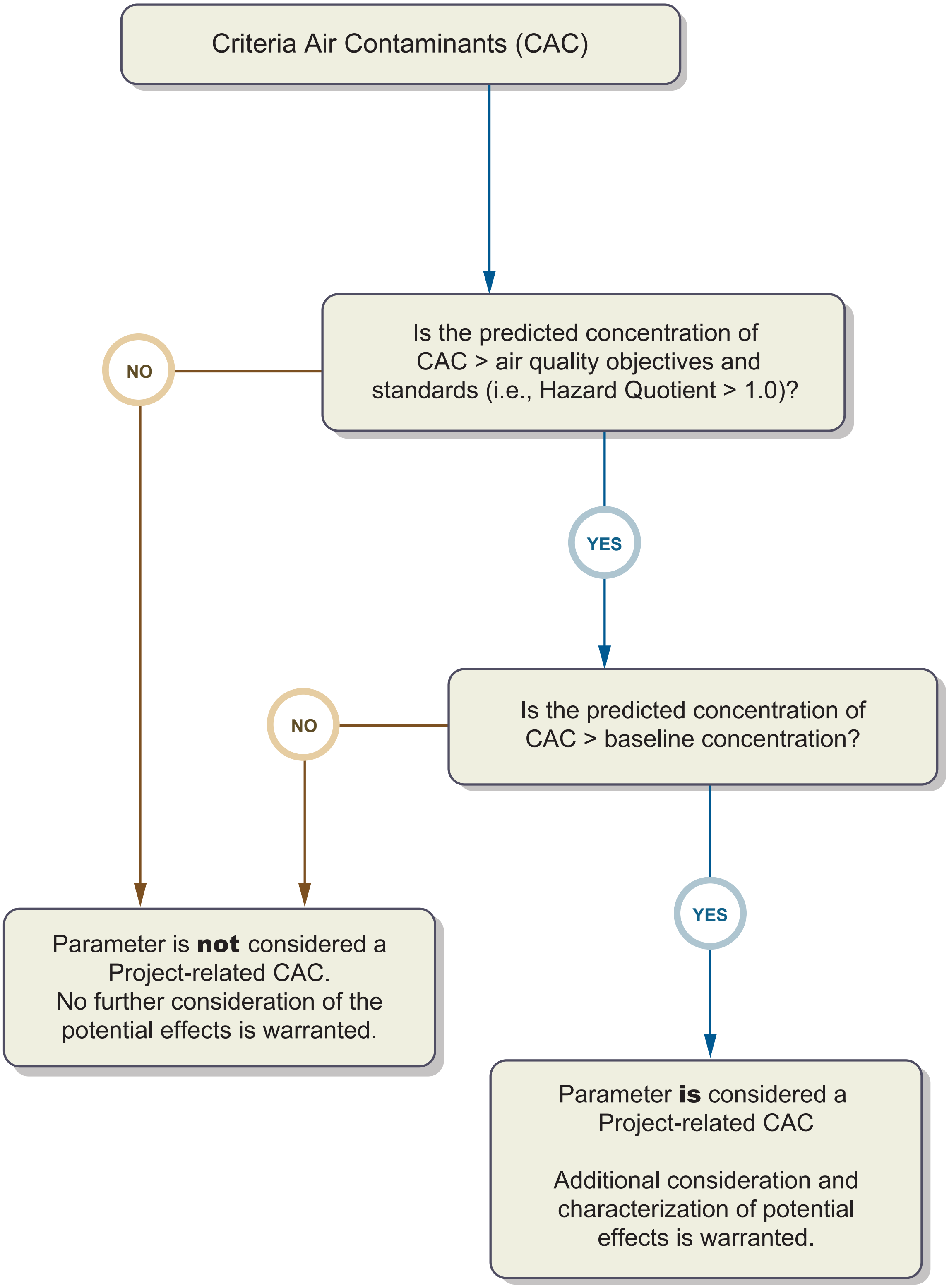
Problem Formulation

Potential Exposure to Human Receptors

A variety of age groups are often considered in risk assessment due to differences in sensitivity to air contaminants. When evaluating the risks to human health from exposure to contaminants, human receptor selection generally depends on the type of contaminant evaluated. For instance, the receptor selected for threshold contaminants is either the group that has the greatest exposure per unit body weight per day, which are typically children, or individuals who are particularly sensitive to potential adverse effects (e.g., elderly, asthmatics).

Figure 21.6-1

Screening Process for Selection of Criteria Air Contaminants for Air Quality Effects Assessment



However, the Project is in a remote location with limited site access, and sensitive people are not expected to be in the vicinity of sources of CACs from the Project (i.e., within the air quality RSA, close to the camps). Public access to the Project sites will be controlled. Other potential human receptors in the region (e.g., tourists and hunters) are more likely to be further away from Project-related CAC sources and these people will only experience background air quality, or transiently exposure to COPCs while passing through areas close to Project infrastructure. Air quality is assumed to reach background concentrations outside of the air quality RSA (Chapter 7, Air Quality Predictive Study).

Consequently, health effects from the exposure to air contaminants was assessed for individuals that are expected to be present near the Project sites regularly during the Construction and Operation phases, who are adults with sensitivity to air contaminants similar to an average, normal population. Therefore, the primary potential receptors considered in the assessment are off-duty workers residing at worker camps and non-workers residing at the Skii km Lax Ha Lodge.

The various worker camps may only be occupied during certain times during the Project phases and the potential for effects to receptors at these locations was only considered during the phases in which the camp is expected to be occupied. Therefore, the receptor locations considered during the Construction phase include: Worker Mine Site Existing Camp 1, Worker Mine Site Existing Camp 2, Worker Bowser Staff House, Worker Transfer Station Camp, Worker Bowser Cabin 1, Worker Bowser Cabin 2, Worker Bowser Cabin 3, Worker Bowser Cabin 4, and Skii km Lax Ha Lodge. The receptor locations considered during the Operation phase include: Worker Mine Site Operation Camp, Worker Transfer Station Camp, and Skii km Lax Ha Lodge.

Screening for Contaminants of Potential Concern in Air

The results of the CAC screening process for the Construction and Operation phases are shown in Tables 21.6-4 and 21.6-5, respectively. Concentrations of CACs were modelled for receptor sites, as shown in Figure 21.4-2, which are the hunting and trapping cabins and Project worker camps.

The modelling tools and inputs described in Chapter 7, Air Quality Predictive Study, allowed CAC concentrations to be predicted from model simulations. The air quality model predicted 1-hour, 24-hour, and annual averages for SO_2, NO_2, and CO; 24-hour averages for PM_{10}; and 24-hour and annual averages for TSP and $PM_{2.5}$ concentrations from Project-related emissions during the Construction and Operation phases.

Predicted SO_2 and CO concentrations at all human receptor locations that were included in the air quality dispersion model were below the BC AAQO. Therefore, no risks to human health were identified for these two CACs during the Construction or Operation phases of the Project (Table 21.6-4).

The NO_2 air concentration of 81.5 $\mu g/m^3$ at the Worker Mine Site Existing Camp 1 is predicted to exceed the annual NO_2 BC AAQO concentration of 60 $\mu g/m^3$ during the Construction phase of the Project (Table 21.6-4). NO_2 concentrations for all the other human receptor locations during the Construction and Operation phases were below the 1-hour, 24-hour, and annual BC AAQO concentrations (Tables 21.6-4 and 21.6-5); therefore, the risk to human health at these other receptor locations is considered acceptable and they will not be considered further.

The 24-hour TSP concentrations at Worker Mine Site Existing Camp 1, Worker Mine Site Existing Camp 2, and Worker Transfer Station Camp were predicted to exceed the TSP AAQO guideline of 120 $\mu g/m^3$ during the Construction Phase. The Annual TSP BC AAQO of 60 $\mu g/m^3$ was predicted to be exceeded at the Worker Mine Site Existing Camp 1 and Worker Bower Staff House during the Construction phase of the Project (Table 21.6-4), while the 24-hour TSP BC AAQO of 120 $\mu g/m^3$ was predicted to be exceeded at the Worker Mine Site Existing Camp 1, Worker Mine Site Existing Camp 2, and Worker Transfer Station Camp.

Table 21.6-5. Selection of Criteria Air Contaminants at Human Receptor Locations during the Operation Phase

				Worker Mine Site Operation Camp							Worker Transfer Station Camp						
Criteria Air Contaminant	Averaging Period	British Columbia Ambient Air Quality Objectives[1] (µg/m³)	National Ambient Air Quality Objectives - Maximum Desirable[2] (µg/m³)	Baseline Concentration (µg/m³)	Predicted Air Concentration (µg/m³)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?	Baseline Concentration (µg/m³)	Predicted Air Concentration (µg/m³)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	16.8	No	0.0372	n/a	n/a	No	4.0[4]	4.65	No	0.0103	n/a	n/a	No
	24-hour	160	-	4.0[4]	7.46	No	0.0466	n/a	n/a	No	4.0[4]	4.22	No	0.0264	n/a	n/a	No
	Annual	25	-	2.0[4]	2.98	No	0.1192	n/a	n/a	No	2.0[4]	2.04	No	0.0815	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	104.2	No	0.261	n/a	n/a	No	21[4]	94.8	No	0.237	n/a	n/a	No
	24-hour	200	-	21[4]	84.5	No	0.423	n/a	n/a	No	21[4]	70.8	No	0.354	n/a	n/a	No
	Annual	60	-	5.0[4]	28.18	No	0.470	n/a	n/a	No	5.0[4]	15.2	No	0.253	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	373	No	0.0261	n/a	n/a	No	100[4]	159	No	0.0111	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	191	No	0.0347	n/a	n/a	No	100[4]	143	No	0.0259	n/a	n/a	No
TSP	24-hour	120	-	10[4]	194.0	Yes	1.616	n/a	n/a	Yes	10[4]	81.8	No	0.681	n/a	n/a	No
	Annual	60	-	10[4]	43.7	No	0.728	n/a	n/a	No	10[4]	22.0	No	0.366	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	94.6	Yes	1.893	Yes	27.84	Yes	3.4[5]	47.4	No	0.947	n/a	n/a	No
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	17.65	No	0.706	n/a	n/a	No	1.3[5]	5.85	No	0.234	n/a	n/a	No
	Annual	8	8.8[3]	1.3[5]	5.92	No	0.740	n/a	n/a	No	1.3[5]	2.61	No	0.327	n/a	n/a	No

				Skii km Lax Ha Lodge						
Criteria Air Contaminant	Averaging Period	British Columbia Ambient Air Quality Objectives[1] (µg/m³)	National Ambient Air Quality Objectives - Maximum Desirable[2] (µg/m³)	Baseline Concentration (µg/m³)	Predicted Air Concentration (µg/m³)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	14.2	No	0.0316	n/a	n/a	No
	24-hour	160	-	4.0[4]	7.12	No	0.0445	n/a	n/a	No
	Annual	25	-	2.0[4]	2.77	No	0.111	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	105	No	0.262	n/a	n/a	No
	24-hour	200	-	21[4]	91.1	No	0.455	n/a	n/a	No
	Annual	60	-	5.0[4]	39.4	No	0.657	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	249	No	0.0174	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	197	No	0.0358	n/a	n/a	No
TSP	24-hour	120	-	10[4]	98.8	No	0.823	n/a	n/a	No
	Annual	60	-	10[4]	44.8	No	0.746	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	62.0	Yes	1.24	Yes	18.2	Yes
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	10.0	No	0.400	n/a	n/a	No
	Annual	8	8.8[3]	1.3[5]	5.35	No	0.669	n/a	n/a	No

Notes:

[1] Government of British Columbia (2013).

[2] Environment Canada (1999).

[3] CCME (2012).

[4] Baseline concentrations of SO_2, NO_2, CO, and TSP are based on surveys conducted at the Diavic Diamond Mine (Diavic) in the Northwest Territories, 300 km northeast of Yellowknife and are considered to be typical background concentrations for remote areas with few anthropogenic sources.

[5] $PM_{2.5}$ and PM_{10} baseline concentrations are the annual averages used for the Galore Creek Copper-Gold-Silver Project (Galore) located 100 km northwest of the Project.

COPC = contaminant of potential concern.

CO = carbon monoxide.

NO_2 = nitrogen dioxide.

SO_2 = sulphur dioxide.

TSP = total suspended particles.

$PM_{2.5}$ = particulate matter up to 2.5 µm in size.

PM_{10} = particulate matter up to 10 µm in size.

Concentration used for calculating chronic exposure dose is the predicted maximum concentration for 24-hour averaging.

Shaded cells indicate that a CAC was selected for further assessment as a COPC.

n/a = not applicable. These CACs were not compared against baseline concentrations since they were below guideline.

In the Operation phase, the predicted 24-hour TSP at the Worker Mine Site Operation Camp exceeds the TSP BC AAQO concentration of 120 $\mu g/m^3$ (Table 21.6-5). The TSP concentrations at the other receptor locations were below the BC AAQOs during Construction and Operation phases (Tables 21.6-4 and 21.6-5); therefore, the risk to human health at these other receptor locations is considered acceptable and they will not be considered further.

The 24-hour PM_{10} and 24-hour and annual $PM_{2.5}$ concentrations during the Construction phase of the Project were predicted to exceed the BC AAQO concentrations for all modelled receptor locations except the Worker Transfer Station Camp (Table 21.6-4). Predicted 24-hour PM_{10} concentrations at the Worker Mine Site Operation Camp and Skii km Lax Ha Lodge exceeded the BC AAQO concentration of 50 $\mu g/m^3$ (Table 21.6-5). The PM_{10} and $PM_{2.5}$ predicted at the other receptor locations during the Construction and Operation phases were below the BC AAQOs (Tables 21.6-4 and 21.6-5); therefore, the risk to human health at these other receptor locations is considered acceptable and they will not be considered further.

Summary of Problem Formulation

The CACs that were screened into the HHRA included NO_2, TSP, PM_{10}, and $PM_{2.5}$; all other CACs or air contaminants considered were below air quality objectives and standards. Table 21.6-6 provides the CACs selected at each human receptor location during the Construction and Operation phases of the Project.

Table 21.6-6. Criteria Air Contaminants of Concern at Human Receptor Locations during Construction and Operation Phases of the Project

Human Receptor Location	Construction	Operation
Worker Mine Site Existing Camp 1	annual NO_2, 24-hour TSP, annual TSP, 24-hour PM_{10}, 24-hour $PM_{2.5}$, and annual $PM_{2.5}$	n/a
Worker Mine Site Existing Camp 2	24-hour TSP,24-hour PM_{10}, 24-hour $PM_{2.5}$, and annual $PM_{2.5}$	n/a
Worker Bowser Staff House	annual TSP, 24-hour PM_{10}, 24-hour $PM_{2.5}$, and annual $PM_{2.5}$	n/a
Worker Transfer Station Camp	24-hour TSP, and 24-hour PM_{10}	No COPC identified
Worker Mine Site Operation Camp	n/a	24-hour TSP, and 24-hour PM_{10}
Worker Bowser Cabin 1	24-hour PM_{10}, 24-hour $PM_{2.5}$, and annual $PM_{2.5}$	n/a
Worker Bowser Cabin 2	24-hour PM_{10}, 24-hour $PM_{2.5}$, and annual $PM_{2.5}$	n/a

(continued)

Table 21.6-6. Criteria Air Contaminants of Concern at Human Receptor Locations during Construction and Operation Phases of the Project (completed)

Human Receptor Location	Construction	Operation
Worker Bowser Cabin 3	24-hour PM_{10}, 24-hour $PM_{2.5}$, and annual $PM_{2.5}$	n/a
Worker Bowser Cabin 4	24-hour PM_{10}, 24-hour $PM_{2.5}$, and annual $PM_{2.5}$	n/a
Skii km Lax Ha Lodge	24-hour PM_{10}, 24-hour $PM_{2.5}$, and annual $PM_{2.5}$	24-hour PM_{10}

n/a: not applicable since camp is not in use in this phase of the Project.

NO_2, TSP, and PM_{10} are considered to be threshold contaminants (i.e., COPCs that begin to have health effects above a certain threshold, but are not considered to be carcinogenic). Although there is some evidence to suggest that particulate matter, and $PM_{2.5}$ in particular, has carcinogenic properties, it has been considered here as a non-threshold chemical since slope factors have not yet been determined (see Section 21.5.4.2).

<u>Exposure Assessment</u>

A more detailed risk analysis was conducted where predicted concentrations of CACs exceeded the air quality guidelines for each receptor location in the Construction or Operation phases.

The air quality exposure assessment evaluated the potential human health effects from the inhalation of NO_2, TSP, PM_{10}, and $PM_{2.5}$ for the selected worker camps and non-workers human health air quality receptor locations by calculating estimated daily exposures from inhalation (EDEI) for the relevant Project phases.

For the exposure assessment of CACs that exceeded guidelines and baseline in the initial screening, the predicted maximum concentration for the 24-hour averaging period was used to calculate the chronic exposure dose due to inhalation of the COPC. The 24-hour, rather than annual, averaging period was used to represent the concentration to which human receptors would be exposed to on a daily basis during their rotation at the site (for workers). The exposure doses for the worker camps and non-worker human receptor locations are estimated using the following equation (Health Canada 2009):

$$EDEI = \frac{C_{air} \times RAF_{inh} \times IR \times D1 \times D2 \times D3}{BW}$$

where:

EDEI = estimated daily exposure from inhalation of (non-carcinogenic) COPC in air (mg/kg BW/day)

C_{air} = maximum concentration of COPC in air (mg/m^3)

RAF_{inh} = inhalation relative absorption factor (unitless, assumed to be 1)

IR = inhalation rate (assumed to be 16.6 m^3/day for adults; Health Canada 2009)

BW = body weight (assumed to be 70.7 kg; Richardson 1997)

D1 =	exposure frequency; fraction of hours per day spent at site (unitless; assumed to be 12 hours per day for worker camps, and 24 hours per day for Skii km Lax Ha Lodge)
D2 =	exposure frequency; fraction of days per week spent at site (unitless; assumed to be seven days per week for all human receptor locations)
D3 =	exposure frequency; fraction of weeks per year spent at site (unitless; assumed to be 183 days per year based on two weeks on/two weeks off rotation for worker camps, and 365 days a year for Skii km Lax Ha Lodge)

The EDEI is the average daily dose from the inhalation route that a human receives due to frequenting the site (Health Canada 2009). To estimate the fraction of time exposed, it was assumed that off-duty workers occupy the Project camp areas for 12 hours a day (i.e., 12 hours at the receptor location during off-duty hours). The off-duty workers were assumed to be exposed to air emissions for six months per year (182 days) due to shift rotations with two weeks on and two weeks off. This exposure duration is considered a conservative estimate since actual exposure times may be lower due to vacation or other leave from work, or due to time spent away from the camps during off-duty time. It was assumed that people will be exposed to Project-related emissions for 24 months (2 years) during the Construction phase and for 22 years during the Operation phase.

For the Skii km Lax Ha Lodge, it was assumed that the residents spend 24 hours a day throughout the year (365 days a year) during the Construction and Operation phases of the Project at the Lodge. This is a very conservative assumption because it is highly unlikely that an individual would spend all day, every day at the Lodge throughout the life of the Project.

Tables 21.6-7 and 21.6-8 present the CACs that were selected for further evaluation at specific receptor locations, and the calculated exposure dose of air contaminants (EDEIs) for off duty workers or residents at the Skii km Lax Ha Lodge during the Construction and Operation phases of the Project.

Toxicity Assessment

The potential key effects on human health due to exposure to CACs are described in Section 21.5.2.1. Toxicity assessment involves the classification of the potential effects of substances and the estimation of the amount of a substance that can be received by an organism without adverse health effects, using an appropriate toxicity benchmark such as a TRV. For threshold substances (i.e., not considered to be a carcinogen), adverse effects are expected to only occur above a certain dose rate. The guidelines for NO_2, TSP, PM_{10}, and $PM_{2.5}$ were reviewed and the BC AAQOs were used as a TRV for risk due to inhalation of CACs.

An inhalation tolerable daily intake (TDI) was derived based on the TRV, and the average inhalation rate and body weight for an adult (RAIS 2013):

$$TDI = \frac{TRV \times IR \times RAF_{inh}}{BW}$$

where:

TDI =	tolerable daily intake through inhalation (mg/kg BW/day)
TRV	toxicity reference value (mg/m^3)
IR =	inhalation rate (assumed to be 16.6 m^3/day for adults; Health Canada 2009)
RAF_{inh} =	inhalation relative absorption factor (unitless, assumed to be 1)
BW =	body weight (assumed to be 70.7 kg; Richardson 1997)

Tables 21.6-7 and 21.6-8 show the TDIs for TSP, PM_{10}, and $PM_{2.5}$. Table 21.6-7 also provides the TDIs for NO_2 at Worker Mine Site Existing Camp 1 receptor location.

Risk Characterization

The TDI was used for comparison with the predicted EDEI for each air emission COPC and is expressed as an HQ. An HQ is the ratio between the exposure likely to be incurred by the person and the amount of exposure that is considered to be safe. It was calculated using the following equation (Health Canada 2009):

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

where:

HQ = hazard quotient

EDEI = estimated daily exposure from inhalation of COPC in air (mg/kg BW/day)

TDI = tolerable daily intake through inhalation (mg/kg BW/day)

The HQs for CACs at worker camps and non-worker human receptor locations for air quality that were screened in during the Construction and Operation phases are presented in Tables 21.6-7 and 21.6-8, respectively. All HQs calculated for the predicted CAC concentrations during the Construction and Operation periods at the worker camps were below 1.0, indicating that the potential for risk to health in workers residing in these camps from inhalation of these CACs is acceptable.

As presented in Table 21.6-7, the HQs for predicted 24-hour and annual $PM_{2.5}$ for Worker Mine Site Existing Camp 1 were slightly above 1.0 during the Construction Phase (1.06 and 1.32, respectively). In addition, the HQs for predicted 24-hour PM_{10} exposure for the non-worker human receptor location (i.e., Skii km Lax Ha Lodge) were slightly above 1.0 during the Construction (HQ = 2.16) and Operation (HQ = 1.24) phases (Tables 21.6-7 and 21.6-8), which indicates there is relatively low potential for risk from $PM_{2.5}$ and PM_{10} inhalation. However, Pretivm has committed to additional mitigation, if needed, which is not considered in determining the potential residual effects for air quality (i.e., not included in the HQ calculations).

21.6.3 Residual Effects due to Drinking Water Quality

21.6.3.1 Methodology and Assumptions

In order for there to be a potential for effects to human health due to contamination present in drinking water within the drinking water LSA, the following criteria must be met:

- contaminants must be present in the water potentially used for drinking water within the drinking water LSA at concentrations high enough that effects in humans may occur;
- human receptors (consumers) must be present; and
- human receptors must drink water from within the drinking water LSA water bodies.

Water quality at the mine site area was scoped out of the drinking water assessment since there is no operable pathway in that area for human exposure to drinking water from surface sources. Since changes to the quality of surface water in the Knipple Lake / Bowser River watershed and Wildfire Creek/Scott/Todedada watersheds are expected to be negligible or minimal (i.e., no discharges in this area), no water quality model was developed for these watersheds. Therefore, drinking water at Knipple Lake / Bowser River watershed and Wildfire Creek/Scott/Todedada watersheds was assessed qualitatively.

Table 21.6-7. Risk Characterization for Criteria Air Contaminants that Exceeded Guidelines at Human Receptor Locations during the Construction Phase

Parameter	Units	Worker Mine Site Existing Camp 1												Worker Mine Site Existing Camp 2							
		NO_2, Annual Baseline	NO_2, Annual Predicted	Total TSP, 24-hour Baseline	Total TSP, 24-hour Predicted	Total TSP, Annual Baseline	Total TSP, Annual Predicted	Total PM_{10}, 24-hour Baseline	Total PM_{10}, 24-hour Predicted	Total $PM_{2.5}$, 24-hour Baseline	Total $PM_{2.5}$, 24-hour Predicted	Total $PM_{2.5}$, Annual Baseline	Total $PM_{2.5}$, Annual Predicted	Total TSP, 24-hour Baseline	Total TSP, 24-hour Predicted	Total PM_{10}, 24-hour Baseline	Total PM_{10}, 24-hour Predicted	Total $PM_{2.5}$, 24-hour Baseline	Total $PM_{2.5}$, 24-hour Predicted	Total $PM_{2.5}$, Annual Baseline	Total $PM_{2.5}$, Annual Predicted
C_{air}	mg/m^3	0.0050	0.0815	0.0100	0.246	0.0100	0.0912	0.00340	0.160	0.00130	0.106	0.00130	0.0421	0.0100	0.146	0.00340	0.0991	0.00130	0.0540	0.00130	0.0163
RAF_{inh}	unitless	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
IR	m^3/day	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
D1	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
D2	unitless	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D3	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BW	kg	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
EDEI	**mg/kg BW/day**	**0.000297**	**0.00485**	**0.000594**	**0.0146**	**0.000594**	**0.00542**	**0.000202**	**0.00953**	**0.0000773**	**0.00629**	**0.0000773**	**0.00250**	**0.000594**	**0.00868**	**0.000202**	**0.00589**	**0.0000773**	**0.00321**	**0.0000773**	**0.000968**
Standard/TRV[1]	mg/m^3	0.06	0.06	0.12	0.12	0.06	0.06	0.05	0.05	0.025	0.025	0.008	0.008	0.12	0.12	0.05	0.05	0.025	0.025	0.008	0.008
TDI Inhalation[2]	mg/kg BW/day	0.014	0.014	0.028	0.028	0.014	0.014	0.012	0.012	0.006	0.006	0.002	0.002	0.028	0.028	0.012	0.012	0.006	0.006	0.002	0.002
Risk Characterization	**HQ**	**0.0209**	**0.341**	**0.0209**	**0.515**	**0.0418**	**0.381**	**0.0170**	**0.804**	**0.0130**	**1.06**	**0.0407**	**1.32**	**0.0209**	**0.305**	**0.0170**	**0.497**	**0.0130**	**0.542**	**0.0407**	**0.510**

Parameter	Units	Worker Bowser Cabin 3						Worker Bowser Cabin 4						Worker Bowser Staff House							
		Total PM_{10}, 24-hour Baseline	Total PM_{10}, 24-hour Predicted	Total $PM_{2.5}$, 24-hour Baseline	Total $PM_{2.5}$, 24-hour Predicted	Total $PM_{2.5}$, Annual Baseline	Total $PM_{2.5}$, Annual Predicted	Total PM_{10}, 24-hour Baseline	Total PM_{10}, 24-hour Predicted	Total $PM_{2.5}$, 24-hour Baseline	Total $PM_{2.5}$, 24-hour Predicted	Total $PM_{2.5}$, Annual Baseline	Total $PM_{2.5}$, Annual Predicted	Total TSP, 24-hour Baseline	Total TSP, 24-hour Predicted	Total PM_{10}, 24-hour Baseline	Total PM_{10}, 24-hour Predicted	Total $PM_{2.5}$, 24-hour Baseline	Total $PM_{2.5}$, 24-hour Predicted	Total $PM_{2.5}$, Annual Baseline	Total $PM_{2.5}$, Annual Predicted
C_{air}	mg/m^3	0.00340	0.1066	0.00130	0.0312	0.00130	0.0130	0.00340	0.102	0.00130	0.0302	0.00130	0.0125	0.0100	0.116	0.00340	0.110	0.00130	0.0310	0.00130	0.0131
RAF_{inh}	unitless	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
IR	m^3/day	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
D1	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
D2	unitless	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D3	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BW	kg	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
EDEI	**mg/kg BW/day**	**0.000202**	**0.00634**	**0.0000773**	**0.00186**	**0.0000773**	**0.000770**	**0.000202**	**0.00607**	**0.0000773**	**0.00180**	**0.0000773**	**0.000745**	**0.000594**	**0.00693**	**0.000202**	**0.00653**	**0.0000773**	**0.00184**	**0.0000773**	**0.000777**
Standard/TRV[1]	mg/m^3	0.05	0.05	0.025	0.025	0.008	0.008	0.05	0.05	0.025	0.025	0.008	0.008	0.12	0.12	0.05	0.05	0.025	0.025	0.008	0.008
TDI Inhalation[2]	mg/kg BW/day	0.012	0.012	0.006	0.006	0.002	0.002	0.012	0.012	0.006	0.006	0.002	0.002	0.028	0.028	0.012	0.012	0.006	0.006	0.002	0.002
Risk Characterization	**HQ**	**0.0170**	**0.534**	**0.0130**	**0.313**	**0.0407**	**0.406**	**0.0170**	**0.512**	**0.0130**	**0.303**	**0.0407**	**0.393**	**0.0209**	**0.243**	**0.0170**	**0.551**	**0.0130**	**0.310**	**0.0407**	**0.410**

(continued)

Table 21.6-7. Risk Characterization for Criteria Air Contaminants that Exceeded Guidelines at Human Receptor Locations during the Construction Phase (completed)

		Worker Bowser Cabin 1						Worker Bowser Cabin 2					
Parameter	**Units**	**Total PM_{10}, 24-hour Baseline**	**Total PM_{10}, 24-hour Predicted**	**Total $PM_{2.5}$, 24-hour Baseline**	**Total $PM_{2.5}$, 24-hour Predicted**	**Total $PM_{2.5}$, Annual Baseline**	**Total $PM_{2.5}$, Annual Predicted**	**Total PM_{10}, 24-hour Baseline**	**Total PM_{10}, 24-hour Predicted**	**Total $PM_{2.5}$, 24-hour Baseline**	**Total $PM_{2.5}$, 24-hour Predicted**	**Total $PM_{2.5}$, Annual Baseline**	**Total $PM_{2.5}$, Annual Predicted**
C_{air}	mg/m^3	0.00340	0.0994	0.00130	0.0329	0.00130	0.0132	0.00340	0.0975	0.00130	0.0316	0.00130	0.0129
RAF_{inh}	unitless	1	1	1	1	1	1	1	1	1	1	1	1
IR	m^3/day	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
D1	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
D2	unitless	1	1	1	1	1	1	1	1	1	1	1	1
D3	unitless	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
BW	kg	70	70	70	70	70	70	70	70	70	70	70	70
EDEI	**mg/kg BW/day**	**0.000202**	**0.00591**	**0.0000773**	**0.00196**	**0.0000773**	**0.000787**	**0.000202**	**0.00579**	**0.0000773**	**0.00188**	**0.0000773**	**0.000769**
Standard/TRV[1]	mg/m^3	0.05	0.05	0.025	0.025	0.008	0.008	0.05	0.05	0.025	0.025	0.008	0.008
TDI Inhalation[2]	mg/kg BW/day	0.012	0.012	0.006	0.006	0.002	0.002	0.012	0.012	0.006	0.006	0.002	0.002
Risk Characterization	**HQ**	**0.0170**	**0.499**	**0.0130**	**0.330**	**0.0407**	**0.415**	**0.0170**	**0.489**	**0.0130**	**0.317**	**0.0407**	**0.405**

		Worker Transfer Station Camp				Skii km Lax Ha Lodge					
Parameter	**Units**	**Total PM_{10}, 24-hour Baseline**	**Total PM_{10}, 24-hour Predicted**	**Total PM_{10}, 24-hour Baseline**	**Total PM_{10}, 24-hour Predicted**	**Total PM_{10}, 24-hour Baseline**	**Total PM_{10}, 24-hour Predicted**	**Total $PM_{2.5}$, 24-hour Baseline**	**Total $PM_{2.5}$, 24-hour Predicted**	**Total $PM_{2.5}$, Annual Baseline**	**Total $PM_{2.5}$, Annual Predicted**
C_{air}	mg/m^3	0.0100	0.161	0.00340	0.0880	0.00340	0.108	0.00130	0.0283	0.00130	0.0116
RAF_{inh}	unitless	1	1	1	1	1	1	1	1	1	1
IR	m^3/day	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6	16.6
D1	unitless	0.5	0.5	0.5	0.5	1	1	0.5	0.5	0.5	0.5
D2	unitless	1	1	1	1	1	1	1	1	1	1
D3	unitless	0.5	0.5	0.5	0.5	1	1	0.5	0.5	0.5	0.5
BW	kg	70	70	70	70	70	70	70	70	70	70
EDEI	**mg/kg BW/day**	**0.000594**	**0.00959**	**0.000202**	**0.00523**	**0.000806**	**0.02562**	**0.0000773**	**0.00168**	**0.0000773**	**0.000689**
Standard/TRV[1]	mg/m^3	0.05	0.05	0.05	0.05	0.05	0.05	0.025	0.025	0.008	0.008
TDI Inhalation[2]	mg/kg BW/day	0.012	0.012	0.012	0.012	0.012	0.012	0.006	0.006	0.002	0.002
Risk Characterization	**HQ**	**0.0501**	**0.809**	**0.0170**	**0.441**	**0.0680**	**2.16**	**0.0130**	**0.283**	**0.0407**	**0.363**

Notes:

C_{air} = maximum air concentration of COPC at receptor including background (mg/m^3).

RAF_{inh} = inhalation relative absorption factor (unitless, assumed to be 1).

IR = receptor inhalation rate (assumed to be 16.6 m^3/day for adults (Health Canada 2009)).

D1 = fraction of hours per day spent at site (exposure time; unitless; assumed to be 12 hours over 24 hours).

D2 = fraction of days per week spent at site (exposure frequency; unitless; assumed to be 7 days per week).

D3 = fraction of weeks per year spent at site (exposure frequency; unitless; assumed to be 183 days per year based on two week on/two week off rotation).

BW = body weight (70 kg).

*EDEI = estimated daily exposure from inhalation of (non-carcinogenic) COPC in air (mg/kg BW/day), calculated as EDEI=(Cair*RAF*IR*D1*D2*D3)/BW.*

[1] TRV = Toxicity reference value; the National Ambient Air Quality Objectives - Maximum Desirable2 (µg/m^3).

*[2] TDI Inhalation = tolerable daily intake (mg/kg BW/day); calculated as TDI = Standard*IR*RAF_{inh}/BW.*

HQ = Hazard quotient, calculated as HQ = EDEI/TDI.

(n/a) = not applicable.

Grey shading indicates HQs greater than one and/or ILCRs greater than 1 $x10^{-5}$ (1-in-100,000).

Table 21.6-8. Risk Characterization for Criteria Air Contaminants that Exceeded Guidelines at Human Receptor Locations during the Operation Phase

Parameter	Units	Worker Mine Site Operation Camp				Skii km Lax Ha Lodge	
		Total TSP, 24-hour Baseline	Total TSP, 24-hour Predicted	Total PM_{10}, 24-hour Baseline	Total PM_{10}, 24-hour Predicted	Total PM_{10}, 24-hour Baseline	Total PM_{10}, 24-hour Predicted
C_{air}	mg/m^3	0.0100	0.194	0.00340	0.0946	0.00340	0.0620
RAF_{inh}	unitless	1	1	1	1	1	1
IR	m^3/day	16.6	16.6	16.6	16.6	16.6	16.6
D1	unitless	0.5	0.5	0.5	0.5	1	1
D2	unitless	1	1	1	1	1	1
D3	unitless	0.5	0.5	0.5	0.5	1	1
BW	kg	70	70	70	70	70	70
EDEI	**mg/kg BW/day**	**0.000594**	**0.0115**	**0.000202**	**0.00563**	**0.000806**	**0.0147**
Standard/TRV[1]	mg/m^3	0.12	0.12	0.05	0.05	0.05	0.05
TDI Inhalation[2]	mg/kg BW/day	0.028457143	0.028	0.012	0.012	0.012	0.012
Risk Characterization	**HQ**	**0.0209**	**0.405**	**0.0170**	**0.475**	**0.0680**	**1.24**

Notes:

C_{air} = maximum air concentration of COPC at receptor including background (mg/m^3).

RAF_{inh} = inhalation relative absorption factor (unitless, assumed to be 1).

IR = receptor inhalation rate (assumed to be 16.6 m^3/day for adults (Health Canada 2009)).

D1 = fraction of hours per day spent at site (exposure time; unitless; assumed to be 12 hours over 24 hours).

D2 = fraction of days per week spent at site (exposure frequency; unitless; assumed to be 7 days per week).

D3 = fraction of weeks per year spent at site (exposure frequency; unitless; assumed to be 183 days per year based on two week on/two week off rotation).

BW = body weight (70 kg).

*EDEI = estimated daily exposure from inhalation of (non-carcinogenic) COPC in air (mg/kg BW/day), calculated as EDEI=(Cair*RAF*IR*D1*D2*D3)/BW.*

[1] TRV = Toxicity reference value; the National Ambient Air Quality Objectives - Maximum Desirable2 ($\mu g/m^3$).

*[2] TDI Inhalation = tolerable daily intake (mg/kg BW/day); calculated as TDI = Standard*IR*RAF_{inh}/BW.*

HQ = Hazard quotient, calculated as HQ = EDEI/TDI.

(n/a) = not applicable.

Grey shading indicates HQs greater than one and/or ILCRs greater than 1 x10^{-5} (1-in-100,000).

21.6.3.2 Qualitative Assessment of the Potential for Residual Effects on Human Health due to Drinking Water Quality

Project workers and residents of Skii km Lax Ha Lodge are expected to be present inside the drinking water LSA throughout the life of the Project and will obtain drinking water from a groundwater well. The proponent is committed to providing drinking water that meets BC and Canadian DWQGs (for chemical and bacteriological quality) to workers. Skii km Lax Ha Lodge residents currently use the same drinking water source as the Bowser worker camps. Health effects from drinking water sources for Project workers or residents at Ski km Lax Ha Lodge are not expected as drinking water will be treated to meet established provincial drinking water guidelines and criteria.

Other potential users of drinking water in the drinking water LSA include Skii km Lax Ha, Nisga'a Nation, and Tahltan Nation, and local hunters and guide outfitting companies. There are several current use locations close to Project infrastructure (see Section 21.3.3.2 for further details). Surface water within the Knipple Lake / Bowser River watershed, and Wildfire Creek/Scott/Todedada watersheds, may be used as a drinking water source during the hunting, trapping, and gathering of country foods or when travelling within these areas.

Due to Project design and mitigation measures in place (Section 21.5.3.2), contamination of potential sources of drinking water accessed by First Nations, Nisga'a, or recreational land users is unlikely during the Construction, Operation, Closure, and Post-closure phases of the Project. With the Spill Prevention and Response Plan (Section 29.14) in place, the likelihood of accidental spills occurring is minimized; however, it is possible that a change to the water quality due to small spills may occur along the Brucejack Access Road. In order for a spill to affect First Nations, Nisga'a, or recreational land users, they must consume drinking water from affected water sources downstream of a potential spill site during the short period of time before the spill is cleaned up or remediated. Given the transient or short-term nature of land use, the restrictions on public access to the Brucejack Access Road, and the limited quantities of surface water an individual may consume during their trips, it is very unlikely that residual health effects due to the potential contamination of drinking water will occur.

Metals occur naturally in environmental media (e.g., water, soil, and vegetation) due to local physical and geological processes, and their concentrations could potentially change as a result of Project activities that cause deposition of dust containing metals or due to ML/ARD. Total arsenic, lead, and mercury concentrations within the Knipple Lake and Bowser River watershed were occasionally elevated under baseline conditions (Section 21.3.3) but are not known to have affected human health. With the implementation of mitigation and management measures, the natural levels of arsenic, lead, and mercury (or other metals) in these waterbodies are not anticipated to change materially due to Project-related activities through any of the Project phases (Chapter 13, Assessment of Potential Surface Water Quality Effects, and Section 21.5.3.2) and drinking water quality is expected to remain similar to baseline conditions during Construction, Operation, Closure, and Post-closure phases of the Project.

21.6.4 Residual Effects due to Country Foods Quality

21.6.4.1 Methodology and Assumptions

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.

In order for there to be a potential for effects to human health due to contaminants present in country foods within the country foods LSA, the following criteria must be met:

- contaminants must be present in the country foods at concentrations high enough that effects in humans may occur;

- human receptors (consumers) must be present and hunt, harvest, or collect the country foods from within the country foods LSA; and
- the country foods collected from within the LSA must be consumed.

A screening process was used to select COPCs in country foods based on their potential to affect human health. Metals were the primary type of contaminants considered since other chemicals are unlikely to be present as a result of Project activities at high enough concentrations to lead to effects on human health, after mitigation and management measures are taken into consideration (Section 21.5.4.2). Metals occur naturally in environmental media (e.g., water, soil, and vegetation) due to local physical and geological processes, and their concentrations could potentially change due to Project activities as a result of deposition of dust containing metals or effluent discharge containing metals.

Because country foods take up contaminants from environmental media, the quality of the food is directly related to the quality of the environmental media. To determine the potential effects to country foods, a screening process was developed for selection of COPCs (Figure 21.6-2). When considering country foods that could affect human health, COPC concentrations predicted by modeling were screened against three assessment criteria, namely applicable guidelines, baseline concentrations, and the potential to bioaccumulate in the food chain. If the predicted concentrations of metals in each of the environmental media were below guidelines and below or equal to baseline levels then there would be no predicted human health effects due to changes in the quality of country foods. In cases where no guidelines are available, the bioaccumulative properties of the contaminants were considered for the selection of COPCs.

BC-specific guidelines were preferentially used when available, and mean modelled concentrations of potentially metal-containing water were compared to the following BC guidelines:

- British Columbia's Water Quality Guidelines (BC MOE 2013d); and
- British Columbia's Working Water Quality Guidelines (BC MOE 2006b).

Where BC guidelines were unavailable, CCME guidelines were used in the screening process. The CCME has established the following environmental quality guidelines:

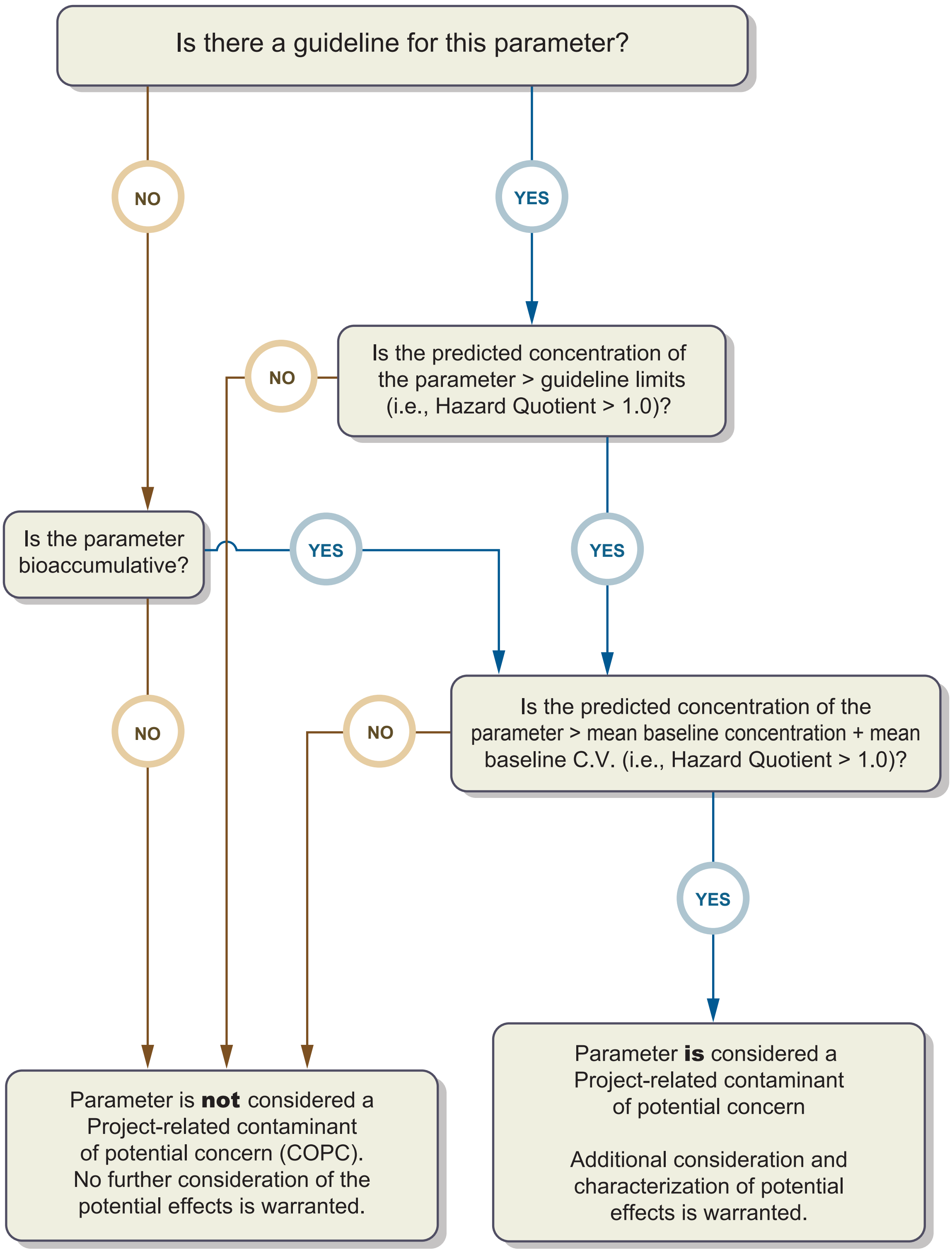
- Water Quality Guidelines for the Protection of Aquatic Life – Freshwater (CCME 2012d); and
- Soil Quality Guidelines for Protection of Environmental and Human Health – Agricultural (CCME 2012c).

Hazard quotients (HQs) were calculated by dividing the predicted mean concentrations of a metal by the guideline limit in each relevant medium. COPCs with an HQ less than 1.0 were screened out of the country foods assessment since these metals would not be expected to cause adverse effects in human receptors due to consumption of country foods exposed to contaminants in the environmental media.

Metals with an HQ greater than 1.0 relative to the guideline were considered in a second screening step. In this step, the predicted metal concentrations were compared to the mean baseline concentration plus the mean baseline concentration coefficient of variation (CV). This baseline concentration was selected because when considering spatial variability in media quality across the country foods LSA, field sampling variability, uncertainty in laboratory methods, and conservatism within the modelling, any contaminant concentration less than the baseline concentration (plus CV) is unlikely to be sufficiently distinguishable from background levels to be considered a Project-related effect. This step was done to ensure that all country foods COPCs identified and carried through the country foods effects assessment were only those COPCs with concentrations that were predicted to increase due to Project-related activities.

Figure 21.6-2

Screening Process for Selection of Contaminants of Potential Concern for Country Foods Effects Assessment



For assessing the potential for risk to human health due to contaminants, it is also important to consider the bioaccumulation potential of the contaminant. Metals without a guideline were assessed for their potential to bioaccumulate or biomagnify in the food chain.

At the end of the screening process for each environmental medium, metals were retained as COPCs in the country foods and assessed for their potential to cause health effects in human receptors if they had:

- HQ greater than 1.0 relative to the guideline **and** an HQ greater than 1.0 relative to baseline concentrations; or
- no guideline with the known potential to bioaccumulate **and** an HQ greater than 1.0 relative to baseline concentrations.

This country foods screening level risk assessment is consistent with methodology used for the country foods baseline screening level risk assessment (Appendix 21-A, Brucejack Gold Mine Project: Country Foods Baseline Assessment) and uses the same approach (problem formulation, exposure assessment, toxicity assessment, risk characterization, and uncertainty analysis; Section 21.3.3).

21.6.4.2 Risk Assessment for Human Health due to Country Foods

The quality of country foods is directly related to the quality of the surrounding environmental media (e.g., soil, water, and vegetation). Chemicals accumulated from the environment may be present in the edible tissue portions of the country foods consumed by people. The potential for adverse effects in human consumers due to contaminants present in country foods depends on the concentration of the chemical, which type and portion of the country food is eaten (e.g., roots or leaves, muscle tissue or liver), life stage of the consumer (e.g., toddler or adult), quantity of food consumed, and frequency of consumption.

<u>Problem Formulation</u>

Selection of Country Foods for Evaluation

Consistent with the baseline study for country foods (Appendix 21-A, Brucejack Gold Mine Project: Country Foods Baseline Assessment), the same country foods were selected for evaluation (Table 21.6-9). For the rationale behind the selection process for country foods, refer to Section 21.3.3 or Appendix 21-A. It was assumed that the predicted quality of these country foods was representative of other potential country foods that might be collected, providing an indication of the potential for human health risk due to incidental consumption of metals in country foods from the LSA.

Table 21.6-9. Country Foods Selected for Evaluation

Category	Country Food	Species Name
Large Mammal	Moose	*Alces alces*
Small Mammal	Snowshoe hare	*Lepus americanus*
Bird	Grouse	*Phasianidae* sp.
Vegetation	Berries	Mixture of berries[1]

[1] Consisted of Alaska blueberry, thinleaf huckleberry, bog blueberry, and Canada Buffaloberry.

Since the water quality within the Brucejack Transmission Line and Brucejack Access Road area of the country foods LSA is expected to remain similar to background conditions (Section 21.6.3 and Chapter 13, Assessment of Potential Surface Water Quality Effects), the predicted water quality during all Project phases, and hence the quality of fish from these water bodies, is expected to be similar to that measured in baseline studies. Therefore, fish were not considered further in this country foods effects assessment since the potential risk to human consumers is not expected to change relative to the baseline as a result of Project activities.

In total, the quality (in terms of metal concentration) of four country foods from four different groups (i.e., moose, snowshoe hare, grouse, and berries) was estimated for the Operation phase of the Project.

Potential Exposure to Human Receptors

Potential human receptors for country foods include members of Skii km Lax Ha, Nisga'a Nation, Tahltan Nation, and Gitanyow Nation, and local hunters and guide outfitting companies. Skii km Lax Ha traditional territory encompasses the country foods LSA and therefore Skii km Lax Ha are the most relevant human receptor for assessing the human health effects from consuming country foods. Current Skii km Lax Ha country food harvest sites closest to Project infrastructure include a cranberry picking area along the Bowser River west of Bowser Lake (near the Brucejack Access Road), a hunting and trapping area on the north side of Mount Anderson (used for harvesting moose, grizzly bear, mountain goat, and martens), and a corridor along the Salmon River close to the Brucejack Transmission Line (Chapter 24, Assessment of Potential Commercial and Non-commercial Land Use Effects) where mountain goat and hoary marmot are harvested while traveling between Stewart, BC and other places in their territory (Chapter 24).

Public access will be restricted along the Brucejack Access Road through the Transportation and Access Management Plan (Section 29.16) and the Wildlife Management and Monitoring Plan (Section 29.21), as well as the implementation of a no hunting policy. These mitigation measures, while primarily intended to ensure safety to employees and the public, will also incidentally decrease the potential for hunting and gathering country foods from areas closest to the Project infrastructure. The areas closes to the Project infrastructure are the ones most likely to be affected by the Project emissions.

Human Receptor Characteristics

Both adults (older than 19 years of age) and toddlers (six months to four years of age) were evaluated for susceptibility to selected COPCs (Health Canada 2010b, 2010c). Toddlers are often considered to be at the most susceptible life stage for effects due to chemical exposures because of their higher relative ingestion rates per unit body weight and their rapid adsorption and metabolic rates during this important growth period, compared to adults. Although children are not likely to be in the LSA or RSA, they may eat country foods that are collected from the LSA or RSA by a family member.

The human receptor characteristics used in this assessment were body weight (kg), number of meals per year, and exposure frequency of the selected country foods (Tables 21.6-10 and 21.6-11). The body weights for adults and toddlers were based on guidance provided by Health Canada (2010a, 2010c).

Country foods consumption frequency presented in Table 21.6-11 are based on a study on First Nation traditional diet in the region (Jin 2006) and a Skii km Lax Ha Country Foods Consumption Questionnaire (Appendix A of Appendix 21-A, Brucejack Gold Mine Project: Country Foods Baseline Assessment). As a conservative measure, the highest exposure frequency among from the available data was used in the assessment. No data were collected on the serving sizes of toddlers; it was assumed that a toddler would eat country foods at the same frequencies as adults and with a 43% reduction of the adult serving size (Richardson 1997). This approach is the same as that used in the country foods baseline assessment (Section 21.3.3 and Appendix 21-A).

Table 21.6-10. Human Receptor Ingestion Rates

	Receptor Groups	
Receptor Characteristics	**Toddlers**	**Adults**
Body Weight (kg)[a]	16.5	70.7
Country Foods Serving Size (kg/serving)[b,c]		
Moose	0.0916	0.213
Snowshoe Hare	0.150	0.348
Grouse	0.129	0.299
Berries[d]	0.120	0.280

[a] Based on Health Canada guidelines (Health Canada 2010a).
[b] Based on First Nation traditional diet in the region (Jin 2006).
[c] Toddlers ingestion rates are assumed to be 43% of adult ingestion rates, based on Richardson (1997).
[d] Includes Alaska blueberry, thinleaf huckleberry, bog blueberry, and Canada Buffaloberry.

Table 21.6-11. Human Receptor Consumption Frequencies

Receptors Characteristics	**Consumption Frequency**			
First Nation	**Skii km Lax Ha**		**Tahltan**	
Country Foods	**Number of Meals per Year**[a]	**Exposure Frequency (F)**[a]	**Number of Meals per Year**[b]	**Exposure Frequency (F)**[b]
Moose	156	0.427	364	0.997*
Snowshoe Hare	12	0.0329*	3	0.008
Grouse	12	0.0329*	6	0.016
Berries[c]	156	0.427*	12	0.033

Exposure frequency was calculated as a proportion of the number of days per year that a country food is consumed
** Indicates the more conservative human receptor exposure frequencies, which were used in this assessment.*
[a] Based on Skii km Lax Ha Country Foods Questionnaire (Appendix 21-A).
[b] Based on First Nation traditional diet in the region (Jin 2006).
[c] Includes Alaska blueberry, thinleaf huckleberry, bog blueberry, and Canada Buffaloberry.

The ingestion rate and frequency of each country food was assumed to reasonably represent the consumption pattern of people who consume the most of each country foods from the study area (Tables 21.6-10 and 21.6-11). For further information on human receptor characteristics, see Section 7.4 of Appendix 21-A.

Screening for Contaminants of Potential Concern

Because country foods take up contaminants from environmental media (i.e., freshwater, soil, and vegetation), the quality of the foods is directly related to the quality of the environmental media (Figure 21.5-1). To determine the potential for human health effects due to consumption of country foods, predicted changes to the environmental media were screened against relevant guidelines and baseline concentrations for each of the environmental media. Note that CCME Soil Quality Guidelines for agricultural land use are considered to protect primary, secondary, and tertiary consumers from adverse effects due to ingestion of the contaminated soil and food (CCME 1999a). Therefore, selection of COPCs based on vegetation quality was not used in this assessment since there are no guidelines specific to vegetation and the soil quality guidelines are considered to be protective against effects to vegetation or higher trophic level consumers. The following sections provide details of screening of country foods COPCs from each of the relevant environmental media.

Selection of COPCs based on Predicted Freshwater Quality

Due to the Project design and mitigation measures that have been proposed (Section 21.5.3.2 and Chapter 13, Assessment of Potential Surface Water Quality Effects, Sections 13.4.2, Identifying Potential Effects on Surface Water Quality, and 13.5.3, Identifying Key Effects: Off-site Areas), there will be no effluent, waste rock, or tailing discharges to water bodies within the Brucejack Transmission Line and Brucejack Access Road areas. Road rehabilitation, maintenance, and dust generated from the use of the road will be the only possible sources of metals for the water bodies within the transmission line and access road areas. However, these sources are considered to be relatively minor (Section 21.6.3; Chapter 13) and, therefore, water quality within these areas of the country foods LSA is not expected to be measurably changed due to any of the Project-related activities or infrastructure during the Construction, Operation, Closure, or Post-closure phase of the Project. Since no Project-related water quality effects are expected for the transmission line and access road areas of the country foods LSA, no freshwater metal COPCs were identified as having the potential to affect the quality of country foods. Tables 21.3-4 and 21.3-5 provide the mean baseline water quality for Knipple Lake / Bowser River watershed, which was assumed to be the same as surface water quality during the various phases of the Project in the transmission line and access road areas.

Selection of COPCs based on Predicted Soil Quality

There will be no effluent, treated water, or tailings discharges to any of the water bodies or terrestrial environment within the Brucejack Transmission Line and Brucejack Access Road areas during any phase of the Project. The only potential pathway through which metals may enter soil as a result of Project activities is from atmospheric deposition of metals in fugitive dust.

Prediction of Soil Quality

The US EPA has published methods for use in human health risk assessments for calculating contaminant concentrations in soil due to atmospheric dust deposition (US EPA 2005). Calculations of the incremental increase in soil metal concentrations were done based on predicted metal concentrations in dustfall, determined using data from the air quality dispersion model (Chapter 7, Air Quality Predictive Study) and baseline dustfall results (Appendix 7-A, Brucejack Gold Mine Project: 2012 Meteorology Baseline Report).

Air emissions are expected to be highest during the Construction and Operation phases of the Project. Air emissions in the form of fugitive dust during the Closure and Post-closure phases were considered to be negligible. Therefore only the Construction and Operation phases were modelled (Section 7.4.3, Identifying Key Potential Effects on Air Quality).

Air quality dispersion modelling was done for total annual dustfall for the worst-case year (i.e., the year with the highest anticipated activities and dustfall amounts) during the Construction phase. Since the Project activity levels and dustfall amounts are not expected to vary greatly between different years of the Operation phase, air quality dispersion modelling for the Operation phase was done for total dustfall averaged over a year for a typical activity level (Chapter 7, Air Quality Predictive Study).

For the purpose of soil quality modeling, the following assumptions were made:

- the dust deposition that was modelled during the worst-case scenario year of Construction phase will occur during each of the two years in the Construction phase;
- the dust deposition that was modelled during a typical year of the Operation phase will occur each year throughout the 22 years of the Operation phase;

- All dust deposited onto soil was conservatively assumed to remain in place, and not run-off during rain events;
- predictions did not take into account freezing effects or complete overage of the road by snow in the colder months of the year which will decrease or eliminate dust resuspension and reduce dustfall levels; and
- the Project-related metal proportions in dust during the Construction and Operation phases in the Brucejack Access Road and Brucejack Transmission Line areas are similar to the background dust metal proportions measured during baseline studies. This assumption was made because the Project is an underground mine, the access road is already largely constructed, and dustfall along the Brucejack Access Road and Brucejack Transmission Line is mainly associated with the re-suspension of dust in the area, rather than with the handling of ore and waste rock.

The air quality modelling domain does not include the entire Brucejack Access Road. An average of the predicted dust deposition for the two soil sample locations along the Brucejack Access Road at the edge of the air quality modelling domain (BJ018 and 12-7169 sample locations) were used to estimate dust deposition for the soil sample locations that were located outside of the air quality modeling domain along the Brucejack Access Road.

CALPUFF model results for dustfall amounts were multiplied with the metal proportions in the dust measured during baseline studies (based on the average of 98th percentiles of the baseline dust metal concentrations) to predict the metal concentrations in the dust for Construction and Operation phases of the Project (Section 7.3.4, Identifying Key Potential Effects on Air Quality). Appendices 21-B and 21-C provide predicted metal concentrations in fugitive dust for the Construction and Operation phases of the Project, respectively.

Predicted soil metal concentrations were calculated by adding the baseline soil concentration measured at each site to the incremental increase in soil metal concentration predicted using the US EPA methodology and formulas (US EPA 2005). For the Construction phase, once the incremental change in soil metal concentration was calculated, it was added to the metal concentration measured during baseline studies at that site to arrive at a predicted soil metal concentration. For the Operation phase, the incremental change in the soil metal concentration was added to the predicted soil concentration at the end of Construction phase to estimate the soil metal concentration for the Operation phase of the Project.

The incremental increase in soil metal concentrations was calculated for each metal using the equation below, as suggested by US EPA (2005):

$$C_S = 100 \times \left(\frac{D}{Zs \times BD}\right) \times t_D$$

where:

Cs =	Average soil concentration over exposure duration (mg COPC/kg soil)
100 =	Unit conversion factor (from mg-m^2 to kg-cm^2)
D =	Yearly dry deposition rate of contaminant (g/m^2-year)
t_D =	Time period over which deposition occurs (years)
Z_s =	Soil mixing zone depth (cm)
BD =	Soil bulk density (g/cm^3)

The time period (t_D) over which dust deposition may occur was assumed to be two years for the Construction phase and 22 years for the Operation phase. Metals deposited with fugitive dust were assumed to mix with the top 2 cm of soil (Z_s), as recommended by US EPA (2005) for untilled soils. The bulk density (BD) for soil was set at the default value of 1.5 g soil/cm^3 soil, as recommended by the US EPA (2005). Weathering and degradation were considered to only be significant for organic contaminants (e.g., PAHs) and not metals (US EPA 2005), thus a soil loss constant was not necessary (i.e., it was assumed that none of the metals were lost to weathering or degradation).

Appendices 21-D and 21-E provide the predicted Construction and Operation phase concentrations of soil and the predicted incremental change in the soil concentration for each phase.

Tables 21.6-12 and 21.6-13 provide the results of the soil screening process for the Construction and Operation phases of the Project.

During the Construction phase, the predicted concentrations of metals in soils, even using conservative modelling assumptions, were not substantially different from the metal concentrations measured under baseline conditions (Table 21.6-12). Therefore, no COPCs were identified based on predicted soil quality during the Construction phase for inclusion in the country foods effects assessment.

Generally, predicted metal concentrations in soil for the Operation phase of the Project in the Brucejack Transmission Line and Brucejack Access Road areas of the country foods LSA were either lower than CCME Guidelines for the Protection of Environmental and Human Health for agricultural land, or were lower than the mean baseline concentration plus mean baseline concentration coefficient of variation. Results of the modelling indicate that the loading of most metals to soils as a result of Project activities during the Operation phase is minimal and is within the range of natural variability.

The only exception was the predicted soil concentration of selenium from the Operation phase of the Project. The Operation phase predicted soil concentration of selenium was greater than the CCME Soil Quality Guidelines for the Protection of Environmental and Human Health for agricultural land (HQ of 1.39, relative to guideline), and greater than concentrations measured during baseline (HQ of 1.27, relative to baseline). Therefore, based on predicted soil quality, selenium was selected as a COPC for the Operation phase of the Project and was carried forward for consideration in the country foods effects assessment to estimate the risk to human health from the consumption of country foods containing selenium.

Results of Screening of Contaminants of Potential Concern for Country Foods

No COPCs were identified based on predicted water quality for inclusion in the country foods effects assessment. Selenium was identified as the Project-related COPCs for country foods based on potential incremental changes in soil quality due to Project activities during the Operation phase of the Project. Therefore, a screening level risk assessment was conducted for the potential for selenium in country foods during the Operation phase to affect human health.

<u>Predicted Concentrations of Selenium in Country Foods</u>

Tissue concentrations for moose, snowshoe hare, and grouse were estimated using a food chain model. The food chain model predicts metal concentrations in animal tissue by estimating the fraction of metals that are retained in the tissues when wildlife ingest environmental media such as vegetation, soil, and surface water. The food chain model followed the methodology described in Golder and Associates (2005) and is the same model used in the baseline country foods assessment (Appendix C of Appendix 21-A, Brucejack Gold Mine Project: Country Foods Baseline Assessment).

Table 21.6-12. Selection of Contaminants of Potential Concern based on Soil Quality during the Construction Phase for the Country Foods Effects Assessment

Metals	Predicted Mean Soil Concentration (mg/kg)	Screening Step 1: CCME Soil Guidelines[1] (mg/kg)	Screening Step 1: Hazard Quotient relative to Guideline	Screening Step 1: Predicted Concentration > Guideline?	Screening Step 1: Bioaccumulative	Screening Step 2: Baseline Soil Concentration Plus C.V.[2] (mg/kg)	Screening Step 2: Hazard Quotient relative to Baseline	Screening Step 2: Predicted Concentration > Baseline Plus C.V.?	Retained as a COPC?
Aluminum	20357	-	-	-	Low				No
Antimony	1.35	20	0.0675	No	Low				No
Arsenic	15.3	12	1.27	Yes	Variable	24.2	0.633	No	No
Barium	79.2	750	0.106	No	Low				No
Beryllium	0.375	4	0.094	No	Low				No
Bismuth	0.159	-	-	-	Low				No
Cadmium	0.387	1.4	0.276	No	Moderate to high				No
Calcium	2148	-	-	-	Low				No
Chromium	50.7	64	0.792	No	Low				No
Cobalt	11.2	40	0.280	No	Low				No
Copper	34.4	63	0.546	No	Low				No
Iron	37867	-	-	-	Low				No
Lead	9.4	70	0.135	No	Low to high (plants)				No
Lithium	21.6	-	-	-	Low				No
Magnesium	7625	-	-	-	Low				No
Manganese	748	-	-	-	Low				No
Mercury	0.087	6.6	0.0132	No	High as methylmerury				No
Molybdenum	1.76	5	0.353	No	Low				No
Nickel	39.2	50	0.784	No	Low to moderate				No
Phosphorus	1080	-	-	-	Low				No
Potassium	938	-	-	-	Low				No
Selenium	0.87	1	0.869	No	Moderate to high	1.09	0.793	No	No
Silver	0.634	20	0.0317	No	Low				No
Sodium	270	-	-	-	Low				No
Strontium	15.0	-	-	-	Low				No
Thallium	0.155	1	0.155	No	Moderate				No
Tin	1.01	5	0.202	No	Low				No
Titanium	397	-	-	-	Low				No
Uranium	0.394	23	0.0171	No	Low				No
Vanadium	66.9	130	0.515	No	Low				No
Zinc	77.7	200	0.389	No	High				No

Notes:

CCME = Canadian Council of Ministers of the Environment.

[1] CCME (2013). Soil Quality Guidelines for the Protection of Environmental and Human Health - Agricultural.

[2] Mean baseline soil concentration plus mean baseline soil concentration coefficient of variation samples collected in 2012.

(-) = no guideline or no value.

Gray shade indicates predicted concentrations are below CCME guidelines or if no guideline is available, contaminant does not have bioaccumulative properties; therefore, a second screening is not required and the contaminant is not retained as a COPC.

Bold and box indicates concentrations above baseline concentrations and CCME guidelines.

COPC = Contaminants of potential concern.

C.V. = Coefficient of variation.

Table 21.6-13. Selection of Contaminants of Potential Concern based on Soil Quality during the Operation Phase for the Country Foods Effects Assessment

Metals	Predicted Mean Soil Concentration (mg/kg)	Screening Step 1				Screening Step 2			Retained as a COPC?
		CCME Soil Guidelines[1] (mg/kg)	Hazard Quotient relative to Guideline	Predicted Concentration > Guideline?	Bioaccumulative	Baseline Soil Concentration Plus C.V.[2] (mg/kg)	Hazard Quotient relative to Baseline	Predicted Concentration > Baseline Plus C.V.?	
Aluminum	20398	-	-	-	Low				No
Antimony	2.90	20	0.145	No	Low				No
Arsenic	15.4	12	1.29	Yes	Variable	24.2	0.639	No	No
Barium	80.1	750	0.107	No	Low				No
Beryllium	0.688	4	0.172	No	Low				No
Bismuth	0.473	-	-	-	Low				No
Cadmium	0.427	1.4	0.305	No	Moderate to high				No
Calcium	2476	-	-	-	Low				No
Chromium	51.0	64	0.797	No	Low				No
Cobalt	11.2	40	0.281	No	Low				No
Copper	50.6	63	0.804	No	Low				No
Iron	37967	-	-	-	Low				No
Lead	9.92	70	0.142	No	Low to high (plants)				No
Lithium	24.7	-	-	-	Low				No
Magnesium	7745	-	-	-	Low				No
Manganese	759	-	-	-	Low				No
Mercury	0.118	6.6	0.0179	No	High as methylmerury				No
Molybdenum	1.81	5	0.363	No	Low				No
Nickel	40.6	50	0.813	No	Low to moderate				No
Phosphorus	1395	-	-	-	Low				No
Potassium	2197	-	-	-	Low				No
Selenium	1.49	1	1.49	Yes	Moderate to high	1.09	**1.36**	Yes	Yes
Silver	0.648	20	0.0324	No	Low				No
Sodium	1529	-	-	-	Low				No
Strontium	16.6	-	-	-	Low				No
Thallium	0.217	1	0.217	No	Moderate				No
Tin	1.07	5	0.215	No	Low				No
Titanium	403	-	-	-	Low				No
Uranium	0.400	23	0.0174	No	Low				No
Vanadium	67.5	130	0.520	No	Low				No
Zinc	82.3	200	0.412	No	High				No

Notes:

CCME = Canadian Council of Ministers of the Environment.

[1] CCME (2013). Soil Quality Guidelines for the Protection of Environmental and Human Health - Agricultural.

[2] Mean baseline soil concentration plus mean baseline soil concentration coefficient of variation samples collected in 2012.

(-) = no guideline or no value.

Gray shade indicates predicted concentrations are below CCME guidelines or if no guideline is available, contaminant does not have bioaccumulative properties; therefore, a second screening is not required and the contaminant is not retained as a COPC.

Bold and box indicates concentrations above baseline concentrations and CCME guidelines.

COPC = Contaminants of potential concern.

C.V. = Coefficient of variation.

Predicted Water Selenium Concentration for Use in the Wildlife Food Chain Model

No water quality changes are expected within the Brucejack Transmission Line and Brucejack Access Road areas of the country foods LSA, since predicted water quality during all Project phases for these water bodies are expected to be the same as the baseline (see Section 21.6.4.3). Therefore, for the purposes of the wildlife food chain model, the predicted selenium concentration is 0.000836 mg/L. This concentration is equivalent to the mean baseline concentration of water quality data from within the country foods LSA.

Predicted Soil Selenium Concentration for Use in the Wildlife Food Chain Model

Predicted soil metal concentrations were calculated by adding the baseline soil concentration measured at each site to the incremental increase in soil metal concentration predicted using the US EPA methodology and formulas (US EPA 2005). The selenium concentration in soil in the country foods LSA (excluding the mine site area) during the Operation phase was predicted to be 1.49 mg/kg dw mg/kg dw (Section 21.6.4.3).

Predicted Vegetation and Berry Quality Selenium Concentrations for Use in the Wildlife Food Chain Model

The concentration of metals in or on vegetation is dependent on the amount of uptake of metals from soil and the amount of metals deposited onto the above ground surfaces of the plant from dust in the air.

Uptake of Selenium from Soil by Vegetation and Berries

Soil-to-plant biotransfer factor (BTFs) for metals can be used to account for the metal uptake from soil. BTFs represent the relationship between metal concentrations in soil relative to metal concentrations in plant tissues. For vegetation (e.g., lichen, sedge, and willow), this was done by calculating a BTF for selenium for each baseline sampling site where both soil and vegetation were collected at the same time and measurable concentrations of the metals were present. Locations where soil and vegetation were co-sampled during baseline studies for the Brucejack Transmission Line and Brucejack Access Road areas of the country foods LSA included sites BJ018, BJ030, and V030. The site-specific soil-to-vegetation BTFs for selenium are shown in Table 21.6-14. The raw baseline data can be found in Chapter 16, Assessment of Potential Terrestrial Ecology Effects, of the Application/EIS.

Table 21.6-14. Site-specific Selenium Biotransfer Factor for Soil-to-Vegetation in the Operation Phase

	BJ018	**BJ030**	**V030**
Metals	***Stereocaulon spp.***	***Stereocaulon spp.***	***Cladina stygia***
Selenium	0.0470	0.1750	0.0881

For berries, tissue selenium concentrations measured during baseline studies were below method detection limits, so a site-specific BTF could not be calculated due to uncertainty in the actual concentrations of these metals. Therefore, for berries, a published selenium BTF value of 0.05 from Staven et al. (2003) was used instead.

The BTF values were used to predict metal concentrations in vegetation or berries by multiplying the BTF by the predicted soil concentrations, where available (Appendices 21-D and 21-E). These predictions are presented in Appendices 21-F for vegetation and in Appendices 21-G for berries for the Operation phase of the Project.

For baseline sampling sites that did not have co-collection of soil and vegetation, or soil and berries, it was not possible to predict the amount of metal taken up from the soil via the root (since baseline or predicted soil data was not available for the site). Therefore, it was assumed that the predicted concentration of selenium via root uptake would be equivalent to the baseline concentration of selenium measured in the tissue. This is a reasonably conservative assumption since it assumes that all of the metal measured in the vegetation or berry sample arrived there through root uptake and does not consider metals that may have been on the external surfaces of the samples.

Deposition of Dust onto Vegetation and Berry above Ground Surfaces

Plants also experience direct deposition of dust to their above ground surfaces, and the contribution of metals in dustfall on above ground surfaces of vegetation was calculated using the equation provided by the US EPA (US EPA 2005):

$$Pd = \frac{1000 \times D \times Rp \times [1.0 - exp(-kp \times Tp)]}{Yp \times kp}$$

where:

- *Pd* = plant surface concentration due to direct deposition (mg COPC/kg wet weight)
- *1,000* = unit conversion factor (mg/g)
- *D* = yearly average dry deposition (g/m^2-year)
- *Rp* = interception fraction of the edible portion of plant (unitless)
- *kp* = plant surface loss coefficient ($year^{-1}$)
- *Tp* = length of plant exposure to deposition per harvest of the edible portion (year)
- *Yp* = yield or standing crop biomass of the edible portion of the plant (productivity; kg wet weight/m^2)

The interception fraction of the edible portion of plant (*Rp*) was set to 0.39 for berries, which is the default value provided by the US EPA (2005), and 0.769 for vegetation, which is the value the US EPA recommends for silage (US EPA 2005). The plant surface loss coefficient (*kp*) was set to the default value of 18 $year^{-1}$ recommended by the US EPA (2005). The length of plant exposure to deposition per harvest of the edible portion of the plant (*Tp*) was set to 0.329 year since the vegetation experiences approximately 4 months of ice-free growing conditions annually (120 days divided by 365 days). The yield or standing crop biomass of the edible portion of the plant (*Yp*) was set to 0.25 kg ww/m^2 for berries, which the US EPA (2005) recommends for exposed fruits, and was set to 5.66 for vegetation, which the US EPA (2005) recommends for exposed vegetables.

Predicted Total Metal Concentrations in Vegetation and Berries

The total predicted metal concentration for selenium in vegetation or berries was then calculated as the concentration predicted due to root uptake plus the concentration on surface due to deposition. Results are provided in Appendices 21-F for vegetation, and Appendices 21-G for berries. The total predicted vegetation concentration of selenium was 0.353 mg/kg ww. The total predicted berry concentration of selenium was 0.119 mg/kg ww. There are uncertainties associated with the vegetation and berries BTF used for calculation of the predicted selenium concentrations because BTFs were not site-specific and were based on literature instead. These uncertainties are discussed in Soil to Plant Biotransfer Factors section under the Uncertainty Analysis section of 21.6.4.2. Measured selenium concentrations in berries were below detection limit in berry samples tested.

Summary of Predicted Concentration for Use in the Wildlife Food Chain Model

Table 21.6-15 provides the mean predicted selenium concentration for freshwater, soil, vegetation, and berries for the Operation phase of the Project.

Table 21.6-15. Summary of Predicted Concentration of Selenium in Environmental Media during the Operation Phase

Contaminant of Potential Concern	Predicted Mean Water Concentration[1] (mg/L)	Predicted Mean Soil Concentration[2] (mg/kg dw)	Predicted Mean Vegetation Concentration[3] (mg/kg ww)	Predicted Mean Berry Concentration[4] (mg/kg ww)
Selenium	0.000836	1.49	0.353	0.119

Based on the predicted water, soil, and vegetation selenium concentrations during the Operation phase (Table 21.6-15), the food chain model, as described in Appendix C of Appendix 21-A, was used to predict selenium concentrations in animal tissue (meat). Table 21.6-16 provides the predicted moose, snowshoe hare, and grouse tissue selenium tissue concentrations for the Operation phase of the Project.

Table 21.6-16. Predicted Concentrations of Selenium in Country Foods during the Operation Phase Using Food Chain Modelling

Country Foods	Concentration of Selenium in Meat Tissue Due to Surface Water Intake	Concentration of Selenium in Meat Tissue Due to Soil Intake	Concentration of Selenium in Meat Tissue Due to Vegetation Intake	Total Concentration of Selenium in Meat
Moose	4.74×10^{-5}	5.07×10^{-4}	7.84×10^{-3}	8.40×10^{-3}
Snowshoe hare	2.46×10^{-7}	1.21×10^{-5}	8.43×10^{-5}	9.66×10^{-5}
Grouse	6.59×10^{-5}	1.18×10^{-1}	3.34×10^{-2}	1.51×10^{-1}

All concentrations are expressed in mg/kg wet weight.

Dolly Varden / bull trout were assessed as country foods for the baseline human health country foods assessment. Fish tissue concentrations for Dolly Varden / bull trout for all phases of the Project, including the Operation phase, were assumed to be similar to the baseline levels since no water quality changes within the Brucejack Transmission Line and Brucejack Access Road areas are expected (see Section 21.6.4.3 and Chapter 13, Assessment of Potential Surface Water Quality Effects, for additional details). Therefore, the potential for human health effects is considered to be negligible due to Project-related changes in the quality of fish.

Exposure Assessment

The amount of selenium that people are exposed to from consuming country foods depends on several factors including:

- the concentration of selenium in terrestrial wildlife resulting from ingestion of environmental media (e.g., water, soil, and vegetation);
- the concentration of selenium in aquatic species resulting from uptake of metals from water, sediment, and their diet;
- the concentration of selenium in vegetation resulting from uptake from environmental media or deposition of selenium in fugitive dust; and
- human receptor characteristics (e.g., consumption amount, frequency, body weight).

These parameters are included in the exposure estimate equations to determine the estimated daily intake (EDI) of selenium through the consumption of country foods during the Operation phase of the Project. The EDI of selenium for toddlers and adults was based on the predicted tissue metal concentrations in moose, snowshoe hare, grouse, and berries, and the human receptor characteristics (for additional details on the calculation of EDIs, see Appendix 21-A, Brucejack Gold Mine Project: Country Foods Baseline Assessment). The following equation was used to calculate the EDI of selenium from the consumption of country foods.

$$EDI_{food} = \frac{IR \times C_{food} \times F_s}{BW}$$

where:

EDI_{food} = estimated daily intake of selenium from country food (mg COPC/kg BW/day)

IR = ingestion rate (kg/day)

C_{food} = mean concentration of selenium in food (mg/kg)

F_s = fraction of year consuming country food (unitless)

BW = body weight (assumed to be 70.7 kg; Richardson 1997)

The EDI for selenium for each country food for toddler and adult receptors is presented in Table 21.6-17.

Table 21.6-17. Estimated Daily Intake of Selenium by Human Receptors

Country Foods	Human Receptors	
	Toddler	Adult
Moose	4.65×10^{-5}	2.52×10^{-5}
Snowshoe hare	2.99×10^{-8}	1.56×10^{-8}
Grouse	3.87×10^{-5}	2.10×10^{-5}
Berries	3.73×10^{-4}	2.02×10^{-4}

Toxicity Assessment

To estimate human health risk a TRV, expressed as a TDI (tolerable daily intake), is used as a benchmark for the amount of selenium that can be taken into the human body without experiencing adverse health effects. The term tolerable is used because it signifies permissibility rather than acceptability for the intake of contaminants unavoidably associated with the consumption of otherwise wholesome and nutritious (country) foods (Herrman and Younes 1999). For further details on how TRVs are derived and selected, see Section 9 of Appendix 21-A, Brucejack Gold Mine Project: Country Foods Baseline Assessment.

Selenium is an essential element and is required for human nutrition. Health Canada (2010b) provides an age- and body weight-adjusted tolerable upper limit for selenium of 6.2 and 5.7 µg/kg BW/day (toddlers and adults, respectively), which was used for the country foods effects assessment. This was based on a no observed adverse effect level (NOAEL) in adults of 0.8 mg/kg BW/day in a cohort study by Yang and Zhou (1994) and a NOAEL in children of 0.007 mg/kg BW/day (Shearer and Hadjimarkos 1975).

Risk Characterization

Selenium is not a known or suspected carcinogen; therefore, only non-cancer risks were assessed. Human health risk estimates were quantified using exposure ratios, and were calculated as:

$$\text{Exposure Ratio (ER)} = \frac{\text{Estimated Daily Intake (EDI)}}{\text{Tolerable Daily Intake (TDI)}}$$

The ERs of selenium associated with the consumption of moose, snowshoe hare, grouse, and berries were well below the threshold ratio of 0.2 and the risk based on the modelled selenium concentrations is considered acceptable for all consumers of these country foods (Table 21.6-18).

No residual effects on human health due to the consumption of country foods was identified through this predictive, quantitative screening level risk assessment.

Table 21.6-18. Human Exposure Ratios Based on Predicted Selenium Tissue Concentrations

	Country Foods Receptors	
Country Foods	**Toddler**	**Adult**
Moose	7.50×10^{-3}	4.43×10^{-3}
Snowshoe hare	4.65×10^{-6}	2.74×10^{-6}
Grouse	6.25×10^{-3}	3.69×10^{-3}
Berries	6.01×10^{-2}	3.55×10^{-2}

<u>Uncertainty Analysis</u>

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

Many of the uncertainties associated with the effects assessment for country foods are the same as the uncertainties encountered during the baseline assessment for country foods (Appendix 21-A, Country Foods Baseline Assessment). These uncertainties related to laboratory non-detection of metal concentrations, locations of country foods harvested, consumption amounts and frequencies, and toxicity reference values are fully described in Section 11 of Appendix 21-A. There are a few additional uncertainties that are specific to the effects assessment for country foods, which are discussed in the following sections.

Soil to Plant Biotransfer Factors

Biotransfer factors were used to model Project-related plant COPC concentrations. Modelling of plant COPC concentrations has a higher level of uncertainty than measuring concentrations. Biotransfer factors were calculated on a site-specific basis from baseline concentrations in co-collected soil and plant baseline samples. This method assumes that the plant obtained the COPCs entirely from the soil that was analyzed and excludes uptake from other sources. This approach is conservative as it would over-estimate the soil-to-plant BTF (since some of the uptake could come from other sources, such as deposition of dust on surfaces). Where concentrations were below method detection limits, BTFs could not be calculated reliably and were substituted with non-site specific literature-based BTFs. This added uncertainty to the modelling of plant COPC concentrations.

Soil and plant predicted COPC concentrations are based on the dustfall deposition generated from the air quality dispersion modelling. There are uncertainties associated with the air quality dispersion model. For example, mitigation measures and assumptions included in the air dispersion model include rainfall, other precipitations, and watering of the road to reach 2% moisture ratio, achieving at least 75% of control efficiency of the dust. However, it does not take into account freezing effects or complete coverage of the road by snow in the colder months of the year, which will decrease or eliminate dust dispersion. Due to the climate of the region with the observed mean monthly temperature range below freezing (-4 to -20ºC) for the winter period (November to March; Rescan 2013a), the air dispersion model likely over-predicts dust deposition. Over-prediction of the dustfall deposition results in over-prediction of soil and vegetation COPCs. For a complete list of assumptions, mitigations, and parameters included in the air dispersion model, refer to Chapter 7, Air Quality Predictive Study.

Wildlife Tissue Concentrations

Concentrations of metals in the tissue of moose, snowshoe hare, and grouse were predicted using a food chain model. As with all modelled data, the results are highly dependent on the accuracy of literature-based input parameters and the quality of the model itself. Many of the uncertainties associated with the use of food chain modelling are the same as described in the Country Foods Baseline Report (Appendix 21-A). In addition to these uncertainties, the food chain model used to support the effects assessment is based on predicted concentrations in environmental media. Predicted concentrations inherently have a greater uncertainty than laboratory-measured concentration data.

Consumption Frequencies and Harvesting Locations

For the effects assessment it was assumed that the consumption frequencies and harvesting locations would not change relative to what was used in the baseline country foods assessment (Appendix 21-A). However, this may not be the case since consumption patterns and harvesting locations for country foods may change over time.

21.6.5 Summary of Residual Effects on Human Health

The potential for residual effects on human health due to Project infrastructure or Project-related activities has been identified through several potential exposure routes (i.e., sub-components of the human health VC). The main pathways, or sub-components, for Project-related effects to human health are through noise, or changes to air quality, drinking water quality, or country foods quality.

Mitigation measures such as those detailed in the Air Quality Management Plan (Section 29.2), Noise Management Plan (Section 29.11), and Water Management Plan (Section 29.19), and the implementation of various policies and Best Management Practices will help decrease the potential for residual effects on human health due to noise, air quality, drinking water, and country foods. Although mitigation measures may substantially decrease the potential for residual effects, for most sub-components residual effects on human health were identified.

Project-related noise has the potential to cause residual effects to human health, particularly at sites adjacent to the Brucejack Access Road (Section 21.6.1). Changes in air quality (Section 21.6.2), particularly due to NO_2, PM_{10}, and $PM_{2.5}$, may have residual effects to human health at receptor locations closest to proposed infrastructure (Section 21.6.2). Changes in drinking water quality (outside of the mine site area) have the potential to affect human health; because the effects assessment for drinking water quality in the Brucejack Transmission Line and Brucejack Access Road areas was qualitative, the potential for residual effects cannot be ruled out (Section 21.6.3).

In contrast, no residual effects on human health due to the consumption of country foods was identified through a predictive, quantitative screening level risk assessment, as described in Section 21.6.4 of this assessment.

Table 21.6-19 provides a summary of the potential for Project-related residual effects to human health from the four sub-components (i.e., noise, air quality, drinking water quality, and country foods quality).

21.7 CHARACTERIZING RESIDUAL EFFECTS, SIGNIFICANCE, LIKELIHOOD AND CONFIDENCE ON HUMAN HEALTH

The first section in the residual effects characterization for each sub-component of human health presented below contains a characterization of standard criteria (i.e., the magnitude, geographic extent, duration, frequency, reversibility, resiliency, and ecological or social context associated with each residual effect). Table 21.7-1 provides definitions of the characterization criteria for human health effects due noise, while Table 21.7-2 provides definitions of characterization criteria for human health effects due to air quality, and drinking water. These tables and their generic context are not repeated for each sub-component addressed in Sections 21.7.1 to 21.7.4 below. Note that since no residual effects on human health due to the consumption of country foods were identified, this sub-component is not carried further in this section.

21.7.1 Residual Effects Characterization for Human Health due to Noise

21.7.1.1 Characterizing Human Health Residual Effects due to Noise

Predicted noise levels at several worker camps and a non-worker human receptor location (Skii km Lax Ha Lodge) during the Construction and Operation phases exceed the noise guidelines (WHO 1948; see Section 21.6.1 for further details). To prevent excess amount of noise at the worker camps, camp buildings will be built with material to reduce noise travel.

Short-term construction noise effects are unavoidable during major construction projects and are expected during the operation of industrial sites such as mines, but should be minimized to the extent possible by adhering to best management practices. During the Construction phase, the maximum predicted daytime noise exceedance is 14 dBA above the acceptable noise guideline for sleep disturbance at the worker camp at the Worker Transfer Station Camp and 7 dBA above acceptable levels at the Worker Bowser Staff House. During the Operation phase, only Worker Mine Site Operation Camp and Worker Transfer Station Camp will be used. The Worker Transfer Station Camp noise levels are predicted to exceed the sleep disturbance limit during both day (by 6 dBA) and night (by 4 dBA). Therefore the magnitude of human health effects due to noise at worker camps is rated as major during both the Construction and Operation phases.

These predicted exceedances could be mitigated through adequate glazing and construction design to attenuate outdoor to indoor noise levels. The camp structures will be built with adequate sound insulation and the noise attenuation from outdoor-to-indoor is anticipated to be higher than 27 dBA. An attenuation factor of 30 dBA can be assumed in cold climates (such as the Project area) where building shells are more airtight than structures in warmer climates. Since noise attenuation is likely higher than the values used in the assessment, the assessment is conservative which allows higher confidence in the characterization.

For non-worker noise receptor locations, specifically at the Skii km Lax Ha Lodge, predicted noise levels exceed the acceptable Ldn by 17 dBA and are associated with an increase in %HA by 3.5% beyond the guideline level of 6.5%. Therefore the magnitude of human health effects due to noise at the Skii km Lax Ha Lodge is also considered major. However, the Skii km Lax Ha Lodge was built with triple paned windows and two inch by six inch insulated walls with two inch foam insulation (G. Simpson, pers. comm). The noise attenuation from outdoor to indoor is likely to be higher than what was assumed in the assessment. The residents of the Skii km Lax Ha Lodge have built the lodge to be close to the Bowser Camp facilities and for proximity to the Project. They are hired as third party contractors to work at the Project. Therefore, Skii km Lax Ha Lodge residents are unlikely to experience annoyance due to noise levels from the Project. George Simpson from Skii km Lax Ha, and owner and resident of the Skii km Lax Ha Lodge, has indicated that if predicted noise levels are realized during the Construction or Operation phase and lead to noise levels that are unacceptable to residents, Skii km Lax Ha Lodge residents are willing to apply mitigation measures to reduce the noise levels or relocate if necessary (G. Simpson, pers. comm.).

Table 21.6-19. Summary of Residual Effects on Human Health

Sub-component	Project Phase (timing of effect)	Project Component/ Physical Activity	Description of Cause-Effect[1]	Description of Mitigation Measure(s)	Description of Residual Effect
Noise (due to sleep disturbance for off-duty workers)	Construction and Operation	Construction and operational equipment, road activity	Project Construction and Operation noise sources are predicted to increase noise levels at Project worker accommodations, which could affect off-duty worker health.	Noise Management Plan (Section 29.11)	Predicted exceedance of noise guidelines at Project worker accommodations by up to 7 dBA during construction and up to 4 dBA during operation may cause sleep disturbance.
Noise (due to sleep disturbance, speech interference and high annoyance for non-workers)	Construction and Operation	Construction and operational equipment, road activity, helicopter and aircraft activity	Project Construction and Operation noise sources are predicted to increase noise levels, which could affect non-worker health.	Noise Management Plan (Section 29.11)	Predicted exceedance of noise guidelines for sleep disturbance, speech interference, complaints and %HA at Skii km Lax Ha Lodge.
Air Quality (potential effects on off-duty workers)	Construction and Operation	Construction and Operation activities	SO_2, NO_2, CO, TSP, PM_{10}, and $PM_{2.5}$ levels increase in concentration, which may cause adverse health effects in off-duty workers.	Maintaining equipment, installing a scrubber, installing baghouse, and watering the roads	Predicted SO_2, NO2, CO, TSP, $PM_{2.5}$, and PM_{10} increased in concentration. Annual NO_2 levels during the Construction, and TSP, PM_{10}, and $PM_{2.5}$ during Construction and Operation phases exceed the BC AAQOs for some of the worker camps.
Air Quality (potential effects on non-workers)	Construction and Operation	Construction and Operation activities	SO_2, NO_2, CO, TSP, PM_{10}, and $PM_{2.5}$ levels increase in concentration, which may cause adverse health effects in non-worker human receptors.	Maintaining equipment, installing a scrubber, installing baghouse, and watering the roads	Predicted SO_2, NO_2, CO, TSP, $PM_{2.5}$, and PM_{10} increased in concentration. 24-hour PM_{10} and 24-hour and annual $PM_{2.5}$ concentrations during Construction. 24-hour PM_{10} concentrations during Operation phase exceed the BC AAQOs for Skii km Lax Ha Lodge.

(continued)

Table 21.6-19. Summary of Residual Effects on Human Health (completed)

Sub-component	Project Phase (timing of effect)	Project Component/ Physical Activity	Description of Cause-Effect[1]	Description of Mitigation Measure(s)	Description of Residual Effect
Drinking Water Quality (potential effects on off-duty workers)	Construction and Operation	Construction and Operation activities	Project-related activities along the Transmission Line or Access Road corridors may lead to introduction of contaminants or suspended solids into adjacent waterways; potential for Project-related spills/leaks to affect surface water quality.	BMPs, ML/ARD Management Plan (Section 29.10), Water Management Plan (Section 29.19), Soils Management Plant (Section 29.13), Transportation and Access Management Plan (Section 29.16), Aquatic Effects Monitoring Plan (Section 29.3), Spill Management and Emergency Response Plan (Section 29.14), Air Quality Management Plan (Section 29.2; to minimize dust generation)	None expected, since workers (including off-duty workers) will be provided with potable drinking water by the Proponent.
Drinking Water Quality (potential effects on non-workers)	Construction and Operation	Construction and Operation activities	Project-related activities along the Transmission Line or Access Road corridors may lead to introduction of contaminants or suspended solids into adjacent waterways; potential for Project-related spills/leaks to affect surface water quality.	BMPs, ML/ARD Management Plan (Section 29.10), Water Management Plan (Section 29.19), Soils Management Plant (Section 29.13), Transportation and Access Management Plan (Section 29.16), Aquatic Effects Monitoring Plan (Section 29.3), Spill Management and Emergency Response Plan (Section 29.14), Air Quality Management Plan (Section 29.2) to minimize dust generation)	Potential for water quality changes in Transmission Line or Access road corridor due to localized introduction of contaminants or suspended solids into waterways adjacent to Project infrastructure; potential for Project-related spills/leaks to affect surface water quality.
Country Foods (potential effects on country foods consumers)	Construction and Operation	Construction and Operation activities	Potential changes in the quality of environmental media (e.g., soil or water) could affect the quality of country foods, which could subsequently affect the health of human consumers of country foods.	Water Management Plan (Section 29.19), Aquatic Effects Monitoring Plan (Section 29.3), Spill Management and Emergency Response Plan (Section 29.14), Air Quality Management Plan (Section 29.2)	None expected, since a quantitative, screening level risk assessment of the potential for effects due to predicted metal concentrations in country foods did not find any unacceptable health risks associated with country foods consumption.

[1] *"Cause-effect" refers to the relationship between the Project component/physical activity that is causing the change or effect in the condition of the receptor VC, and the actual change or effect that results.*

Table 21.7-1. Definitions of Characterization Criteria for Residual Effects on Human Health due to Noise

Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Resiliency	Social Context
Low:	Short-term:	Once:	Local:	Reversible short-term:	Low:	Low:
Noise level experience is below or at the guidelines or equivalent to baseline noise levels	Effect lasts less than a year	An effect that occurs once or infrequently during any phases of the Project	An effect is limited to the Project footprint	An effect that can be reversed relatively quickly	The receptor is considered to be of low resiliency following disturbances	The receptor is considered to have little to no unique attributes
Moderate:	Medium-term:	Sporadic:	Landscape:	Reversible medium-term:	Neutral:	Neutral:
Differs from the average baseline condition to a small degree and is 0 to 5 dBA above guidelines	Effect lasts more than a year but less than 11 years	An effect that occurs at sporadic or intermittent intervals during any phases of the Project	An effect extends beyond the Project footprint to a broader area (limited to portions of RSA)	An effect that can be reversed after a few years	The receptor is considered to be moderately resilient following disturbances	The receptor is considered to have some unique attributes
High:	Long-term:	Regular:	Regional:	Reversible long-term:	High:	High:
Differs substantially from baseline conditions and is more than 5 dBA above guidelines	Effect lasts more than 11 years but less than 30 years	An effect that occurs regularly during an phases of the Project	An effect extends across the RSA	An effect that can be reversed after many years	The receptor is considered to be highly resilient following disturbances	The receptor is considered to be unique
	Far Future:	Continuous:	Beyond Regional:	Permanent:		
	Effect lasts more than 30 years	An effect that occurs regularly during an phases of the Project and beyond	An effect extends beyond the RSA possibly across or beyond the province	An effect cannot be reversed		

Table 21.7-2. Definitions of Characterization Criteria for Residual Effects on Human Health due to Air Quality and Drinking Water

Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Resiliency	Social Context
Low: No change from baseline conditions or below applicable guidelines (i.e., HQ ≤ 1 for non-carcinogenic compounds)	Short-term: Effect lasts less than a year	Once: An effect that occurs once or infrequently during any phases of the Project	Local: An effect is limited to the Project footprint	Reversible short-term: An effect that can be reversed relatively quickly	Low: The receptor is considered to be of low resiliency following disturbances	Low: The receptor is considered to have little to no unique attributes
Moderate: Some change from Baseline or above applicable guidelines, and health effects are possible (i.e., 1 < HQ < 10 for non-carcinogenic compounds)	Medium-term: Effect lasts more than a year but less than five years	Sporadic: An effect that occurs at sporadic or intermittent intervals during any phases of the Project	Landscape: Drinking Water and Country Foods Quality: An effect extends beyond the Project footprint but is limited to the LSA. Air Quality: An effect extends beyond the Project footprint to a broader area (limited to portions of RSA)	Reversible medium-term: An effect that can be reversed after a few years	Neutral: The receptor is considered to be moderately resilient following disturbances	Neutral: The receptor is considered to have some unique attributes
High: Significant change from baseline or significantly greater than guidelines, and health effects are probable (i.e., HQ ≥ 10 for non-carcinogenic compounds)	Long-term: Effect lasts more than five years but less than ten years Far Future: Effect lasts more ten years	Regular: An effect that occurs regularly during an phases of the Project Continuous: An effect that occurs regularly during an phases of the Project and beyond	Regional: An effect extends across the RSA Beyond Regional: An effect extends beyond the RSA possibly across or beyond the province	Reversible long-term: An effect that can be reversed after many years Permanent: An effect cannot be reversed	High: The receptor is considered to be highly resilient following disturbances	High: The receptor is considered to be unique

While the magnitude of noise effects is considered major during Construction and Operation, additional mitigation measures not considered in the assessment could be incorporated during the Project detailed design phase that could reduce the potential magnitude of effects to minor.

The duration of the residual for effects due to noise during the Construction phase is considered medium-term because effects may last between one to two years (i.e., throughout the duration of construction). Duration of residual effect during the Operation phase is considered long term because effects may last up to 22 years (i.e., throughout the duration of Operation)

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.

The spatial extent is assessed to be landscape, as noise levels are predicted to increase in the immediate vicinity of the Project, but would be expected to diminish logarithmically with distance from the source.

Noise and its predicted influence on human health are reversible in the short term. People with decreased personal abilities such as the blind or hearing impaired, people with medical problems (e.g., sleeping disorders, illness, or depression), babies and young children, the elderly, and shift works may be more susceptible to noise and have lower resiliency (WHO 1999). However, only adults are expected to be present within the noise RSA; the resiliency was assessed to be low since many of the people present will work shifts and may, therefore, be more sensitive to noise.

Although proper sleep and noise levels are important for the safe construction and operation of the mine, given the variability in people's tolerance for noise, the context is considered to be neutral (Table 21.7-3).

21.7.1.2 Likelihood for Residual Effects on Human Health due to Noise

Given the remoteness of the Project, its limited accessibility, limited land-use activities, and the adaptive management and monitoring plans that have been proposed, the likelihood of occurrence of residual effects due to elevated noise levels is considered to be low. In addition, most people who will be present and potentially exposed to noise levels will be workers for the Project. Workers would likely anticipate that noise levels would be elevated at an operational mine site, may be more likely to accept the elevated noise levels, and may be able to adapt to or further mitigate (e.g., through use of ear-plugs) the elevated noise levels so that sleep disturbance is not experienced.

The Skii km Lax Ha Lodge has already been constructed and is in use. It is a permanent residence for Skii km Lax Ha, and was built with adequate sound insulation to today's standards with triple-paned windows and two inch by six inch insulated walls with two inch foam insulation on the outside (G. Simpson, pers. comm.). Therefore, it is considered likely that the building will reduce the amount of noise emitted from the nearby infrastructure efficiently and to a greater extent than what was assumed in the noise effects assessment. If noise levels at the Skii km Lax Ha Lodge exceed the guidelines, installation of thicker glass for windows may reduce the noise levels. As mentioned, residents of the Skii km Lax Ha Lodge would be willing to apply mitigation measures or relocate the lodge if necessary. Therefore, the likelihood of occurrence of residual health effects due to elevated noise levels at the Skii km Lax Ha Lodge is considered low.

21.7.1.3 Significance of Residual Effects on Human Health due to Noise

With mitigation, the residual effect to human health due to exposure to noise is considered not significant at worker camps and non-worker noise receptor locations. In addition, monitoring will be conducted as per regulations and to address complaints should they occur (Section 8.7, Mitigation Measures for Noise).

Table 21.7-3. Characterization of Residual Effects, Significance, Confidence and Likelihood on Human Health

Residual Effects	Human Receptors	Evaluation Criteria								Likelihood *(low, medium, high)*	Significance *(not significant, significant)*	Confidence *(low, medium, high)*
		Timing	Magnitude *(low, moderate, high)*	Duration *(short-term, medium-term, long-term, far future)*	Frequency *(once, sporadic, regular, continuous)*	Geographic Extent *(local, landscape, regional, beyond regional)*	Reversibility *(reversible short-term, reversible long term, irreversible)*	Resiliency *(low, neutral, high)*	Context *(low, neutral, high)*			
Noise (due to sleep disturbance for off-duty workers)	Worker Camps	Construction	High	Medium term	Regular	Landscape	Reversible short-term	Low	Neutral	Low	Not significant	High
Noise (due to sleep disturbance, speech interference and high annoyance for non-workers)	Skii km Lax Ha Lodge	Construction	High	Medium term	Regular	Landscape	Reversible short-term	Low	Neutral	Low	Not significant	High
Noise (due to sleep disturbance for off-duty workers	Worker Camps	Operation	High	Long term	Regular	Landscape	Reversible short-term	Low	Neutral	Low	Not significant	High
Noise (due to sleep disturbance and high annoyance for non-workers)	Skii km Lax Ha Lodge	Operation	High	Long term	Regular	Landscape	Reversible short-term	Low	Neutral	Low	Not significant	High
Air Quality (potential effects on off-duty workers)	Worker Camps	Construction	Moderate	Far Future	Regular	Landscape	Irreversible	Low	High	Low	Not significant	High
Air Quality (potential effects on off-duty workers)	Worker Camps	Operation	Moderate	Far Future	Regular	Landscape	Irreversible	Low	High	Low	Not significant	High
Air quality (potential effects on non-workers)	Non-workers	Construction	Moderate	Far Future	Regular	Landscape	Irreversible	Low	High	Low	Not significant	High
Air quality (potential effects on non-workers)	Non-workers	Operation	Moderate	Far Future	Regular	Landscape	Irreversible	Low	High	Low	Not significant	High
Water quality (potential effects on non-workers)	Non-workers	Construction and Operation	Low	Short term	Sporadic	Local	Reversible short-term	Neutral	High	Low	Not significant	High

21.7.1.4 Characterization of Confidence for Residual Effects on Human Health due to Noise

Noise levels during Construction and Operation phases of the Project were estimated by BKL Consultants Ltd. (2013) using quantitative methods (See Chapter 8, Noise Predictive Study, for further details). Potential human health effects due to changes in noise levels were determined by comparison of the predicted noise levels to the available guidelines (WHO 1999). Since a quantitative approach was used to estimate risk to human health due to noise, the confidence level on the residual effects on human health at the worker camps due to noise is considered high.

Some of the noise guidelines such as sleep disturbance should be compared to indoor noise instead of outdoor noise. For the non-worker receptors, it was assumed that the outdoor-to-indoor transmission loss with doors closed and windows partially open was 15 dBA (US EPA 1974). For worker camps, it was assumed that doors and windows would be fully closed, allowing an attenuation of outdoor sound levels by approximately 27 dBA (US EPA 1974), an attenuation factor of 30 dBA can be assumed in cold climates (such as the Project area) where building shells are more airtight than structures in warmer climates. The assessment is thus conservative and allows higher confidence in the characterization.

21.7.2 Residual Effects Characterization for Human Health due to Air Quality

21.7.2.1 Characterizing Human Health Residual Effects for Air Quality

HQs (relative to guidelines) calculated for SO_2, CO, and TSP were below 1.0, indicating the potential for health risk to adults from inhalation of these CACs is low. There are uncertainties associated with the air quality dispersion model. For example, mitigation measures and assumptions included in the air dispersion model include natural mitigation such as precipitation. Moreover, watering of the road to reach 2% moisture ratio would achieve 75% of reduction of the dust which includes the reduction of TSP, $PM_{2.5}$ and PM_{10} and dustfall levels. However, the model does not take into account freezing effects or complete coverage of the road by snow in the colder months of the year, which will decrease or eliminate dust resuspension and reduce TSP, $PM_{2.5}$, and PM_{10} and dustfall levels. Due to the climate of the region with the observed mean monthly temperature range below freezing (-4 to -20ºC) for the winter period (November to March, Rescan 2013a), the air dispersion model over-predicts dust deposition, TSP, $PM_{2.5}$, and PM_{10} levels for both the winter months and the annual predictions.

Predicted NO_2, TSP, PM_{10}, and $PM_{2.5}$ levels at several worker camps during the Construction and Operation phases exceed the BC AAQO (see Section 21.6.2.4). Predicted annual NO_2 at the Worker Mine Site Existing Camp 1 during the Construction phase was above the BC AAQO. However, when a more detailed assessment was done, incorporating receptor characteristics and exposure time to NO_2, all the HQs were below 1.0, suggesting that the magnitude for potential human health risk to adults from inhalation of NO_2 would be minor.

Predicted 24-hour TSP levels at the Worker Mine Site Existing Camp 1, Worker Mine Site Existing Camp 2, and Worker Transfer Station Camp, as well as annual TSP levels at Worker Mine Site Existing Camp 1 and Worker Bowser Staff House during the Construction phase exceeded the relevant guidelines. In addition, predicted 24-hour TSP levels at Worker Mine Site Operation Camp during the Operation phase of the Project exceeded the relevant guidelines. However, when a more detailed assessment was done, incorporating receptor characteristics and exposure time to TSP, all the HQs were below 1.0, suggesting that the magnitude for potential human health risk to adults from inhalation of TSP would be minor.

During the Construction phase of the Project, predicted 24-hour PM_{10}, as well as annual and 24-hour $PM_{2.5}$ levels at the Skii km Lax Ha Lodge, were above BC AAQOs. After further consideration of receptor characteristics and exposure time, the HQ for 24-hour PM_{10} was 2.16, while the HQs for annual and

24-hour $PM_{2.5}$ levels were 1.06 and 1.32, respectively. During the Operation phase of the Project, predicted 24-hour PM_{10} level at the Skii km Lax Ha Lodge was above BC AAQOs. Further consideration of receptor characteristics and exposure time found that the HQ for 24-hour PM10 was 1.24. An HQ of greater than 1.0 does not necessarily indicate that a health risk does exist, but indicates that the predicted exposure is greater than the established safe exposure limit and there is potential for elevated risk to human health.

Among all CACs during the Construction and Operation phases of the Project, PM_{10} had the highest magnitude for potential effects on human health (as determined by the HQ calculated when considering receptor characteristics and exposure time). Therefore, the potential residual effects associated with PM_{10} was used to represent the remaining CACs in the characterization and significance ratings during the Construction and Operation phase shown in Table 21.7-3.

The magnitude of the potential residual effects to human health due to air quality during the Construction and Operation phases of the Project at worker camps and the Skii km Lax Ha Lodge is considered moderate. This is because the predicted PM_{10} levels are above applicable guidelines, and the HQ is between 1 and 10, suggesting that health effects are possible. However, there are additional mitigation measures that could be applied in order to decrease the magnitude of the potential effect, if monitoring during the Construction or Operation phases indicates that risk to human health is possible.

The descriptor for the duration of the residual effect is based on how long the potential effect may last in a human receptor, and is not directly tied to the duration of the exposure (i.e., the length of the Construction or Operation phases). Therefore, the duration of the potential residual effects due to exposure to PM_{10} is considered far future (i.e., may last more than ten years). This is due to potential chronic effects such as lower respiratory chronic obstructive pulmonary disease, lung cancer, reduction in lung function, and reduction in life expectancy that may be attributed to exposure to elevated PM_{10} levels (Health Canada 1999c; WHO 2004). Since some of the effects that can occur following long-term exposure to elevated PM10 levels are chronic conditions, the residual effect is considered irreversible.

The frequency of potential residual effect is considered to be regular, as PM_{10} concentrations may exceed guideline on a regular basis. The extent of air quality exceedance for PM_{10} was limited to certain areas within the RSA; therefore, the extent of potential human health effects due to exceedance of PM_{10} is the landscape category (Section 7.8, Predicted Changes on Air Quality).

There may be people with increased susceptibility to poor air quality (such as people with asthma or other respiratory problems) who will have a lower resiliency to the elevated PM_{10} concentrations. Therefore, resiliency is considered to be low. Air quality is an important environmental resource to people and therefore the context of air quality due to emissions of PM_{10} is considered to be high (Table 21.7-3).

21.7.2.2 Likelihood for Residual Effects on Air Quality

The air quality at the worker camps and non-worker human receptor locations (Skii km Lax Ha Lodge) will be monitored and if a particular area or process results in exceedance of air quality guidelines, additional engineering controls, such as the use of high efficiency particulate air (HEPA) filters or other adaptive management policies, will be implemented. Given the remoteness of the Project, its limited use, and the adaptive management and monitoring plans in place, the likelihood of occurrence of residual effects due to elevated CAC levels within the worker camps and non-workers human receptor locations is considered low.

21.7.2.3 Significance of Residual Effects on Air Quality

Limited to no risk is expected from predicted SO_2, NO_2, CO, and TSP concentrations since the HQ for these CACs were below 1.0, indicated negligible or low potential for human health effects due to exposure to these parameters. Therefore, the human health residual effects from these CACs are considered not significant.

Although predicted PM_{10} and $PM_{2.5}$ levels exceed guidelines at some of the worker camps and the Skii km Lax Ha Lodge during the Construction and Operation phases (see Section 21.6.2.4), the air quality at the camps and Skii km Lax Ha Lodge will be monitored as proposed in the Air Quality Management Plan (Section 29.2) and if a particular area or process results in exceedance of air quality guidelines, other adaptive management policies will be implemented. If CAC levels are elevated, installation of HEPA filters at building air intakes will reduce CAC levels to background levels. Therefore, residual effects from all CACs are considered not significant.

Based on the preceding significance descriptors and the availability of additional mitigation (that has not been considered in the significance assessment) that can be implemented if monitoring results indicate possible health effects due to elevated CACs (i.e., PM_{10} and $PM_{2.5}$), the residual effect is considered not significant for worker camps and non-worker receptor locations.

21.7.2.4 Characterization of Confidence for Residual Effects on Air Quality

Ambient air quality for Construction and Operation phases of the Project were estimated, using quantitative methods (see Chapter 7, Air Quality Predictive Study, for further details). Human health effects due to changes in CACs in ambient air were also based on a quantitative estimate of risk for SO_2, NO_2, CO, TSP, PM_{10}, $PM_{2.5}$ using HQs. Since a quantitative approach was used to estimate risk to human health due to air quality for SO_2, NO_2, CO, TSP, and PM_{10}, the confidence level on the residual effects on human health due to air for these CACs is considered high.

21.7.3 Residual Effects Characterization for Human Health due to Drinking Water Quality

21.7.3.1 Characterizing Human Health Residual Effects for Drinking Water Quality

Based on the area of use, the spatial boundary of this effects assessment includes the Project footprint, and areas potentially accessible to the public including the Brucejack Access Road and Brucejack Transmission Line areas. No significant changes to the surface water quality in these areas due to Project infrastructure or activities are anticipated, and it is predicted that surface water quality in the relevant areas of the drinking water LSA will be within the range of natural variability that was measured during baseline conditions. Although no specific COPCs (e.g., metals) were identified in drinking water that could affect human health, it is possible that residual effects may occur due to deposition of dust on surface waters, ML/ARD, accidents, and potential leaks and spills.

Due to the proposed adaptive management practices, mitigation measures, and best management practices, if water quality were to be affected due to Project activities or infrastructure, the magnitude of the residual effect would likely be minor since any potential changes would likely be within the range of natural variability or below guideline limits. Potential users of the drinking water quality LSA may experience short-term health effects (i.e., duration is short), if any changes in human health were to occur.

The potential residual effects will be localized (i.e., geographic extent is local) and low in frequency (i.e., sporadic) since water quality is likely to be similar to baseline conditions, the potential for exposure to untreated surface water is low due to access restrictions, and land users would only be present transiently and for relatively short periods of time.

The potential residual effect would be reversible in the short term. Guidelines for drinking water are based on chronic exposures and, therefore, comparison of surface water concentrations to these guidelines when considering transient land use (and transient drinking water use) is likely to overestimate the risk since exposure would be acute and an individual is likely to recover quickly from the exposure (if effects were to occur at all). In addition, it is not recommended that surface water be consumed for drinking water unless it is treated. Since there are no children expected to be within the drinking water LSA, the resiliency of the receptors is considered to be neutral.

Overall, the potential for residual effects to human health due to the consumption of (untreated) drinking water is not significant (Table 21.7-3).

21.7.3.2 Likelihood for Residual Effects on Drinking Water Quality

The likelihood of residual effects on human health due to drinking water quality as a result of Project activities and infrastructure is low. This is due to the low probability of Project effects on the surface water quality within the Bowser River; Todedada Lake, Scott Creek, and Wildfire Creek watersheds; and due to the limited potential for (non-worker) human receptors to be present in areas in which potential effects to water quality could occur. Any consumption of untreated surface water will be rare and occasional.

Filtered treated water will be available to camp workers and residents of Skii km Lax Ha Lodge. Therefore, the likelihood of human health effects due to drinking water is considered low.

21.7.3.3 Significance of Residual Effects on Drinking Water Quality

With mitigation, the residual effect to human health due to consumption of (untreated) surface water as drinking water is considered not significant.

21.7.3.4 Characterization of Confidence for Residual Effects on Drinking Water Quality

The assessment of potential for effects to human health due to drinking water quality has a high level of confidence. This is because most of the potential receptors that would be present for the most time during the life of the Project (i.e., Project workers and residents at Skii km Lax Ha Lodge) would not be expected to experience residual effects since potable drinking water would be provided by the proponent.

For other non-worker land users, access to the LSA and RSA via the Brucejack Access Road would be restricted. Access over-land is possible, but it is likely that potential users would be transient and would only consume (untreated) surface water for drinking water sporadically (if at all).

In order for effects to human health to occur due to changes in drinking water quality, potential contaminants must be present at concentrations high enough to cause health effects, at concentrations that are outside of the normal range of natural variability measured during baseline studies. Since the magnitude of effects to surface water quality are expected to be minor (i.e., very similar to baseline) in areas in which it might be used as drinking water, the risk due to Project-related activities or infrastructure to drinking water are not predicted to be different than baseline risk.

21.8 SUMMARY OF RESIDUAL EFFECTS AND SIGNFICANCE FOR HUMAN HEALTH

Potential effects to human health from Project-related changes in noise levels, air quality, and water quality may affect off-duty workers and land users that hunt, trap, collect berries, or recreate near the Project area. After considering mitigation measures, potential residual effects due to changes in noise levels were identified for off-duty workers at some of the accommodation camps and non-workers at the Ski km Lax Ha Lodge. The potential for residual effects to human health from changes in air quality was identified for non-workers and off-duty workers at the Project accommodation camps. The potential for effects to human health due to drinking water consumption is low, since the potential sources of contaminants in the Brucejack Transmission Line and Brucejack Access Road areas are minimal and mitigation measures to control potential sources of contaminants have been proposed.

Overall, the effects to human health from changes in noise, air quality, and drinking water quality were assessed as not significant (Table 21.8-1). No Project-related residual effects to human health due to consumption of country foods were identified.

21.9 CUMULATIVE EFFECTS ASSESSMENT FOR HUMAN HEALTH

Cumulative effects are defined in this Application/EIS as “effects which are likely to result from the designated project in combination with other projects and activities that have been or will be carried out”. This definition follows that in Section 19(1) of the *Canadian Environmental Assessment Act, 2012* (2012) and is consistent with the IFC Good Practice Note on Cumulative Impact Assessment (ESSA Technologies Ltd. and IFC 2012), which refers to consideration of other existing, planned and/or reasonably foreseeable future projects and developments. Cumulative effects assessment (CEA) is a requirement of the AIR (BC EAO 2014) and the EIS Guidelines (CEA Agency 2013b) and is necessary for the proponent to comply with the *Canadian Environmental Assessment Act, 2012* (2012) and the BC *Environmental Assessment Act* (2002).

The CEA Agency issued an Operational Policy Statement in May 2013 entitled *Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act 2012* (CEA Agency 2013a) which provides a method for undertaking CEA. Recently the British Columbia Environmental Assessment Office (BC EAO) also released the updated *Guideline for the Selection of Valued Components and the Assessment of Potential Effects* (BC EAO 2013), which includes advice for determining the need for a cumulative impact assessment. The CEA assessment methodology adopted in this Application/EIS therefore follows the guidance of the CEA Agency as outlined above, as well as the selection criteria in BC EAO (2013).

The method involves the following key steps (Figure 21.9-1) which are further discussed in the proceeding sub-sections:

- scoping;
- analysis;
- identification of mitigation measures;
- identification of residual cumulative effects; and
- determination of significance.

21.9.1 Establishing the Scope of the Cumulative Effects Assessment

The scoping process involves identification of the human health sub-components for which residual effects are predicted, definition of the patio-temporal boundaries of the assessment, and an examination of the relationship between the residual effects of the Project and those of other projects and activities.

Table 21.8-1. Summary of Residual Effects, Mitigation, and Significance on Human Health due to Noise, Air Quality, and Drinking Water

Residual Effects	Project Phase(s)	Mitigation Measures	Significance
Health Effects due to Noise			
Sleep Disturbance (Workers at camps)	Construction and Operation	• Noise Management Plan • Following all relevant regulatory requirements. • Manage and minimize the effect of noise from operations on receptors. • Maintain an effective response mechanism to deal with issues and complaints. • Monitoring will be conducted as per regulations and to address complaints should they occur (Section 8.7, Mitigation Measures for Noise). • Building the camps from material known to prevent/reduce noise penetration.	Not Significant
Speech Interference, Sleep Disturbance, and Percent Highly Annoyed (Non-workers)	Construction and Operation	• Noise Management Plan • Following all relevant regulatory requirements. • Manage and minimize the effect of noise from operations on receptors. • Maintain an effective response mechanism to deal with issues and complaints • Monitoring will be conducted as per regulations and to address complaints should they occur (Section 8.7, Mitigation Measures for Noise).	Not Significant
Health Effects due to Air Quality			
Health Effects due to SO_2, NO_2, TSP, PM_{10}, and $PM_{2.5}$ emissions (Workers at camps and non-workers)	Construction and Operation	• Air quality will be monitored and mitigation strategies will be adjusted accordingly to meet BC MOE Air Quality Standards and the Air Quality Management Plan (Section 29.2). • Emission control systems (e.g., scrubbers, bughouses, and filters) will be used on stack and relevant ventilation systems to reduce emissions. • Vehicles will be maintained regularly, switching to alternative fuel such as biodiesel or natural gas, using diesel with lower sulphur content, using add-ons such as cabin heaters to reduce idling, optimizing driving speed to reduce fuel usage and fugitive road dust, use larger haul trucks to minimize the number of trips required, minimize drop distance of material into surge bin, stockpiles or between conveyor belts. Mitigation measures included in the project design, such as underground mining process. • Air Quality Management Plan (Section 29.2) • Maintenance of equipment and vehicles on a regular basis • Watering unpaved access road to maintain a minimum of a 2% moisture ratio and achieving at least 75% of dust control efficiency.	Not Significant

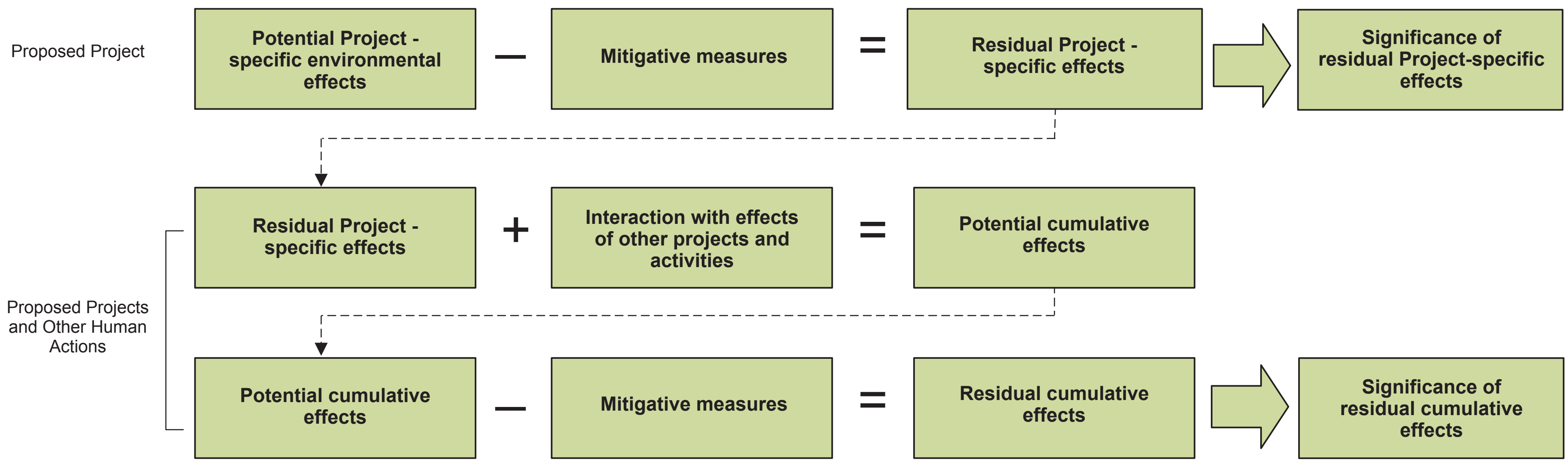
(continued)

Table 21.8-1. Summary of Residual Effects, Mitigation, and Significance on Human Health due to Noise, Air Quality, and Drinking Water (completed)

Residual Effects	Project Phase(s)	Mitigation Measures	Significance
Health Effects due to Quality of Drinking Water			
Health Effects due to drinking water (non-workers)	Construction and Operation	• There will be no an authorized access within the Project vicinity. • Safe transportation and storage of process chemicals, fuels, and oils as described in the Chapter 5, Project Description. • Effective management of spills and emergencies according to the Spill Prevention and Response Plan (Section 29.14). • Effects of metals on water quality will be mitigated through Project design. • Dust deposition on surface water will be minimized according to the Air Quality Management Plan.	Not Significant

Figure 21.9-1

Steps to Cumulative Effects Assessment



21.9.1.1 Identifying Intermediate Components and Receptor Valued Components for the Cumulative Effects Assessment

The sub-components included in the human health CEA were selected using four criteria following BC EAO (2013):

- there must be a residual environmental effect of the Project being proposed;
- that environmental effect must be demonstrated to interact cumulatively with the environmental effects from other projects or activities;
- it must be known that the other projects or activities have been or will be carried out and are not hypothetical; and
- The cumulative environmental effect must be likely to occur.

No Project residual effects to human health were identified due to consumption of country foods (Section 21.6.4). Therefore, human health effects due to consumption of country foods are not included in this CEA.

Project-related residual effects to human health were identified due to changes in noise levels (Section 21.6.1), air quality (Section 21.6.2), or water quality (Section 21.6.3), and Section 21.7 provides the significance assessment for Project residual effects.

The indicators of Project residual effects from noise on human health that are included in this CEA are:

- sleep disturbance at the worker camps during the Construction and Operation phases;
- sleep disturbance of non-workers at the Skii km Lax Ha Lodge during the Construction and Operation phases; and
- Speech interference and %HA for non-workers at the Skii km Lax Ha Lodge.

The parameters or indicators for air quality effects on human health that are included in this CEA are:

- NO_2;
- SO_2;
- CO;
- TSP;
- PM_{10}; and
- $PM_{2.5}$.

The parameters or indicators for drinking water quality effects on human health that are included in this CEA are:

- concentrations of total and dissolved metals, nutrients, turbidity, and TSS.

21.9.1.2 Potential Interaction of Projects and Activities with the Project for Human Health

A review of the interaction between potential effects of the Project and potential effects of other projects and activities on human health was undertaken. The review assessed the projects and activities identified in Section 6.9.2 of the Assessment Methodology (Chapter 6), including:

- regional projects and activities that are likely to affect the human health VC, even if they are located outside the direct zone of influence of the Project;
- effects of past and present projects and activities that are expected to continue into the future (i.e., beyond the effects reflected in the existing conditions of the human health VC, Section 21.3); and
- Activities not limited to other reviewable projects, if those activities are likely to affect the human health VC cumulatively (e.g., forestry, mineral exploration, commercial recreational activities).

A matrix identifying the potential cumulative effect interactions for human health is provided in Table 21.9-1 below.

Table 21.9-1. Potential Cumulative Effect Interactions for Human Health

Projects and Activities	Noise	Air Quality	Drinking Water
Historical			
Eskay Creek Mine			
Galore Creek Project (access road only)			
Goldwedge Mine			
Granduc Mine (Past Producer)			
Johnny Mountain Mine			
Kitsault Mine (Past Producer)			
Silbak Premier Mine			
Snip Mine			
Snowfield Exploration Project			
Sulphurets Advanced Exploration Project			
Swamp Point Aggregate Mine			
Present			
Brucejack Exploration and Bulk Sample Program			
Forrest Kerr Hydroelectric Power Facility			
Present (cont'd)			
Long Lake Hydroelectric Power Facility			
McLymont Creek Hydroelectric Power Facility			
Northwest Transmission Line			
Red Chris Mine			
Reasonably Foreseeable Future			
Arctos Anthracite Coal Project			
Bear River Gravel Project			
Bronson Slope Project			
Coastal GasLink Pipeline Project			
Galore Creek Project			
Granduc Copper Mine			
KSM Project			
Kinskuch Hydroelectric Project			

(continued)

Table 21.9-1. Potential Cumulative Effect Interactions for Human Health (completed)

Projects and Activities	Noise	Air Quality	Drinking Water
Reasonably Foreseeable Future (cont'd)			
Kitsault Mine			
Kutcho Project			
LNG Canada Export Terminal Project			
Northern Gateway Pipeline Project			
Prince Rupert Gas Transmission Project			
Prince Rupert LNG Project			
Schaft Creek Project			
Spectra Energy Gas Pipeline Project			
Storie Moly Project			
Treaty Creek Hydroelectric Project			Grey
Turnagain Project			
Volcano Creek Hydroelectric Project			

Notes:
Grey = possible interaction between project components/Projects and Activities and the human health VC
Black = likely interaction between project components/Projects and Activities and the human health VC

Potential Interactions for the Noise Sub-Component

The potential for noise effects on human health diminishes with distance from a source (Chapter 8, Noise Predictive Study, Section 8.3.3.2, Methods). A review of interaction between predicted noise levels from the Brucejack Gold Mine Project and the potential effects of other projects and activities on noise was undertaken based on Section 6.9.2, of the Assessment Methodology; details of the potential interactions can be found in Section 8.10.1.3, Potential Interaction of Projects and Activities with the Brucejack Gold Mine Project for Noise.

Noise levels will immediately return to baseline levels after a project's noise sources are removed; therefore, past projects or activities were not included in the CEA for noise since they would not be expected to interact with a future project (i.e., development of the Project). A matrix identifying the potential cumulative effect interactions for noise is provided in Table 21.9-1.

Potential Interactions for the Air Quality Sub-Component

A review of interaction between predicted changes on air quality from the Brucejack Gold Mine Project and the potential effects of other projects and activities on air quality was undertaken based on the Section 6.9.2 of the Assessment Methodology; details of the potential interactions can be found in Section 7.10.1.2, Potential Interaction of Projects and Activities with the Brucejack Gold Mine Project for Air Quality.

The CACs used as indicators of air quality will return to baseline levels within a short period of time after a project's air emission sources are removed; therefore, historic projects or activities were not included in the CEA for noise since they would not be expected to interact with a future project (i.e., development of the Project). A future project or activity was considered to have the potential for an interaction if the project or activity was within the Project air quality RSA (Section 21.4.2.1, Figure 21.4-4). A matrix identifying the potential cumulative effect interactions for air quality is provided in Table 21.9-1.

Potential Interactions for the Drinking Water Sub-component

A review of the interaction between predicted changes on surface water quality (for the purposes of drinking water) from the Brucejack Gold Mine Project and the potential effects of other projects and activities on drinking water quality was undertaken based on Section 6.9.2 of the Assessment Methodology.

The potential interaction matrix considered the potential interactions identified in the Surface Water Quality chapter (Section 13.9.1.2, Potential Interaction of Projects and Activities with the Project for Surface Water Quality). Since the Project residual effects on human health via drinking water were limited to the Brucejack Transmission Line and Brucejack Access Road areas and confined to the Project LSA, for the purposes of the CEA, only projects or activities that have the potential to affect drinking water quality in these areas were considered. A matrix identifying the potential cumulative effect interactions for drinking quality is provided in Table 21.9-1.

21.9.1.3 Spatio-temporal Boundaries of the Cumulative Effects Assessment

The CEA boundaries define the maximum limit within which the effects assessment is conducted. They encompass the areas within, and times during which, the Project is expected to interact with the human health VCs and its sub-components and with other projects and activities, as well as the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities (administrative boundaries), and limitations in predicting or measuring changes (technical boundaries). The definition of these assessment boundaries is an integral part of the human health CEA, and encompasses possible direct, indirect, and induced effects of the Project on human health through its sub-components.

Spatial and Temporal Boundaries for Noise

Noise effects are typically restricted to within 10 km of the noise source. For noise, there are no current projects or activities within 10 km of the Project and therefore there are no potential spatial interactions between the Project and current projects or activities.

The only foreseeable future project or activity within 10 km of the Project is the proposed KSM Project (Figure 21.9-2). The KSM Project may also increase noise levels perceived by human receptors which are affected by the Project, and may result in further exceedances of the sleep disturbance and other relevant noise guidelines.

Noise generation is typically associated with the Construction or Operation phases of a project. Based on the information provided in Chapter 6, Assessment Methodology (Section 6.9.2) about the durations and timelines for other projects and activities, the Project timeline is expected to overlap temporally with the proposed KSM Project.

Spatial and Temporal Boundaries for Air Quality

The spatial linkages between the Project and the other projects are shown in Figure 21.9-3. For air quality, spatial linkage is defined as any project that has sources that may cause changes in air quality inside the Project air quality RSA. Projects that may have spatial interaction with the Brucejack Gold Mine Project are:

- the proposed KSM Project; and
- The proposed Treaty Creek Hydroelectric Project.

Figure 21.9-2

Noise CEA Boundary Showing all other Projects and Activities Relevant to Noise in the Vicinity of the Brucejack Gold Mine Project

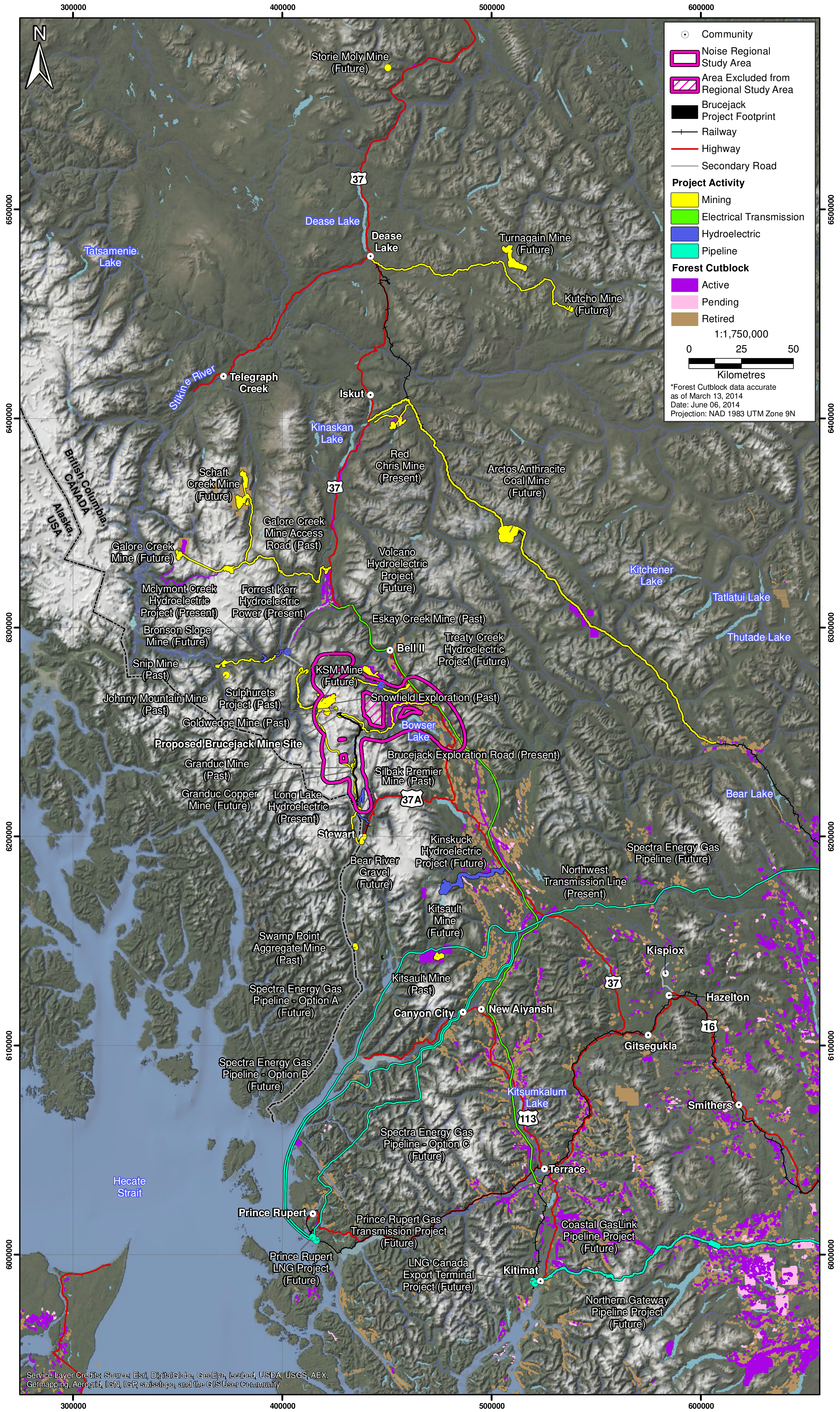
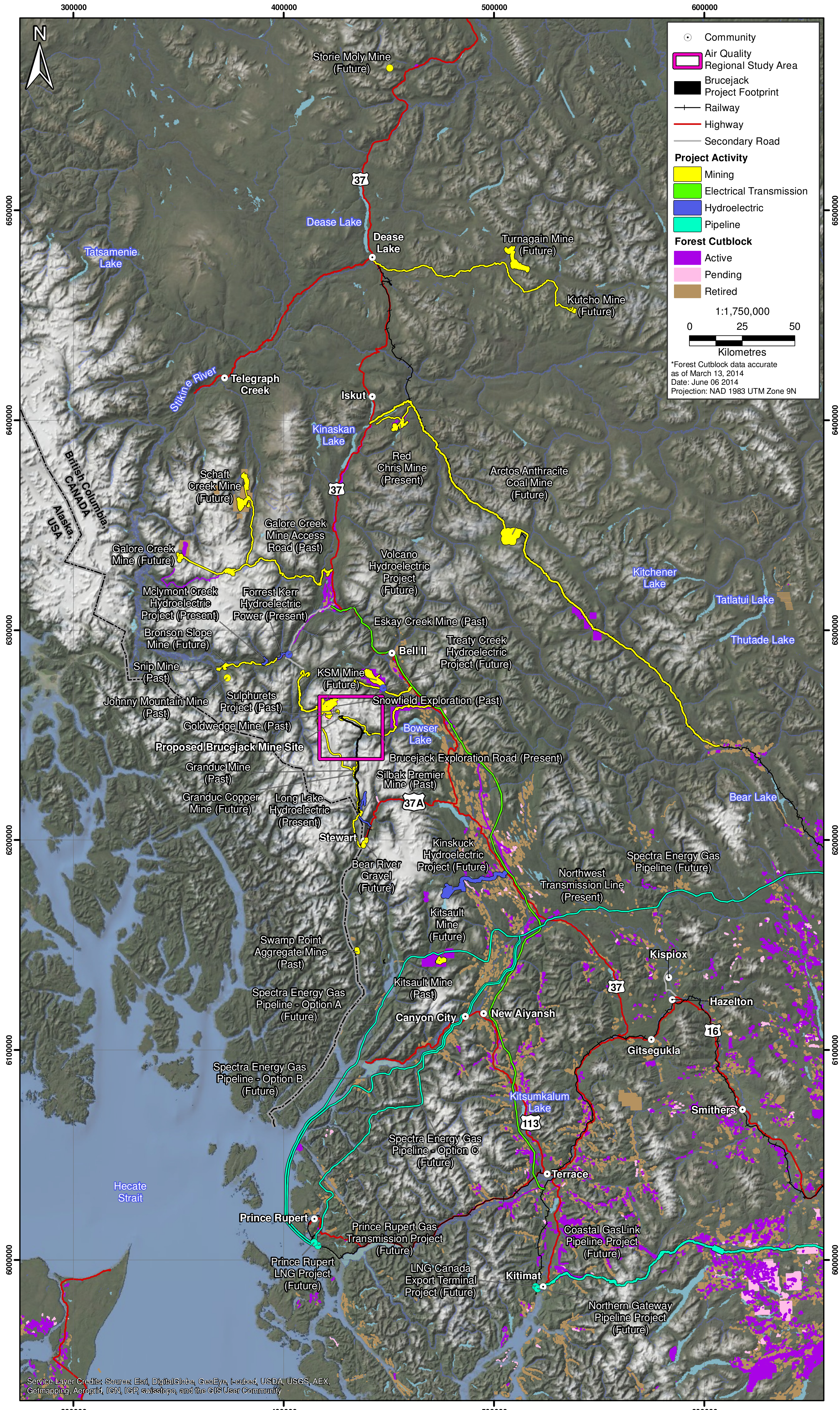


Figure 21.9-3

Air Quality CEA Boundary Showing all other Projects and Activities Relevant to Air Quality in the Vicinity of the Brucejack Gold Mine Project



The Construction Phase of the Project is expected to last two years and the Operation Phase lasting approximately 22 years following Construction. Based on the information provided in Chapter 6, Assessment Methodology (Section 6.9.2) about the durations and timelines for other projects and activities, the Project timeline is expected to overlap temporally with the following reasonably foreseeable future projects:

- KSM Project; and
- Treaty Creek Hydroelectric Project.

Spatial and Temporal Boundaries for Drinking Water Quality

The potential for spatial linkages between the Project and the other projects are shown in Figure 21.9-4. A spatial overlap of human health residual effects due to changes in drinking water from the Brucejack Gold Mine Project with potential effects to water quality from other projects is geographically restricted to watershed boundaries that are shared between the projects. It is further restricted by the watersheds in which Project residual effects may occur (i.e., Knipple Lake, Bowser River, and Wildfire, Scott Creek and Todedada Creek watersheds). Therefore, watersheds such as Sulphurets Creek and the Unuk River were excluded from consideration for cumulative effects, since Project residual effects to drinking water quality were not identified in these areas.

The past projects and human activities that may affect surface water quality and spatially overlap potential effects from the Project are:

- the Eskay Creek Mine (effluent flows into the Unuk River);
- the Goldwedge Mine (historical Catear property that is currently discharging to Brucejack Lake);
- Sulphurets Advanced Exploration Project (waste rock deposition along Brucejack Creek, reclamation activities);
- the Granduc Mine (concentrator effluent flowed into the Bowser River Valley to Bowser Lake; access corridor overlaps); and
- Silbak Premier Mine (in Bowser River watershed).

Present and future projects and human activities that may affect surface water quality and spatially overlap potential effects from the Project are:

- the Northwest Transmission Line (access corridor overlaps within Bell-Irving River watershed);
- the Granduc Copper Mine (access corridor overlaps, future mining activities);
- Brucejack Exploration (blasting and drilling program, access road use); and
- the KSM Project (discharge into Sulphurets; development in Sulphurets Creek and Mitchell Creek; access corridor overlaps).

Since it is possible for effects to surface water quality to persist after a project or activity ceases, the temporal boundaries used in the CEA were the same as those used in the assessment of Project residual effects. These are described in Section 21.4.2.2 and in Chapter 13, Assessment of Potential Surface Water Quality Effects (Section 13.4.2.2, Operation), and include the full duration of each of the four phases of the Project. All of the projects listed under spatial interaction for drinking water have the potential to have temporal interaction as well. Effects to surface water quality from past projects and human activities may temporally overlap with potential effects from the Project, if discharge from the activities persists in the aquatic environment or if habitat has not had sufficient time to recover from past effects.

Temporal linkages for past human actions within the watersheds potentially affected by the proposed Brucejack Gold Mine Project were considered in the development of the baseline program. Past human actions with a temporal linkage to potential water quality effects include:

- the Eskay Creek Mine;
- Silbak Premier Mine;
- Sulphurets Advanced Exploration Project; and
- the Granduc Mine.

Present and future projects and human activities with potential effects to surface water quality that could overlap temporally with potential effects from the Project are:

- the Granduc Copper Mine;
- Brucejack Exploration and Bulk Sample Program; and
- the KSM Project.

21.9.1.4 Potential for Cumulative Effects

Potential for Cumulative Effects to Human Health from Noise

The only foreseeable future project or activity within 10 km of the Project is the proposed KSM Project. Noise generated by the proposed KSM Project and the Brucejack Gold Mine Project may affect the same human receptors, resulting in an exceedance of a relevant noise guideline. The KSM Project's timeline is similar to the Brucejack Gold Mine Project's proposed timeline; therefore, the projects have both spatial and temporal interactions. Potential human health cumulative effects due to noise for the Project are summarized in Table 21.9-2.

Project residual effects to human health due to noise were identified and characterized (Section 21.7.1). Although the proposed KSM Project is within 10 km of the Project, as described in Sections 21.9.2.1 and 8.10.2, no measurable cumulative effects on human health due to noise are expected.

Potential for Cumulative Effects to Human Health from Air Quality

The only foreseeable project or activity that could act cumulatively with the Brucejack Gold Mine Project is the KSM Project. The mine area of the KSM Project will be located approximately 5 km northwest of the Brucejack Mine Site and the processing plant will be located approximately 15 km northeast of the Brucejack Mine Site; therefore, there will be spatial interaction between the proposed KSM Project and the Brucejack Gold Mine Project. As noted in the preceding section for noise, there is potential for temporal overlap of the Project with the proposed KSM Project. Potential human health cumulative effects due to air quality for the Project are summarized in Table 21.9-2.

Potential for Cumulative Effects to Human Health from Drinking Water

Metals or other contaminants from historical projects including the Goldwedge Mine, the Granduc Mine, the Silbak Premier Mine, the Sulphurets Advanced Exploration Project, the Brucejack Exploration and Bulk Sample Program, and Long Lake Hydroelectric Project would have been considered during baseline studies since they contribute to background, existing water quality. Provided that no new changes occur in the conditions at these historical mines or ongoing activities, metal or contaminant inputs that could affect drinking water quality should remain stable or decrease over time. No additional cumulative effects along the Brucejack Access Road or Brucejack Transmission Line corridors related to these projects would be expected with development of the Brucejack Gold Mine Project beyond what was already considered in baseline studies; therefore, these projects or activities will not be considered further in the CEA for human health.

Figure 21.9-4

Drinking Water CEA Boundary Showing all other Projects and Activities Relevant to Drinking Water in the Vicinity of the Brucejack Gold Mine Project

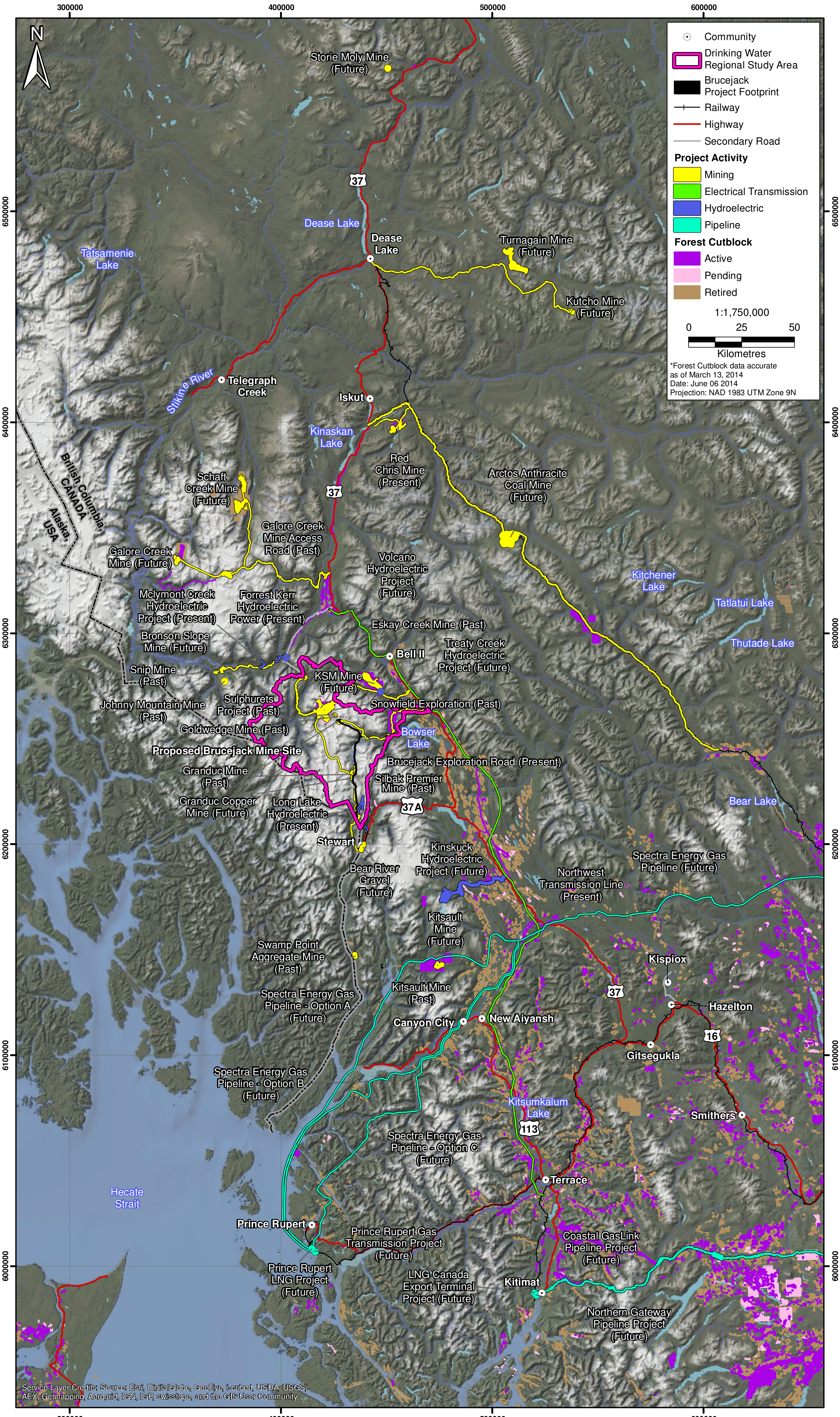


Table 21.9-2. Potential Cumulative Effects between the Brucejack Gold Mine Project Human Health and Other Projects and Activities

	Brucejack Gold Mine Project	Past Project or Activity	Existing Project or Activity	Reasonably Foreseeable Future Project or Activity	Type of Potential Cumulative Effect
Potential for health effects due to change in noise for worker camps and non-worker human receptor locations	X	-	-	-	Not applicable
Potential for health effects due to change in air quality for worker camps and non-worker human receptor locations	X	-	-	KSM Project	Additive
Potential for health effects due to change in drinking water quality	X	-	-	-	Not applicable

The Treaty Creek Hydroelectric Project is still in the early planning stages and is considered in the drinking water CEA because of its close proximity to the Project. As currently proposed, it is located approximately 25 km north east of the Brucejack Gold Mine Project. Northern Hydro Limited has proposed three inter-connected run-of-river hydroelectric projects on Treaty Creek, Todedada Creek and an un-named creek with a combined installed capacity of 24.3 MW (BC MFLNRO 2012). The potential for temporal overlap is unknown, since the project lifespan for the Treaty Creek Hydroelectric Project is not available (see Section 6.9.2.3, Reasonably Foreseeable Future Projects). Spatial overlap would also not be expected since there are no residual effects of the Brucejack Gold Mine Project to drinking water quality on Treaty Creek or Todedada Creek. Therefore, this project is not considered further in the drinking water quality CEA.

The NTL is an approximately 344 km electricity transmission line (BC Hydro 2012). The 287-kilovolt capacity line generally follows the Highway 37 corridor, running from the Skeena Substation at Terrace and connecting with a new substation near Bob Quinn Lake (BC Hydro 2012) and parallels the eastern surface water quality cumulative effects boundary (Figure 13.9-2). BC Hydro received an EA Certificate in February 2011 and construction began in January 2012. The project is expected to be operational in 2014 (BC Hydro 2012). The transmission line will extend the existing provincial electrical grid into northwestern BC making mining, power and other resource projects in these remote regions more economically feasible (BC Hydro 2012). No water quality effects from the NTL are expected to interact with residual effects from the Brucejack Gold Mine Project; therefore, the NTL was excluded from the surface water quality CEA.

The proposed reopened Granduc Copper Mine is located 40 km northwest of Stewart in northwestern BC and previously operated between 1971 and 1984 (see Section 13.9.1.4, Potential for Cumulative Effects). Castle Resources Inc. acquired the Granduc property from Bell Copper in July 2010, and began exploration drilling with the aim of redeveloping the mine (Marketwire 2010; Scales 2012). Castle Resources Inc. is currently working on environmental studies and permitting and the proposed mine is planned to begin its operations phase in 2016, if approved, which indicates that a temporal overlap is possible. The drainage from the proposed Granduc Copper Mine is to the Bowser River, Bowser Lake, and ultimately to the Bell-Irving River, suggesting that there is potential for cumulative spatial interaction between the proposed Granduc Copper Mine and Project infrastructure. However, the project is still in the very early planning stages and no data on expected water quality effects are available. This Project was excluded from the surface water quality CEA given the absence of technical information.

The KSM Project identified residual effects on surface water quality due to increased selenium concentrations downstream of the mine site (i.e., Sulphurets Creek and the Unuk River). No other residual effects to water quality were identified downstream of the Processing and Tailing Management Area (eastern portion) of the KSM Project. Water quality predictions for the proposed KSM Project show that residual effects to water quality in the Bell-Irving River would not be expected (Rescan 2013c), and any potential residual effects to surface water quality from the KSM Project in the Processing and Tailing Management Area is limited to very localized areas close to the tailing management facility. Similarly, for the Brucejack Gold Mine Project, residual effects to drinking water quality are limited to the localized area adjacent to the Brucejack Access Road (associated with the upgrading, use, and maintenance of the road) and the magnitude was assessed to be negligible since any change in water quality is unlikely to be different than baseline conditions. Therefore, there is no spatial overlap between the proposed KSM Project and the Brucejack Gold Mine Project residual effects to drinking water quality, since Project-specific residual effects are limited to non-overlapping areas.

To summarize, Project residual effects to human health due to drinking water quality were identified and characterized (Section 21.7.3). Since Project residual drinking water quality effects due to Project infrastructure or activities along the Brucejack Transmission Line or Brucejack Access Road corridors are considered to be negligible (i.e., within the range of natural variability), the magnitude of any potential cumulative residual effect would have to be driven by the interacting project and the overall cumulative residual effect is unlikely to be due to the Brucejack Gold Mine Project. In addition, there are no permanent residents in the area in which Project-related residual effects may occur; it is unlikely that transient land users would experience high enough exposure levels to have adverse effects to health. Although there are several other current or reasonably foreseeable projects that may have temporal overlap with the Brucejack Gold Mine Project, no measurable cumulative effects on human health due to water quality are likely due to either lack of spatial overlap in residual effects or lack of technical information to use in the cumulative effects assessment. Therefore, cumulative effects to human health due to drinking water quality are not considered further in this CEA (Table 21.9-2).

21.9.2 Analysis of Cumulative Effects

21.9.2.1 Cumulative Effects on Human Health from Air Quality

The cumulative effects of air quality on human health were assessed using future case without the Project and future case with the Project. The following sections provide details of these two scenarios.

Screening of Contaminants of Potential Concern in Air

The change in air quality predicted for the proposed KSM Project needs to be considered in the CEA since there is spatial and temporal overlap with the Project. The residual effect on air quality due to the proposed KSM Project was assessed in the KSM Project Application/EIS (Rescan 2013c). The increase in pollutant concentrations or dust deposition levels predicted in the KSM Project effects assessment plus the background levels were used to predict future concentrations of CACs in the Brucejack Gold Mine Project air quality RSA if only the KSM Project was in operation. The calculation is shown as follows:

$$\begin{aligned}&Future\ case\ concentration\ of\ CACs\ without\ the\ Project\\&= Background + Incremental\ increase\ from\ KSM\ Project\end{aligned}$$

To determine the future predicted concentrations when both the Brucejack Gold Mine Project and KSM Project are in operation, the incremental increases to the maximum predicted CAC concentrations or dust deposition for both projects were added to the background levels. The calculation is shown as follows:

$$\begin{gathered} \textit{Future case concentration of CACs with the Project} = \\ \textit{Background} + \textit{Incremental increase from Brucejack} + \textit{Incremental increase from KSM Project} \end{gathered}$$

The screening process for selection of CACs is the same as described in Section 21.6.2.1 of this chapter (Figure 21.6-2). Concentrations of criteria air contaminants (TSP, PM_{10}, $PM_{2.5}$, NO_2, SO_2, and CO) for the cumulative assessment were modelled for human receptor locations where Project residual effects were identified, which are the Worker Mine Site Operation Camp, the Worker Transfer Station Camp, and the Skii km Lax Ha Lodge. Within the Project air quality RSA, the contribution of air emissions from the proposed KSM Project to air quality would be much smaller than the contribution of Project-related sources, since the potential for effects on air quality diminishes with distance from the source of emissions.

The predicted future case concentrations at the three human receptor locations without the Project (i.e., just the contribution of air emissions from the proposed KSM Project, plus background levels) were screened against BC AAQO. The predicted CACs for the future case without the Project were below AAQO and all the HQs were less than 1.0 during the Operation phase (Table 21.9-3), indicating that the risk to human health due to the proposed KSM Project alone is below acceptable levels since these contaminants would not be expected to cause adverse health effects due to air in that receptor location.

The predicted cumulative concentrations of CACs (i.e., the Project plus the proposed KSM Project, plus background) during the Operation phase in the future case with the Project were below the BC AAQOs for SO_2, NO_2, and CO concentrations at all human receptor locations that were included and therefore do not pose a risk to human health (Table 21.9-4).

The cumulative predicted 24-hour averaged TSP concentration at the Worker Mine Site Operation Camp exceeded the 24-hour averaged TSP BC AAQO concentration of 120 $\mu g/m^3$ (Table 21.9-4). Cumulative predicted 24-hour PM_{10} concentrations at the Worker Mine Site Operation Camp and the Skii km Lax Ha Lodge also exceeded the BC AAQO concentration of 50 $\mu g/m^3$. Therefore, the potential cumulative residual effects of TSP and PM_{10} on human health requires additional assessment to determine the magnitude of the risk.

<u>Cumulative Risk Assessment for Human Health due to Air Quality</u>

Methodology for the risk assessment of cumulative air quality effects from the KSM Project and the Brucejack Gold Mine Project followed the methodology described in Section 21.6.2.1 of this chapter.

Problem Formulation

The CACs that were screened into the cumulative air quality assessment for human health included TSP at the Worker Mine Site Operation Camp, and PM_{10} at the Worker Mine Site Operation Camp and the Skii km Lax Ha Lodge. TSP and PM_{10} are considered to be threshold contaminants (i.e., COPCs that begin to have health effects above a certain threshold but are not carcinogenic), as described in Section 21.6.2.2.

Exposure Assessment

To estimate the fraction of time exposed, it was assumed that off-duty workers occupy the Project camp areas for 12 hours a day, with worker shifts lasting 12 hours a day. The off-duty workers were assumed to be exposed to the emissions for six months per year (182 days) due to shift rotations of two weeks on and two weeks off. This exposure duration is considered a conservative estimate since actual exposure times may be lower due to vacation or other leave from work. It was assumed that people will be exposed to Project related emissions for 22 years for the Operation phase.

For the Skii km Lax Ha Lodge, it was assumed that the residents of the lodge spend 24 hours a day there through the year (365 days a year) during the entire Operation phase of the Project. This is a conservative assumption because it is unlikely that an individual spends all of their time at the Lodge throughout the entire Operation phase of the Project.

Formulas and calculations used follow the same methodology described in the Exposure Assessment section of Section 21.6.2.2. Table 21.9-5 shows the cumulative exposure dose of air contaminants (EDEI) for off-duty workers and residents at the Skii km Lax Ha Lodge during the Operation phase of the Project.

Toxicity Assessment

Toxicity assessment of the selected CACs for the cumulative assessment follows the same methodology and rational provided in the Toxicity Assessment section of Section 21.6.2.2. Table 21.9-5 shows the standard or TRV selected for use as a toxicity threshold for human health effects due to air quality.

Risk Characterization

Risk characterization of the potential for health effects due to CAC exposure follows the methodology described in the Risk Characterization section of Section 21.6.2.2 of this assessment. Table 21.9-5 provides the results of the risk characterization.

At the Brucejack Worker Mine Site Operation Camp, all HQs calculated using the predicted cumulative concentrations of TSP and PM_{10} during the Operation phase were below 1.0, indicating that the potential for health risk to adults from inhalation of these pollutants is low.

At the Skii km Lax Ha Lodge, the HQ for cumulative PM_{10} exposure during the Operation phase was calculated to be 1.26, which is slightly greater than the HQ associated with the Project residual effect (HQ of 1.24, Section 21.6.2.2). The difference between the HQs for the Project residual effect on air quality due to PM_{10} concentrations and the cumulative residual effect due to PM_{10} concentrations is less than 2%. This suggests that, although the HQ is slightly greater than 1.0 in the future case cumulative scenario with the Project, this is primarily due to the Project residual effect (i.e., proximity to Project-related sources of air emissions) and the contribution of air emissions from other projects on air quality at receptor locations in the Project air quality RSA is negligible.

21.9.3 Mitigation Measures to Address Cumulative Effects

21.9.3.1 Mitigation Measures to Address Cumulative Human Health Effects due to Air Quality

Mitigation measures have been integrated into the design of the Project, such as dust control through the use of baghouses and the wetting of the access roads, and certain mitigation measures have been proposed by both the KSM Project and Brucejack Gold Mine Projects.

Table 21.9-3. Screening of Criteria Air Contaminants during the Operation Phase for Future Case without the Project at Human Receptor Locations at the Brucejack Gold Mine Project

Criteria Air Contaminants		Averaging Period	British Columbia Ambient Air Quality Objectives[1] ($\mu g/m^3$)	National Ambient Air Quality Objectives - Maximum Desirable[2] ($\mu g/m^3$)	Worker Mine Site Operation Camp: Baseline Concentration ($\mu g/m^3$)	KSM Incremental Increase ($\mu g/m^3$)	Future Case Concentration without the Project ($\mu g/m^3$)	Percent Increase due to KSM (%)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Selected as a COPC?	Worker Transfer Station Camp: Baseline Concentration ($\mu g/m^3$)	KSM Incremental Increase ($\mu g/m^3$)	Future Case Concentration without the Project ($\mu g/m^3$)	Percent Increase due to KSM (%)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Selected as a COPC?
SO_2		1-hour	450	-	4.0[4]	3.11	7.11	43.7	No	0.0158	No	4.0[4]	0.464	4.46	10.4	No	0.00992	No
		24-hour	160	-	4.0[4]	1.26	5.26	23.9	No	0.0117	No	4.0[4]	0.0543	4.05	1.34	No	0.00901	No
		Annual	25	-	2.0[4]	0.04	2.04	1.79	No	0.00453	No	2.0[4]	0.00402	2.00	0.200	No	0.00445	No
NO_2		1-hour	400	-	21[4]	40.1	61.1	65.6	No	0.136	No	21[4]	7.18	28.2	25.5	No	0.0626	No
		24-hour	200	-	21[4]	13.9	34.9	39.8	No	0.0775	No	21[4]	1.33	22.3	5.95	No	0.0496	No
		Annual	60	-	5.0[4]	0.411	5.41	7.6	No	0.0120	No	5.0[4]	0.0685	5.07	1.35	No	0.0113	No
CO		1-hour	14,300	15,000	100[4]	150	249.5	59.9	No	0.555	No	100[4]	25	125.1	20.1	No	0.278	No
		8-hour	5,500	6,000	100[4]	69	169.3	40.9	No	0.376	No	100[4]	8.17	108.2	7.55	No	0.240	No
Non-fugitive	TSP	24-hour	120	-	10[4]	42.2	52.2	80.8	No	0.116	No	10[4]	2.25	12.2	18.3	No	0.0272	No
		Annual	60	-	10[4]	1.11	11.1	10.0	No	0.0247	No	10[4]	0.156	10.2	1.54	No	0.0226	No
	PM_{10}	24-hour	50	-	3.4[5]	17.2	20.6	83.5	No	0.0457	No	3.4[5]	0.968	4.37	22.2	No	0.00971	No
	$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	0.691	1.99	34.7	No	0.00442	No	1.3[5]	0.108	1.41	7.67	No	0.00313	No
		Annual	8	8.8[3]	1.3[5]	0.07	1.37	5.07	No	0.00304	No	1.3[5]	0.0137	1.31	1.04	No	0.00292	No

Criteria Air Contaminants		Averaging Period	British Columbia Ambient Air Quality Objectives[1] ($\mu g/m^3$)	National Ambient Air Quality Objectives - Maximum Desirable[2] ($\mu g/m^3$)	Skii km Lax Ha Lodge: Baseline Concentration ($\mu g/m^3$)	KSM Incremental Increase ($\mu g/m^3$)	Future Case Concentration without the Project ($\mu g/m^3$)	Percent Increase due to KSM (%)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Selected as a COPC?
SO_2		1-hour	450	-	4.0[4]	0.700	4.70	14.9	No	0.0104	No
		24-hour	160	-	4.0[4]	0.0871	4.09	2.13	No	0.00908	No
		Annual	25	-	2.0[4]	0.00411	2.00	0.205	No	0.00445	No
NO_2		1-hour	400	-	21[4]	10.1	31.1	32.4	No	0.0690	No
		24-hour	200	-	21[4]	1.38	22.4	6.17	No	0.0497	No
		Annual	60	-	5.0[4]	0.08	5.08	1.50	No	0.0113	No
CO		1-hour	14,300	15,000	100[4]	30	129.8	23.0	No	0.288	No
		8-hour	5,500	6,000	100[4]	10	109.8	8.91	No	0.244	No
Non-fugitive	TSP	24-hour	120	-	10[4]	2.62	12.6	20.7	No	0.0280	No
		Annual	60	-	10[4]	0.157	10.2	1.55	No	0.0226	No
	PM_{10}	24-hour	50	-	3.4[5]	1.13	4.53	24.9	No	0.0101	No
	$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	0.111	1.41	7.85	No	0.00313	No
		Annual	8	8.8[3]	1.3[5]	0.0139	1.31	1.06	No	0.00292	No

Notes:

[1] *Government of British Columbia (2013).*

[2] *Environment Canada (1999).*

[3] *CCME (2012).*

[4] *Baseline concentrations of SO_2, NO_2, CO, and TSP are the maximum 30-day averaging concentrations measured by passive air sampling stations in 2012, which are compared most appropriately to annual guidelines. US EPA conversion factors were used to convert the 30-day average into 1-hour and annual averaging periods.*

[5] *CO and TSP baseline concentrations are the annual averages used for the Bathurst Inlet and Road Project (BIPR; located northwest of the study area), which is representative of background levels typical in Nunavut. US EPA conversion factors were used to convert into 1-hour, 8-hour, and 24-hour averaging periods.*

COPC = contaminant of potential concern.

CO = carbon monoxide.

NO_2 = nitrogen dioxide.

SO_2 = sulphur dioxide.

TSP = total suspended particles.

$PM_{2.5}$ = particulate matter up to 2.5 µm in size.

PM_{10} = particulate matter up to 10 µm in size.

Concentration used for calculating chronic exposure dose is the predicted maximum concentration for 24-hour averaging.

Grey shading indicates concentrations above baseline concentration.

Bold and box indicates concentrations above guidelines.

Table 21.9-4. Screening of Criteria Air Contaminants during the Operation Phase for Future Case with the Project at Human Receptor Locations at the Brucejack Gold Mine Project

				Worker Mine Site Operation Camp									
Criteria Air Contaminants	Averaging Period	British Columbia Ambient Air Quality Objectives[1] (µg/m³)	National Ambient Air Quality Objectives - Maximum Desirable[2] (µg/m³)	Baseline Concentration (µg/m³)	Predicted Air Concentration (µg/m³)	KSM Incremental Increase (µg/m³)	Future Cumulative Concentration	Percent Increase due to KSM (%)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient in relation to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	16.8	3.11	19.9	15.7	No	0.0441	n/a	n/a	No
	24-hour	160	-	4.0[4]	7.46	1.26	8.72	14.4	No	0.0194	n/a	n/a	No
	Annual	25	-	2.0[4]	2.98	0.04	3.02	1.2	No	0.00670	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	104	40.1	144	27.8	No	0.321	n/a	n/a	No
	24-hour	200	-	21[4]	84.5	13.9	98.4	14.1	No	0.219	n/a	n/a	No
	Annual	60	-	5.0[4]	28.2	0.411	28.6	1.4	No	0.0635	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	373	150	523	28.6	No	1.1621	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	191	69.3	260	26.6	No	0.579	n/a	n/a	No
TSP	24-hour	120	-	10[4]	194	42.2	236	17.9	Yes	0.525	Yes	59.0	Yes
	Annual	60	-	10[4]	43.7	1.11	44.8	2.5	No	0.0995	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	94.6	17.2	112	15.4	Yes	0.248	Yes	28.0	Yes
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	17.6	0.691	18.3	3.8	No	0.0407	n/a	n/a	No
	Annual	8	8.8[3]	1.3[5]	5.92	0.0694	5.99	1.2	No	0.0133	n/a	n/a	No

				Worker Transfer Station Camp									
Criteria Air Contaminants	Averaging Period	British Columbia Ambient Air Quality Objectives[1] (µg/m³)	National Ambient Air Quality Objectives - Maximum Desirable[2] (µg/m³)	Baseline Concentration (µg/m³)	Predicted Air Concentration (µg/m³)	KSM Incremental Increase (µg/m³)	Future Cumulative Concentration	Percent Increase due to KSM (%)	Predicted Concentration > Guideline?	Hazard Quotient relative to Guideline	Predicted Concentration > Baseline?	Hazard Quotient in relation to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	4.65	0.464	5.11	9.08	No	0.0114	n/a	n/a	No
	24-hour	160	-	4.0[4]	4.22	0.0543	4.28	1.27	No	0.0095	n/a	n/a	No
	Annual	25	-	2.0[4]	2.04	0.00402	2.04	0.197	No	0.0045	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	94.8	7.18	102	7.04	No	0.227	n/a	n/a	No
	24-hour	200	-	21[4]	70.8	1.33	72.2	1.84	No	0.160	n/a	n/a	No
	Annual	60	-	5.0[4]	15.2	0.0685	15.2	0.450	No	0.034	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	159	25.1	184	13.6	No	0.4093	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	143	8.17	151	5.41	No	0.3353	n/a	n/a	No
TSP	24-hour	120	-	10[4]	81.8	2.25	84.0	2.67	No	0.187	n/a	n/a	No
	Annual	60	-	10[4]	22.0	0.156	22.1	0.707	No	0.049	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	47.4	0.968	48.3	2.00	No	0.107	n/a	n/a	No
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	5.85	0.108	5.96	1.81	No	0.013	n/a	n/a	No
	Annual	8	8.8[3]	1.3[5]	2.61	0.0137	2.63	0.520	No	0.006	n/a	n/a	No

(continued)

Table 21.9-4. Screening of Criteria Air Contaminants during the Operation Phase for Future Case with the Project at Human Receptor Locations at the Brucejack Gold Mine Project (completed)

				Skii km Lax Ha Lodge									
Criteria Air Contaminants	Averaging Period	British Columbia Ambient Air Quality Objectives[1] (μg/m^3)	National Ambient Air Quality Objectives - Maximum Desirable[2] (μg/m^3)	Baseline Concentration (μg/m^3)	Predicted Air Concentration (μg/m^3)	KSM Incremental Increase (μg/m^3)	Future Cumulative Concentration	Percent Increase due to KSM (%)	Predicted Concentration > Baseline?	Hazard Quotient relative to Guideline	Predicted > Baseline?	Hazard Quotient relative to Baseline	Selected as a COPC?
SO_2	1-hour	450	-	4.0[4]	14.2	0.700	14.9	4.68	No	0.0332	n/a	n/a	No
	24-hour	160	-	4.0[4]	7.12	0.0871	7.20	1.21	No	0.0160	n/a	n/a	No
	Annual	25	-	2.0[4]	2.77	0.00411	2.77	0.149	No	0.00615	n/a	n/a	No
NO_2	1-hour	400	-	21[4]	105	10.1	115	8.74	No	0.256	n/a	n/a	No
	24-hour	200	-	21[4]	91.1	1.38	92.4	1.49	No	0.205	n/a	n/a	No
	Annual	60	-	5.0[4]	39.4	0.0760	39.5	0.192	No	0.0878	n/a	n/a	No
CO	1-hour	14,300	15,000	100[4]	249	29.8	279	10.7	No	0.620	n/a	n/a	No
	8-hour	5,500	6,000	100[4]	197	9.79	207	4.73	No	0.459	n/a	n/a	No
TSP	24-hour	120	-	10[4]	98.8	2.62	101	2.58	No	0.225	n/a	n/a	No
	Annual	60	-	10[4]	44.8	0.157	44.9	0.350	No	0.100	n/a	n/a	No
PM_{10}	24-hour	50	-	3.4[5]	62.0	1.13	63.1	1.78	Yes	0.140	Yes	15.8	**Yes**
$PM_{2.5}$	24-hour	25	27[3]	1.3[5]	10.0	0.111	10.1	1.10	No	0.0225	n/a	n/a	No
	Annual	8	8.8[3]	1.3[5]	5.35	0.0139	5.36	0.259	No	0.0119	n/a	n/a	No

Notes:

[1] Government of British Columbia (2013).

[2] Environment Canada (1999).

[3] CCME (2012).

[4] Baseline concentrations of SO2, NO2, CO, and TSP are based on surveys conducted at the Diavic Diamond Mine (Diavic) in the Northwest Territories, 300 km northeast of Yellowknife and are considered to be typical background concentrations for remote areas with few anthropogenic sources.

[5] $PM_{2.5}$ and PM_{10} baseline concentrations are the annual averages used for the Galore Creek Copper-Gold-Silver Project (Galore) located 100 km northwest of the Project.

COPC = contaminant of potential concern.

CO = carbon monoxide.

NO_2 = nitrogen dioxide.

SO_2 = sulphur dioxide.

TSP = total suspended particles.

$PM_{2.5}$ = particulate matter up to 2.5 μm in size.

PM_{10} = particulate matter up to 10 μm in size.

Concentration used for calculating chronic exposure dose is the predicted maximum concentration for 24-hour averaging.

Grey shading and bold text indicates concentrations above baseline and guideline concentrations.

n/a = not applicable. These CACs were not compared against baseline concentrations since they were below guideline.

Table 21.9-5. Risk Characterization for Future Case with the Project for Criteria Air Contaminants at Human Receptor Locations during the Operation Phase

Parameter	Units	Worker Mine Site Operation Camp		Skii km Lax Ha Lodge
		Cumulative Total TSP, 24-hour Predicted	Total PM_{10}, 24-hour Predicted	Total PM_{10}, 24-hour Predicted
C_{air}	mg/m^3	0.236	0.112	0.0631
RAF_{inh}	unitless	1	1	1
IR	m^3/day	16.6	16.6	16.6
D1	unitless	0.5	0.5	1
D2	unitless	1	1	1
D3	unitless	0.5	0.5	1
BW	kg	70	70	70
ED	yr	n/a	n/a	n/a
AT	yr	n/a	n/a	n/a
EDEI	**mg/kg BW/day**	**0.0140**	**0.00665**	**0.0150**
Standard/TRV[1]	mg/m^3	0.12	0.05	0.05
TDI Inhalation[2]	mg/kg BW/day	0.0285	0.0119	0.0119
Risk Characterization	**HQ**	**0.493**	**0.561**	**1.26**

Notes:
C_{air} = maximum air concentration of COPC at receptor including background (mg/m^3).
RAF_{inh} = inhalation relative absorption factor (unitless, assumed to be 1).
IR = receptor inhalation rate (assumed to be 16.6 m^3/day for adults (Health Canada 2009).
D1 = fraction of hours per day spent at site (exposure time; unitless; assumed to be 12 hours over 24 hours).
D2 = fraction of days per week spent at site (exposure frequency; unitless; assumed to be 7 days per week).
D3 = fraction of weeks per year spent at site (exposure frequency; unitless; assumed to be 183 days per year based on two week on/two week off rotation).
BW = body weight (70 kg).
*EDEI = estimated daily exposure from inhalation of (non-carcinogenic) COPC in air (mg/kg BW/day), calculated as EDEI=(Cair*RAF*IR*D1*D2*D3)/BW.*
[1] TRV = Toxicity reference value; the National Ambient Air Quality Objectives - Maximum Desirable2 ($\mu g/m^3$).
*[2] TDI Inhalation = tolerable daily intake (mg/kg BW/day); calculated as TDI = Standard*IR*RAF_{inh}/BW.*
HQ = Hazard quotient, calculated as HQ = EDEI/TDI.
(n/a) = not applicable.
Grey shading indicates HQs greater than one and/or ILCRs greater than 1 $x10^{-5}$ (1-in-100,000).

Mitigation measures provided in Section 21.5.2.2 and the associated management and monitoring plans (Chapter 29) are applicable to the potential cumulative changes. Air quality will be monitored at worker camps and the non-worker human receptor location (i.e., Skii km Lax Ha Lodge) during the life of the project. If CAC levels are found to have become elevated, installation of HEPA filters will reduce CAC levels to background levels.

21.9.4 Cumulative Residual Effects for Human Health

Cumulative residual effects are those effects remaining after the implementation of all mitigation measures and are summarized in Table 21.9-6.

Table 21.9-6. Summary of Cumulative Residual Effects on Human Health

Human Health and its Sub-Components	Timing of Cumulative Residual Effect[1]	Description of Cause-Effect[2]	Description of Additional Mitigation (if any)	Description of Cumulative Residual Effect
Health effects due to air quality	Operation	Increase in NO_2, SO_2, CO, TSP, PM_{10}, and $PM_{2.5}$ levels which could affect human health due to inhalation of CACs	None	Slight increase (2%) in HQs due to PM10 at the Skii km Lax Ha Lodge

[1] Refers to the Project phase or other timeframe during which the effect to human health due to cumulative residual effects may occur.
[2] "Cause-effect" refers to the relationship between the Project component/physical activities that is causing the change or effect in the condition of the receptor VC, and the actual change or effect that results.

21.9.5 Characterizing Cumulative Residual Effects, Significance, Likelihood, and Confidence for Human Health

The cumulative residual effects for each human health sub-component were characterized by considering the Project's incremental contribution to the cumulative residual effect under two scenarios:

- Future case without the Project: a consideration of residual effects from all other past, existing, and future projects and activities on a sub-component without the Brucejack Gold Mine Project.
- Future case with the Project: a consideration of all residual effects from past, existing, and future projects and activities on a sub-component with the Brucejack Gold Mine Project.

This approach helps predict the relative influence of the Brucejack Gold Mine Project on the residual cumulative effect for each sub-component, while also considering the role of other projects and activities in causing that effect.

21.9.5.1 Cumulative Residual Effects on Human Health due to Air Quality

Past, existing, and reasonably foreseeable future projects are included in the assessment of cumulative residual effects on human health due to air quality. Table 21.9-7 characterizes the cumulative residual effects, likelihood, determination of significance, and level of confidence in the cumulative assessment of significant of air quality on human health.

Cumulative Residual Effects Characterization for Human Health due to Air Quality

The only project that may have the potential for cumulative residual effects to human health with the Brucejack Gold Mine Project based on air quality in the foreseeable future is the proposed KSM Project. The cumulative residual effects are considered to be the same as for the Project residual effect. This was considered reasonable because, at the maximum, the HQ calculated for the cumulative residual effects was within 2% or less of the HQ calculated for Project residual effects. This indicates that the proposed KSM Project has a negligible influence on the potential for residual effects at human receptor locations within the Project air quality LSA.

Table 21.9-7. Significance Determination of Cumulative Residual Effects for Human Health – Future Case with the Project

		Cumulative Residual Effects Characterization Criteria									
Cumulative Residual Effects	**Human Receptors**	**Timing**	**Magnitude** *(low, moderate, high)*	**Duration** *(short-term, medium-term, long-term, far future)*	**Frequency** *(once, sporadic, regular, continuous)*	**Geographic Extent** *(local, landscape, regional, beyond regional)*	**Reversibility** *(reversible short-term, reversible long-term, irreversible)*	**Resiliency** *(low, neutral, high)*	**Context** *(low, neutral, high)*	**Likelihood** *(low, medium, high)*	**Significance of Adverse Cumulative Residual Effects** *(not significant, significant)*	**Confidence** *(low, medium, high)*
Air quality (potential effects on off-duty workers)	Workers at camps	Construction and Operation	Moderate	Far future	Regular	Landscape	Irreversible	Low	High	Low	Not significant	High
Air quality (potential effects on non-workers)	Non-workers	Construction and Operation	Moderate	Far future	Regular	Landscape	Irreversible	Low	High	Low	Not significant	High

The effects descriptors shown in Table 21.9-7 for air quality cumulative residual effects are the same as those for the Project residual effects. The rationale for the selection of these effects descriptors is provided in Section 21.7.2.1.

Likelihood and Confidence of Cumulative Residual Effects on Human Health due to Air Quality

Predicted cumulative TSP at Worker Mine Site Operation Camp and PM_{10} levels at Worker Mine Site Operation Camp and Skii km Lax Ha Lodge exceed the BC AAQO (see Section 21.6.2.4). HQs calculated for TSP and PM_{10} at the Worker Mine Site Operation Camp were below 1.0, indicating negligible potential for health risk to adults from inhalation of these CACs. Predicted cumulative 24-hour PM_{10} levels at the Skii km Lax Ha Lodge was 1.26 which is above the threshold of 1.0. An HQ of value greater than 1.0 does not necessarily indicate that a health risk exists, but indicates that predicted exposure is greater than the established safe exposure limit and there is potential for elevated risk to be present.

The air quality at the worker camps and non-workers human receptor location (Skii km Lax Ha Lodge) will be monitored and if a particular area or process results in exceedance of air quality guidelines, engineered air such as use of high efficiency particulate air (HEPA) filters (US EPA 2008) or other adaptive management policies will be implemented. Given the remoteness of the Project, its limited use, and the adaptive management and monitoring plans in place, the likelihood of occurrence of residual effects due to elevated CAC levels within the worker camps and non-workers human receptor locations is considered low.

Significance of Cumulative Residual Effects on Human Health due to Air Quality

Limited to no risk is expected from predicted SO_2, NO_2, CO, TSP, and $PM_{2.5}$ concentrations since the HQ for these CACs were below 1.0, indicated negligible or low human health effects due to exposure to these parameters. Therefore, the human health residual effects from these CACs are considered not significant. Although predicted cumulative PM_{10} levels exceed guideline at Worker Mine Site Operation Camp and the Skii km Lax Ha Lodge are elevated (see Section 21.6.2.4), the air quality at the camps and Skii km Lax Ha Lodge will be monitored and if a particular area or process results in exceedance of air quality guidelines, engineered air such as use of high efficiency particulate air (HEPA) filters (US EPA 2008) or other adaptive management policies will be implemented. In addition, predictions did not take into account freezing effects or complete overage of the road by snow in the colder months of the year which will decrease or eliminate dust resuspension and reduce TSP, $PM_{2.5}$, and PM_{10}, and dustfall levels. If CAC levels are elevated, installation of HEPA filters at building air intakes will reduce CAC levels to background levels. Therefore, residual effects from all CACs are considered not significant.

21.10 EFFECTS ASSESSMENT CONCLUSIONS FOR HUMAN HEALTH

A summary of the assessment of effects to human health is presented in Table 21.10-1.

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 effects of noise, the inhalation of air, ingestion of water, and the ingestion of country foods. It is recognized that health is more than just physical well-being. For instance, social, cultural, nutritional, and economic factors also play in a person's overall health status. These health indicators have been assessed in other sections of the EIS. Chapter 21 follows a science-based approach recommended by Health Canada to assess the potential for people to experience adverse health effects by exposure to noise and exposure to contaminants of potential concern in air, water, and country foods.

Table 21.10-1. Summary of Project and Cumulative Residual Effects, Mitigation, and Significance for Human Health

Residual Effects	Project Phase(s)	Mitigation Measures	Significance of Residual Effects	
			Project	Cumulative
Health Effects due to Noise				
Noise (Impact on workers due to sleep disturbance)	Construction and Operation	• Noise Management Plan (Section 29.11) • Following all relevant regulatory requirements and published best practice recommendations • Manage and minimize the impact of noise from operations on receptors • Maintain an effective response mechanism to deal with issues and complaints • Ensuring that result of noise monitoring comply with applicable guidelines. • If necessary based on monitoring results, barriers will be constructed to prevent/reduce noise travel to the camps • Building the camps from material known to prevent/reduce noise penetration	Not significant	Not significant (not applicable, no cumulative effects identified)
Speech Interference, Sleep Disturbance, and Percent Highly Annoyed (Non-workers)	Construction and Operation	• Noise Management Plan (Section 29.11) • Following all relevant regulatory requirements and published best practice recommendations • Manage and minimize the impact of noise from operations on receptors • Maintain an effective response mechanism to deal with issues and complaints • Ensuring that result of noise monitoring comply with applicable guidelines • Replacing the windows at the Skii km Lax Ha Lodge with thicker windows to prevent/reduce noise penetration	Not significant	Not significant (not applicable, no cumulative effects identified)
Health Effects due to Air Quality				
Health Effects due to SO_2, NO_2, TSP, PM_{10}, and $PM_{2.5}$ emissions (Workers at camps and non-workers)	Construction and Operation	• Air quality will be monitored and mitigation strategies will be adjusted accordingly to meet BC MOE Air Quality Standards and the Air Quality Management Plan (Section 29.2). • Emission control systems (e.g., scrubbers, bughouses, and filters) will be used on stack and relevant ventilation systems to reduce emissions. • Vehicles will be maintained regularly, switching to alternative fuel such as biodiesel or natural has, using diesel with lower sulphur content, using add-ons such as cabin heaters to reduce idling, optimizing driving speed to reduce fuel usage and fugitive road dust, use larger haul trucks to minimize the number of trips required, minimize drop distance of material into surge bin, stockpiles or between conveyor belts. Mitigation Measures included in the project design, such as underground mining process • Air Quality Management Plan (Section 29.2) • Maintenance of equipment and vehicles on a regular basis • Watering unpaved access road to maintain a minimum of a 2% moisture ratio and achieving at least 75% of dust control efficiency.	Not significant	Not significant

(continued)

Table 21.10-1. Summary of Project and Cumulative Residual Effects, Mitigation, and Significance for Human Health (completed)

Residual Effects	Project Phase(s)	Mitigation Measures	Significance of Residual Effects	
			Project	**Cumulative**
Health Effects due to Quality of Drinking Water				
Health Effects due to drinking water (non-workers)	Construction and Operation	• There will be no an authorized access within the Project vicinity • Safe transportation and storage of process chemicals, fuels, and oils as described in the Project Description (Chapter 5) • Effective management of spills and emergencies according to the Spill Management Plan (Section 29.14) • Effects of metals on water quality will be mitigated through Project design • Dusting on surface water quality will be minimized according to the Air Quality Management Plan (Section 29.2)	Not significant	Not significant (not applicable, no cumulative effects identified)

The Brucejack Gold Mine Project location is located in a remote area; therefore, the assessment focused on temporary and seasonal land users (e.g., Nisga'a Nation, First Nations, and residents hunters, trappers, berry pickers, recreationalists, guide-outfitters, and trapline holders). While worker's 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 replied on data measured during baseline studies, and future modelled predictions of noise levels, air quality, water quality, and country foods quality. These predicted data were used to model and assess potential effects of the proposed Project to human health. There can be uncertainties associated with the models and, therefore, highly conservative assumptions were made. This likely resulted in an overestimation of human health risks.

The following paragraphs summarise the results for the assessment of the four different sub-components:

21.10.1 Human Health Effects due to Noise

Noise effects only occur during Project activities during the Construction and Operation phases. Noise effects are only expected to potentially occur at worker camps during off-duty hours and Skii km Lax Ha Lodge. Potential noise effects at worker camps are limited to sleep disturbance. Residents (non-workers) of the Skii km Lax Ha Lodge may experience sleep disturbance, interference with speech communications, and complaints due to noise (% highly annoyed) during the Construction and Operation phases of the Project.

Based on the mitigation measures proposed for implementation and the availability of additional mitigation measures not considered in the assessment, the residual effect on human health due to noise is considered not significant at worker camps and non-worker human receptor locations. Noise levels at the worker camps and non-workers human receptor location (Skii km Lax Ha Lodge) should be monitored as per the proposed Noise Management Plan (Section 29.11) so if the noise levels at these human receptor locations exceed guidelines additional mitigation measures are taken to protect health.

No cumulative residual effects on human health due to noise were identified due to the remote location of the Project (and the rapid dissipation of noise with distance), the non-persistence of noise once the source of noise is removed, and the logarithmic nature of noise (see Section 21.9.5.1).

21.10.2 Human Health Effects due to Air Quality

The Project may 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. Results of the human health residual effects due to air quality for the Construction and Operation phases were based on $PM_{2.5}$ and PM_{10} levels, respectively. This is because $PM_{2.5}$ levels resulted in the highest HQs among CACs during the Construction while PM_{10} had the highest HQs among CACs for the Operation phase. TSP, $PM_{2.5}$, and PM_{10} are estimated using conservative methods that will over estimate particulate production.

Limited risk is expected from exposure to predicted SO_2, NO_2, CO, and TSP concentrations since the HQ for these CACs were below 1.0, indicated negligible or low potential human health effects due to exposure to these parameters. Therefore, the human health residual effects from these CACs are considered not significant.

Although predicted PM_{10} and $PM_{2.5}$ levels exceed guideline at some of the worker camps and the Skii km Lax Ha Lodge during the Construction and Operation phases (see Section 21.6.2.4), the air quality at the camps and Skii km Lax Ha Lodge will be monitored and if a particular area or process results in exceedance of air quality guidelines, engineered air such as use of high efficiency particulate air (HEPA) filters (US EPA 2008) or other adaptive management policies will be implemented. If CAC levels are elevated, installation of HEPA filters at building air intakes will reduce CAC levels to background levels. Therefore, residual effects from all CACs are considered not significant.

The cumulative residual effects are considered to be the same as for the Project residual effect. This was considered reasonable because, at the maximum, the HQ calculated for the cumulative residual effects was within 2% or less of the HQ calculated for Project residual effects. This indicates that the proposed KSM Project has a negligible influence on the potential for residual effects at human receptor locations within the Project air quality LSA.

21.10.3 Human Health Effects due to Drinking Water Quality

Potential residual human health effects due to drinking water quality were associated with ML/ARD as well as erosion and sedimentation. Considering these potential effects on human health due to consumption of surface water, based on the design of the proposed Project as well as mitigation to minimize effects, the overall potential Project-related residual effects on human health due to drinking water is assessed as not significant.

Since Project residual drinking water quality effects due to Project infrastructure or activities along the Brucejack Transmission Line or Brucejack Access Road corridors are considered to be negligible (i.e., within the range of natural variability), the magnitude of any potential cumulative residual effect would have to be driven by the interacting project and the overall cumulative residual effect is unlikely to be due to the Brucejack Gold Mine Project. In addition, there are no permanent residents in the area in which Project-related residual effects may occur; it is unlikely that transient land users would experience high enough exposure levels to have adverse effects to health. Although there are several other current or reasonably foreseeable projects that may have temporal overlap with the Brucejack Gold Mine Project, no measurable cumulative effects on human health due to water quality are likely, due to either lack of spatial overlap in residual effects or lack of technical information to use in the cumulative effects assessment. Therefore, no cumulative effects to human health due to drinking water quality were identified.

21.10.4 Human Health Effects due to Country foods Quality

Human health effects from the ingestion of country foods were assessed for the Construction and Operation phases of the Project. However, effects were found to be negligible and have been rated as not significant. No cumulative effects due to dustfall are expected. Therefore, no cumulative human health residual effects due to ingestion of country foods are expected.

REFERENCES

1985. *Explosives Act*, RSC. C. E-17.

1992. *Transportation of Dangerous Goods Act, 1992*, SC. C. 34.

2001. *Drinking Water Protection Act*, SBC C. C. 9.

2002. *Environmental Assessment Act*, SBC 2002. C. 43.

2012. *Canadian Environmental Assessment Act, 2012*, SC 2012. C. 19. s. 52.

Drinking Water Protection Regulation, B.C. Reg. 200/2003.

Hazardous Waste Regulation, BC Reg. 63/88.

Municipal Wastewater Regulation, BC Reg. 87/2012.

Open Burning Smoke Control Regulation, BC Reg. 145/93.

Occupational Health and Safety Regulation, BC Reg. 296/97.

Waste Discharge Regulation, BC Reg. 320/2004.

Alberta EUB. 2007. *Directive 038 - Noise Control*. Energy Resources Conservation Board: Calgary, Alberta.

AMEC. 2011. *Kitsault Mine Project Environmental Assessment* Appendix 6.2-A Atmospheric Environment Baseline Report: Vancouver, British Columbia.

ANSI. 2005. *Quantities and Procedures for Description and Measurement of Environmental Sound - Part 4: Noise Assessment and Prediction of Long-term Community Response*. Washington, DC: American National Standards Institute, Standards Secretariat Acoustical Society of America.

BC Air Quality. 2013. *Levels of Government Involved*. BC Air Quality. http://www.bcairquality.ca/regulatory/levels-of-government.html (accessed May 2013).

BC EAO. 2013. *Guideline for the Selection of Valued Components and the Assessment of Potential Effects*. British Columbia Environmental Assessment Office. http://www.eao.gov.bc.ca/pdf/EAO_Valued_Components_Guideline_2013_09_09.pdf (accessed May 2014).

BC EAO. 2014. *Brucejack Gold Mine Project: Application Information Requirements for Pretium Resources Inc.'s Application for an Environmental Assessment Certificate*. Prepared by the British Columbia Environmental Assessment Office: Victoria, BC.

BC Hydro. 2012. *Northwest Transmission Line Project*. http://www.bchydro.com/energy_in_bc/projects/ntl.html (accessed October 2012).

BC ILMB. 2000. *Cassiar Iskut - Stikine Land and Resource Management Plan*. http://www.ilmb.gov.bc.ca/slrp/lrmp/smithers/cassiar/index.html (accessed May 2013).

BC MEMPR. 2008. *Health, Safety and Reclamation Code for Mines in British Columbia*. British Columbia Ministry of Energy, Mines, and Pertoleum Resources (BC MEMPR). Mining and Minerals Division: Victoria, BC.

BC MFLNRO. 2012. *Nass South Sustainable Resource Management Plan*. http://www.ilmb.gov.bc.ca/slrp/srmp/south/nass/index.html (accessed May 2013).

BC MOE. 1979. *Pollution Control Objectives for The Mining, Smelting, and Related Industries of British Columbia*. British Columbia Ministry of Environment: Victoria, BC.

BC MOE. 2006a. *British Columbia approved water quality guidelines. 2006 Edition*. British Columbia Ministry of Environment, Environmental Protection Division.: Victoria, BC.

BC MOE. 2006b. *A Compendium of Working Water Quality Guidelines for British Columbia. Ministry of Environment, Science and Information Branch*. http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html#table1 (accessed accessed in 2009).

BC MOE. 2011. *Proposed Small Electrical Power Generating Facility Code of Practice*. http://env.gov.bc.ca/epd/codes/sepgf/index.htm (accessed May 2014).

BC MOE. 2013a. *B.C. Ambient Air Quality Objectives - Updated August 12, 2013*. British Columbia Ministry of Environment. http://www.bcairquality.ca/reports/pdfs/aqotable.pdf (accessed September 15, 2013).

BC MOE. 2013b. *New Ambient Air Quality Criteria for MP2.5: Development Process*. BC Air Quality. http://www.bcairquality.ca/regulatory/pm25-development.html (accessed May 2013).

BC MOE. 2013c. *Summary of Air Quality Legistlation*. BC Air Quality. http://www.bcairquality.ca/regulatory/air-legislation-summary.html (accessed May 2013).

BC MOE. 2013d. *Tier 1 Ecological Risk Assessment Policy Decision Summary*. British Columbia Ministry of Environment. http://www.bcairquality.ca/reports/pdfs/aqotable.pdf (accessed November 5, 2013).

BC MOE. 2013e. http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input (Water Licences Query accessed June 2013).

BirdLife International 2012. *Dendragapus fuliginosus. IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2*. www.iucnredlist.org (accessed 15 February 2013).

BKL Consultants Ltd. 2013. *Brucejack Mine Project: Draft Environemtal Noise Modelling Study*. BKL Consultants Ltd: North Vancouver, BC.

Campbell, R. W., N. K. Dawe, I. Mctaggart-Cowan, J. M. Cooper, G. W. Kaiser, and M. C. E. McNall. 1990. *The birds of British Columbia. Volume 2. Nonpasserines: Diurnal birds of prey through woodpeckers*. Victoria, BC: UBC Press.

1999. *Canadian Environmental Protection Act*, SC 33.

CCME. 1999a. *Canadian Soil Quality Guidelines for the Protection of Environemntal and Huamn Health: Introduction. In: Canadian quality guidelines*. Canadian Council of Ministers of the Environment: Winnipeg, MB.

CCME. 1999b. *Canadian water quality guidelines for the protection of aquatic life: Chromium - Hexavalent chromium and trivalent chromium. In: Canadian environmental quality guidelines, 1999*. Canadian Council of Ministers of the Environment: Winnipeg, MB.

CCME. 2012a. *Canadian Air Quality Guidelines for Protection of Human Health and Environment: Summary Table*. Environment Canada. Canadian Council of Ministers of the Environment. http://ceqg-rcqe.ccme.ca (accessed July 2013).

CCME. 2012b. *Canadian Sediment Quality Guidelines for Protection of Aquatic Life: Summary Table*. Environment Canada. Canadian Council of Ministers of the Environment. http://ceqg-rcqe.ccme.ca (accessed December 2012).

CCME. 2012c. *Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health (Agricultral Land): Summary Table*. Environment Canada. Canadian Council of Ministers of the Environment. http://ceqg-rcqe.ccme.ca (accessed December 2012).

CCME. 2012d. *Canadian Water Quality Guidelines for Protection of Aquatic Life: Summary Table*. Environment Canada. Canadian Council of Ministers of the Environment. http://ceqg-rcqe.ccme.ca (accessed December 2012).

CEA Agency. 2013a. *Assessing Cumulative Environmental Effects under the Canadian Environmental Assessment Act, 2012*. Canadian Environmental Assessment Agency. https://www.ceaa-acee.gc.ca/default.asp?lang=En&n=1DA9E048-1 (accessed May 2014).

CEA Agency. 2013b. *Environmental Impact Statement Guidelines for the Brucejack Gold Mine Project*. Canadian Environmental Assessment Agency: Vancouver, BC.

Cirrus. 1998. *Diavik Diamond Project - Environmental effects report, climate and air quality*. Report prepared for Diavik Diamond Mines Inc. by Cirrus Constants: Yellownife, NT.

Environment Canada. 2010. *National Ambient Air Quality Objectives*. http://www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=24441DC4-1 (accessed May 2013).

Environment Canada. 2013. http://www.ec.gc.ca/rnspa-naps/ (National Air Pollution Surveillance Program (NAPS) accessed July 2013).

ESSA Technologies Ltd. and IFC. 2012. *Good Practice Note - Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets*. Jointly prepared by ESSA Technologies Ltd. and the International Finance Corporation – World Bank: Richmond Hill, ON and Washington, DC.

Golder and Associates. 2005. *Guidance Document for Country Foods Surveys for the Purpose of Human Health Risk Assessment*. Prepared for Health Canada.

Health Canada. 1992. *Guidelines for Canadian Recreational Water Quality*. Minister of National Health and Welfare: Ottawa, ON.

Health Canada. 1998. *National Ambient Air Quality Objectives and Canada-wide Standars for Air Pollutants*.

Health Canada. 1999a. The Basics. In: Canadian handbook on health impact assessment. In *Canadian handbook on health impact assessment*. Ottawa: Health Canada. http://publications.gc.ca/collections/Collection/H46-2-99-235E-1.pdf (accessed March 2013).

Health Canada. 1999b. *National Ambient Air Quality Objectives for Ground-Level Ozone*.

Health Canada. 1999c. *National Ambient Air Quality Objectives for Particulate Matter: Addendum to the science assessment document*. ISBN 0-662-28088-1. Federal - Provincial Working Group on Air Quality Objectives and Guidelines for Health Canada: Ottawa, Ontario.

Health Canada. 2000. *Decision-Making Framework for Identifying, Assessing, and Managing Health Risks. Health Canada*. http://www.hc-sc.gc.ca/ahc-asc/pubs/hpfb-dgpsa/risk-risques_tc-tm-eng.php (accessed October 29, 2013).

Health Canada. 2004. *Canadian Handbook on Health Impact Assessments Volume 4. Appendix A: Air Quality and Related Health Effects*. A Report of the Federal/Provincial/Territorial Committee on Environmental and Occupational Health: Ottawa, ON.

Health Canada. 2008. *Drinking Water In The Great Canadian Outdoors*. http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/outdoor-plein_air-eng.php (accessed October 3, 2013).

Health Canada. 2009. *Supplemental guidance on human health risk assessment on air quality ($HHRA_{AIR}$)*. Contaminated Sites Division, Health Canada: Ottawa, ON.

Health Canada. 2010a. *Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment (PQRA), Version 2.0. Revised 2012*. Ottawa, ON.

Health Canada. 2010b. *Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2.0*. Health Canada: Ottawa, ON.

Health Canada. 2010c. *Federal Contaminated Site Risk Assessment in Canada, Part V: Guidance on Human Health Detailed Quantitative Risk Assessment for Chemicals (DQRA chem)*. Health Canada: Ottawa, ON.

Health Canada. 2010d. *Federal Contaminated Site Risk Assessment in Canada, Supplemental Guidance on Human Health Risk Assessment for Country Foods (HHRA foods)*. Health Canada: Ottawa, ON.

Health Canada. 2010e. *Useful Information for Environmental Assessments*. 978-1-001-15153-3. Health Canada: Ottawa, ON.

Health Canada. 2010f. *Water Quality - Reports and Publications: Fluoride*. http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/2011-fluoride-fluorure/index-eng.php#a912 (accessed October 2013).

Health Canada. 2012a. *Guidance for Fine Particulate Matter (PM2.5) in REsidential Indoor Air*. http://www.hc-sc.gc.ca/ewh-semt/alt_formats/pdf/pubs/air/particul-eng.pdf (accessed December 2013).

Health Canada. 2012b. *Guidelines for Canadian Recreational Water Quality*. Health Canada: Ottawa, ON.

Health Canada. 2013. *Ambient Levels of Nitrogen Dioxide*. http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=C8BFC3F2-1 (accessed December 2013).

Herrman, J. and M. Younes. 1999. Background to the ADI/TDI/PTWI. *Regul Toxicol Pharmacol*, 30: S109-S13.

JECFA. 1972. *Cadmium*. Joint FAO/WHO Expert Committee on Food Additives (JECFA). http://www.inchem.org/documents/jecfa/jecmono/v004je04.htm (accessed March 2013).

JECFA. 1982. *Zinc*. Joint FAO/WHO Expert Committee on Food Additives (JECFA). http://www.inchem.org/documents/jecfa/jeceval/jec_2411.htm (accessed March 2013).

JECFA. 2000. *Lead. In: Safety Evaluation of Certain Food Additives and Contaminants*. Prepared by the Fifty-third meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). http://www.inchem.org/documents/jecfa/jecmono/v44jec12.htm (accessed March 2013).

JECFA. 2005. *Cadmium. In: Summary of Evaluations Performed by the Join FAO/WHO Expert Committe on Food Additives*. Joint FAO/WHO Expert Committee on Food Additives (JECFA). http://www.inchem.org/documents/jecfa/jeceval/jec_297.htm (accessed March 2013).

JECFA. 2007. *Aluminum. In: Safety evaluation of certain food additives*. Prepared by the sixty-seventh meeting of the Joint FAO/WHO Expert Committee on Food Additives (JEFCA). (accessed March 2013).

JECFA. 2011. *Safety evaluation of certain food additives and contaminants*. Prepared by the seventy-third meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). (accessed March 2013).

Jin, A. 2006. [unpublished]. Survey of traditional food and medicine consumption among Tahltan people in Dease Lake, Telegraph Creek and Iskut, BC, 2005-2006.

Marketwire. 2010. *Castle Resources Provides Granduc Operations Update.* http://www.marketwire.com/press-release/Castle-Resources-Provides-Granduc-Operations-Update-TSX-VENTURE-CRI-1316570.htm (accessed September 2010).

McKendry, I. G. 2006. *Background Concentrations of $PM_{2.5}$ and Ozone in British Columbia, Canada.* Prepared for British Columbia Ministry of Environment: n.p.

Michaud, D. S., Bly, S.H.P., Keith, S.E. 2008. Using a change in present highly annoyed with noise as a potential health effect meaure for projects under the Canadian Environmental Assessment Act. *Canadian Acoustics*, 36 (2): 13-28.

Newhawk Gold Mines Ltd. 1989. *Stage I: Environmental and Socioeconomic Impact Assessment for the Sulphurets Property*. Vancouver, BC.

NLG, Province of BC, and Government of Canada. 2000. *Nisga'a Final Agreement*. Nisga'a Lisims Government, Province of British Columbia, and Goverment of Canada: New Aiyansh, BC.

Price, W. 2005. *Case Studies of ML/ARD Assessment and Mitigation: Placement of the Sulphurets Waste Rock in Brucejack Lake*. MEND Report 9.1c CANMET-MMSL 05-023(CR). July 2005 version.: n.p.

RAIS. 2013. *Chemical Factors*. http://rais.ornl.gov/index.html (accessed December 2013).

Rescan. 2006. *Galore Creek Project: Application for Environmental Assessment Certificate*. Prepared for NovalGold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2010. *KSM Project: 2009 Country Foods Baseline Report*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013a. *Brucejack Gold Mine Project: Project Description (Provincial)*. Prepared for Pretium Resources Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013b. *Brucejack Gold Mine Project: Skii km Lax Ha Traditional Knowlege and Traditional Use Report*. Prepared for Pretium Resources Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013c. *KSM Project: Application for an Environmental Assessment Certificate/Environmental Impact Statement*. Prepared for Seabridge Gold Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan RTEC. 2008. *Schaft Creek Project Noise Baseline Report*. Prepared for Copper Fox Metals Inc. by Rescan Tahltan Environmental Services Ltd.: Vancouver, BC.

Richardson, G. M. 1997. *Compendium for Canadian Human Exposure Factors for Risk Assessment*. Ottawa, ON: O'Conner Associates Environmental Inc.

RTEC. 2010. *Schaft Creek Project: 2008 and 2009 Meteorology and Air Quality Baseline*. Prepared for Copper Fox Metals Inc. by Rescan Tahltan Environmental Services Ltd.: Vancouver, BC.

Sample, B. E., M. S. Aplin, R. A. Efroymson, G. W. Suter II, and C. J. E. Welsh. 1997. *Methods and Tools for Estimation of the Exposure of Terrestrial Wildlife to Contaminants*. ORNL/TM-13391. Oak Ridge National Laboratory, US Department of Energy: Oak Ridge, TN.

Scales, M. 2012. Craving Copper: Castle Resources sets sights on reopening the Granduc Mine. *Canadian Mining Journal*, January 2012: 18-19.

Shearer, R. R. and D. M. Hadjimarkos. 1975. Geographic distribution of selenium in human milk. *Arch Environ Health*, 30: 230-33.

Staven, L. H., K. Rhoads, B. A. Napier, and D. L. Strenge. 2003. *A Compendium of Transfer Factors for Agricultural and Animal Products*. PNNL-13421. Pacific Northwest National Laboratory US Department of Energy: Richland, WA.

US EPA. 1974. *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*. US EPA. http://nepis.epa.gov/ (accessed July 2013).

US EPA. 1997. *Mercury Study Report to Congress. Vol. III: Fate and transport of mercury in the environment*.

US EPA. 1999. *Draft Revised Guidelines for Carcinogen Risk Assessment (External Draft, July 1999)*. U.S. Environmental Protection Agency, Risk Assessment Forum: Washington, DC.

US EPA. 2000. *Risk Assessment and Fish Consumption Limits*. In Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Washington, DC: Office of Science and Technology, Office of Water. (accessed December 2012).

US EPA. 2005. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities.

US EPA. 2006. *Nitrates and Nitrites TEACH Chemical Summary: US EPA, Toxicity and Exposure Assessment for Children's Health*. US EPA. http://www.epa.gov/teach/chem_summ/Nitrates_summary.pdf (accessed

US EPA. 2008. *Residential Air Cleaners (Second Edition): A summary of Avaiable Information*. US EPA. http://nepis.epa.gov/ (accessed November 1, 2013).

WHO. 1948. *Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 states (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948*. World Health Organization: New York, NY.

WHO. 1999. *Guidelines for Community Noise*. A68672. World Health Organization: Geneva.

WHO. 2004. *Health Aspects of Air Pollution: Results from the WHO Project "Sytstematic Review of Health Aspects of Air Pollution in Europe"*. Copenhagen, Denmark.

WHO. 2013. *IARC: Outdoor air pollution a leading environmental cause of cancer deaths*. WHO press release. October 17, 2013. http://www.iarc.fr/en/media-centre/iarcnews/pdf/pr221_E.pdf (accessed March 2014).

Williamson, S. J., D. Keppie, R. Davidson, D. Budeau, S. Carrier, D. Rabe, and M. Schroeder. 2008. *Spruce Grouse Conservation Plan*. Association of Fish and Wildlife Agencies: Washington, DC.

Wright, D. G. and G. E. Hopky. 1998. Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters. *Canadian Technical Report of Fisheries and Aquatic Sciences*, 2107: iv + 34p.

Yang, G.-Q. and R.-H. Zhou. 1994. Further observations on the human maximum safe dietary selenium intake in a seleniferous area of China. *J Trace Elem Electrolytes Health Dis* 8: 159-65.

<u>Personal Communications</u>

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