32. Effects of the Environment on the Project

32.1 INTRODUCTION

The Brucejack Gold Mine Project (the Project) property is located at 56°28'20" N latitude by 130°11'31" W longitude, which is approximately 950 kilometres (km) northwest of Vancouver, British Columbia (BC), 65 km north-northwest of Stewart, BC, and 21 km south-southeast of the closed Eskay Creek Mine. The Project is located within the Regional District of Kitimat-Stikine. The site is currently accessed on ground by a 73-km-long exploration access road from Highway 37 and by helicopter from staging sites near the former Granduc Mine site north of Stewart.

The Project is located above the tree line in a mountainous area with an elevation at the mine site area of 1,400 metres above sea level (masl); surrounding peaks reach 2,200 masl. Glaciers and ice fields border the mineral deposits to the north, south, and east. Recent and rapid deglaciation has resulted in over-steepened and unstable slopes in many areas. Recently deglaciated areas typically have limited soil development, consisting of glacial till and colluvium. Lower elevation areas along the access road with mature vegetation generally have a well-developed organic soil layer.

The Project is a proposed underground gold and silver mining operation, targeting the West and Valley of the Kings mineralized zones. Over a 22-year mine life, the mine will produce approximately 16 Mt (million tonnes) of ore at a rate of up to 2,700 tonnes per day.

The overall footprint of the Brucejack Mine Site and immediate infrastructure will be about 393 ha, and will consist of roads, a power transmission line, the mine site area, tailings and waste rock disposal, an aerodrome, a transfer facility, and camp facilities. There is an existing 73-km exploration access road from Highway 37 to the mine site, about 10 km of which is on the Knipple Glacier. This road will be upgraded and serve as the main access to the mine site area and is referred to throughout the Application for an Environmental Assessment Certificate/Environmental Impact Statement (Application/EIS) as the Brucejack Access Road. The Project will tie into the provincial electrical power grid via a transmission line route that would extend 55 km southeast and south from the Brucejack Mine Site to the recently completed Long Lake Hydroelectric Project, near Stewart.

This assessment of the effects of the environment on the Project is consistent with Section 19(h) of the *Canadian Environmental Assessment Act, 2012* (2012), which defines "environmental effects," in part, as "any change to the Project that may be caused by the environment."

The Application/EIS assesses the potential for environmental factors to affect the Project during the Construction, Operation, Closure, and Post-closure phases. A range of climate conditions are considered, including precipitation (wet, dry, and normal), temperature (warm, cold, and normal), floods, low-flow, freeze-thaw cycles, and changes in permafrost. Geophysical effects, such as mass movements, glaciers, seismic activity, and volcanic activity are also discussed. The effects and likelihood of wildfires on the Project are considered. Finally, this document describes and assesses how climate change could affect the Project, both directly through changes to air temperature and precipitation, and indirectly through secondary effects on the environment. Measures to mitigate these potential effects, and contingency plans and response options, are identified. These components of the effects of the environment on the Project are in accordance with the Brucejack Gold Mine Project Application Information Requirements (BC EAO 2014).

32.2 CLIMATE AND METEOROLOGY

The regional climatology and climatic processes are first described in this section, followed by a brief summary of climatic data from nearby long-term regional meteorological stations, and meteorological data collected in the Project area as part of the baseline monitoring program. This discussion provides a description of typical climatic conditions in the Project area.

Weather extremes are important in terms of the effects of the environment on the Project. Therefore, subsequent sections describe the causes, occurrences, and effects of storms (rainstorms and snowstorms), drought, extreme temperatures, and wind.

32.2.1 Climate

32.2.1.1 Regional Climate

The regional climate of northwestern BC is dominated by weather systems that develop over the Pacific Ocean. Climate in the Project area is also influenced by the local mountainous topography and glaciers, which produce large spatial climatic differences, in both horizontal distance and elevation.

The Pacific Ocean is the major moisture source for BC. In northwestern BC, precipitation decreases with distance from the coast. Mountain ranges that parallel the coast cause air masses to rise, causing the air to cool as it expands, and reduces the moisture-holding capacity of the air. This water vapour is forced to condense into water droplets and results in cloud formation and precipitation. Once over the mountain summit, the now dryer air descends and warms, which reduces the amount of clouds through evaporation. The result is a dramatic reduction of precipitation in the rain-shadow on the leeward side of the mountain range. This is known as the orographic effect (Reksten 1995). The Project area lies in a transition zone between the very wet Pacific coastal region and the drier interior of BC. In terms of air temperature, the Project area is also in a transition zone between the coast, which moderates temperatures, and the more continental climate of the interior.

32.2.1.2 Regional Climatic Patterns

The winter climate of the region is strongly affected by the strength of the Aleutian Low, a low-pressure cell that forms in winter over the Bering Sea. The Aleutian Low rotates counter-clockwise, and along the coast it advects warm air and water poleward. The Pacific Decadal Oscillation (PDO) is a statistical measure of the anomalies in sea surface temperatures the Pacific, which are controlled by the strength of the Aleutian Low (Mantua et al. 1997). The PDO is characterized by long-term modes that are stable over decadal timescales. When the Aleutian Low is strong, the PDO is defined as positive, and the climate of the northwest Pacific tends to be warmer and wetter than usual. The opposite is true for a negative PDO. The PDO was in a negative phase for much of the 1940s to mid-1970s, and then in 1977 the PDO transitioned back to a positive phase, which lasted until about 2005. Since approximately 2005 the PDO has been in a negative phase. The phase and strength of the PDO has been linked to changes in river flow, glacial mass balance, and salmon abundance in the Pacific Northwest (Dettinger, Cayan, and McCabe 1993; Mantua et al. 1997; Hodge et al. 1998; Bitz and Battisti 1999; Gedalof and Smith 2001; Neal, Walter, and Coffeen 2002).

Specifically, in the Project area, winter (December to March) air temperatures have strong correlation coefficients (r) with the PDO (r = approximately 0.6). Winter precipitation is much less strongly correlated (r = approximately 0.3 to 0.4; NOAA 2013). Stronger correlation coefficients between winter precipitation and the PDO exist in Alaska (positive correlation) and in eastern Washington and Idaho (negative correlation). While studies from these areas have reported strong links between the PDO and hydroclimate, similarly strong relationships would not be expected in the Project area. It is also important to note that the PDO is a winter phenomenon, and it has little to no direct control over summer climate in the north Pacific; however, winter climatic anomalies can have hydrologic effects the following spring and summer (e.g., storage and melt of snowpack; Neal, Walter, and Coffeen 2002).

Given that the PDO is defined by sea surface temperatures in the Pacific, it is linked to the El Niño Southern Oscillation (ENSO). During La Niña winters, the Aleutian Low tends to be westward of its normal location and has higher pressure than normal (Rodionov, Overland, and Bond 2005). During positive phases of the PDO there is an increased propensity of ENSO positive events, and vice versa. The average period of ENSO is about five years, so higher-frequency ENSO signals are superimposed on top of lower-frequency PDO signals.

32.2.1.3 Local Climate

Local topography affects air temperature and precipitation in the Project area, due to the large elevation range. The elevation at the mine site is about 1,400 masl, with surrounding peaks up to 2,200 masl. The treeline is at about 1,200 masl. The Brucejack Access Road extends down to 472 masl where it intersects with Highway 37 near the Bell-Irving River. Air temperature differences caused by the lapse rate (the decrease in air temperature with elevation) are therefore large. At higher elevations, the reduced moisture holding capacity of cool air causes precipitation. In the nearby Teigen Creek Valley, precipitation was found to increase at a nominal rate of 5% per 100 m (Rescan 2013e). Mountains in the Project area also slow down cyclonic storms, which can lead to prolonged and sometimes heavy rainfalls.

To account for the large spatial climatic variability in the Project area, three meteorological stations were set up on site between 2009 and 2011. Each was established to collect site-specific data at representative elevation throughout the Project area, and each continues to operate and collect data: Brucejack Lake (1,360 masl), Scott Creek (780 masl), and Wildfire Creek (720 masl). The meteorological datasets are summarized in subsequent sections of this chapter, and are presented in detail in the meteorology baseline report (Appendix 7-A, 2012 Meteorology Baseline Report).

Longer-term meteorological datasets from current and former stations operated by Meteorological Services of Canada have also been analyzed from four regional weather stations. These include the Brucejack Lake, Unuk River Eskay Creek, Bob Quinn, and Stewart Airport stations (Table 32.2-1). Note that in British Columbia, in general, precipitation increases with proximity to the coast, and also, more specifically, with elevation.

Table 32.2-1. Meteorological Service of Canada Weather Stations near the Project Area

Station Name	Brucejack Lake	Unuk River Eskay Creek	Bob Quinn	Stewart Airport
Station ID	1071092	1078L3D	1200R0J	1067742
Elevation (masl)	1,372	887	610	7
Distance and Direction from Brucejack Lake	< 2 km	30 km N	56 km N	63 km S
Period of Operation	1988-1990	1984-2010	1977-1994	1974-2012
Mean Annual Temperature (^{o}C)	-0.5	1.0	3.1	6.0
Daily Maximum Air Temperature	13.2	15.0	20.4	19.6
Daily Minimum Air Temperature	-15.1	-10.4	-11.8	-5.7
Mean Annual Precipitation (mm)	a	2,014	642	1,852
Total Rainfall (mm)	a	741	463	1,313
Total Snowfall (mm)	a	1,269	179	570

[a] *insufficient data quality and length*

32.2.2 Precipitation

Annual total precipitation at the Brucejack Lake weather station (2010-2013), ranged from 1,100 to 2,000 millimetres (mm); 52% of this precipitation fell as snow. At the lower elevation stations, average annual precipitation ranged from 820 to 1,400 mm, and slightly less than half fell as snow. The greater precipitation at the Brucejack Lake station is caused by its higher elevation and its more westerly location. Precipitation records were adjusted for wind-induced gauge undercatch, and gaps were filled with data from nearby stations (Rescan 2013c).

Precipitation in the Project area is typically frequent, but generally of low magnitude. At the Brucejack Lake meteorological station, precipitation exceeded 5 mm per day on 25% of days over the period of record. At the Scott Creek and Wildfire creek stations, the same occurred on about 22% of days. At the Brucejack Lake meteorological station, only 30% of monitored days had no precipitation.

Estimating annual average precipitation for the Project area is difficult because there is a large range of elevations within the Project footprint (and precipitation is dependent on elevation), and also because the on-site data covers a relatively short temporal period (2010 to 2013). BGC Engineering Inc. (2014) investigated the temporal and spatial distribution of precipitation throughout the Project area. The results of this analysis recommend that average annual precipitation for the mine site (located at 1,400 m) is between 1,900 (dry year) to 2,034 (wet year) mm. These numbers are consistent with the upper end of on-site data recorded at the Brucejack Lake weather station located at 1,372 m. For the context of this chapter the annual precipitation for the Brucejack Mine Site will be referred to as approximately 2,000 mm per year.

Snow depths reach maxima between February and March. Baseline work has highlighted the large spatial variability in snowpack, with large accumulations in sheltered areas and low accumulations at exposed, wind-swept areas. Snow depth was monitored with sonic depth sensors on meteorological stations, and with detailed snow surveys in the field. At Brucejack Lake, the lack of a vegetation canopy and high winds causes a spatially and temporally fluctuating snowpack, and a generally low accumulation (typically less than 0.5 m) at the meteorological station. However, snow depth at a nearby snow-survey site ranged from 2.5 to 2.9 m, and drifts up to 10 m have been observed in the lee of obstacles. Maximum snow depths recorded at the Wildfire Creek and Scott Creek meteorological stations ranged from 1.8 to 2.2 m.

Precipitation-related risks to the Project and mitigation measures are presented in Table 32.2-2 and discussed in the following sections.

32.2.2.1 Typical Precipitation

<u>Effects on the Project</u>

In winter, frequent low-magnitude snowfall could increase avalanche hazard (Section 32.5.2), and increase the risk of accidents due to reduced visibility and hazardous road conditions on the Brucejack Access Road. Sustained snowfall has the potential to form thick drifts, which could damage buildings and structures in the Project area.

<u>Mitigation Measures</u>

Timescales for the abovementioned effects caused by typical rainfall rates are long, and a monitoring program would identify potential hazards and damage before they occur.

Table 32.2-2. Precipitation-related Risks and Mitigation Measures

Classification	Project Component	Potential Risks to the Project	Mitigation Measures [a]
Roads	Brucejack Access Road, mine site area roads Crossing structures Knipple Glacier Road	Snow drifts. Mass movements including avalanche danger. Reduced visibility. Downed trees. Reduced access to/from site during storms.	Where possible, roads will be located outside of avalanche zones; however, some sections of the access road pass through avalanche zone. For these sections implementation of avalanche hazard management plan will provide direction for safe travel. And will include. Signage in areas of elevated avalanche risk will increase awareness. Avalanche technicians on site to assess risk. Snow removal and road repair equipment on site. See Section 32.5, for more information on mass movements.
Power	Transmission line	Snow avalanche. Mass movements. Wind damage during thunderstorms from downed trees or direct wind damage.	Where possible, transmission lines will be located outside of avalanche zones; however, some sections will pass through avalanche zones Every effort will be made to either locate towers outside of direct avalanche paths or use towers capable of withstanding the force of an avalanche. Backup power plant. Construct transmission towers designed to withstand snow creep and avalanches and maintain vegetation height in right-of-way below height that could impact the power line in the event trees fall. Implement Avalanche Management Plan. Signage in areas of elevated avalanche risk. Avalanche technicians on site to assess risk. See Section 32.5 for more information on mass movements.
Brucejack Mine Site	Water management components (pond, pipelines, diversion channels, treatment plant)	Flooding	See Section 32.3 (Surface Water Flow)
	Mine infrastructure (ore conveyor, crushers, mill, power station, etc.)	Increased flows into shafts and stopes. Snow drifts. Mass movements including avalanche danger.	Pumps to remove water from underground. Snow removal equipment on site. Implementation of Avalanche Management Plan. Signage in areas of elevated avalanche risk. Avalanche technicians on site to assess risk. See Section 32.5, for more information on mass movements.
	Ventilation shafts	Snow drifts	Snow removal equipment on site. Cowling on ventilation intakes to shield from snow.
Bowser Aerodrome and Knipple Transfer Station Area	n/a	Snow loading. Mass movements including avalanche danger.	Snow removal equipment on site. Siting infrastructure outside avalanche zones. Implementation of Avalanche Management Plan. Signage in areas of elevated avalanche risk. Avalanche technicians on site to assess risk. See Section 32.5, for more information on mass movements.
Waste	Tailings		Design pipeline to withstand large waves.
	Waste rock	Storm-generated waves	Reduce waste rock disposal during periods of high waves.
	Incinerator	Snow loading. Mass movements including avalanche danger.	Site infrastructure will be located outside of avalanche zones. Snow removal equipment on site. Implementation of avalanche hazard management plan. Signage in areas of elevated avalanche risk. Avalanche technicians on site to assess risk. See Section 32.5 for more information on mass movements.
Camp	Mechanical shop, warehouse, personnel housing Personnel	Snow loading. Mass movements including avalanche danger. Reduced visibility. Increased travel hazards during storms.	Stopping or slowing work in adverse weather conditions. Reduced access to/from site during storms. Site infrastructure will be located outside of avalanche zones. Avalanche hazard training and equipment for personnel and implementation of Avalanche Management Plan. Avalanche technicians on site to assess risk. Training required for storm effects.

[a] *Weather reports will be monitored to mitigate all precipitation-related risks to the project.*

Monitoring and mitigating the effects of typical levels of precipitation will consist of:

- pumping of seepage water from the underground workings;
- monitoring weather forecasts;
- monitoring access road conditions, on land and on the Knipple Glacier;
- monitoring on-site snow depths;
- performing regular safety inspections of Project area buildings and infrastructure;
- frequent plowing and snow removal to mitigate effects to structures; and
- making aggregate available and applying it to increase road safety when necessary.

Access roads will be constructed to standards and design criteria that are sufficient for the normal climate of the area, and with design tolerances to withstand extreme weather. For example, the Brucejack Access Road will be 5 to 6 m wide, with 0.3 by 0.8 m drainage ditches. The grade of the road will be a maximum of 12% sustained, with pitches less than 150 m long up to 18%. The maximum grade break will be 7% per 15 m of travel (Cypress Forest Consultants Ltd. 2011). Roads will be surfaced with crushed aggregate as necessary to control erosion.

32.2.2.2 Storms (High Rainfall and Snowfall)

At the current Brucejack Lake meteorological station, only 9 out of 1,100 monitored days had precipitation (rain and snow) events that exceeded 50 mm per day (0.8% of monitored days), and 28 days exceeded 25 mm precipitation (2.5% of monitored days).

Similarly large events at lower elevations are less frequent, particularly along the access road which is in the rain shadow of the mountains at Brucejack mine site. The 24-hour 10-year return period rainfall event at the Unuk River Eskay Creek Environment Canada weather station is 102 mm (station is located at 887 masl and 30 km north of Brucejack Lake; Table 32.2-1; BGC Engineering Inc. 2013). Higher precipitation would be expected at the higher elevation mine site, but suitably long precipitation records are not available to calculate return periods at higher elevations.

Severe winter snowstorms which cause sustained periods of high snowfall are probable and thick snow drifts may form. Within the region half of the annual precipitation falls as snow between October and April. .

<u>Effects on the Project</u>

Extreme rainfall could cause reduced traffic speed along the Brucejack Access Road, or temporary road closures. The Knipple Glacier portion of the Brucejack Access Road could develop channels during heavy precipitation events, potentially temporarily disrupting site access until the road surface is reconfigured.

During mine operation, high precipitation levels could increase the amount of groundwater seepage and precipitation that flows into mine stopes and shafts. This seepage would increase de-watering costs.

Severe rainstorms in Project catchments could trigger flooding events, especially if they coincide with periods of peak snowmelt or glacial melt. Flood-related effects could include damage to the Brucejack Access Road and bridges and culverts, as well as damage from mass movements such as debris flows. Flood-related effects and mitigation measures are presented in more detail in Section 32.3.2, and mass movements are discussed in Section 32.5.1.

Thunderstorms may be accompanied by hail, lightning, and damaging winds. A thunderstorm is classified as severe when it contains hail larger than 1.9 centimetres and winds gusting in excess of 93 km per hour (50 knots). Large hail from severe thunderstorms could damage building infrastructure, cause temporary blockages in the diversion channels, and create unsafe working conditions. High-speed winds related to thunderstorms could create large waves in Brucejack Lake (Section 32.2.4). Access roads could also become blocked with downed trees. Lightning could cause forest fires under dry conditions (Section 32.6), and damage infrastructure such as buildings and power lines. Finally, thunderstorms could temporarily prevent air traffic, disrupting the mobilization of personnel to and from the Project site.

Snow storms could impede the movement of mobile equipment on the access roads and at the Brucejack Mine Site. Related problems could include reduced traction and visibility. Use of the causeway on Brucejack Lake for dumping waste rock may be limited during times of high snowfall. Fixed-wing flights may need to be delayed until the aerodrome is cleared. Helicopter pads will be cleared, but helicopter use will be suspended during times of heavy snowfall. Poor visibility could cause dangerous conditions during rain events, blizzards, or fog. Temporary closure of access roads can be expected when visibility is severely restricted. Increased loads from snow and ice accumulation on buildings and other infrastructure may cause structural damage. Particular attention will be given to removing snow accumulations from mine ventilation intakes and returns. Increased snow loading on the steep valley walls increases the likelihood of a snow avalanche (Section 32.5.2).

In the event of storms, transportation could be delayed, but the mine will have storage capacity for fuel and concentrate to manage short-term road closures. Development may be curtailed due to inability to dispose of waste rock, but production should be able to continue as long as fuel and power are available.

Mitigation Measures

Mitigation measures specific to flooding caused by extreme rainfall are discussed in Section 32.3.2, and Section 32.5.1 provides a description of mitigation measures related to mass movements.

Weather forecasts will be monitored for advanced warning of incoming storms and temperature extremes, providing time to prepare for extreme weather. Preparation will include mobilizing equipment to key areas for maintenance, providing site personnel safe refuge, and shutting down operations if necessary. Building supplies will be kept on site to facilitate rapid repairs following extreme weather. Emergency supplies will include materials to repair buildings, power transmission poles, and bridges.

Site infrastructure and equipment will be placed above high-water marks around Brucejack Lake. Most power transmission poles will be properly installed single steel monopole towers, which are resistant to damage by wind and lightning. Electrical cables on power transmission towers are designed to withstand anticipated wind and snow loads.

Removal of excess snow from the mine site area, roadways, the aerodrome, and other Project infrastructure will be managed and scheduled to maintain safe working conditions while minimizing interferences with production. Crushed aggregate will be available for distribution on roads. Strategically located stockpiles of suitable crushed rock will be established. The mine production fleet will include extra equipment—such as graders, loaders, trucks, and scrapers—to manage snow and maintain production levels as much as possible.

Groundwater that seeps into underground workings will be pumped to the water treatment plant. The pumping system has been designed to accommodate flows from 2,140 to 4,080 m^3 per day (BGC Engineering Inc. 2013). The design capabilities of the pumping system exceed the expected pump requirements. Expected requirements were determined using groundwater modelling that incorporated a variety of potential hydraulic conductivities. Modelling also considered how groundwater inflows will change over the Project lifespan as water is pumped from the underground and used in processing the ore (BGC Engineering Inc. 2013).

All buildings and infrastructure are designed for predicted snow and ice buildup. Suitable cowling will be required at ventilation intakes and returns to prevent blockage by snow. The surface water diversion channels are designed to be sufficiently wide for channel maintenance, including removal of debris and snow.

Storm-related visibility issues at the Brucejack Mine Site will be addressed with supplementary road lighting, global positioning systems in mobile equipment, and communications protocols. Operating protocols will ensure safe and efficient traffic flow during periods of reduced visibility.

32.2.2.3 Drought (Low Precipitation)

The Project area typically experiences annual precipitation of approximately 2,000 mm per year. This value is dependent on the elevation and location relative to the overall Project area. The proposed Brucejack Mine Site experiences increased precipitation due to its high elevation (1,370 masl), whereas portions of the access road experience less precipitation as they are located at lower elevations. Return periods for dry years have been calculated for the Unuk River Eskay Creek precipitation dataset (station is located at 887 masl and 30 km north of Brucejack Lake; see Table 32.2-1; BGC Engineering Inc. 2013). The 10-year dry return period is 1,773 mm per year, and the 100-year dry return period is 1,373 mm (BGC Engineering Inc. 2013).

<u>Effects on the Project</u>

Effects of low precipitation on river discharge and water quality are discussed in Section 32.3.3. Prolonged periods of low precipitation could increase the risk of wildfires (Section 32.6), reduce river discharge (Section 32.3.3), and decrease visibility on roads due to dust caused by vehicle traffic.

<u>Mitigation Measures</u>

Mitigation measures for wildfires are described in Section 32.6, and mitigation measures for low flows are discussed in Section 32.3.3. Dust on roads will be mitigated with water sprays in dry periods and by reducing speed limits where necessary.

32.2.3 Air Temperature and Freeze-Thaw Cycles

Of the three meteorological stations in the Project area, average annual air temperature is the lowest at Brucejack Lake (-2.0 to -0.5°C) due to its high elevation. At the lower elevation Scott Creek station, average annual air temperature was warmer (1.4 to 1.7°C).

Minimum mean monthly air temperatures ranged from -10.6°C at Brucejack Lake to -8.5°C at Wildfire Creek. Minimum recorded air temperatures have been -30°C in the Project area. Maximum mean monthly air temperatures ranged from 6.0°C at Brucejack Lake to 13.9°C at Scott Creek. Maximum recorded air temperature in the Project area is just below 30°C. The warmest mean daily air temperature recorded at Brucejack Lake is 11.7°C, the warmest at Scott Creek is 19.1°C, and the warmest at Wildfire Creek is 18.1°C.

Air temperature-related risks to the Project and related mitigation measures are presented in Table 32.2-3, and discussed in the following sections.

Table 32.2-3. Air Temperature-related Risks and Mitigation Measures

Classification	Project Component	Potential Risks to the Project	Mitigation Measures [a]
Roads	Brucejack Access Road, mine site area roads	Icing during cold periods. Extended period of snow cover during cold periods, increasing clearing requirements. Freeze-thaw damage to roads.	Regular monitoring of roads for freeze-thaw damage and snow drifts.
	Crossing structures	Icing during cold periods. Extended period of snow cover during cold periods, increasing clearance requirements. Freeze-thaw damage to crossing structures.	Regular monitoring of crossing structures for freeze-thaw damage and snow drifts.
	Knipple Glacier Road	Melt and lowering of surface.	Glacier monitoring, reconfiguring load-on and load-off ramps as necessary, monitoring crossings and crevasses. See Section 32.5.3.
Power	Transmission line	Extended warm and dry periods could increase wildfire risk.	Keep vegetation and brush cut low to reduce fire hazard.
Brucejack Mine Site	Water management components (pond, pipelines, diversion channels, water treatment plant)	Extended period of water freeze-up. Freeze-thaw damage to pipelines.	Appropriate design, construction methods, and equipment.
	Mine infrastructure (ore conveyor, crushers, mill, power station, etc.)	Cold-related damage to equipment. Increased power demand during hot and cold periods. Extended period of snow cover during cold periods, increasing clearing requirements. Extended warm and dry periods could increase wildfire risk.	
	Ventilation shafts	Cold-related damage to equipment.	
Bowser Aerodrome and Knipple Transfer Station	n/a	Extended period of water freeze-up. Freeze-thaw damage to airstrip surface. Cold-related damage to equipment.	Appropriate design, construction methods, equipment and annual maintenance of airstrip surface.
Waste	Tailings	Freeze-up of tailings pipeline	Constant flow through pipeline will minimize risk of freeze-up.
	Waste rock	Extended period of water freeze-up.	Bubbler system in Brucejack Lake to create an ice-free zone. Experience in past has not found this to be a problem.
	Incinerator	Extended period of snow cover during cold periods	Increased clearing during cold and snowy periods.
Camp	Mechanical shop, warehouse, personnel housing	Cold-related damage to equipment. Increased power demand during hot and cold periods. Extended period of snow cover during cold periods, increasing clearing requirements. Extended warm and dry periods could increase wildfire risk.	Regular maintenance on equipment and infrastructure.
	Personnel	Cold-related injuries (frostbite, exposure, hypothermia). Heat-related: heat exhaustion, dehydration, heat stroke. Accidents from distraction during hot/cold periods. Extended warm and dry periods could increase wildfire risk.	Staff education on risks of hot and cold weather. Appropriate personal protective equipment and communications gear. Tracking of personnel when in remote areas.

[a] *Weather reports will be monitored to mitigate all air temperature-related risks to the project. Regular monitoring of Project infrastructure for hazards and damage will be conducted.*

32.2.3.1 Effects on the Project

Given the climatic data presented in Section 32.2.1, the effects on the Project from extreme cold air temperatures will likely be more common and severe than the effects from extreme warm air temperatures.

Effects of Extreme Cold

Extremely low air temperatures could adversely affect workers' health, causing such conditions as frostbite and hypothermia. Without immediate medical treatment, the effects of such conditions could be fatal. Workers can become distracted and prone to accidents under extreme low temperatures. Equipment and machinery is more likely to malfunction or become damaged during extreme low temperatures, increasing the potential for worker-related accidents. Extreme low temperatures may be accompanied by snow and blowing snow, which could affect surface transport of materials and personnel, and could temporarily slow mine operations. Increased heating requirements on site would also result from extreme low temperatures, increasing power demand.

Extended cold spells could result in an extended winter, increased snow accumulation, and a longer ice-covered period for Brucejack Lake. As a result, the access road, haul roads, and diversion channels would require more clearing. Extreme low temperatures could also increase the risk of pipelines freezing. Cold spells could cause later melting of the winter snowpack, delaying spring runoff.

Effects of Extreme Warmth

Extreme high temperatures may also adversely affect workers' health, causing conditions such as heat exhaustion, dehydration, and heat stroke. Workers can become distracted and more prone to accidents under extreme high temperatures. Equipment and machinery is more likely to malfunction during extreme high temperatures, increasing the risk of accidents and malfunctions. Increased air conditioning requirements on site would result from extreme high temperatures, increasing power demand.

With sustained warm air temperatures, more precipitation would fall as rain than as snow, and earlier melting of the snowpack could cause proportional increases in runoff during the winter and early spring. Increased volumes of glacial melt could occur during periods of warmth in summer. Storms where precipitation falls as rain rather than snow could cause more rapid runoff, potentially increasing the frequency of landslides and channel debris flows. Costs of maintaining the diversion channels and access roads could subsequently increase. Extremely high temperatures coinciding with dry periods could increase the likelihood of wildfires occurring in the area (discussed in Section 32.6).

Effects of Freeze-Thaw Cycles

At high elevations in northern BC, freeze-thaw is likely a concern in spring, summer, and fall. At lower elevations, it is more of a concern in fall, winter, and spring. Freeze-thaw cycles are a causal factor of failing road surfaces, and can cause damage to power transmission lines.

32.2.3.2 Mitigation Measures

Weather forecasts will be monitored, which will provide time to prepare for air temperature extremes. Health and safety policies will be implemented. Job hazard analyses will be undertaken before work is performed. This will allow risks such as adverse weather conditions, to be identified before work commences. Staff will be educated through formal training programs to ensure they understand the risks of working under extreme high and low temperatures, and to ensure they have a good knowledge of any related procedures. Personnel will be required to wear appropriate personal protective equipment, including cold weather gear, while working outside. Movement of personnel throughout the

Project area will be monitored and tracked at all times, and radio communication will be maintained with anyone working in remote areas.

If required, an aerator system will be used to keep a portion of Brucejack Lake ice-free, allowing year-round deposition of waste rock in the lake. In colder winters this system, if required, would be in operation longer, increasing electricity demands.

Suitable equipment and design systems will be purchased for the Project to enable operation under extreme low temperatures. Equipment will be maintained to ensure proper operation. Roads and power lines will be built to withstand freeze-thaw cycles.

32.2.4 Wind

Wind at Brucejack Lake is predominantly from the east, and is strongest in winter. Nearly 25% of the time, wind blows over 11 m per second in winter. In summer, winds are calmer (mostly in the 1 to 3 m/s range). At Scott Creek, winds blow from the northeast and southwest, along the valley, and are relatively slow for most of the year. The same can be said for wind at the Wildfire Creek station, although winds there more typically blow from the southeast.

32.2.4.1 Effects on the Project

High winds during periods of below-freezing air temperatures would contribute to lowered windchill and blowing snow. Blowing snow would reduce visibility, limiting access to and from the Brucejack Mine Site. High winds could cause downed trees, which could block access roads. Power lines, antennas, and buildings could be susceptible to damage by winds if improperly designed or installed. Effects of high winds would be particularly severe during snowfall and may cause thick snow drifts. High winds may also cause large waves in Brucejack Lake, potentially affecting near-shore infrastructure.

32.2.4.2 Mitigation Measures

Meteorological stations are recording on-site winds, which will guide design techniques necessary to mitigate potential damage by wind. Weather forecasts will be monitored to anticipate and prepare for severe winds. Infrastructure will be built, and material will be stored, above high-water marks in Brucejack Lake to prevent damage by wind-generated waves. At the Brucejack Mine Site one of the four 500-kilowatt, 600-volt diesel generators installed for construction activities will be redeployed as a dedicated back-up power supply for the permanent camp, while the remaining three generators will be available for critical power needs such as pumps and tunnel fans. During blackouts, non-essential machinery will be shut down until power is re-established.

32.3 SURFACE WATER FLOW

Detailed results from the Project area hydrometric program are provided in the surface water baseline study (Appendix 10-A, 2012 Surface Water Hydrology Baseline Report). The hydrometric baseline program involved monitoring a network of hydrometric stations in rivers within and near the Project area to provide site-specific hydrologic data (Table 32.3-1). Hydrometric data were obtained from near the Brucejack Mine Site (Brucejack Lake outlet), along the Brucejack Access Road (Scott, Todedada, and Wildfire creeks), and from rivers within the same regional drainage networks as the Project area (Unuk River, Sulphurets Creek, and Sulphurets Lake). Data collection included data sharing with stations in the nearby KSM Project area where applicable. Baseline work also involved analyzing long-term datasets from regional Water Survey of Canada stations. This regional analysis allowed prediction of recurrence intervals for floods and low flows within the Project area.

Table 32.3-1. Physiographic Characteristics of Monitored Watersheds within the Project Area

Drainage	Watershed	Hydrometric Station	Area (km^2)	Minimum Elevation (m)	Maximum Elevation (m)	Median Elevation (m)	Glacier Coverage (%)	Tributary to
Unuk	Unuk River	UR-H1	400	221	2,265	1,130	14.5	n/a
	Sulphurets Creek	SC-H1	299	217	2,559	1,479	37.7	Unuk River
	Sulphurets Lake	SL-H1	84	572	2,559	1,610	48.7	Sulphurets Creek
	Brucejack Lake	BJL-H1/BJL-H1a	12[a], 17[b]	1,345	2,383	1,537[a]	29.5[a]	Sulphurets Creek
Bell-Irving	Scott Creek	Scott-Hydro	75	401	2,361	1,180	21.3	Bowser River
	Todedada Creek	Todedada-Hydro	61	574	2,235	1,179	24.8	Treaty Creek
	Wildfire Creek	Wildfire-Hydro	67	464	1,865	950	1.9	Bell-Irving River

[a] *Based on the Knight Piésold watershed area calculation, excluding the East Lake contribution (Knight Piésold Ltd. 2011)*
[b] *Based on the Knight Piésold watershed area calculation, including the East Lake contribution (Knight Piésold Ltd. 2011)*

32.3.1 Typical Surface Water Flows

Runoff in the Project area is typically sourced from snowmelt, rainfall, and glacial melt, depending on watershed elevation, time of year, weather conditions, and glacial cover. Discharge is lowest in winter, with larger, lower elevation rivers continuing to flow, and smaller, higher elevation streams reducing to near zero flow. When air temperature rises above freezing in late May to early June, discharge rises rapidly, and is fed primarily by snowmelt and episodic rain-on-snow events. Snowmelt continues into summer at higher elevations, feeding rivers in the Project area. In glacierized catchments, flows are augmented by glacial melt, especially at times of peak summer warmth and in years with low snow accumulation. Autumn rainfall is particularly common, which can result in significant rainfall-runoff events.

The hydrologic regime of the area is complex. Runoff generated separately by snowmelt, rainfall, and glacial melt often temporally overlap. There is large spatial variability in precipitation and air temperature (Sections 32.2.2, 32.2.3). Hydrometric indices for typical flow conditions in monitored watersheds are presented in Table 32.3-2 (Appendix 10-A, 2012 Surface Water Hydrology Baseline Report).

Brucejack Lake likely episodically receives runoff from East Lake, about 500 m to the east. Typically, East Lake drains through glacial conduits to the east, and does not drain into Brucejack Lake. However, if these conduits are blocked, stage in East Lake rises until it overtops into Brucejack Lake. Anecdotal evidence suggests that this situation has occurred during the spring in some years. When this overtopping occurs, the drainage area of Brucejack Lake increases to about 17 km^2 from 10.1 km^2 (Table 32.3-2). Increases to typical discharge, peak flow, and low flow would be expected (Table 32.3-2). The likelihood of continued episodic input of East Lake water into Brucejack Lake is assessed in the climate change section (Section 32.7.3).

32.3.1.1 Effects on the Project

Normal flows will not affect Project infrastructure, since infrastructure will be designed to withstand floods with long return periods. The effects of floods are discussed in Section 32.3.2.

Table 32.3-2. Flow Conditions in the Project Area

Hydrometric Station	Drainage Area (km^2)	Annual Peak Flow, Q_2 (m^3/s, QRT)[c]	Average Estimated[g] Runoff (mm)
BJL-H1	11.7[a]	11	1,695[d]
	17.0[b]	15	1,836[d]
SL-H1	84	53	2,866[e]
SC-H1	299	146	2,420[e]
UR-H1	400	184	2,080[f]
Scott-Hydro	75	48	1,645[e]
Todedada-Hydro	61	41	2,216[f]
Wildfire-Hydro	67	44	1,222[e]

[a] *Based on the Knight Piésold watershed area calculation, excluding the East Lake contribution (Knight Piésold Ltd. 2011)*
[b] *Based on the Knight Piésold watershed area calculation, including the East Lake contribution (Knight Piésold Ltd. 2011)*
[c] *Q2 is the two-year return period, calculated using quantile regression technique (QRT). Results from the Parameter Regression technique (PRT) are presented in Appendix 10-A, 2012 Surface Water Hydrology Baseline Report, but results from the two techniques vary by 3% on average (3.9% standard deviation).*
[d] *Estimated using lower regional regression relation:* $y = 232.7786e^{0.0013x}$
[e] *Estimated using regional regression relation:* $y = 358.2060e^{0.0013x}$
[f] *Estimated using upper regional regression relation:* $y = 483.2283e^{0.0013x}$
[g] *Based on regional analysis*
[h] *mean values*

32.3.1.2 Mitigation Measures

As the Project design takes into consideration longer return-period events, mitigation measures specific to normal surface water flow conditions are required. Measures designed to mitigate damage due to flooding are discussed in Section 32.3.3.2.

32.3.2 Floods

Floods in northwestern BC are produced by rapid snowmelt, rainfall-runoff events, glacial melt, glacial outbursts, or a combination of the four. Snowmelt-generated floods are most likely to occur in late May, June, or July. Intense rainfall-runoff events are most common in autumn, but can occur throughout the melt season. Glacial influence on runoff may also be substantial in many Project area watersheds. Sediments in Bowser Lake contain a record of substantial flood events caused by storm events and/or glacial-lake outburst floods (Gilbert, Desloges, and Clague 1997).

A large flood event occurred during the baseline data collection period in early September 2011 (Appendix 10-A, 2012 Surface Water Hydrology Baseline Report). Over an eight-day period, 265 mm of rain fell at Brucejack Lake, which was approximately 12% of the annual average precipitation predicted by Climate BC. The event damaged hydrometric stations and caused substantial channel geometry changes. Estimates of discharge during this flood event are provided in Appendix 10-A.

Return period peak flow values for watersheds monitored within the Project area are listed in Table 32.3-3. Return periods were calculated using data from long-term regional Water Survey of Canada stations. Results from the quantile regression technique (QRT), where watershed area is regressed against the estimated peak annual flows with different return periods, are presented below. Return periods were also calculated using the parameter regression technique (PRT), where peak flows are assumed to follow a Log-Pearson III distribution. PRT results are presented in the 2012 surface water baseline report (Appendix 10-A, 2012 Surface Water Hydrology Baseline Report). Results were similar from both techniques (average difference of 3%, with a 5% standard deviation).

Table 32.3-3. Estimates of Peak Flows (m^3/s) at Project Area Hydrometric Stations Based on the Quantile Regression Technique

Watershed	Drainage Area (km^2)	Estimated Peak Flow Based on Regional QRT (m^3/s)					
		Q_5	Q_{10}	Q_{20}	Q_{50}	Q_{100}	Q_{200}
BJL-H1	12[a]	20	26	31	39	44	50
	17[b]	26	34	41	51	58	65
SL-H1	84	86	109	131	161	183	205
SC-H1	299	223	276	329	399	453	508
UR-H1	400	277	343	407	492	559	626
Scott-Hydro	75	78	100	120	147	168	188
Todedada-Hydro	61	68	86	104	128	145	163
Wildfire-Hydro	67	72	92	111	136	155	174

[a] *Lower estimate of the drainage area without East Lake Watershed*
[b] *Higher estimate of the drainage area with East Lake Watershed*

An event with a given return period (T_R) has an annual probability of occurring (EP) of:

$$T_R = 1/EP$$

However, for each additional year (n), the risk of a return period being exceeded (R) increases, where:

$$R = 1-(1-EP)^n$$

The formulas above are from Bedient, Huber and Vieux (2012). Risks for various return periods are calculated in Table 32.3-4 assuming a 22-year mine life. For example, there is a 19.8% chance that a 1-in-100-year event will occur at least once in 22 years.

Table 32.3-4. Return Period Probabilities in a Single Year, and over the 22-year Proposed Mine Life

Return Period (T_R)	Annual Exceedance Probability (EP)	Risk of Occurrence over 22-year Mine Life (R, %)
1 in 10 year	0.100	90.2
1 in 20 year	0.050	67.6
1 in 50 year	0.020	35.9
1 in 100 year	0.010	19.8
1 in 200 year	0.005	10.4
1 in 500 year	0.002	4.3

Streamflow-related risks to the Project and mitigation measures are presented in Table 32.3-5, and discussed in the following sections.

32.3.2.1 Effects on the Project

Floods can damage river crossings, including bridges and culverts. Floods can cause erosion and deposition of sediment, negatively affecting water quality. Floods can trigger mass wasting, when stream beds undercut steep banks (Section 32.5.1).

Floods can cause rapid channel avulsion. Avulsion could cause damage to any infrastructure in the new channel. An area of avulsion risk is the Brucejack Access Road where it crosses the Bowser River floodplain.

Table 32.3-5. Surface Water Flow-related Risks and Mitigation Measures

Classification	Project Component	Potential Risks to the Project	Mitigation Measures [a]
Roads	Brucejack Access Road, mine site area roads	Damage to roads by floods.	Design of roads to withstand Q_{100} flows.
	Crossing structures	Damage to crossing structures by floods.	Design of crossing structures to withstand Q_{100} flows. Armoring river banks with rip-rap to protect infrastructure and bank erosion.
	Knipple Glacier section of road	Melting of glacial ice by supraglacial flow.	Grading and reconfiguring of road as needed.
Power	Brucejack Transmission Line	Damage to infrastructure during floods.	Placing project-related infrastructure (e.g., transmission line towers) above high water marks wherever possible.
Brucejack Mine Site	Water management components (pond, pipelines, diversion channels, water treatment plant)	Damage to infrastructure during floods. For contact water pond, risk of overflowing and discharging directly to Brucejack Lake, bypassing treatment.	Sizing diversion and drainage channels, and contact water pond to contain runoff from the Q_{200} return period rainfall event. Maintain a dewatered volume in the mine that will allow dewatering of underground can be stopped during times of extreme flow, to focus on dewatering the collection pond.
	Mine infrastructure (ore conveyor, crushers, mill, power station, etc.)	No risk identified.	No mitigation measures required.
	Ventilation shafts	No risk identified.	No mitigation measures required.
Bowser Aerodrome and Knipple Transfer Station	n/a	Damage to aerodrome infrastructure by floods.	Build outside of floodplain where possible. Grading where necessary.
Waste	Tailings	Reduced water quality in times of drought.	Water quality decline mitigated through treatment in WTP.
	Waste rock	Reduced water quality in times of drought.	Water quality decline mitigated through treatment in WTP.
	Incinerator	No risk identified.	No mitigation measures required.
Camp	Mechanical shop, warehouse, personnel housing	No risk identified.	No mitigation measures required.
	Personnel	Increased risks for personnel travelling near creeks during floods. Reduced water quality during drought and low flows.	Reduced travel during floods for personnel travelling near creeks. Treatment of potable water.

[a] *Weather reports will be monitored to mitigate all streamflow-related risks to the project. Regular monitoring of Project infrastructure for hazards and damage.*

The Bowser Aerodrome is proposed to be built on the Bowser River floodplain. The area has substrate and vegetation characteristics consistent with areas that are subjected to flooding. These include rounded, cobble-sized sediments, and sparse vegetation dominated by *Salix* spp. Soil and ecosystem characteristics are detailed in Appendix 16-A, 2012-2013 Terrestrial Ecosystem Baseline Study. Flooding of these Project components could disrupt movement of personnel and equipment to and from the Brucejack Mine Site.

There is the potential for the contact water pond to overflow in a flood. If the pond overflows, its discharge would report directly to Brucejack Lake.

Significant damage to any transport-related infrastructure could delay delivery of supplies and personnel to the Project area. Workers could be stranded at the Brucejack Mine Site, and cross-shift workers could not arrive.

As an underground mine, no direct effects from flooding are expected to the mine. Sustained precipitation could increase shallow groundwater pumping requirements; related effects and mitigation measures are discussed in Section 32.2.1.2.

32.3.2.2 Mitigation Measures

Project infrastructure will be designed to withstand flood events. Specifically, the effects of flooding will be mitigated by:

- monitoring weather forecasts to anticipate and prepare for large rainfall events;
- slowing or stopping work if rainfall runoff is anticipated to cause unsafe working conditions;
- placing Project-related infrastructure above flood-prone areas wherever possible;
- designing contact water pond to contain runoff from the Q_{200} return period rainfall event;
- sizing contact and non-contact diversion and drainage channels to contain runoff from the Q_{200} event;
  - contact water from the upper laydown area (where the waste rock transfer and pre-production ore will be stored) and the mill building/portal site (which requires an extensive cut into bedrock, some of which is currently assumed to be PAG) will be captured by the collection ditch system and conveyed to a surface water collection pond for storage and treatment;
  - contained runoff will be pumped to the water treatment plant for treatment prior to release into Brucejack Lake;
  - contact water from groundwater seepage to the underground mine tunnels will be sent to the water treatment plant for treatment before being used in the process plant or discharged directly to Brucejack Lake during periods when tailings are being disposed of subaqueously;
  - contact water ponds will be sized to contain runoff from the 24-hour, 200-year return period rain-on-snow event (220 mm);
  - the water treatment plant has been designed with a maximum capacity of 9,600 m^3/d. The system will be scaleable such that additional units can be added if required;
  - non-contact water will be captured by the diversion channel(s) and discharged into either Brucejack Lake or Brucejack Creek, depending on the area served by whichever diversion ditch;
- designing roads to be resistant to extreme flooding, specifically:
  - minimum 500-mm diameter culvert pipe (larger for classifiable streams);

- ditches measuring 0.3 by 0.8 m to convey water away from the road surface. Ditches will be constructed along Wildfire Road, Scott Creek Road, and at the Knipple Glacier roll-on ramp ;
- rip-rap to armor river banks where necessary to protect infrastructure (i.e., bridges);
- culverts designed to discharge a Q_{100} storm event without static head at the entrance, and to discharge a 100-year storm event utilizing available head at the entrance (Cypress Forest Consultants Ltd. 2011; Appendix 5-A, Tetra Tech Feasibility Study and Technical Report). It is not anticipated that crossings on the existing exploration access road will require upgrades for mine operations (Rescan 2013d);

- monitoring engineered structures at access road stream crossings for signs of failure after large storm events and after freshet;
- assess flood hazard for construction period of the Bowser Aerodrome ; and
- using alternative methods (e.g., helicopter) to access the Project area during times of road closure and bridge washout for delivery of essential supplies and transport of workers, if required.

32.3.3 Low Flows

Low flows estimates are provided below for the open-water period (June to September; Table 32.3-6), and for the entire year (Table 32.3-7; Appendix 10-A, 2012 Surface Water Hydrology Baseline Report).

Table 32.3-6. Estimated June to September Low Flow Indices for the Watersheds in the Project Area

Watershed	Drainage Area (km^2)	5 Year 7-Day Low Flow (Jun-Sep) (m^3/s)	10 Year 7-Day Low Flow (Jun-Sep) (m^3/s)	20 Year 7-Day Low Flow (Jun-Sep) (m^3/s)
BJL-H1	12	0.21	0.17	0.14
SL-H1	84	1.84	1.53	1.31
SC-H1	299	7.43	6.27	5.48
UR-H1	400	10.25	8.70	7.62
Scott-Hydro	75	1.61	1.33	1.14
Todedada-Hydro	61	1.30	1.07	0.92
Wildfire-Hydro	67	0.88	0.73	0.64

Table 32.3-7. Estimated Annual Low Flow Indices for the Watersheds in the Project Area

Watershed	Drainage Area (km^2)	5 Year 7-Day Low Flow (Annual) (m^3/s)	10 Year 7-Day Low Flow (Annual) (m^3/s)	20 Year 7-Day Low Flow (Annual) (m^3/s)
BJL-H1	12	0.03	0.02	0.02
SL-H1	84	0.23	0.19	0.16
SC-H1	299	0.91	0.77	0.65
UR-H1	400	1.25	1.05	0.90
Scott-Hydro	75	0.20	0.17	0.14
Todedada-Hydro	61	0.17	0.13	0.11
Wildfire-Hydro	67	0.18	0.15	0.13

32.3.3.1 Effects on the Project

Water availability is not expected to be problematic during times of drought. The majority of water for the process plant will be provided by collecting underground mine seepage water. Preliminary water balance results suggest that a small amount (about 0.03%, or 5 m^3/s) may be supplied from Brucejack Lake (BGC Engineering Inc. 2013). However, this source would not be limited in drought years.

Potable water sources could be affected during times of drought if the dilution capacity of the receiving environment is reduced and water quality is affected. However, potable water will be treated at all times to meet drinking water standards.

32.3.3.2 Mitigation Measures

Mitigation measures relating to potential drought-induced water quality concerns include:

- monitoring water quality at the outlet of Brucejack Lake throughout the life of the Project;
- developing a water management plan that accounts for low-runoff years (BGC Engineering Inc. 2013); and
- If ongoing water quality exceedances are recorded at times of low flow, modify discharges and water treatment to Brucejack Lake.

32.4 PERMAFROST

Borehole thermistors were placed in two locations at about 1,610 masl in the nearby KSM Project area, (Rescan 2013b). Results were used to map terrain where permafrost was likely. This mapping also covered the Brucejack Mine Site and Brucejack Lake. No evidence of permafrost was recorded in the boreholes. In addition, it was estimated that permafrost was unlikely at elevations less than 1,600 masl, regardless of snow cover and aspect. At elevations of 2,000 masl, it was estimated that permafrost could be up to 150-m thick. Brucejack Lake is at about 1,360 masl, so permafrost is not expected to affect Project infrastructure.

32.5 GEOPHYSICAL EFFECTS

Geophysical effects are those effects arising from interactions of geohazards with Project infrastructure and personnel. The Project is located in an area that, due to the interactions of terrain, climate, and glacial history, has naturally high occurrences of geohazards. During the life of the Project there is the potential that geohazards could affect Project infrastructure and personnel, and that the Project infrastructure could affect terrain stability.

Geohazards, such as landslide or snow avalanche processes, have the potential to result in some undesirable outcomes, such as damage to infrastructure, endangering or injuring personnel, or damage to environmental values (e.g., soil quality and quantity, fish habitat, and water quality). Geohazards are identified through terrain stability mapping, landslide identification, and snow avalanche track mapping. The term “geohazard” refers to the specific nature of the active process, including type (e.g., shallow seated landslide), frequency, and magnitude, but does not imply consequences or outcomes. Geohazard scenarios are used to describe the potential outcomes of a geohazard event. They assess the interaction between the geohazard and some predetermined component of value, such as specific infrastructure. However, consequences associated with the interaction—such as negative economic, social, or environmental effects—are not part of the scenario description. Geohazard risk is concerned with estimating the likelihood of an event occurring, as well as the consequence in terms of economic, social, or environmental effects.

Geohazards are divided into two types, including those associated with landslides and those associated with snow avalanches. Landslides are defined as the rapid downslope movement of unconsolidated soil and rock by the force of gravity without the aid of a transporting medium such as water, ice, or wind (Trenhaile 2009). Under this definition, landslides therefore encompass numerous types of slumps, falls, slides, and flows. Snow avalanches are the rapid flow of snow down a sloping surface, and are usually triggered by a mechanical failure within the snowpack.

32.5.1 Landslides

32.5.1.1 Effects on the Project

Baseline studies, carried out by BGC Engineering Inc. and presented in Appendices 11-A and 11-B, Brucejack Project Geohazard and Risk Assessment and Brucejack Transmission Line Geohazards Assessment, respectively, determined that geohazards were present within the Project area. Five general facility areas were assessed by BGC Engineering Inc. The western edge of the facility footprint extends to the base of a slope subject to rockfall hazards. No landslide geohazards were identified at the other Brucejack Mine Site facilities. Overall, risks to the Brucejack Mine Site from landslides are classified as low. Not being near a shoreline means that there is no risk of landslide-generated tsunamis.

The Brucejack Access Road was assessed to be at moderate risk from landslides, while risk to personal safety is low. Most of the road alignment traverses stable terrain; however, potential locations for debris avalanches, debris flows, and rockfalls have been identified. Incidental failures along gully sidewalls are evident but not extensive, and are usually confined within gullies above the road network. Failures are unlikely to be imminent, and are unlikely to occur frequently. However, landslides are possible, especially under extreme geomorphic, hydrologic, or climatic conditions (Cypress Forest Consultants Ltd. 2011). Mass movements on the access road could damage trucks and injure personnel. Damage to the road surface could cause temporary road closure, causing a disruption to mine site ingress and egress.

A 55-km transmission line will be constructed from the Brucejack Mine Site to the Long Lake Hydro Project near Stewart. This route was recently selected, and a detailed hazard assessment of the pole locations along the route has not yet taken place. However, a preliminary assessment showed areas that are affected by avulsion, rockfall, and debris avalanche (Appendix 5-E, Geohazard and Risk Assessment). The primary risk to the transmission line from mass movements is damage to the towers, which could sever the transmission lines and cause power outages at the Brucejack Mine Site. Tower placement will be guided by a detailed hazard assessment.

32.5.1.2 Mitigation Measures

Mitigation will be used to reduce the risk associated with identified geohazard scenarios to an acceptable level. These strategies will reduce the risk in the following ways:

- reduce the probability of the geohazard occurring;
- reduce the geohazard magnitude (e.g., volume and peak discharge);
- reduce the geohazard intensity (e.g., run-out distance, velocity, and impact forces);
- reduce the spatial probability of impact (likelihood that the geohazard will reach or impact the element at risk);
- reduce the temporal probability of impact (likelihood of workers being present in the zone subject to the hazard); and

- reduce the vulnerability (the degree of loss to a given element at risk within the area affected by the snow avalanche or landslide hazard).

Specifically, the road alignment was chosen to minimize risks from geohazards wherever possible (Cypress Forest Consultants Ltd. 2011). Mass movements are sometimes triggered during rain storms, and weather forecasts are monitored for upcoming precipitation events. Access vehicles carry radios to communicate any road hazards. Road travel will be limited at times of high risk. Slopes at high risk of failure may be reinforced and monitored.

Risk from geohazards will be considered when selecting the placement of transmission towers. Towers in critical locations will be metal, and their bases will be reinforced as required to provide protection. Power outages at the Brucejack Mine Site will be mitigated with diesel generators that will be used as a back-up power source. During power outages, non-essential machinery may be shut down until power is re-established.

32.5.2 Snow Avalanches

Avalanches are classified as either “point release” (when a small amount of snow sets more snow in motion) or “slab avalanches” (when a plate or slab of cohesive snow begins to slide as a unit before breaking up; Jamieson 2011). Both types of avalanches frequently occur in the Project area. Avalanches pose the highest relative risk of any geohazard in the Project area, primarily due to their high frequency of occurrence (Appendix 5-E, Geohazard and Risk Assessment). Avalanche season for the Project area normally begins in October at the higher elevations (above 1,400 masl), and often extends until late June or early July. At valley bottom elevations, avalanches can be expected from November to late May, although they can occur earlier or end later in extreme years (Appendix 5-F, Preliminary Avalanche Hazard Management Plan for Mine Construction and Operations).

Common avalanche locations have been mapped (Appendix 5-E, Geohazard and Risk Assessment). An avalanche hazard assessment has been completed for the Project. Facilities and access routes are exposed to approximately 15 avalanche paths or areas. Avalanche magnitude varies between size two and four. A size two avalanche could bury, injure or kill a person (typical mass = 100 tonnes, run = 100 metres, force = 10 kilopascals). A size four avalanche could destroy a railway car, large truck, several buildings, or up to four hectares of forest (typical mass = 10,000 tonnes, run = 2,000 m, force = 500 kilopascals; Jamieson 2011). Avalanche frequency varies between annual and 1:100 years (Appendix 5-A, Tetra Tech Feasibility Study and Technical Report).

32.5.2.1 Effects on the Project

Baseline studies, carried out by BGC Engineering Inc. and presented in Appendices 11-A and 11-B, Brucejack Project Geohazard and Risk Assessment and Brucejack Transmission Line Geohazards Assessment, respectively, determined that snow avalanches pose a risk to Project facilities and personnel.

In the absence of proper mitigation measures, avalanches could pose a significant hazard to personnel, including injury or death, and could damage Project infrastructure. Much of the site infrastructure and alignments for the Brucejack Access Road and Brucejack Transmission Line may be subject to risks from avalanches. On the Brucejack Access Road, there are several areas (both on the road and on the glacier) that are subject to frequent avalanches capable of severely damaging vehicles, injuring occupants, and delaying the flow of traffic, especially during storms when helicopter-based avalanche control is not feasible. Avalanche danger is particularly high on the northwest side of Mount Anderson, around the 30 km mark on the Brucejack Access Road route (Cypress Forest Consultants Ltd. 2011).

At the Brucejack Mine Site, there are several known avalanche paths that affect the pre-production ore storage and waste rock transfer areas, diversion channels, and site access roads. Paths are particularly common on the slopes immediately adjacent to the south shore of Brucejack Lake (Appendix 5-A, Tetra Tech Feasibility Study and Technical Report). Overall, unmitigated avalanche danger is rated as moderate for facilities, and is a high safety risk. Specific areas with known runout zones have been flagged and mapped in the Geohazard and Risk Assessment (BGC Engineering Inc. 2013). Return frequencies for avalanches and their expected sizes are also assessed in the same document.

Brucejack Transmission Line tower locations have not yet been assessed in detail for avalanche risk. However, the proposed Brucejack Transmission Line route crosses many avalanche paths. Potential effects include damage to towers or conductors, and interruption of power service to the mine. Final design will incorporate a detailed assessment of avalanche risk.

32.5.2.2 Mitigation Measures

Hazards to personnel will be mitigated by preparing and following an Avalanche Management Plan during avalanche season (Appendix 5-F, Avalanche Hazard Assessment). A preliminary plan is in place that will be developed further as additional information on the specifics of construction and operation of the mine become available. The plan seeks to minimize risks, while minimizing disruptions to operations. Detailed mitigation measures are provided in the existing Avalanche Safety Plan; key components include:

- providing appropriate training to personnel (e.g., worker safety sessions);
- providing appropriate equipment to personnel (e.g., transceivers, shovels, probes, harnesses, and rope rescue equipment);
- monitoring local avalanche conditions. Using alternate routes where possible (e.g., the length of road on the south side of Brucejack Lake between the Knipple Glacier and the Brucejack Mine Site often has high avalanche risks. However, an alternate snow route over the Valley of the Kings is available in winter. This bypass road traverses around to the south of the property, eventually meeting up at km 71 of the Brucejack Access Road. This road also provides access to the upper elevations of the site for avalanche control measures). Restricting access to high-risk areas where necessary;
- communicating to personnel avalanche conditions and unsafe areas;
- ensuring trained personnel are on site and make decisions and can relay information to workers;
- controlling avalanches using explosives; and
- ensuring that Brucejack Transmission Line towers are not placed in avalanche runout zones. Critical towers will be constructed of metal, not wood. Where required, towers will be reinforced and bases at high risk will be equipped with" splitting wedges" or earthworks to minimize the force of avalanche impacts on towers. Snow berms will be constructed annually in high risk areas, and snow walls can be constructed for longer-term protection.

32.5.3 Glaciers

The Project area is highly influenced by glaciers. The Brucejack Access Road includes an approximately 10 km segment over the Knipple Glacier, with the roll-on point above the glacier terminus and the roll-off point in the mid-accumulation zone of the main flow of the glacier. In winter, the glacier surface will be snow covered; in summer, travel will be on glacier ice. Glacial influence also extends to streamflow and surficial cover. Large watersheds in the vicinity of the Project are highly glacierized (Table 32.3-1), and outwash and till cover much of the Project area.

The overall regional trend for glaciers in the vicinity of the Project over the last several centuries is retreat at termini, and surface lowering. This trend is due to changes in air temperature and precipitation following the 600-year-long Little Ice Age, which ended in the mid-nineteenth century; however, in recent decades the rate of ice loss has accelerated (Section 32.7). No evidence of glacial surges has been directly recorded, and no indirect evidence from crevasses and moraines has been observed.

The terminus of the Knipple Glacier recently receded 300 m in 11 years. A total of 30 to 50 m of ablation has occurred between 1999 and 2011 (Cypress Forest Consultants Ltd. 2011). Retreat rates on Knipple Glacier are similar to rates recorded on the Mitchell and McTagg glaciers in the nearby KSM Project area (Rescan 2012).

32.5.3.1 Effects on the Project

Travel on glaciers is potentially hazardous for personnel and vehicles. Glacier dynamics have the potential to change the viability of the road, and/or require extensive ongoing maintenance of road structures. Crevasses and mill holes pose a risk to small vehicles or personnel on foot. The structural integrity of crossings can be compromised by typical glacier movement. Snow avalanches are also a risk on the glacier section of the Brucejack Access Road (Section 32.5.2).

The roll-on point for the Knipple Glacier portion of the Brucejack Access Road is a critical location in terms of glacial effects on the Project. The terminus has lowered during the exploration phase of the Project, requiring the relocation of the roll-on point to km 58.6 of the Brucejack Access Road. This repositioning allowed the route to bypass an area at high risk from avalanches and rockfalls.

Annual lowering in excess of eight metres per year can be expected at the lower road elevations (Appendix 10-B, Assessment of Potential Interactions between Brucejack Gold Mine Project and Channel Morphology). Surface ablation will likely have more of an effect on the roll-on site than retreat of the terminus, given current rates of surface lowering and retreat, and given that the terminus is currently about 2 km from the roll-on point.

Glacial meltwater affects the water balance of Brucejack Lake by affecting the quantity of water that enters and exits the lake. When there is water input to the lake, water spills out the outlet if lake level exceeds the outlet level. When there is little to no water input, the lake level elevation is soon controlled by the outlet of the lake (and small amounts of evaporation from the lake surface). So long as waste rock is deposited below this elevation, no glacial meltwater effects on water quality at the lake outlet are expected.

32.5.3.2 Mitigation Measures

Mitigation measures are in place to reduce glacier-related hazards. A Transportation and Access Management Plan (Section 29.16) has been developed for travel on the glacier section of the Brucejack Access Road, and include:

- monitoring the glacier (e.g., for surface lowering, for development of crevasses, for alteration of crossings, for avalanche and snow conditions);
- monitoring traffic along the glacier access road; and
- ensuring the road and road travel are safe (e.g., by marking, by travelling in convoys, by reconfiguring the road as necessary, by ensuring safety protocols are in place and being used, and by providing appropriate safety equipment).

32.5.4 Seismic Activity

The Pacific coast is the most earthquake-prone region of Canada due to the presence of offshore active faults, particularly dominated by the north-westward motion of the Pacific Plate relative to the North American Plate. Seismic activity in the region is associated with the known active faults in the region: the Queen Charlotte Fault to the west and Eastern Denali, Fairweather, and Transition faults to the northwest. However, earthquake frequency and size decrease when moving inland from the coast, and away from the active plate boundaries. Seismic activity is relatively low in the immediate area of the Project.

The closest seismograph station to the Project area is at Dease Lake, about 230 km north-northeast of Brucejack Lake. Significant Canadian earthquakes from 1600 to 2006 have been mapped (Lamontagne et al. 2008). The closest "damaging and significant" historical earthquakes occurred on Haida Gwaii, about 380 km southwest of the Project. These events had magnitudes up to 8.1 on the Richter scale (M). From 1985 to 2013, the largest earthquake within 400 km of the Project area was a 7.7 M event near Haida Gwaii that occurred in October 2012. The only earthquake within 200 km of the Project area was a 4.2 M event (a "light" earthquake, slightly felt, but during which none to minimal damage occurs), which occurred about 65 km west of the Project on April 29, 2013 (NRCan 2013).

An analysis of seismic hazards in the Project area was performed using the 2010 National Building Code of Canada seismic hazard calculator (NRCan 2013). Peak Ground Acceleration (PGA) is a measure of how hard the earth shakes, and is measured in units of acceleration due to gravity (g). PGA was calculated for the Project area for three return periods, assuming firm ground (Table 32.5-1; return period formulae are presented in Section 32.3.2). The United States Geological Survey developed a table of intensity descriptions for PGA (USGS 2013). A PGA of 0.025 g would be perceived as light, and would not cause structural damage. A PGA of 0.080 would be perceived as a moderate quake, with "very light" potential structural damage.

Table 32.5-1. Exceedance Probability, Risk, and Peak Ground Acceleration for Seismic Events at Brucejack Lake

Annual Exceedance Probability	Risk of Occurrence over 22-year Mine Life (R)	1 in X Year Event	PGA (g)
0.01	0.198	100	0.025
0.0021	0.043	500	0.059
0.001	0.022	1000	0.080

32.5.4.1 Effects on the Project

All Project components could be affected by a seismic event. The highest risk areas are the mine portals and ventilation shafts due to the risk of cave-ins trapping workers. Seismic activity could result in slope failures of waste rock within Brucejack Lake which would lead to elevated TSS within the lake and lake discharge (BGC Engineering Inc. 2014). The fuel storage area is at risk from spills and pipelines are at risk of rupture. Earthquakes could trigger mass movements such as landslides and snow avalanches, which could damage Project infrastructure, particularly roads and transmission lines. Soft sediments—particularly clays—have the potential for liquefaction in seismic events, which could damage any infrastructure built on top of them.

32.5.4.2 Mitigation Measures

A mine rescue emergency response plan will be developed. The plan will ensure that there are always trained first response personnel on site when there are workers employed underground. The number and type of first responders depends on the number of workers employed underground. There will also be on-site personnel trained in first aid, firefighting, rescue techniques, and hazardous material handling and clean up. Appropriate emergency equipment will be on site. For more details, please refer to the Emergency Response Plan (Section 29.6).

Site infrastructure will be located in areas that avoid or minimize exposure to weak, unconsolidated soils or soils that are assessed to be potentially liquefiable, where practical. Where infrastructure is to be built on weak, compressible, or potentially liquefiable foundation soils, deep foundation support or foundation treatment (soil replacement, preloading, dynamic compaction, vibro-compaction, vibro-replacement, or deep soil mixing) will be incorporated into the design.

At the waste rock dumping area, procedures will be developed to minimize slope instabilities associated with the advancing front of the waste rock pile (Section 32.5.1.2, Mitigation Measures).

All structures will be thoroughly assessed for stability and integrity after seismic events.

32.5.5 Volcanic Activity

No volcanic eruptions have occurred in BC in recent history (Public Safety Canada 2013; Smithsonian Institution 2013). However, several volcanoes near the Project area are listed as active, but “sleeping” (Emergency Management BC 2013). The Project area is within the southern portion of the Stikine Volcanic Belt (also called the Northern Cordilleran Volcanic Province), which extends from just north of Prince Rupert into the Yukon. Within 100 km of the Project site, this belt includes Lava Fork and Hoodoo Mountain to the northwest. Mount Edziza is about 200 km to the north of the Project area, while Tseax Cone is about 200 km to the south.

The Tseax Cone erupted as recently as 1775. The eruption was responsible for the destruction of a Nisg̲a’a village and the death of some 2,000 people, most likely due to asphyxiation by carbon dioxide.

A group of small basaltic cones called the Iskut-Unuk River Cones exist near the Project area, to the west. One of the cones, Lava Fork (“The Volcano”), erupted relatively recently: radiocarbon dating of wood found within basalt yielded a date of 150 years Before Present (BP [1950]; Wood and Kienle 1990).

Hoodoo Mountain last erupted approximately 9,000 years ago, while Mount Edziza has erupted on numerous occasions within the last 10,000 years, with the most recent activity about 1,400 years ago, when two large lava fields and several smaller cinder cones formed.

Although volcanoes do not erupt frequently in the region, they do present a number of hazards. In addition, the timing, size, and composition of the eruption are difficult to predict. Hazards associated with eruptions include lava flows, ballistic projectiles, widespread ash, pyroclastic flows (avalanches of hot ash, hot gas, and volcanic rock), pyroclastic surges (similar to flows but less dense and can travel much faster), landslides and debris avalanches, and lahars (slurry of water and rock particles).

32.5.5.1 Effects on the Project

Lava flow from an eruption could start wildfires (Section 32.6) and dam local rivers. The gas and ash released has the potential to be a human health hazard, and airborne ash could disrupt air traffic to and from mining camps.

If Hoodoo Mountain erupted, it could cause large-scale, rapid melting of the 3.2 km^3 ice cap and possibly the two glaciers on either side of the mountain, with subsequent flooding of the Iskut drainage (Russell et al. 1998). To generate catastrophic flooding, the eruption would need to be sufficiently large to melt most of the ice cap in a period of days. The Project area and infrastructure are on the east side of a drainage divide, whereas Hoodoo Mountain is on the west side, so no effects from flooding would be anticipated.

The pumice deposit near Mount Edziza highlights one of the important volcanic hazards associated with the Mount Edziza volcanic complex: the possibility of a large, explosive volcanic eruption (Souther 1992). An explosive eruption could produce an ash cloud that would affect large parts of northwestern Canada.

Future eruptions from Lava Fork pose little threat, as the style of eruption is expected to involve passive fluid lava flows.

32.5.5.2 Mitigation Measures

Volcanic eruptions are often preceded by a series of small earthquakes (Emergency Management BC 2013). The National Public Alerting System (Canada) and Integrated Public Alert and Warning System (USA) will be monitored for regional seismic activity.

Should a volcanic eruption occur in the region, assigned site personnel will maintain contact with authorities to determine the likely hazards for the Project area. All site personnel will be informed of the eruption, and a risk assessment will determine whether normal operations should be adjusted.

In the event of an ash cloud, individual worker exposure will be limited, and face masks or other respiratory devices will be used. Ongoing air monitoring will test for gases emitted, to protect human health against inhalation of volcanic gas such as increased carbon dioxide concentrations.

Diversion channels will be monitored and cleaned to ensure there is no blockage from ash and debris fallout from an eruption. Road maintenance crews will be available to clear debris from the access road.

32.6 WILDFIRES

Wildfires are common landscape disturbances throughout forested and grassland ecosystems in BC. On average, 2,000 wildfires occur in BC every year; approximately 40% are caused by human activity, and 50% by lightning ignition (BC MFLNRO 2012). Probability of wildfire occurrence is dependent on fire behaviour, ignition potential, and suppression capability.

Fires are one of the most significant natural disturbances in BC, and the characterization of fire history aids in predicting fire frequency and severity. Natural disturbance frequencies and types have been identified for ecosystems across BC, and five classes have been created and assigned to Biogeoclimatic Ecosystem Classification (BEC) zones. These Natural Disturbance Types (NDT) summarize the dominant disturbances for each BEC zone and provide an indication of the disturbance type, extent, and frequency (BC MOF 1995). In the Project area, three types are present: NDT 1 (ecosystems with rare stand-initiating events), NDT 5 (alpine tundra and subalpine parkland ecosystems), and NDT 3 (ecosystems with frequent stand-initiating events; Rescan 2011c). NDT 1 and 5 are the predominant disturbance types in the RSA. NDT 1 has a mean wildfire return interval between 250 years for the Coastal Western Hemlock and Interior Cedar-Hemlock, and 350 years for the Engelmann Spruce-Subalpine Fir and Mountain Hemlock biogeoclimatic zones. NDT 5 has no indicated fire return interval due to the infrequency of fire in these ecosystems. NDT 3 is also present in the RSA but is relatively uncommon. Fire return interval for NDT 3 is 150 years and fires are often landscape-level in extent.

To provide a more regionally specific assessment of fire history, the use of fire ignition records is pertinent. The BC Government Wildfire Management Branch maintains a spatial database of fires back to 1951 (WMB 2013). The database indicates fire location, date, and cause (human or lightning), and is useful in determining wildfire probability for an area. Only 11% of fires since 1950 were human caused; the remainder were started by lightning (Table 32.6-1). Since 1951, there have been 61 fires in the Project area. During the 1970s to 1990s, 15 to 21 fires occurred each decade (Table 32.6-1). In the 2000s, only one fire start was recorded, and one has occurred since 2010. Over the last 63 years, there was an average of one fire per year in the Project area. While the Project footprint area has experienced no fires within the last 10 years (BC MFLNRO 2012), a 2,000 ha fire occurred 1 km north of the proposed Bowser Aerodrome in 1989, and would have resulted in evacuation of the facility.

Table 32.6-1. Fire Occurrences for Each Decade by Cause in the Project Area

	Number of Fires by Cause		
Decade	**Lightning**	**Human**	**Total**
1950	1	0	1
1960	7	0	7
1970	13	2	15
1980	12	3	15
1990	20	1	21
2000	0	1	1
2010	1	0	1
Total	**54**	**7**	**61**

Based on the wildfire record over the previous 63 years and the NDTs that dominate the Project area, ignition potential and wildfire probability are low. This is most likely due to a combination of factors: the area receives a high amount of annual precipitation, snow often remains well into the growing season, large areas and depressions are generally moist from meltwater, and the continuity of forested fuel types is broken by sparsely vegetated areas with low associated fire behaviour. However, as indicated by the 1989 fire near the proposed Bowser Aerodrome, forest fires do occur in the region and mitigation measures should be considered to reduce wildfire risk and ensure human safety.

32.6.1 Effects on the Project

Human safety is a prime consideration for project planning. During a wildfire event, egress along the Brucejack Access Road could be restricted—or impossible—due to smoke or fire. Helicopter use may also be limited due to smoke, and personnel may be required to evacuate. Fire at the Brucejack Mine Site is unlikely due to its location above the treeline; however, the mine site may be affected by smoke. Operating time could be lost if workers are required to help contain a fire and if working conditions become unhealthy or unsafe as a result of fire or smoke.

The damage or loss of bridges along the Brucejack Access Road in the event of a fire would hinder road access or egress to or from the Brucejack Mine Site. Depending on the size of the crossing and the severity of the fire, a damaged/burnt bridge deck would result in road closures of half a day to two weeks. Wood box culverts used at small stream crossings would require inspection after a fire and may need to be replaced. There are nine open-bottom wood box culverts on the Brucejack Access Road; the remaining 237 culverts are constructed of corrugated metal pipe.

Consideration of the effect of fire on the Brucejack Transmission Line is warranted. Aside from repair and replacement post-fire, the main concern is potential contact with the Brucejack Transmission Line by adjacent falling trees. Contact between trees and the lines can ignite a wildfire that could spread and threaten adjacent values at risk. Fuels created during clearing of the Brucejack Transmission Line right-of-way are also a consideration from a safety and liability perspective.

Hazard tree assessments may also be required along the Brucejack Transmission Line, access roads, and adjacent to structures after a fire. Fire damage to trees can result in loss of structural integrity or accelerated decay processes that can cause premature tree failure. Removal of these trees would be required to ensure worker safety.

A fire would also have secondary effects related to the loss of surface vegetation cover in the local catchment area. Increased amounts of runoff with elevated levels of total suspended solids would report to the diversion channels, requiring increased maintenance. Additionally, slope stability may be compromised by vegetation loss and could lead to more frequent landslides or avalanches.

32.6.2 Mitigation Measures

To reduce the chance of infrastructure loss and/or damage due to wildfires, the following mitigation will be incorporated:

- fire fighter training for designated permanent employees (Provincial S-100 Basic Fire Suppression and Safety training) and ensuring sufficient trained personnel are on site during the fire season to action a fire;
- ensuring employees have access to appropriate personal protective gear to action a wildfire;
- developing an evacuation plan in case of wildfire, in particular one that considers loss of the egress route along the Brucejack Access Road;
- erecting fire danger signs in visible locations that are updated throughout the fire season to ensure personnel are aware of current fire hazard conditions;
- locating water pumps and fire-fighting equipment strategically around the Project to help contain/extinguish any fire;
- equipping a vehicle with firefighting tools (shovels, pulaskis, and axes), water, and portable pumps to supply initial attack to accessible fires;
- incorporating vegetation management;
- creating 30-m zones around all structures where vegetation is maintained in a low hazard state;
- conducting hazard assessments to ensure risk of fire to structures is acceptable;
- using mining equipment such as dozers in the case of a fire to remove vegetation around the infrastructure, thus removing fuel for the fire;
- bridges designed to be fire resistant, major bridge designs incorporate steel sub-structures, leaving only the wooden decks vulnerable to fire;
- constructing transmission towers: all towers will be metal, which will decrease the potential for loss of power to the mine and reduce post-fire repair and replacement efforts;
- incorporating regular inspections for hazard trees as part of a Vegetation Management Plan for the Brucejack Transmission Line. Conducting regular inspections and vegetation maintenance is important in reducing liability for fire starts and the related costs associated with suppression efforts, timber loss, and damage to other values;
- maintaining vegetation and especially fuels related to clearing of the transmission line right-of-way in a state that supports only low fire behaviour;
- backup generators provided for use in the event of power loss. The generators will have enough power capacity to operate essential equipment;
- properly storing flammable materials in areas where heat and flame is prohibited, and providing proper signage for these areas;

- training personnel in fire response and containment, including:
  - use of fire extinguishers for small fires in buildings;
  - raising an alarm and seeking assistance;
- monitoring British Columbia Ministry of Forests, Lands and Natural Resource Operations fire alerts; and
- complying with all relevant legislation in the BC *Wildfire Act* (2004).

Please refer to Section 29.6, Emergency Response Plan, for complete firefighting emergency response measures.

32.7 CLIMATE CHANGE

32.7.1 Recent Climate Change: Community Observations

Members of the Skii km Lax Ha have made several observations and concerns regarding climate change and environmental responses to climate change (Appendix 25-B, Skii km Lax Ha Traditional Knowledge and Traditional Use Report). For example, warmer air temperatures have been noted over the last 20 years, leading to increased conditions where rivers are unsafe to cross or no longer freeze. More extreme flood events on the rivers have been noted, but lake levels appear to be declining. Less snowfall and increased rainfall have been noted in the region. Increases in stream water temperature have been attributed to increases in parasites in fish. Changes in fish colour, taste, and texture have been noted.

32.7.2 Past Climate Change: Proxy Records and the Meteorological Record

Climatic proxy records such as lake sediments, ice cores, and tree rings are used to reconstruct climate before instrumental records exist. At the last glacial maximum, from 25 to 14 thousand years (ka) BP, ice sheets covered the entirety of northern North America (Bradley 1999). BC was largely covered by the Cordilleran Ice Sheet until deglaciation began around 14 ka BP. Deglaciation ended around 10 ka BP, and temperatures largely cooled until the end of the Little Ice Age (Walker and Sydneysmith 2007). Air temperatures have warmed since the end of the Little Ice Age, which initiated continuing widespread glacial retreat at lower elevations in the province. Prior to the industrial period, climate change was primarily controlled by orbital cycles, solar activity, ocean circulation, and volcanism.

Beginning in the early to mid-twentieth century, instrumental meteorological data sets were of sufficient number and quality to produce province-wide climatic records. From 1900 to 2004, air temperature increased by 0.08 to 0.1^{o}C per decade (Walker and Sydneysmith 2007).

32.7.3 Climate Change Projections for the Project Area

Anticipated climate change in the Project area is summarized in this section. Climate change is also discussed in Chapter 12, Assessment of Potential Climate Effects.

Global climate is unequivocally warming, and will continue to warm in the future (APEGBC 2010; AMS 2012; BCWWA 2013a; IPCC 2013). Heavy precipitation events have become more intense and frequent, and will continue to do so, although confidence in the sign and amount of change is lower than confidence for change in air temperature (AMS 2012). Uncertainty increases when considering local effects and the effects of climate change on the environment, such as vegetation, glaciers, streamflow, and wildfires.

Several cyclical climatic patterns influence the climate of the Project area, including the PDO and ENSO (Section 32.2.1.2). The effects of global warming on these patterns are poorly understood.

However, in a review of global climate model (GCM) results from the Intergovernmental Panel on Climate Change's *Fourth Assessment Report: Climate Change 2007* (IPCC 2007), it was found that the negative phase of the PDO increased in frequency, especially after 2050. ENSO is expected to experience an "El Niño-like" mean state change, but no change in amplitude (Lapp et al. 2012).

Climate change for the Project area was assessed quantitatively using the computer program ClimateWNA (Wang et al. 2006; Wang et al. 2012). The effects of climate change on the environment were assessed qualitatively. ClimateWNA aggregates and downscales GCM outputs for various greenhouse gas (GHG) emissions scenarios and time periods. Downscaling is performed for specific locations based on latitude, longitude, and elevation. For this analysis, data were obtained for the location and elevation of Brucejack Lake.

To address uncertainty in future climate, it is recommended that a range of predictions be considered (BCWWA 2013b). In this analysis, GCM output using the A2, A1b, and B1 GHG scenarios were used, to present a range of possible climatic conditions based on assumptions of future population, economics, and technology. The A2 scenario assumes exponentially increasing atmospheric CO_2 levels continuing to the end of the twenty-first century, reaching 800 parts per million (ppm) by 2100. In the A1b scenario, concentrations stabilize at 720 ppm by the end of the century. The B1 scenario assumes that GHG emissions will plateau between 400 and 500 ppm by mid-century. In 2013, the average $C0_2$ concentration at Mauna Loa was 396.5 ppm. Details of the assumptions in Intergovernmental Panel on Climate Change emission scenarios are available in Nakićenović et al. (2000).

GCM data were extracted for the decades of the 2020s, 2050s, and 2080s. All GCM data available from ClimateWNA for the A2, A1b, and B1 scenarios were extracted (6 to 7 GCMs per scenario). Results for each scenario and decade are presented as averages, and high and low extremes (Figure 32.7-1). Historical climate conditions are represented by presenting two "Climatic normals": 1961 to 1990 and 1981 to 2010.

Monthly average air temperature and precipitation were also extracted and plotted for the A2 scenario and climatic normals (Figure 32.7-2; data shown are averages from all available GCMs). Changes are generally less for the A1b and B1 scenarios (Figure 32.7-2).

32.7.3.1 Air Temperature

Northern BC is expected to warm more than southern BC as a result of climate change (PCIC 2011). ClimateWNA estimates that the average annual air temperature at Brucejack Lake was -2.2°C from 1961 to 1990, and -0.6°C from 1981 to 2010 (Figure 32.7-2, graph "A").

Both the A2 and A1b scenarios predict similar magnitudes of warming for all time periods (about 1°C by 2050, and 3°C by 2080 relative to 2020). Between-GCM variability is large (up to about 2.9°C), but all models predict warming. The least warming is predicted for the B1 scenario, where GHG concentrations stop increasing by mid-century. Climatic normal maximum monthly air temperatures ranged between 13 to 14°C in the past depending on the normal period (Figure 32.7-2, graph "B"). By 2080, GCM predictions indicated maximum monthly air temperatures of about 16 to 17°C.

Monthly air temperatures are expected to increase the most in winter, and increase the least in summer (Figure 32.7-2, graph "A").

32.7.3.2 Precipitation

Precipitation is expected to increase more in the northern part of the province than the southern part of province, especially in winter, spring, and fall (PCIC 2011).

Figure 32.7-1

Global Climate Model Predictions for Brucejack Lake: Annual Averages, Maxima, and Inter-GCM Variability

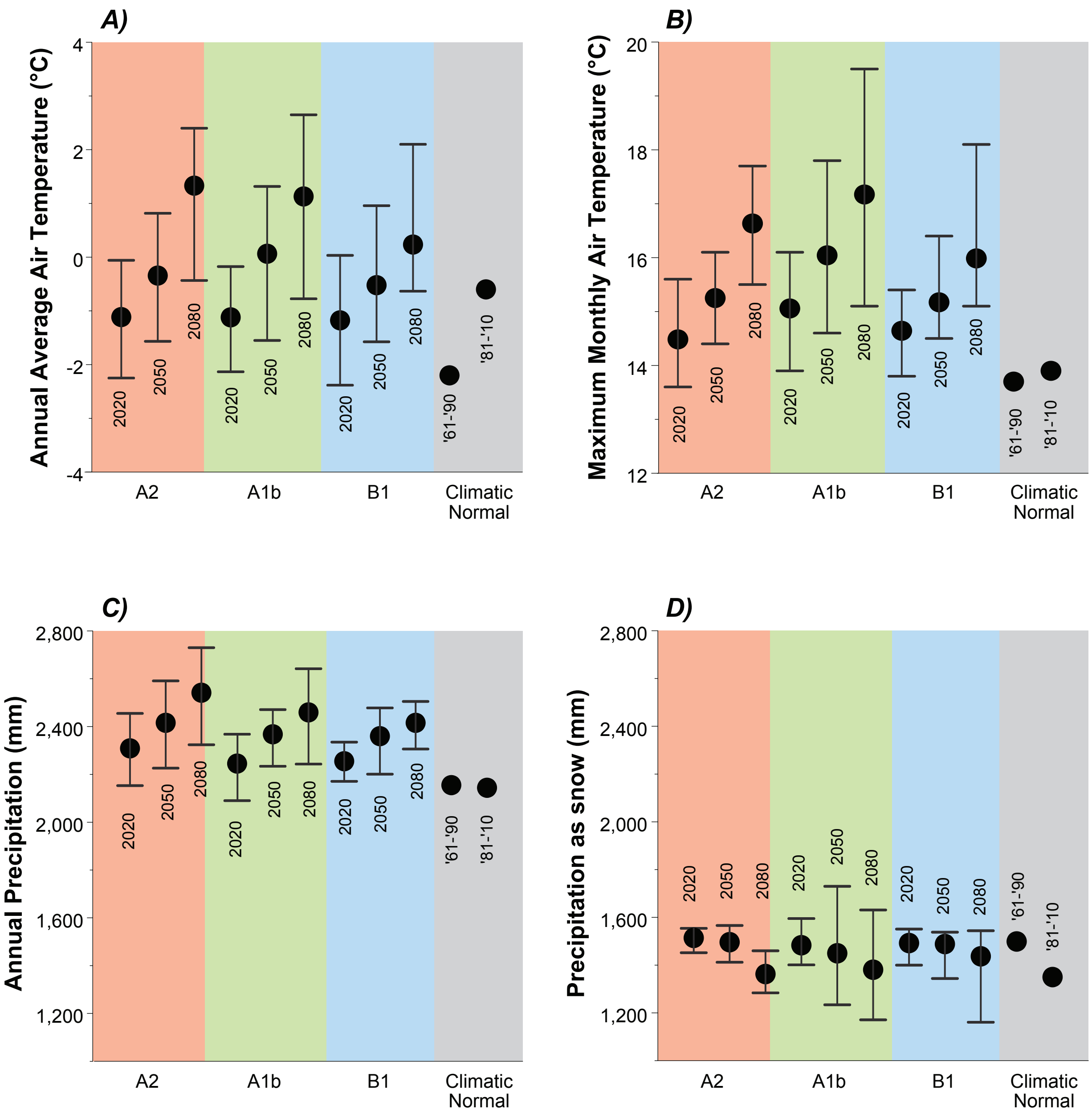
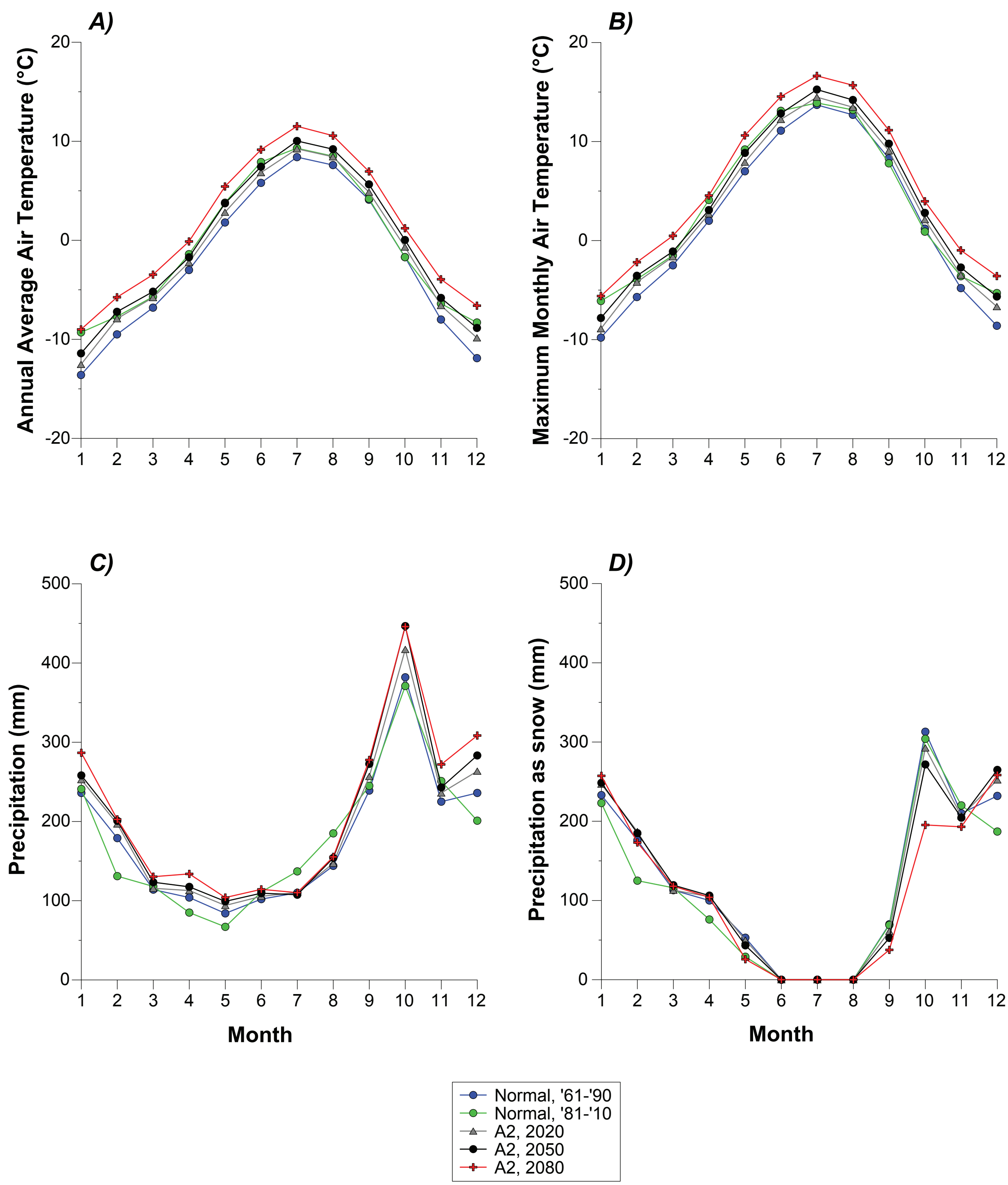


Figure 32.7-2

Global Climate Model Predictions for Brucejack Lake: Monthly Averages for the A2 GCM Scenario and Climatic Normals



Climatic normal annual total precipitation for Brucejack Lake is very similar for both past normal periods (2,155 mm for 1961 to 1990, and 2,165 mm for 1981 to 2010; Figure 32.7-1, graph “C”). An increase in precipitation is predicted for 2020, 2050, and 2080 relative to modern climatic normals (Figure 32.7-1, graph “C”). The greatest increases are expected for the A2 scenario in 2080.

Monthly precipitation totals are expected to increase the most in winter, and increase the least in summer (Figure 32.7-2, graph “B”).

The fraction of precipitation falling as snow is expected to decline in all emissions scenarios and for all time periods (Figure 32.7-1, graph “D”). Decreases in snowpack are greatest for the A2 and A1b scenarios (100 to 150 mm), and relatively small for the B1 scenario (about 20 mm) on average. Since annual total precipitation increases, and the fraction falling as snow decreases, rain events will increase. Also, less water would be stored as snow over winter.

32.7.3.3 Streamflow

An increase in annual average air temperatures will alter streamflow patterns (Walker and Sydneysmith 2007). The freshet date will shift earlier in the season, and flow will extend for longer in winter. Annual runoff could both increase and decrease, depending on elevation, vegetation, physiography, and the magnitude of climate change. An increase in runoff would occur if runoff from snowfall, rainfall, or glacial melt increases, and if these increases are greater than increases in evapotranspiration. A decrease in runoff would occur if evapotranspiration increases exceed increases in precipitation, or if glacial melt declines. Glacial melt could decline if glaciers recede sufficiently.

Increased streamflow in winter would improve winter water quality at the Brucejack Lake outlet from dilution. Reduced snowfall in winter could lead to a smaller freshet. In the melt period, less glacial coverage by snow would reduce the insulating effect of snow, reduce the albedo of glacial ice, and increase absorption of latent and sensible heat into ice, all of which would increase glacial melt.

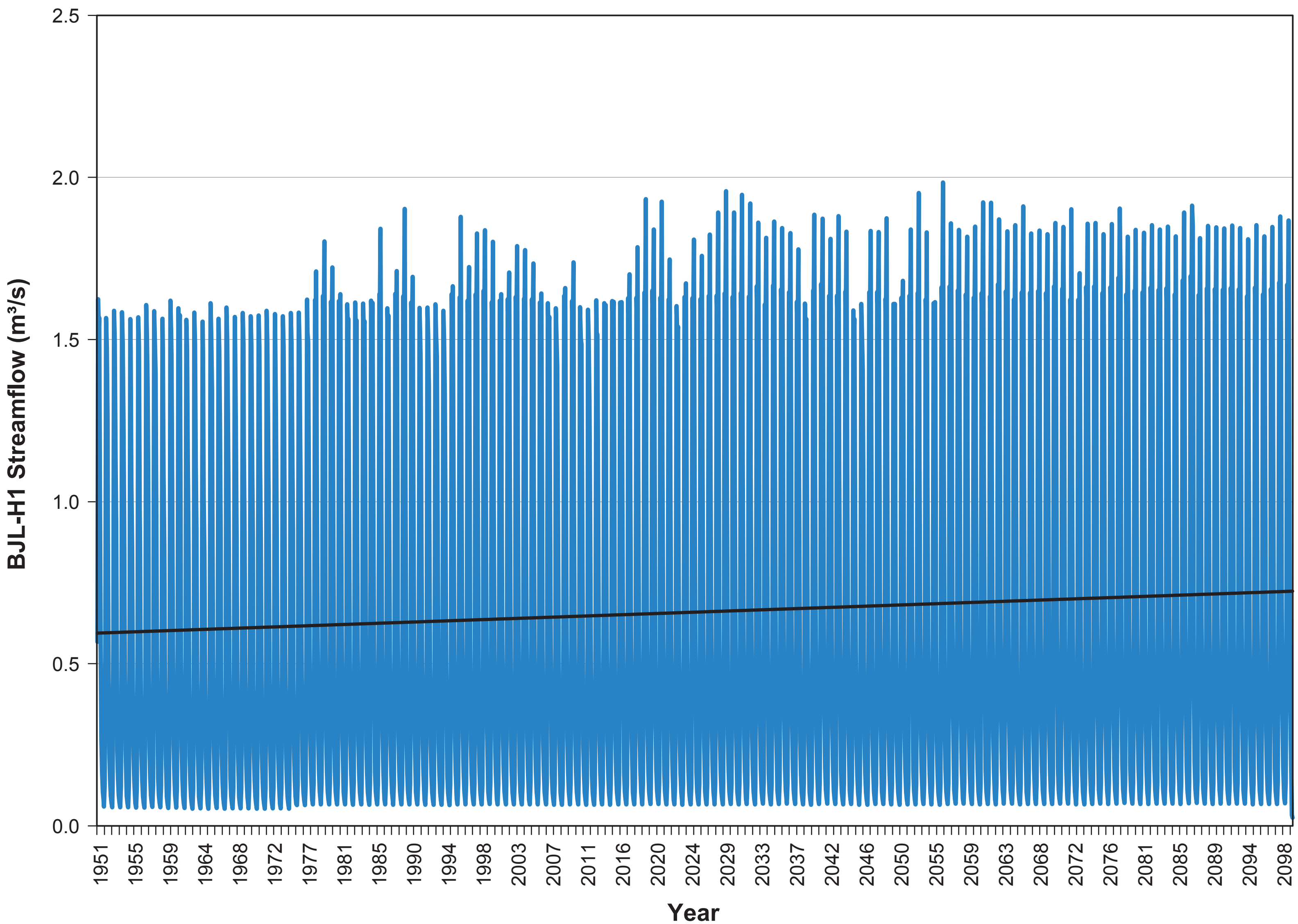
Hydrologic modelling is a technique to disentangle these hydroclimatic and watershed processes. GCM data for future climate change scenarios are fed into a calibrated and validated hydrologic model, which predicts changes to discharge. The direction and magnitude of hydrologic changes in modelled BC catchments are varied due to differing characteristics of the catchments. Coastal snowmelt-fed rivers will likely see increased winter discharge (PCIC 2011; Schnorbus, Werner, and Bennett 2012). Some glacierized watersheds are predicted to have decreased streamflow from climate change (Stahl et al. 2008). Hydrologic modelling in the nearby KSM Project area predicted increasing discharge in rivers, until at least 2080 (Rescan 2013a).

Climate change scenarios developed for Brucejack Lake outflow, under natural conditions, suggest that streamflow will continue to increase until 2100, which was the extent of modelling. Two commonly employed GCM were used to bookend projections for hydrometric monitoring station BJL-H1. These GCM included the A2 and B1 emission scenarios. The A2 emission scenario produces the highest climate forcing by the end of the century; whereas the B1 emission scenario produces the lowest climate forcing by the end of the century. To produce as average climate change forcing results for BJL-H1, results from A2 and B1 GCM scenarios were averaged together.

The resulting average precipitation for the (1990-2009) A2B1 climate forcing scenario was 1900 mm. Average streamflow at BJL-H1 is predicted to increase by 12% throughout the life cycle of the project (Figure 32.7-3). Average streamflow at BJL-H1 is expected to increase from 0.65 m^3/s (1990 to 2009) to 0.73 m^3/s (2080 to 2099) under current climate change emission scenarios. It should be noted that this is an overly simplistic analysis which did not take into account increases in temperature or wind, each of which can contribute to increased evaporative losses and therefore alteration of streamflow rates.

Figure 32.7-3

Global Climate Model Predictions for Brucejack Lake: Annual Average Streamflow at BJL-H1 for the A2B1 GCM Scenario



Source: BGC Engineering Inc., April 23, 2014.

Although results from the above climate change scenarios have not been explicitly incorporated into engineering design of diversion channels, drainage ditches and the collection pond, it is reasonable to suggest that a Q_{200} design flow is sufficient to accommodate a 12% increase in streamflow from 2080 to 2099. Further, it has been noted that until at least 2050, the emissions scenario used has no impact on hydrologic projections in BC watersheds (PCIC 2011). Differences will likely be manifested after 2050.

32.7.3.4 Extreme Events

Although not resolvable in the annual and monthly data analyzed here, extreme events are also likely to increase in frequency and magnitude in the future (Walker and Sydneysmith 2007). Climatic extremes are most likely to be manifested as periods of extreme heat, precipitation, and flooding in the Project area. Storms may increase in frequency and duration due to increases in instability in oceanic and atmospheric circulation arising from stronger temperature differentials projected with climate change. Storm tracks may also change depending on oceanic circulation. Generally effects identified in the air temperature, precipitation, and streamflow sections would be expected to increase in frequency and magnitude over the long-term (Sections 32.2, 32.3).

32.7.3.5 Glacial Recession and Thinning

The Brucejack Lake watershed is currently 29.5% glacierized. Glacial recession will likely only slightly reduce this amount in the Project lifespan, given the high elevation of the mine site, and the relatively short Project lifespan. In addition, the glaciers in the Brucejack Lake watershed are part of an icefield, and do not consist of outlet glaciers that would be more prone to rapid recession.

Glacial recession is expected to impact the connectivity between Brucejack Lake and East Lake. East Lake is located about 500 m to the east of Brucejack Lake. In spring, glacial conduits typically open on the east side of East Lake, and the lake drains rapidly to the east, under the Knipple Glacier. In the past, the East Lake level has occasionally risen sufficiently to overtop a sill on the west side of the lake, draining into Brucejack Lake. When this overtopping occurs, it provides a new source of inflow to Brucejack Lake, increasing discharge, runoff, peak flow, and low flows. The overtopping of the sill and drainage into Brucejack Lake is currently rare. It likely occurred more frequently in the past, when Knipple Glacier was more extensive. It will likely occur less frequently in the future, as glacial recession continues (Appendix 10-A, 2012 Surface Water Hydrology Baseline Report).

32.7.3.6 Mass Movements, Wind Velocity, and Wildfires

The projected increases in precipitation and runoff in the Project area may lead to secondary effects of increased risks of geohazards, and increased wind velocity (Walker and Sydneysmith 2007). If droughts increase in frequency or severity, then wildfires would be expected to also increase. However, the magnitudes of the effects due to climate change are uncertain.

32.7.4 Project-related Adaptation and Mitigation Measures

Climate change impacts are unique in that they cannot be predicted by extrapolating from historical measurements and return periods (BCWWA 2012). Climate change impacts are also unique due to the sustained nature of change, and an increase in the frequency and magnitude of extreme events.

Components of the environment and Project affected by climate change are listed below. Each component is discussed and categorized in terms of the severity of their anticipated impacts. Categories are "null", negligible, moderate, and high (Table 32.7-1). Each is defined relative to the likelihood of change in interaction, risk of effects to Project.

Table 32.7-1. Potential Project Component Sensitivities Arising from Climate Change

Parameters Potentially Affected by Climate Change	Roads			Power	Brucejack Mine Site					Waste			Camp	
	Brucejack Access Road, Mine Site Area Roads	Crossing Structures	Knipple Glacier Road	Brucejack Transmission Line	Water-related (ponds, pipelines, diversion channels, treatment plant)	Mine Infrastructure (ore conveyor, crushers, mills, power station, etc.)	Ventilation Shafts	Bowser Aerodrome	Knipple Transfer Station	Tailings Disposal	Waste Rock Disposal	Incinerator	Mechanical Shop, Warehouse, Personnel Housing	Personnel
Air temperature														
Increase from mean modern	○	○	○	○	○	○	○	○	○	○	○	○	○	● (G)
Freeze-thaw cycles	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	○	○	● (G)	● (G)	○
Extreme heat	○	○	○	○	○	○	○	○	○	○	○	○	○	● (G)
Precipitation														
Increase from mean modern	● (Y)	● (Y)	● (Y)	● (G)	● (Y)	● (G)	● (Y)	● (G)	● (G)	○	○	○	● (G)	● (G)
Extreme rain and snow	● (Y)	● (Y)	● (Y)	● (G)	● (Y)	● (G)	● (Y)	● (Y)	● (G)	○	○	○	● (G)	● (G)
Streamflow														
Change from mean modern	● (G)	● (G)	● (G)	● (G)	● (Y)	● (G)	○	● (Y)	● (G)	○	● (G)	○	○	● (G)
Flooding	● (Y)	● (Y)	● (Y)	● (G)	● (Y)	● (G)	○	● (G)	● (G)	○	○	○	○	● (G)
Drought	○	○	● (G)	● (G)	● (G)	● (G)	○	○	○	○	● (G)	○	○	● (G)
Other														
Glacial recession and thinning	● (G)	● (Y)	● (Y)	○	● (G)	● (G)	○	○	○	○	○	○	○	● (G)
Mass movements	● (Y)	● (Y)	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	● (Y)	● (G)	● (G)	● (G)	● (G)	● (G)
Wind velocity	○	○	○	● (G)	○	● (G)	○	○	○	○	○	○	● (G)	● (G)
Wildfires	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	● (G)	○	○	● (G)	● (G)	● (G)

Notes
○ = *No interaction anticipated.*
● (green) = *Negligible to minor sensitivity.*
● (yellow) = *Moderate sensitivity.*
● (red) = *High sensitivity.*
Sensitivity ranking refers to the likelihood of change in interaction, risk of effects to Project, and consequent effects to the environment
Sensitivity reported here is the additional sensitivity from climate change.
Parameters are considered individually (an increase in heat is considered only for its direct effect, not indirect effects on glacial discharge, wildfires, etc.)
Sensitivities take into account the likelihood of change (e.g., climate-change-induced droughts are less likely than floods)

32.7.4.1 Air Temperature

Project components are designed to withstand a wide range of air temperatures, including the temperature ranges projected by GCMs for various GHG scenarios (Figures 32.7-1 and 32.7-2). Increasing the number of freeze-free days would be beneficial to the Project in some respects, such as reducing heating costs and reducing exposure of personnel to extreme cold. Climate change is predicted to induce milder winters in this region, which would likely produce more freeze-thaw cycles. Milder winters could result in accelerated glacial melting with potential effects on maintenance of the glacier road and its on-ramp. This increase would accelerate road deterioration and increase maintenance costs. More frequent freeze-thaw cycling also has the potential to compromise the strength of other site infrastructure, including power transmission lines; building foundations; and mine portals.

Changes to air temperature and freeze-thaw cycles are expected to have low impact on personnel (Table 32.7-1).

32.7.4.2 Precipitation

Project components are either designed to handle snow, or have management plans in place for handling snow and rain. Although total snow accumulation is projected to decrease over the life of the Project, it is possible that extreme snowfall events will increase in frequency and magnitude. Engineering systems in place could handle increases in snowfall from current ranges.

During mine operation, higher annual precipitation may increase the amount of groundwater seepage, which would increase dewatering costs (moderate sensitivity). Work may slow if access to and from the Project area on roads is limited by snow or overland flow, and snow will need to be cleared from crossing structures (moderate sensitivity). Snow will need to be cleared from ventilation shafts (moderate sensitivity). The water supply for the Project is resistant to periods of drought given its groundwater and lake water sources, the wet climate of the area, and the projected increases in precipitation. Increases in the frequency and magnitude of extreme snow and rain may occasionally limit travel on access roads. All other Project components are ranked as having negligible to low sensitivities to increased precipitation due to climate change.

32.7.4.3 Streamflow and Flooding

Floods can damage river crossings, including bridges and culverts (moderate sensitivity). Latent heat can be absorbed into glacial ice from rain, causing melting and melt features on glaciers (moderate sensitivity). Streams convey water to pipelines and ponds, and drainage ditches that have been designed to withstand floods with long return periods (moderate sensitivity). The proposed aerodrome is located on the Bowser River floodplain, and is at moderate risk of increased sensitivity due to climate change. All other Project components are ranked as having negligible to low sensitivities to increased precipitation due to climate change.

32.7.4.4 Glacial Recession and Thinning

The glacier road roll-on is about 2 km from the current glacier terminus, which is currently retreating. Unless the rate of retreat significantly increases, the terminus is unlikely to reach the roll-on point during the Project lifespan. However, ablation could lower the glacier surface at the roll-on point, and impede access to the glacier road. The roll-on point will be moved to new locations if lowering begins to limit access to the glacier (moderate sensitivity).

Supraglacial drainage and thinning could cause an increase in hazards such as moulins, crevasses, and supraglacial streams (moderate sensitivity).

Several mitigation measures are in place to reduce glacier-related hazards. A Transportation and Access Management Plan has been developed for travel on the glacier road. Please refer to Section 32.5.3 for a summary of glacier travel.

Alteration to the Brucejack Lake water balance would affect lake level by changing glacial melt volumes, precipitation, or evaporation. As discussed in Section 32.5.3.1, this has implications for exposure of waste rock in the lake. However, if water inputs to the lake are reduced, lake level would be maintained at the lake outlet elevation.

32.7.4.5 Mass Movements, Wind Velocity, and Wildfires

Mass movements have the potential to affect Project infrastructure. Landslides, rock falls, and debris flows/floods could affect the Brucejack Access Road for days to weeks, before repairs could be made. Changes in wind may affect power lines. Wildfires could negatively affect surface structures at the Knipple Transfer Station or Bowser Aerodrome and visibility in the Project area. In areas where the risk from mass movements is high, the tailings pipeline will be trenched and backfilled (Appendix 5-E, Geohazard and Risk Assessment). Monitoring and mitigation plans designed for modern conditions are expected to be sufficient to address any increased hazards under a changed climate. All sensitivities are ranked as "null" or negligible.

32.7.5 Climate Change Regulatory Context and Adaptation

32.7.5.1 Regulatory Context of Climate Change

The BC government is currently drafting policy regarding climate change adaptation and how to mainstream adaptation considerations into other regulatory and guidance documents (BC MOE 2010). There is currently no specific legislation applicable to adapting Project components to climate change risk. Infrastructure design for water structures in BC is currently regulated for a wide variety of meteorological risk factors (i.e., temperature extremes, storms, floods), but these provisions are based on analyses of past climate and so do not currently explicitly address climate change projections that may differ from past ranges (APEGBC 2012).

With regards to the effect of the environment on the Project in relation to climate change, the Federal-Provincial-Territorial Committee on Climate Change and Environmental Assessment recommends that: "Potential risks to the project, providing they do not affect the public, public resources, the environment, other businesses or individuals, may be borne by the project proponent and are not generally a concern for jurisdictions (CEA Agency 2003)."

Climate change in the Project area will not increase risks to the public, public resources, the environment, other businesses, or individuals. However, this chapter has discussed the potential effects of climate change on the Project and mitigation measures to allow Pretivm to make this assessment for themselves.

32.7.5.2 Climate Change Adaptation

Climate change adaptation is the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2007). It is distinct from climate change mitigation, which is the reduction in the magnitude and rate of climate change itself (West Coast Environmental Law 2012). Planning for adaptation is difficult, given unknowns in the timing and magnitude of climate change, and the environmental effects of this change.

An adaptive management approach to climate change will be taken for the Project. Adaptive management involves using learning to continuously improve policies and practices. Adaptive management is useful because it allows for flexible responses to change whose timing and magnitude are not known. Adaptive management has six components: assess the problem, design a solution, implement the solution, monitor the results, evaluation, and adjustment (BC MFLNRO 2013).

Project components identified as having moderate sensitivities to impacts from climate change (Table 32.7-1) will be continuously monitored and maintained throughout the Project lifespan. This is particularly important for the glacier road, both for surface conditions and for surface lowering (Section 32.5.3). Also, at the aerodrome, any flood damage to the airstrip will be repaired, and mitigation measures will be employed as needed (Section 32.3.2).

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