4. Project Design and Alternatives Assessment

4.1 INTRODUCTION

This chapter describes the processes and criteria that Pretium Resources Inc. (Pretivm) and its consultants have used to select preferred options, and alternative means, of developing the Brucejack Gold Mine Project (the Project). The Brucejack Mine Site is located within the Regional District of Kitimat-Stikine, approximately 950 kilometres (km) northwest of Vancouver, 65 km north-northwest of Stewart, and 40 km upstream from the British Columbia (BC) and Alaska border (Figures 4.1-1 and 4.1-2). Alternatives are the functionally different design specifications or component locations feasible for use by the Project. The assessment of alternatives demonstrates the key decisions that Pretivm has made to undertake technically and economically feasible mining activities that, in aggregate, minimize adverse effects and maximize beneficial environmental, cultural, and socio-economic effects.

This alternatives assessment for the Project meets the requirements of the *Canadian Environmental Assessment Act*, *2012* (2012), the *Operational Policy Statement Addressing "Purpose of" and "Alternative Means" under the Canadian Environmental Assessment Act*, *2012* (CEA Agency 2013b); and the BC *Environmental Assessment Act* (2003). In addition, this alternatives assessment satisfies the information requirements as outlined in the Canadian Environmental Assessment Agency (CEA Agency) Environmental Impact Statement (EIS) Guidelines for the Brucejack Gold Mine Project (CEA Agency 2013a) and the BC Environmental Assessment Office (BC EAO) Application Information Requirements (AIR; BC EAO 2014).

Throughout the design process, Pretivm has made numerous decisions on how to develop the Project. Some Project decisions have been based on best management practices (BMPs), or involved only one feasible option, rather than deciding between potentially feasible alternatives. This chapter presents the latter kind of decisions based on assessing economic, technical, environmental, and social criteria for the following Project components:

- ore production technologies (e.g., underground extraction and ore-processing methods);
- mine waste disposal including rock, and tailings disposal, and control of sediment in the lake;
- treatment of contaminated water; and
- transportation route and mode for concentrate, materials, and personnel.

4.2 METHODS

This alternatives assessment was conducted using a decision-making framework to systematically evaluate alternatives to determine the best means of undertaking components of the Project. This approach is similar to that used in the alternatives assessments for the KSM (Rescan 2013a), Mt. Milligan (AMEC 2008), and Victor Diamond (AMEC 2004) projects.

Figure 4.1-1
Overall Layout of the Brucejack Project

ERM

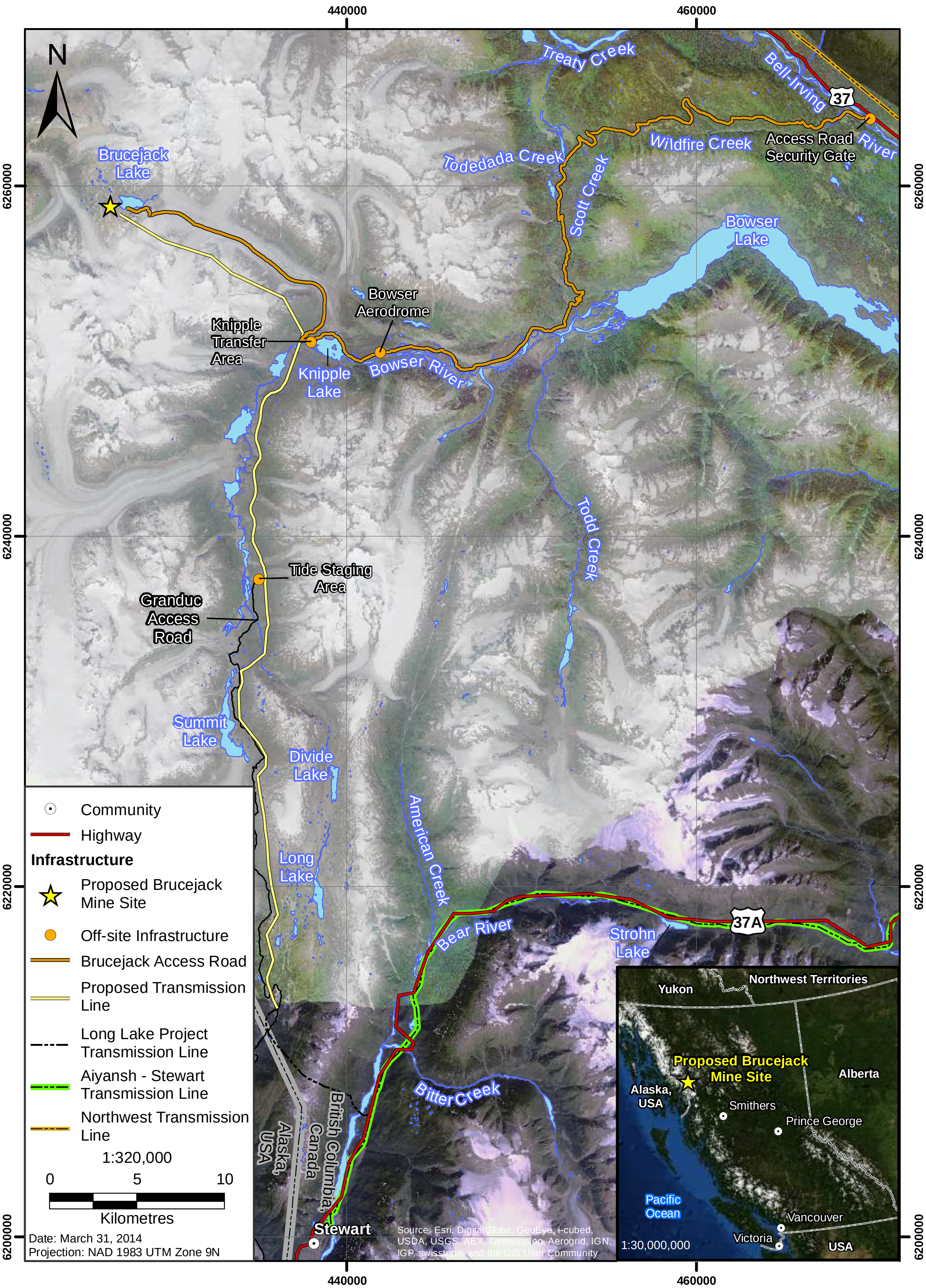
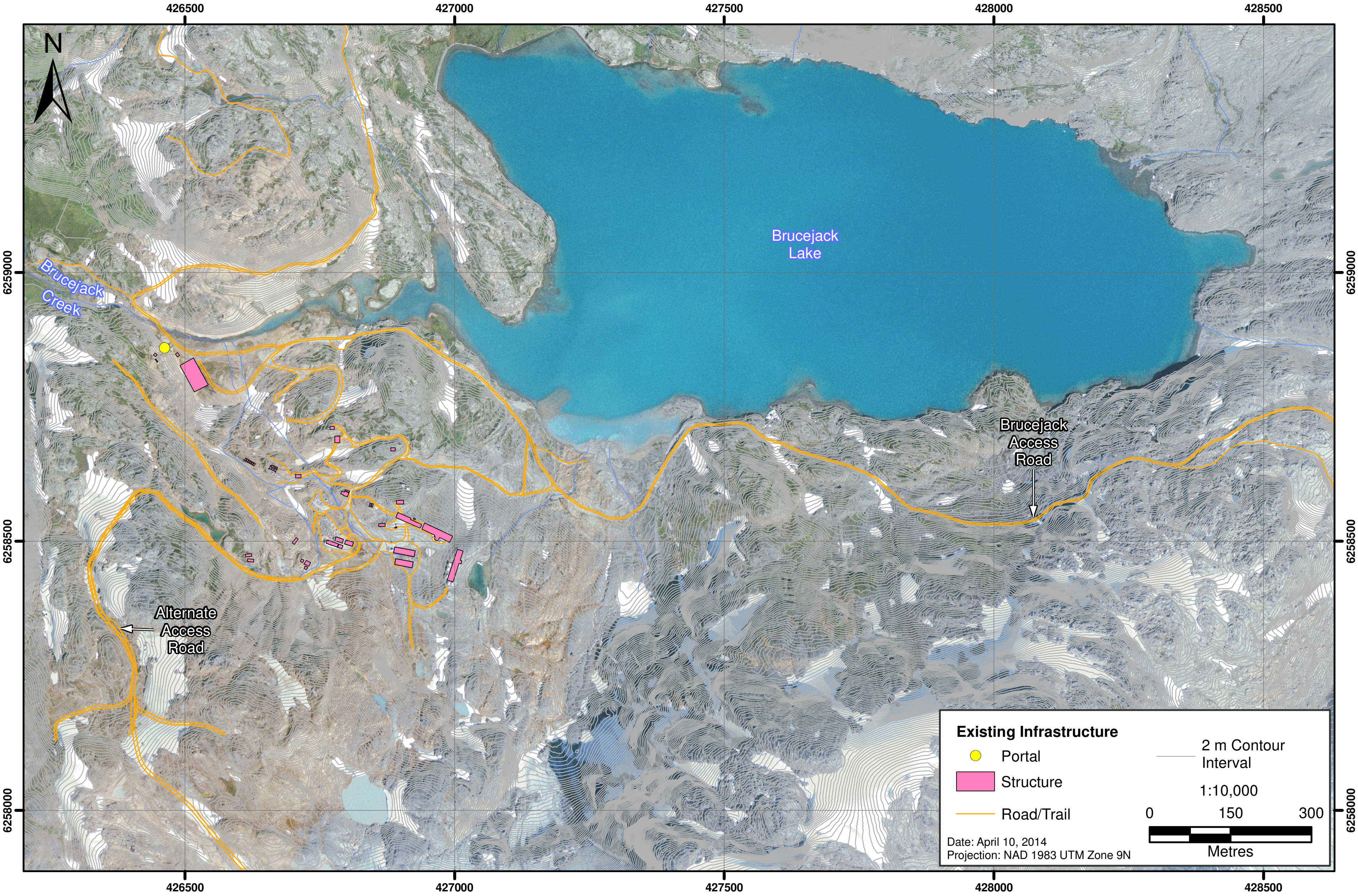


Figure 4.1-2
Mine Area - Current General Arrangement



The alternatives assessment method is also based on best practice decision-making theory as outlined in the *Guidebook to Decision-making Methods* commissioned by the US Department of Energy for decisions on nuclear management (Baker et al. 2001; Fülöp 2005), and others.[1]

4.2.1 Screening Potential Options

Alternative means are the various technically and economically feasible options of carrying out a project. For each of the relevant Project components listed in Section 4.1, a preliminary assessment involving a screening of a long list of potential options has been conducted to scope out those options found to be unfeasible based on basic technical and economic evaluation criteria (a summary of the screening step is provided in Section 4.3). This screening is concordant with Step 1 of the alternative means assessment methodology laid out in the recent CEA Agency Operational Policy Statement (CEA Agency 2013b). Options that do not meet these preliminary criteria have been eliminated from further analysis, while those found to be feasible have been screened in as alternative means to be assessed in more detail (Section 4.2.2). Where screening has narrowed down options to only one feasible selection, this option is the one selected for use by the Project.

4.2.2 Detailed Assessment of Alternative Means of Carrying Out the Project

4.2.2.1 Performance Objectives

The criteria used to conduct the detailed evaluation of the alternative means identified in the screening step (Section 4.2.1) were based on the assessment of appropriate attributes against the four performance objectives listed in Table 4.2-1.

Table 4.2-1. Brucejack Gold Mine Project Alternatives Assessment Performance Objectives

Category	Performance Objective
Environmental	To meet regulations for and minimize adverse effects (and/or maximize positive effects) on intermediate or receptor Valued Components (VCs) in terrestrial, atmospheric, and aquatic systems affected by the Project.
Social	To meet regulations for and minimize adverse effects (and/or maximize positive effects) on social receptor VCs (e.g., cultural, Aboriginal, economic, heritage, archaeological, health, and aesthetic components) as well as on personnel (e.g., Occupational Health and Safety [OH&S]).
Technical	To meet Project design criteria as well as industry and/or regulatory standards and best practices.
Economic	To be supported by Project economics, minimize costs, and/or allow for a positive return on investment.

Performance objectives are based on requirements (e.g., government regulations) to determine feasibility, as well as goals (e.g., environmental best practices and industry standards), to set preference levels against which to compare the attributes of each alternative. The method used to assess alternative means of undertaking the Project against environmental and social performance objectives is equivalent to that outlined in Step 2 of the recent CEA Agency Operational Policy Statement (CEA Agency 2013b). This method involved first identifying the primary intermediate or receptor Valued Components (VCs) potentially affected by each alternatives means, and then comparing differences in potential effects on those components; the method also assesses technical

[1] Rossi, Tickner, and Geiser (2006); GRI (2011); and Lavoie et al. (2010). Alternatives Assessment Framework of the Lowell Center for Sustainable Production ; Global Reporting Initiative's Sustainability Reporting Guidelines; and US EPA Design for the Environment Program's Chemical Alternatives Assessment: Enabling Substitution to Safer Chemicals .

and economic performance objectives in more detail, as well as potentially finding that an alternative means may not be feasible based on more in-depth evaluation.

4.2.2.2 Attribute Ranking System

The attribute ranking system used to assess alternative means against the above four performance objectives set for the Project is equivalent to the methods described to identify a preferred means in Steps 2 and 3 of the recent CEA Agency Operational Policy Statement (CEA Agency 2013b). Attributes are the main, most relevant characteristics that differ between each alternative that can be meaningfully compared and contrasted by how well they perform against the performance objectives. For instance, three site locations for a project facility may have differential effects on a given wildlife species VC; the site that best minimizes those effects would be the preferred alternative under the environmental performance objective. However, if two different project technologies have similar levels of dust creation that could affect health VCs linked to air quality, then this attribute would not provide a meaningful comparison between the alternative technologies, and therefore would not be used in the assessment.

For each Project component screened into the detailed assessment (Section 4.3), the attributes for the alternative means of developing the Project were evaluated against the four performance objectives (summarized in Section 4.4). Each alternatives assessment is summarized in an evaluation table that demonstrates how attributes and alternatives have been ranked against the four performance objectives. Attributes are characterized as being **preferred**, **acceptable**, **challenging**, or **unfeasible** — depending on how well they meet the requirements and goals for each performance objective — using the rationale and colour scheme provided in Table 4.2-2.

Table 4.2-2. Project Alternatives Attribute Rating System

Attribute Ranking against Environmental and Social Performance Objectives		
☑	Preferred	Attribute has the least adverse effects on differentially affected intermediate components or receptor VCs *without mitigation* when compared to other alternatives' attributes; may also provide positive benefits.
☑ or ☒	Acceptable	Attribute minimizes adverse effects on differentially affected intermediate components or receptor VCs *with mitigation*.
☒	Challenging	Attribute has significant adverse effects on differentially affected intermediate components or receptor VCs, and there are technical, financial, or other *barriers to mitigation*.
☒	Unfeasible	Attribute has unacceptable adverse effects on differentially affected intermediate components or receptor VCs that *could not be* reasonably *mitigated*.
Attribute Ranking against Technical Performance Objective		
☑	Preferred	Attribute is the most likely to be effective to implement, with the lowest risk, and contingencies (mitigation) in place to address risks.
☑ or ☒	Acceptable	Attribute is likely to be effective to implement, with contingencies to address risks.
☒	Challenging	Attribute's effectiveness faces significant barriers to implement, or to reduce risk to acceptable levels, even with contingencies.
☒	Unfeasible	Attribute's effectiveness faces unacceptable risk, even with contingencies, or is unfeasible to implement.
Attribute Ranking against Project Economic Performance Objective		
☑	Preferred	Attribute has the lowest costs or gives the best return on investment.
☑ or ☒	Acceptable	Attribute has reasonable costs or gives an acceptable return on investment.
☒	Challenging	Attribute has high costs leading to budgetary issues.
☒	Unfeasible	Attribute is not economically viable under Project budgets.

✓ in the box indicates a relative advantage; ✗ in the box indicates a relative disadvantage. Source: Adapted from Rescan (2013a), Baker et al. (2001), and AMEC (2004, 2008).

As summarized in the alternatives assessment evaluation tables, after the attributes were rated each alternative was then evaluated as a whole, receiving an overall rating of preferred, acceptable, challenging, or unfeasible depending on how its attribute ratings compared against other alternatives. Where attributes have been determined to be acceptable for different alternatives, preference between them is set based on relative advantage or disadvantage.

While preliminary information was used to determine feasibility during the screening step, as more information was sourced on the alternative means, they could still be found to be unfeasible. If any attribute for an alternative was found to be unfeasible, this rating served as a fatal flaw, and the alternative as a whole was rated as unfeasible and eliminated from further consideration. For an alternative to be rated as preferred overall, it contained at least one preferred attribute along with, at worst, acceptable ratings for all of its other attributes (i.e., alternatives with any attributes rated as challenging/unfeasible did not receive preferred rank). When preference between alternatives did not clearly emerge from the assessment, priorities based on the Project requirements and goals, as well as professional judgment, have been used to determine the preferred alternative and the rationale provided in the accompanying text in Section 4.4.

4.3 SCREENING

As discussed in Section 4.2.1, potentially feasible alternative means to develop the Project were identified by first screening out preliminary options' basic technical and economic feasibility criteria in concordance with the CEA Agency relevant Operational Policy Statement (CEA Agency 2013b). Basic technical feasibility criteria used in the screening included:

- technology for the option must be proven at the industrial scale;
- technology must meet required industrial and government standards;
- option must be suitable for the Project climate and terrain;
- option must meet health and safety requirements; and
- option must not exceed acceptable risk levels (i.e., such as from geohazards).

There was one screening stage economic feasibility criterion; that the option must be economically viable based on cost estimates (i.e., of capital or operating expenditures).

Where screening led to only one technically and economically feasible option being identified, this option was selected for use by the Project. A summary of the screening assessment is provided in Table 4.3-1. Any technical or economic fatal flaws that were found for the above-listed feasibility criteria are described in the "Rationale" columns of the table, and brief descriptions of the screening assessments are provided in the following sections where the screening step led to the selection of an option for use by the Project.

Where screening led to more than one option being used by the Project based on basic criteria, these technically and economically feasible options were brought forward into the detailed alternative means assessment for further analysis, described in Section 4.4.

Where screening led to more than one option being for use by the Project based on basic criteria, these technically and economically feasible options were brought forward into the detailed alternative means assessment for further analysis, described in Section 4.4.

Table 4.3-1. Brucejack Gold Mine Project Alternative Means Screening Table Based on Basic Technical and Economic Feasibility Criteria

Major Component of Project	Sub-component	Option	Technically Feasible? (Y/N)	Technical Rationale	Economically Feasible? (Y/N)	Economic Rationale	Screening Result
Project Access and Transport	Ground Access from Highway 37 to Knipple Transfer Area	Use existing exploration access road from the east with some minor upgrades	Y	Use of existing exploration access road, including required upgrades, during Project life is technically feasible.	Y	Few upgrades needed, so economically feasible.	Select
		New road along Bowser River Valley connecting to Granduc Access Road to the south	N	Unfeasible due to steep surrounding terrain and extensive geohazards, such as avalanches along the Bowser River Valley, posing unacceptable risk. This route would also significantly increase travel distance to rail head, and create new disturbance.	N	Would not be economically supported to build a road through the surrounding terrain as would require extensive geohazard and avalanche mitigation, as well as increased concentrate transport cost to rail head.	Discard
		Combination of road access and barge across Bowser Lake	N	Used previously for transport of personnel and some materials and equipment to the vicinity of the proposed Knipple Transfer Area; however, due to the inability to utilize the barge during winter (frozen lake) or poor weather, does not meet criteria for reliable continuous and long-term access to the transfer area, therefore unfeasible.	Y	Economically feasible for limited use as demonstrated in the past. There would be additional costs associated with extra handling (loading and offloading the barge) and management of shipping delays caused by ice or poor weather.	Discard
	Ground Access into the Brucejack Mine Site from Knipple Transfer Area	Existing exploration route (includes ~12 km of travel over Knipple Glacier)	Y	Feasible using specially equipped vehicles over glacier; viability is demonstrated as this route is currently in use for exploration and will accommodate Project scheduling and load requirements.	Y	This route is economically supported because it only requires minor upgrades to existing road.	Select
		A road involving tunnels to avoid glacier travel	N	Mine site is surrounded by glaciers and steep, mountainous terrain with many geohazards; not feasible to build a safe road route in the area without substantial engineered structures such as lengthy tunnels that would also pose more risk to build and operate.	N	Would not be economically supported to build a route through the surrounding terrain as would require significant modification to achieve slope stability and other required road safety features.	Discard
	Personnel Transport Method to Knipple Transfer Area	Fixed-wing air from major centres	Y	Feasible as the proposed Bowser Aerodrome would allow year-round air access, and air travel would reduce transport times for staff compared to land travel, however, in inclement weather conditions, air travel would not be feasible, so a ground access method would also be needed.	Y	Economically feasible.	Assess Further
		Land via private vehicle from Highway 37	Y	Technically feasible.	Y	Economically feasible.	Assess Further
		Land via bus from Highway 37	Y	Technically feasible, as demonstrated through current practice.	Y	Economically feasible.	Assess Further
Power for the Project	Primary Power Supply	Transmission line: east option	Y	Technically feasible.	N	Unfeasible economically.	Discard
		Transmission line: south option	Y	Technically feasible.	Y	Economically feasible.	Select
		Transmission line: Bear River to American Creek, then split to the mine to the west and Highway 37 process plant to the east (for final processing to doré)	N	Technically feasible, but would require significant additional right-of-way. This route was considered to support on-site final flotation concentrate processing, but the decision to complete final processing off-site means this option would no longer be suitable for use, rendering it unfeasible (see Section 4.4.4).	Y	Feasible, but economically no longer supported if flotation concentrate is processed off-site.	Discard
		On-site diesel generation	N	Unfeasible, as logistically unacceptable due to volume of diesel fuel requiring transport to mine site to generate sufficient electricity to power Project, and increases risks.	N	Unfeasible as fuel and transport costs would not be supported by Project economics.	Discard
		On-site hydro	N	Unfeasible, as insufficient capacity to power Project, largely due to seasonal limitations.	N	Unfeasible as hydro power would add significant additional costs, without meeting power requirements.	Discard
		Wind	N	Unfeasible, as insufficient capacity to power Project as not consistent or predicable source of power.	N	Unfeasible as wind energy would add significant additional costs, without meeting power requirements.	Discard
		Onsite solar	N	Unfeasible, as insufficient capacity to power Project.	N	Unfeasible, solar power would not consistently meet power requirements.	Discard
Ore Production and Processing	Mining Method	Open pit	N	Unfeasible, as method is more suitable to near surface ore bodies, not for type and orientation of Valley of the Kings and West Zone orebodies; would also generate much larger volumes of waste rock that would be onerous to manage compared to underground mining.	N	Unfeasible economically, primarily due to very large capital expenditure required and resulting poor rate of return.	Discard
		Underground method 1: block caving / sublevel caving	N	Unfeasible, as this is an unselective method applicable to large bodies of homogenous low-grade ore, so is an inappropriate mining method for geometry and geotechnical conditions of the Project orebodies.	Y	Unfeasible, due to high initial capital costs, and dilution of ore grades, and increased tonnages to be milled/tailings to be disposed, leading to increased costs and delays, as well as unsupported costs to mitigate technical risk.	Discard

(continued)

Table 4.3-1. Brucejack Gold Mine Project Alternative Means Screening Table Based on Basic Technical and Economic Feasibility Criteria (continued)

Major Component of Project	Sub-component	Option	Technically Feasible? (Y/N)	Technical Rationale	Economically Feasible? (Y/N)	Economic Rationale	Screening Result
Ore Production and Processing (*cont'd*)	Mining Method (*cont'd*)	Underground method 2: shrinkage stoping	N	Unfeasible, as this is an inefficient mining method for the style of mineralization; shrinkage stoping is suited to vertical to sub-vertical narrow vein deposits rather than massive deposits like Valley of the Kings and West Zone orebodies.	Y	Economically feasible.	Discard
		Underground method 3: room and pillar	N	Unfeasible, as this method is designed for flat or gently sloping deposits typical of potash, uranium, limestone and salt deposits and so is inappropriate for the geometry and steep inclination of the ore body.	Y	Economically feasible..	Discard
		Underground method 4: long-hole open stoping (LHOS)	Y	Feasible as a suitable method given the type and orientation of ore body; allows mining flexibility, dilution control, and disposal of waste rock and tailings as backfill.	Y	Economically feasible.	Select
		Underground method 5: cut-and-fill	N	Unfeasible, as used on less massive deposits or where a higher degree of selectivity is required, therefore not suitable method. May have localized application in some areas, though none identified.	N	Economically unfeasible as this lower productivity, higher operating cost method is not appropriate as a primary method at Brucejack.	Discard
	Ore Comminution	Option 1: three stages of crushing and two stages of ball mill grinding	Y	Technically feasible.	Y	Economically feasible.	Assess Further
		Option 2: one stage of crushing and grinding in a SAG mill grinding/ball mill grinding/pebble crushing (SABC) circuit	Y	Technically feasible.	Y	Economically feasible.	Assess Further
	Location of Initial Ore Processing into Flotation Concentrate	On-site in a process plant at the mine site	Y	Technically feasible.	Y	Economically feasible.	Select
		Off-site near Highway 37	N	Unfeasible due to logistics of transport of large volumes of ore off-site.	N	Not economically feasible due to prohibitive costs to operate.	Discard
	Location of Final Flotation Concentrate Processing into Gold-silver Doré	On-site by Proponent	Y	Technically feasible.	Y	Economically feasible.	Assess Further
		Off-site by third party	Y	Technically feasible.	Y	Economically feasible.	Assess Further
Wastewater Management	On-site Construction / Operation Camp Treated Sewage Effluent Discharge Location	Discharge into Brucejack Lake	Y	Technically feasible.	Y	Economically feasible.	Select
		Discharge to Brucejack Creek	N	Unfeasible as will likely not meet water quality permitting requirements during low flow periods.	Y	Economically feasible.	Discard
	Contact Water Treatment Method	Veolia ACTIFLO® High Rate Clarifier	Y	Feasible, as technically suitable technology to treat Project contact water contaminants, and viable to achieve water quality guidelines.	Y	Economically feasible	Select
		Reverse osmosis	N	Unfeasible, as, it is not suitable to treat the specific contact water contaminants for the Project. Greater maintenance requirements to clean membranes that require handling and disposal of chemicals not required for other treatment options.	N	Not economically feasible due to increased costs related to technical inefficiencies.	Discard
		Ion exchange	N	Unfeasible, as it is not suitable to treat the specific contact water contaminants for the Project. Greater maintenance requirements to replace and dispose of resin not required for other treatment options.	N	Not economically feasible due to increased costs related to technical inefficiencies.	Discard
	Treated Contact Water Discharge Location	Discharge into Brucejack Lake	Y	Feasible during mine operations, when Brucejack Lake will no longer be used as camp drinking water source as is current practice.	Y	Economically feasible.	Select
		Discharge to Brucejack Creek	N	Unfeasible, as would not be acceptable due to technical challenges to meet water quality permitting requirements during seasonal low flows.	Y	Economically feasible.	Discard
Solid Waste Disposal	Waste Rock Disposal Method	Backfill into stopes of underground mine	Y	Backfilling into stopes is technically feasible for much but not all of the anticipated waste rock volumes, providing structural support allowing underground mining expansion to proceed more safely, and becomes more feasible later in the Project lifespan when large underground volumes are available.	Y	Backfilling is a low cost option that is economically feasible.	Assess Further
		Subaqueous deposition into Brucejack Lake	Y	Technically feasible and lake volume would accommodate waste rock.	Y	Economically feasible.	Assess Further
		Disposal into surface rock storage facilities (RSF)	N	Unfeasible as RSFs would be technically onerous to build in the limited space available on-site with associated geohazards, and would require perpetual management to address water quality issues.	Y	Creation of rock storage facilities would be economically possible were it technically viable.	Discard

(continued)

Table 4.3-1. Brucejack Gold Mine Project Alternative Means Screening Table Based on Basic Technical and Economic Feasibility Criteria (completed)

Major Component of Project	Sub-component	Option	Technically Feasible? (Y/N)	Technical Rationale	Economically Feasible? (Y/N)	Economic Rationale	Screening Result
Solid Waste Disposal (*cont'd*)	Tailings Disposal Method	Backfill as paste into stopes of underground mine	Y	Backfilling of paste into stopes is feasible for almost half of the anticipated tailings volume.	Y	Economically feasible.	Assess Further
		Subaqueous deposition into Brucejack Lake	Y	Deposition of tailings into the lake is technically feasible and the lake has adequate capacity.	Y	Economically feasible.	Assess Further
		Deposition as conventional slurry into a tailings storage facility (TSF)	N	Unfeasible as a TSF would be technically onerous to build and maintain in the challenging terrain of the Project.	Y	Creation of a tailings storage facility would be economically possible were it technically viable.	Discard
		Dry stacking of filtered tailings	N	Unfeasible due to climatic conditions with high average precipitation.	N	Not economically viable due to long-term management of the dry stack tailings.	Discard
	Controlling Sediment Release from the Lake	Process waste rock through a wash plant to remove a component of fine sediment. Wash water treated by settling pond, aided by flocculants.	N	Not feasible in winter when rock will freeze after washing, making transportation and placement unsafe. Would require additional sludge management. Does not address sediment release from tailings.	Y	Economically feasible.	Discard
		Deposit flocculated tailings to base of growing tailings mound.	Y	Technically feasible. Discharge through the mound acts as filter to remove fines for the effluent and dissipates energy of the effluent stream decreasing the ability to suspend material. Reduces potential sediment release at the lake outlet as a result of tailings deposition, does not address sediment release from waste rock. Operations require constant flow through to maintain partial fluidity of tailings mound.	Y	Economically feasible.	Select
		Install a turbidity curtain at lake outlet to remove suspended sediment	Y	Technically feasible. Proven technology used successfully in nearby Eskay Creek Project. Addresses elevated suspended sediment from both tailings and waste rock deposition. Challenges during freeze/thaw and under-ice season.	Y	Economically feasible.	Select
		Install a turbidity curtain around the waste rock dump area	Y	Technically feasible. Proven technology used successfully in nearby Eskay Creek Project. Addresses elevated suspended sediment from waste rock deposition. Challenges during freeze/thaw and under-ice season.	Y	Economically feasible.	Select
		Construct an outlet control structure (dam) to retain water in the lake if TSS levels are too high to allow time for suspended material to settle out of the upper water column	Y	Technically feasible. Effectiveness of a structure for settling suspended material limited by amount of storage capacity of the control structure and the lake, especially during freshet. Restriction of flows would have downstream environmental impacts. Challenges during freeze/thaw and under-ice season. Requires real-time TSS monitoring.	Y	Economically feasible.	Assess Further
		Add flocculants to the lake	N	Not technically feasible due to volumes of flocculant required and related chemical effects on the lake.	Y	Economically feasible.	Discard
	Solid Waste Disposal Method for Non-hazardous Waste	On-site landfill	N	Unfeasible due to there not being an appropriate location on-site to accommodate waste over the Project life, finding soil to cover waste, and managing the site in winter conditions.	Y	On-site waste disposal would be the most economically feasible alternative due to minimized transportation and equipment costs.	Discard
		Off-site landfill	Y	Feasible as this is a standard approach to disposal of waste for mines where off-site facilities are available, and there are available landfill sites located in the mine site region.	Y	Economically feasible.	Assess Further
		Incineration, and disposal in off-site existing landfill	Y	Incineration of solid waste is technically feasible for many solid waste products (i.e., food waste). Some materials (such as plastics and rubber) would not be suitable for incineration.	Y	Economically feasible.	Assess Further

Table Legend:

Select	Utilize option for the Project
Assess Further	Carry forward option into detailed alternatives assessment
Discard	Eliminate option from further consideration

4.3.1 Ground Access from Highway 37 to Knipple Transfer Area

4.3.1.1 Background

The Project will require ground access to mobilize equipment, supplies, and personnel to the Brucejack Mine Site and to transport concentrate from the Brucejack Mine Site to Highway 37 (Figure 4.1-1). Air transport via helicopters can provide site access and transport for selected needs such as personnel and light goods, but would not be feasible for routine transport of heavier equipment and supplies, so has not been considered as an option.

The Project site is currently accessible via a 73-km-long exploration access road (the Brucejack Access Road) from Highway 37. Approximately 12 km of the route traverses Knipple Glacier, between the Brucejack Mine Site and the proposed Knipple Transfer Area (Figure 4.1-1). In addition to the Brucejack Access Road, a barge was also previously used across Bowser Lake to transport personnel and some materials and equipment to the vicinity of the proposed Knipple Transfer Area to support earlier exploration activities.

The following alternatives assessment focuses on the identified alternative routes for ground access from Highway 37 to the Knipple Transfer Area.

4.3.1.2 Technical and Economic Feasibility Assessment

Three ground access options from Highway 37 to the proposed Knipple Transfer Area were assessed in the screening step as outlined in Table 4.3-1. The primary technical and economic feasibility criteria used to assess the three access options—summarized below—included topographic constraints, geohazard risks, and construction/operation costs.

<u>Existing Exploration Access Road (the Brucejack Access Road)</u>

This ground access option would involve utilizing the existing exploration access road as (the Brucejack Access Road) from Highway 37 (Figure 4.1-1). The road will require minor upgrades to support mine traffic during construction and operation, however it is not anticipated that any upgrades to stream crossings would be required.

Use and upgrading of the existing Brucejack Access Road is both technically and economically feasible.

<u>New Road along Bowser River Valley Connecting to Granduc Access Road to the South</u>

This option would involve the development of a new road from the Granduc Access Road to the proposed Knipple Transfer Area along the Bowser River Valley parallel to the proposed transmission line (Figure 4.1-1). This route would be technically and economically challenging to build and operate due to steep surrounding terrain and extensive geohazards such as avalanches, which would make the route risky to operate and costly to maintain due to extensive mitigation required. This route would also significantly increase the relative travel distance to the rail head for concentrate transport and increase the extent of new environmental disturbance caused by the Project.

The screening result is that a new road along Bowser River Valley connecting to Granduc Access Road to the south is technically and economically unfeasible, and so eliminated from further consideration.

<u>Combination of Road Access and Barge across Bowser Lake</u>

This option would involve the use of an existing forestry access road from Highway 37 to Bowser Lake, where a barge would be used to transport equipment, supplies, personnel, and concentrate across

Bowser Lake (Figure 4.1-1), followed by extending the existing road from the lake to the proposed Knipple Transfer Area.

Barging across Bowser Lake was used historically for the transport of personnel and some materials and equipment for projects in the region, therefore, would likely be economically feasible, though associated with higher costs to develop a docking facility and acquire a new barge. However, this option faces the following technical limitations: 1) the inability to utilize a barge during winter (due to freezing) or during inclement weather, 2) the size limitations of the barge for heavier mining equipment, and 3) the temporal constraints the barge would place on Project schedules. This option would also introduce higher risks of spills and contamination issues in Bowser Lake.

This option is technically unfeasible for the above reasons and eliminated from further consideration.

4.3.1.3 Selected Option

The existing Brucejack Access Road is the only cost-effective and technically viable option for ground transport between Highway 37 and the proposed Knipple Transfer Area, and is therefore the selected option.

4.3.2 Ground Access from Proposed Knipple Transfer Area to the Brucejack Mine Site

4.3.2.1 Background

The Project will require ground access to travel between the Brucejack Mine Site and the proposed Knipple Transfer Area (Figure 4.1-1) for the transport of equipment and supplies, personnel, and ore concentrate. The Project site is currently accessed from the base of the Knipple Glacier via a 12-km route traversing the main arm of the Knipple Glacier. The Knipple Glacier road route was used by Newhawk Gold Mines Ltd., a previous operator of the property, in the late 1980s and early 1990s to move personnel and materials to the mine site area. Pretivm reactivated the route in 2012 to support exploration activities. Access across the glacier is accomplished through the use of tracked vehicles. The route is a groomed snow surface during winter months, but it is an ice surface during the summer.

4.3.2.2 Technical and Economic Feasibility Assessment

Three ground access options from Highway 37 to the proposed Knipple Transfer Area were assessed in the screening step, as outlined in Table 4.3-1. Two ground access options from the proposed Knipple Transfer Area to the Brucejack Mine Site were assessed for technical and economic feasibility during screening, as outlined in Table 4.3-1. The primary technical and economic feasibility criteria used to assess access to the three options—summarized below—included topographic constraints, geohazard risks, and construction/operation costs.

<u>Existing Exploration Route (over Knipple Glacier)</u>

This option would involve utilizing the existing access road traversing the main arm of the Knipple Glacier through the use of tracked or otherwise specially equipped vehicles (since conventionally equipped highway vehicles are not suitable for ice transit). This option would require all equipment and supplies to be transferred at the proposed Knipple Transfer Area to specialized vehicles that would proceed along the Knipple Glacier to the Brucejack Mine Site.

Using specialized vehicles over the Knipple Glacier has been demonstrated through exploration use, and the ability of this method and route to accommodate materials and equipment transport through construction and operation would be viable, making this route option technically feasible for use during the Project life. This route is also economically feasible as it only requires minor upgrades.

Road through Tunnel that Avoids Glacier Travel

A mine site access road that would avoid glacier travel, but would necessitate construction of tunnels to pass through the mountainous terrain from the proposed Knipple Transfer Area to the Brucejack Mine Site, was considered. The Brucejack Mine Site is surrounded by glaciers and steep, mountainous terrain with many significant geohazard risks (e.g., avalanches). This road option would require significant engineered structures, such as lengthy tunnels, and slope stabilization that would be risky and economically prohibitive to build and operate safely. Accordingly, it was determined that this option would be technically and economically unfeasible to build and operate safely, and was removed from further consideration.

4.3.2.3 Selected Option

Utilizing the existing Knipple Glacier route is the only cost-effective and technically viable option for ground transport between the proposed Knipple Transfer Area and the Brucejack Mine Site. All other options were considered either technically or economically unfeasible and were removed from further consideration.

4.3.3 Power for the Project

Using electrical power from the provincial electricity grid, supplied via a transmission line from the south, is the only cost-effective and technically viable option. All other options were considered either technically or economically unfeasible and were removed from further consideration.

4.3.4 Mining Method

4.3.4.1 Background

The Brucejack deposits are generally high-grade, sub-vertical, and easily traceable. Over a minimum 22-year mine life, the mine will produce approximately 16 million tonnes (Mt) of ore at a rate of up to 2,700 tonnes per day. The Project will focus on two zones of potentially economical mineralization; Valley of Kings (VOK) Zone and West Zone (WZ). The mine will be targeting gold and silver deposits within the VOK and WZ mineralized zones. Selecting the right mining method is important as it strongly influences several aspects of mine development such as production rates, development schedules, and waste rock volume. The two main methods for recovering ore from hard rock mines are open-pit and underground mining. Both methods use drilling, blasting, and heavy equipment, but have different environmental, social, technical, and economic considerations.

4.3.4.2 Technical and Economic Feasibility Assessment

Six mining method alternatives were assessed for technical and economic feasibility during the pre-screening stage, as summarized in Table 4.3-1:

- open-pit;
- underground method 1: block caving / sublevel caving;
- underground method 2: shrinkage stoping;
- underground method 3: room and pillar;
- underground method 4: long-hole open stoping (LHOS); and
- underground method 5: cut-and-fill.

Technical criteria for selecting a mining method are driven largely around geological and geotechnical considerations, such as: strength of ore, strength of host rock, stress field, structural geology (faults, contacts, joints, folds, etc.), dimensions of ore body (thickness, strike length, height), orientation (dip, plunge), and depth. In addition to the technical considerations, economic and logistical factors also need to be considered, including: availability of skilled labour, equipment, and backfill; health and safety factors; production requirements; value of ore; and costs (operating, capital, and closure).

Open-Pit

Open-pit mining requires the removal of surface materials to expose the ore body, followed by the stepwise development of concentric levels (benches) into the deposit, with an inclined roadway, or ramp, connecting the various mining levels or benches. Open-pit mining methods are best suited to: extraction of shallow ore deposits exposed at or near the surface with shallow overburden; large uniformly distributed deposits; scattered/randomly distributed deposits that are not readily traceable by underground mining methods; and high tonnage, low-grade deposits that are uneconomic using more expensive underground mining techniques.

It was determined that due to the size, shape, orientation, and type of the VOK and WZ deposits, open-pit mining would be technically unfeasible and would generate much larger volumes of waste rock that would be onerous to manage compared to underground mining. This method is also considered economically unfeasible due to the large capital cost and lower financial rate of return.

Underground Mining

Underground mining methods are best suited to ore bodies that are of a higher grade, and easily traceable underground, such as the VOK and WZ deposits being targeted by the Project. Underground mining is generally more selective, producing less waste rock than open-pit mining and posing fewer surface risks (such as exposure to avalanches), although it can be associated with subsidence. The following underground mining methods were evaluated during the screening stage, as summarized in Table 4.3-1.

Underground Method 1: Block Caving / Sublevel Caving

Block cave mining is a mass mining method that allows for the bulk mining of large, relatively homogenous, lower-grade ore bodies. The method uses a grid of tunnels driven under the ore body. The rock mass is then undercut by blasting, ideally with the ore breaking under its own weight.

Use of an unselective method, such as block caving, is technically unfeasible for the Project as it is not geotechnically suitable and would result in dilution of the high-grade VOK and WZ deposits. In addition, caving methods can cause widespread surface subsidence and large surface water inflows, potentially leading to long-term closure issues. This method is also economically unfeasible for the Project as it would result in extremely high initial capital costs, long delays to cash flow, and additional processing costs associated with the high dilution of the ore. Accordingly, this alternative was removed from further consideration.

Underground Method 2: Shrinkage Stoping

Shrinkage stoping is used for steeply-dipping, vertical to sub-vertical narrow ore bodies with self-supporting walls and ore. It is an overhand mining method (mined from the bottom up) that relies on broken ore being left in the stope to be used as the “working floor” and to support the walls.

Shrinkage stoping is more technically suited to vertical to sub-vertical narrow vein deposits rather than massive deposits like the VOK and WZ deposits. This method may have some local benefit for high-grade narrow vein structures within the VOK and WZ deposits; however, it is not viewed as an appropriate primary method for the Brucejack ore bodies and is therefore determined to be technically unfeasible. Due to the massive ore bodies associated with the Project, shrinkage stoping would be an inefficient method and economically unfeasible for the Project as a whole. Accordingly, this alternative was removed from further consideration as the primary mining method. However, shrinkage stoping may be investigated for localized high-grade veins within the overall deposit if more are discovered.

Underground Method 3: Room and Pillar

This method is applicable to relatively flat or gently sloping deposits typical of potash, uranium, limestone, and salt deposits. It employs natural supports (rock pillars), with the ore body excavated as completely as possible leaving ore/waste as pillars to support the hanging wall (back or ceiling). Dimensions of the stopes and pillars depend upon factors such as the stability of the back, stability of the ore, thickness of the deposit, and rock stresses.

This method is technically and economically unfeasible for the Project as it is not appropriate for vertical/sub-vertical mining of Brucejack ore and would be inefficient to implement.

Underground Method 4: Long-Hole Open Stoping

LHOS is a common large-scale underground mining method best suited to vertical or steeply-dipping ore bodies with regular boundaries. LHOS requires the surrounding rock to be strong enough to permit the drilling, blasting, and removal of ore without caving and requirement for artificial support. This type of mining is often accessed by a decline ramp.

LHOS is an appropriate method for the Project given the type and orientation of VOK and WZ deposits. LHOS allows mining flexibility, dilution control, and the disposal of waste rock and tailings mixed with cement into the stopes (paste backfill), so is technically feasible. Both transverse and longitudinal LHOS methods would be used for the Project. LHOS would also be economically feasible.

Underground Method 5: Cut-and-fill

Cut-and-fill mining is a method of short-hole mining used in steeply dipping or irregular ore zones, in particular where the hanging wall limits the use of long-hole methods. Typically, this method is used on less massive deposits or where a higher degree of selectivity is required. The ore is mined in horizontal or slightly inclined slices, with the resulting voids subsequently filled with waste rock, sand, or tailings. Either fill option may be consolidated with concrete, or left unconsolidated.

This method is considered technically feasible for the Project and could have short-term, localized application; however, no opportunities have yet been identified. This lower productivity, higher operating cost method is economically unfeasible as a primary mining method for the Project. Accordingly, this alternative was removed from further consideration.

4.3.4.3 Selected Option

LHOS (transverse and longitudinal) mining is the only cost-effective and technically viable alternative for primary mining of the VOK and WZ deposits.

Shrinkage stoping was identified as potentially having some local benefit for high-grade narrow vein structures within the Brucejack deposit; however, it was not seen to be technically or economically feasible as the primary mining method. Cut-and-fill underground mining could have short-term, localized application at the Brucejack deposit, but no opportunities have yet been identified. This lower productivity, higher operating cost method is not appropriate as a primary mining method for the Project. Open-pit mining is not technically or economically feasible for the Project.

4.3.5 Location of Initial Ore Processing into Flotation Concentrate

4.3.5.1 Purpose and Background

Following the comminution process (Section 4.4.3), initial mineral processing of the crushed ore is required to liberate the gold and silver from the ore into a concentrate (Chapter 5, Project Description). The method to process the ore for the Project will involve conventional bulk sulphide flotation and gravity concentration to ensure the best extraction of gold and silver from the ore. Pretivm investigated whether to conduct this initial ore processing step on-site or off-site, as summarized in Table 4.3-1.

4.3.5.2 Technical and Economic Feasibility Assessment

Conducting initial ore processing into flotation concentrate was investigated for a facility located either on-site or off-site. The primary technical and economic feasibility criteria used to assess access to the two options included topographic constraints, geohazard risks, and operation costs.

<u>On-site Processing</u>

There would be sufficient space secure of geohazard risks to locate a processing facility on-site, making this option technically feasible. This would be the most financially efficient option, so it is also economically feasible.

<u>Off-site Processing</u>

An option for transporting the ore after the comminution phase to a process plant off-site at a lower elevation was investigated. It was found that to transport the ore down from the site would be technically unfeasible due to the large volumes involved, as well as economically very costly and therefore economically unfeasible.

4.3.5.3 Screening Result

Processing the ore into final flotation concentrate on-site was found to be the only technically and economically feasible option, and has been selected for use by the Project.

4.3.6 Sewage Treatment and Discharge Location

4.3.6.1 Background

There are three sites that will require sewage management during the life of the Project: the Brucejack Mine Site construction/operation camp (Figure 4.1-2), the proposed Knipple Transfer Area site, and a temporary construction camp at the Tide Staging Area (Figure 4.1-1). A fourth site, the existing Bowser Construction Camp, has an operating sewage management system that will be decommissioned as soon as the Knipple Transfer Area Camp is operational. As an existing facility that will have a short lifespan it is not discussed further here. Depending on the circumstances, sometimes the selection of a sewerage system may be prescriptive, based on regulations and BMPs, and other times alternatives may be considered. In BC, the design and management of sewerage systems handling less than 22,700 litres per day of sewage flow to ground falls under the Sewerage System Regulation (BC Reg. 326/2004) under the jurisdiction of the BC *Health Act* (1996). Those systems exceeding this flow rate to ground—and all discharge to surface water—are regulated by the Municipal Wastewater Regulation (BC Reg. 87/2012) under the jurisdiction of the *Environmental Management Act* (2003).

Selecting the sewage treatment methodology and discharge location/type under either regulation revolves primarily around technical criteria on type and flow levels of sewage requiring treatment, site conditions, and effluent discharge requirements; economic criteria on capital and operating costs may be a secondary factor. Depending on the circumstances, alternative options may or may not arise for a given system depending on constraints. In-ground septic systems are typically constrained by site conditions. There are three sites that will require sewage management during the life of the Project: the Brucejack Mine Site construction/operation camp (Figure 4.1-2), the proposed Knipple Transfer Area site, and a temporary construction camp at the Tide Staging Area (Figure 4.1-1). Depending on the circumstances, sometimes the selection of a sewerage system may be prescriptive, based on regulations and BMPs, and other times alternatives may be considered. In BC, the design and management of sewerage systems handling less than 22,700 litres per day of sewage flow to ground falls under the Sewerage System Regulation (BC Reg. 326/2004) under the jurisdiction of the BC *Health Act* (1996).. Those systems exceeding this flow rate to ground—and all discharge to surface water—are regulated by the Municipal Wastewater Regulation (BC Reg. 87/2012) under the jurisdiction of the *Environmental Management Act* (2003).

Selecting the sewage treatment methodology and discharge location/type under either regulation revolves primarily around technical criteria on type and flow levels of sewage requiring treatment, site conditions, and effluent discharge requirements; economic criteria on capital and operating costs may be a secondary factor. Depending on the circumstances, alternative options may or may not arise for a given system depending on constraints. In-ground septic systems are typically constrained by site conditions. Regarding treatment methods, for sewerage systems with flows greater than 22,700 litres per day, that fall under the Municipal Wastewater Regulation (BC Reg. 87/2012), "advanced treatment" is defined as any form of treatment, other than dilution, that produces a municipal effluent with biochemical oxygen demand (BOD_5) and total suspended solids (TSS) being 10 milligrams/litre (mg/L) or less each, or meets substitution requirements (BC Reg. 87/2012). As defined under the Standard Practice Manual (BC Ministry of Health 2006) for the Sewerage System Regulation (BC Reg. 326/2004) treatment levels are listed as: Type 1 systems involve only septic tanks; Type 2 systems produce effluent consistently with less than 45 mg/L of TSS and have a 5 day BOD_5 demand of less than 45 mg/L, and; Type 3 systems produce effluent consistently containing less than 10 mg/L of total suspended solids, having a BOD_5 demand of less than 10 mg/L, and a median fecal coliform density of less than 400 Colony Forming Units per 100 millilitres (mL).

Sewage from the existing on-site exploration camp is currently being treated with a bio-reactor type sewage treatment plant with UV disinfection of the effluent prior to discharge; effluent is being discharged to Brucejack Creek. Due to technical site constraints, discharge to ground is not possible on-site, and the existing system or a comparable sewage treatment plant will be used for the Project construction/operation camp. Regarding the discharge location for sewage effluent from the on-site camp, discharge to Brucejack Creek will not meet water discharge criteria with the expansion of the existing on-site camp to a max 440-person camp during the Construction and Operation phases of the Project. Therefore, Pretivm assessed options for a sewage effluent discharge location for the proposed expansion of the on-site camp.

Sewerage systems for the proposed Knipple Transfer Area and Tide Staging Area camps have been designed to meet regulatory specifications and BMPs, rather than through the consideration of alternatives, as summarized in Table 4.3-2.

4.3.6.2 Technical and Economic Feasibility Assessment

The new construction/operations camp at the Brucejack Mine Site (Figure 4.1-2), will fall under the jurisdiction of the Municipal Wastewater Regulation (BC Reg. 87/2012). Technical criteria involving site conditions such as flow levels, as well as effluent discharge requirements, were considered to select a discharge location for the on-site camp sewerage effluent discharge from either Brucejack Creek or Brucejack Lake (Table 4.1-3).

Table 4.3-2. Brucejack Gold Mine Project Sewage Treatment Specifications and Options

Location	Camp Capacity	Applicable Regulation	Sewage Treatment Method	Discharge Location
Knipple Transfer Area	30	Sewerage System Regulation (BC Reg. 326/2004)	Septic system with tanks and drainfield.	Discharge to ground is feasible based on site conditions and flow rates.
Tide Staging Area	90	Sewerage System Regulation (BC Reg. 326/2004)	Septic system with tanks and drainfield.	Discharge to ground using septic tank and septic field.

Brucejack Creek

Due to the technical challenges of treating water to meet effluent discharge criteria in Brucejack Creek during seasonal low flows, this option was rejected as being technically unfeasible for use by the Project (Table 4.3-1). This option was considered to be economically feasible.

Brucejack Lake

Sewage effluent discharge into Brucejack Lake was found to be both technically and economically feasible.

4.3.6.3 Screening Result

Discharge of sewage effluent to Brucejack Lake has been selected for use by the Project as the only feasible option.

4.3.7 Contact Water Treatment Method and Discharge Location

4.3.7.1 Background

Contact water that will be generated by the Project and will require treatment, such as for potential excess TSS, low pH, and contaminants that may exceed government water quality guidelines.

The management of sludge resulting from water treatment was determined utilizing BMPs rather than deciding among alternatives. During the Construction phase, the preferred method is storing the sludge for disposal with Operation phase sludge at a later date, with an option of binding the sludge in concrete or drying and shipping offsite for disposal. During the Operation phase, disposal of the sludge with the tailings is the preferred method.

4.3.7.2 Technical and Economic Feasibility Assessment

Three contact water treatment options and two contact water discharge locations were assessed in the screening step as outlined in Table 4.3-1. The primary technical feasibility criteria used to assess the contact water treatment methods included suitability of method for the contaminants present (Appendix 4-A, Brucejack Underground Preliminary Assessment - Leach Tailings Facility Site Selection), flow levels, effluent water quality criteria, and site conditions. Site selection technical criteria included flow levels and effluent discharge requirements. Capital and operating costs were also considered.

Treatment Option: Veolia ACTIFLO® High Rate Clarifier

The ACTIFLO® High Rate Clarifier is a new water treatment methodology developed and proposed by Veolia. ACTIFLO® flocculates water with microsand and polymer in a proprietary process that is efficient, and has a very small footprint up to 50 times smaller than other systems (Veolia 2014), which is suitable to the space-limited on-site location. Veolia found that the ACTIFLO® system would meet contact water effluent discharge criteria, providing effective maintenance of surface water quality by the Project. Therefore this system was determined to be technically and economically feasible.

Treatment Option: Reverse Osmosis

Reverse osmosis involves using a semi-permeable membrane to purify water of several molecules and ions. Reverse osmosis is a method that can lead to effective water treatment, but has substantially greater maintenance requirements than the high rate clarifier. The semi-permeable membranes require regular cleaning that requires the handling and disposal of chemicals that would otherwise not be required. Thus, it was determined that, this method would not be suitable to treat the type of water contaminants required for the Project, and so is considered technically unfeasible. As this method is considered technically unfeasible, it is also consider economically unfeasible.

Treatment Option: Ion Exchange

Ion exchange is a water treatment method that involves water clarification and purification typically through selectively removing charged inorganic species from water using an ion-specific resin. This method is often used for drinking water treatment, softening, and for the removal of nitrate, arsenate, chromate, and selenate, and is typically used for small systems. Regular and frequent replacement of resin used in this method is a major disadvantage compared to the use of a high rate clarifier, due to the logistical considerations of material handling and disposal of a potentially hazardous material. Thus, it was determined that ion exchange would not be suitable to treat the type of water contaminants required for the Project. Therefore, ion exchange has been deemed technically unfeasible for use by the Project. As this method is considered technically unfeasible, it is also consider economically unfeasible.

Discharge to Brucejack Creek

Similarly to the situation for sewage effluent discharge, it was found that though economically feasible, discharge of contact water effluent to Brucejack Creek would be technically unfeasible due to low flows causing issues in meeting effluent discharge criteria.

Discharge to Brucejack Lake

The current exploration camp drinking water source is Brucejack Lake. During Operation, when potable drinking water will be sourced from groundwater wells, discharging contact water effluent to Brucejack Lake would be economically feasible, as well as technically feasible, as this location would meet effluent discharge criteria.

4.3.7.3 Screening Result

Contact water will be treated through the utilization of the Veolia ACTIFLO® High Rate Clarifier treatment method, and discharge of contact water effluent will be to Brucejack Lake, as other options for contact water management have been determined to not be feasible for use by the Project.

4.4 ALTERNATIVE MEANS ASSESSMENTS

The following discussion provides the detailed alternatives assessment of each relevant Project component (as determined by the EIS Guidelines [CEA Agency 2013a] and AIR [BC EAO 2014]). The results of each assessment are summarized in the alternatives assessment comparison tables (Tables 4.4-1 to 4.4-5).

4.4.1 Access Method (Personnel)

4.4.1.1 Purpose and Background

The Project will require a means for personnel to access the Brucejack Mine Site. All transport of personnel (as well as equipment and materials) between the proposed Knipple Transfer Area and the Brucejack Mine Site will be via the Knipple Glacier Road route using specially equipped vehicles. This approach is the only feasible option for this portion of the access route (refer to Section 4.3.2). In addition, there is not sufficient space at the Brucejack Mine Site to facilitate direct fixed-wing flights to the Brucejack Mine Site for personnel. Accordingly, personnel access options to the site have been assessed up to the point of the proposed Knipple Transfer Area.

4.4.1.2 Alternatives Identification

Three alternatives for the primary transport of personnel to the proposed Knipple Transfer Area were scoped into the assessment as meeting basic technical and economic feasibility criteria during screening (Table 4.3-1), and are described below.

Air Transport by Fixed-Wing Aircraft

A number of remote mine sites across the country provide air transport for their workforces. With the air transport alternative, regular chartered fixed-wing flights from Vancouver, Smithers and/or Terrace will transport mine personnel to the Project aerodrome (Bowser Aerodrome), located west of Bowser Lake (Figure 4.1-1). Once at the Bowser Aerodrome, personnel would be transported to the proposed Knipple Transfer Area by bus.

To support air transport by fixed-wing aircraft to the proposed Knipple Transfer Area, a new aerodrome would be constructed at the site of the overgrown historical gravel airstrip, which will be improved and expanded to provide a safe and maintainable facility for the chartered air traffic. The passenger aircraft used in the design of the aerodrome is the Beechcraft 1900, though the aerodrome facilities are sized sufficiently to allow DE Havilland Dash 8 turboprops and C-130 Hercules aircraft.

Bus Transport

For the bus transport alternative, the intent is to have buses used for primary personnel transport and also as backup for weathered-in flights. Buses will leave and return from Smithers and/or Terrace, with stops along the way at smaller communities such as Hazelton or Meziadin if necessary.

Private Vehicles

The use of private vehicles for personnel along the Project access road from Highway 37 to the proposed Knipple Transfer Area would be technically and economically feasible (Table 4.3-1). This alternative could also include the sub-option of transport by private vehicle to the gatehouse to be located near the junction of Brucejack Access Road and Highway 37 that may be utilized during the Construction and Operation phases. This sub-option would be limited to local staff (Dease Lake, Stewart etc.) on an as-needed basis. Private vehicle use would be restricted beyond the gatehouse, with staff required to park at the gatehouse and be driven by bus to the proposed Knipple Transfer Area.

4.4.1.3 Alternatives Comparison

The air, bus, and private vehicle personnel transport method attribute characteristics were compared against the four performance objectives, as summarized in Table 4.4-1.

Table 4.4-1. Evaluation of Brucejack Gold Mine Project Alternatives for Personnel Transport to Proposed Knipple Transfer Area

Alternative	ATTRIBUTE RATINGS AGAINST FOUR PERFORMANCE OBJECTIVES								FINAL RATING
	Environmental Attributes		Social Attributes		Technical Attributes		Project Economic Attributes		
Land, via Bus Charter	☑ Minimizes GHG emissions per person the most compared to other options ☑ Less surface level CAC, dust, and noise emissions than private vehicles ☑ Less dust deposition effects on soil and plant receptors than private vehicles ☑ Reduces chance of invasive species transport compared to private vehicles ☑ Less disruption, disturbance, and collision-induced mortality of wildlife compared to private vehicles ☑ Reduces likelihood of staff hunting and fishing along the corridor, reducing potential fish and wildlife mortality (particularly for moose), compared to private vehicles	Acceptable	☑ Increases employment compared to using private vehicles ☑ Professional drivers and reduced traffic on access road compared to private vehicles reduces accident OH&S risks ☒ Slower and less convenient access to Project for staff than via plane, but lower driving burden than private vehicle ☑ Reduces hunting/fishing pressure compared to using private vehicles, lowering change of effects on current use of lands and resources for traditional purposes ☑ Reduced dust deposition compared to using private vehicles lowers chance of effects on harvesting of country foods ☑ Provides a consistent/reliable transport method in all but the most severe weather conditions ☑ Lowest OH&S risks of all options during inclement weather	Preferred in Poor Weather Acceptable in Good Weather	☑ There are a number of regional, bussing companies that are capable of providing service for the Project ☒ Longer transport times than air under normal weather conditions ☑ Available during all but the most severe types of weather with appropriate road maintenance	Preferred in Poor Weather Acceptable in Good Weather	☑ Anticipated to best minimize costs	Preferred	PREFERRED In Poor Weather ACCEPTABLE In Good Weather
Air, via Charter Flight	☒ Higher GHG emissions than bus travel per person for air travel generally ☑ Minimizes surface CAC, dust and noise emissions ☑ Minimizes dust deposition effects on soil and plant receptors ☑ Minimizes chance of invasive species transport ☑ Minimizes wildlife movement disruption, disturbance, and collision-induced mortality along corridor ☑ Minimizes likelihood of staff hunting and fishing along the corridor, reducing fish and wildlife mortality (particularly for moose)	Preferred	☒ Higher skilled employment than using private vehicles ☑ Charter planes would best reduce traffic and accident risks along access road ☑ Fixed-wing aircraft provide shortest commute times and ease of access for personnel ☑ Lowest hunting/fishing pressure from staff best reduces chances of effects on current use of lands and resources for traditional purposes ☑ Lowest dust deposition minimizes changes of effects on harvesting of country foods along corridor ☑ Safe and efficient, with acceptable OH&S risks in good weather ☒ Not feasible for use in poor weather conditions linked to OH&S risks	Unfeasible in Poor Weather Preferred in Good Weather	☑ Shortest transport times compared to all options under normal weather conditions ☑ Less management needed to address training and risk mitigation of using roads ☒ Not viable during periods of inclement weather, due to safety risks	Unfeasible in Poor Weather Preferred in Good Weather	☒ Air travel is more costly than ground travel (bus or car)	Acceptable	UNFEASIBLE In Poor Weather PREFERRED In Good Weather

(continued)

Table 4.4-1. Evaluation of Brucejack Gold Mine Project Alternatives for Personnel Transport to Proposed Knipple Transfer Area (completed)

Alternative	ATTRIBUTE RATINGS AGAINST FOUR PERFORMANCE OBJECTIVES								FINAL RATING
	Environmental Attributes		Social Attributes		Technical Attributes		Project Economic Attributes		
Land, via Private Vehicle	☒ Higher GHG, CAC and overall noise emissions than bus and air ☒ Highest dust deposition effects on soil and plant receptors ☒ Highest risk of invasive species transport ☒ Highest risk of wildlife movement disruption, disturbance, and collision- induced mortality than other options ☒ Increases likelihood of staff hunting and fishing in the area that would increase fish and wildlife mortality (particularly for moose); would require management and potential mitigation	Acceptable	☒ Reduced employment levels ☒ Slower access to Project for staff than via plane, and independent commuting increases personnel driving burden and inconvenience ☒ Highest chance to increase fish and wildlife mortality from hunting/fishing pressure, which may affect current use of lands and resources for traditional purposes ☒ Highest chances of dust deposition affecting country food gathering along corridor ☒ Highest OH&S risks of all options to personnel in private vehicles as well as concentrate transport drivers and other contractors from increased traffic on access roads, including higher risks of driving after working long shifts; would require mitigation that may be a challenge to provide for all personnel under varying conditions along remote backcountry road	Challenging	☒ Less reliable maintenance, higher risk of breakdowns, and harder to manage than specialized charter bus ☒ Increased risk of accidents, stalls or other issues on road can lead to scheduling delays, potential spills and haul truck damage, and safety incidents, which would be challenging to manage/mitigate ☒ Limited space for personal vehicle parking at Knipple Transfer Area	Challenging	☒ Additional capex and opex expenditures associated with construction and maintenance of a larger parking area ☒ Higher operating costs than bussing if fuel charges are reimbursed to staff ☒ Potential extra operating costs to assist if employees go off the road in bad weather or have accidents	Acceptable	CHALLENGING

Notes:

☑ = Preferred, ☒ ☑ = Acceptable, ☒ = Challenging, ☒ = Unfeasible; ✓ in the box indicates a relative advantage; ✗ in the box indicates a relative disadvantage. See Section 4.2.2 for description of attribute ranking methodology.

CAC = criteria air contaminant; GHG = greenhouse gas; OH&S = occupational health and safety

Technical and Project Economic Considerations

Under normal operating weather conditions, the use of chartered fixed-wing aircraft to access the proposed Knipple Transfer Area (via the Bowser Aerodrome, with a short bus transfer) would significantly reduce transport times for staff coming from Smithers or Terrace (or other BC locations) compared to use of buses or private vehicles. Air transport would also best accommodate transport of staff from other more distant locations such as Vancouver or Prince George. The air transport alternative also avoids the main technical disadvantages of bus transport and the use of private vehicles, such as increased road traffic, related traffic accidents, and OH&S risks. Although more expensive, the costs of air travel are acceptable. Therefore, fixed-wing air transport is the preferable alternative during good weather conditions considering technical and economic criteria of providing reliable, flexible, efficient, and safe travel for personnel (Table 4.4-1). As mentioned, some private vehicle use may be used to the gatehouse in a limited capacity as well.

Air travel would be unfeasible in inclement weather conditions due to safety risks. Private vehicles are the least safe alternative in good weather conditions, but especially so during inclement weather due to increased traffic, reduced training compared to professional drivers of buses, and vehicles that may be less suitable to backcountry driving. Bus transport methods would therefore be used in inclement weather, providing a safer travel option (with lower OH&S risks) that is also easier to manage (i.e., requires less training and field rescue crew) than private vehicles. Bus transport from Smithers or Terrace to the proposed Knipple Transfer Area is the most cost-effective transportation alternative, compared with the cost of air transport and private vehicles, if considerations of worker attractiveness and retention are excluded. Buses may also still be required to shuttle workers from the Aerodrome to the proposed Knipple Transfer Area. Overall, bus is the preferred transport method in inclement weather considering technical and economic criteria (Table 4.4-1).

Environmental and Social Considerations

The primary intermediate components and receptor VCs that would be subject to differential potential effects (therefore being relevant and comparable attributes) from the Project personnel access alternatives were identified for the environmental and human environments, as listed in Table 4.4-2. A summary of the potential differential effects on these intermediate components and receptor VCs of the personnel transport alternatives is provided in Table 4.4-1 and in the text below.

Regarding greenhouse gas (GHG) emissions, aircraft travel emits more greenhouse gases per person per km, compared with general bus transport (IPCC 1999; Borken-Kleefeld, Fuglestvedt, and Berntsen 2013). However, air travel would minimize air quality (i.e., dust) and noise effects at the surface compared to road use, as well as reduce movement disruption, noise disturbance, and collisions with wildlife. The greater number of private vehicles used compared to bus would lead to higher noise, GHG, criteria air contaminant (CAC) and dust emissions, with the latter associated with higher potential dust deposition effects on soil, plants, and other receptors along the corridor. Private vehicles would also increase disruption, disturbance, and the likelihood of wildlife collisions compared to bus, and introduce the risk of potential staff fishing and hunting along the Brucejack Access Road corridor, which may put more pressure on fish and wildlife (and local moose populations in particular) in the area. Mitigation measures to reduce the potential for wildlife collisions include: reduced speed limits, where possible limiting driving at dusk and at night; driver training and awareness programs; and maintaining adequate lines of sight along roadways. These mitigation measures would be easier to implement for controlled professional bus driver programs. Bus transport is more likely to transfer invasive species than air transport (due to transport of dirt/plant life in tires, undercarriage, etc.), but lower than for private vehicles. For both bus and air travel, mitigation measures would reduce any risk of invasive species introduction to acceptable levels, though this would be harder to enforce with private vehicles. Comparing all environmental attributes, air transport is the preferred method during good weather compared to the other options, while, during inclement weather, transport by bus is the preferred method compared to using private vehicles (as air travel would be unfeasible), as bussing would relatively minimize environmental effects.

Table 4.4-2. Intermediate and Receptor Valued Component Attributes Compared for Personnel Access Method Assessment

Assessment Theme	Identified Component[1]	Compared Attributes[2]
Atmospheric Environment	• Air quality	• Criteria air contaminant (CAC) emissions
	• Climate	• Greenhouse gas (GHG) emissions
	• Noise	• Relative noise emissions
Freshwater Environment	• Fish (general species)	• Relative fishing pressure induced mortality
Terrestrial Environment	• Soil quality	• Dust deposition
	• Ecosystems (alpine, parkland, riparian or forested)	• Dust deposition • Spread of invasive species
	• Wildlife (general)	• Disruption of movement • Sensory disturbance • Mortality from collisions
Human Environment	• Worker wellbeing	• Pressure on workers and convenience relating to driving
	• Labour and income	• Relative number of jobs created • Relative skill level of employment
	• Health	• Potential dust deposition on country foods harvested along corridor
	• Occupational Health and Safety (OH&S)[3]	• Safety during transit
	• Non-commercial land use	• Changes in quantity of currently used wildlife and fishery resources

[1] Components listed include "subject area" and "sub-components" of VCs (see Chapter 6, Table 6.4-4)
[2] Attributes are linked to "indicators" of VCs (see Chapter 6, Table 6.4-4)
[3] Occupation Health and Safety is not within the scope of the Application/EIS, but considered here as an important consideration of Project alternatives

Considering social attributes of the different means of personnel transport, private vehicles are generally less convenient for staff due to slower transit times, more driving burden, and the higher OH&S risks this method introduces that would be challenging to mitigate to ensure safety of personnel. Bussing and air transit would increase job creation compared to private vehicles, with air transit leading to relatively more skilled jobs. Increased dust deposition by bus, and especially private vehicle, traffic may affect the quality of country food resources along the corridor, with related implications for human health for any Aboriginal groups that may use this resource. In addition, the extra hunting and fishing pressure along the corridor may lead to effects on currently used land and fishery resources. Air travel would avoid these kinds of effects along the ground. The result of the social analysis is that during good weather, air travel is socially preferred as this method reduces transit times making this method more generally convenient and appealing to personnel. During inclement weather, when air travel is not viable, bus would provide a socially acceptable alternative transport method.

4.4.1.4 Selected Alternative

During fair weather conditions, air transport by fixed-wing aircraft received preferred ratings in all but the economic performance category, for which it was acceptable, making this the selected alternative for primary transport during normal weather for the Project. During inclement weather, bus transport has been selected for use instead.

4.4.2 Ore Comminution

4.4.2.1 Purpose and Background

Ore comminution at hard rock mines involves the crushing and pulverizing of ore to prepare for the separation of valuable minerals from matrix rock. Hard ore may require substantive comminution, involving up to three stages of crushing followed by grinding operations. For the Project, ore will need to be broken down to under 65 mesh (210 micrometres [μm]) before it can be fed to the next ore processing step of flotation. The proposed underground mine design supports the extraction of 2,700 metric tonnes per day of ore, with a total of 18,986 kilotonnes of ore for the life of the mine. Several crushing and grinding technologies are available to attain the required particle sizes depending on the kind of ore and processing requirements.

4.4.2.2 Alternatives Identification

Based on the specifications of the ore and to optimize the comminution circuit for the Project, two alternative comminution circuit methods were identified in the screening step (Table 4.3-1) as feasible for the Project, as described below.

<u>Option 1: Three-stage Crushing and Two-stage Ball Mill Grinding</u>

For this option, underground jaw crushers first reduce the ore size. Subsequent comminution is achieved by two stages of crushing by cone crushers, followed by grinding the crushed ore through two stages of grinding by ball mills. Grinding for this method can typically be done dry or wet. The ball mill will grind the crushed ore by rotating a cylindrical device, partially filled with crushed ore plus a grinding medium, such as steel balls, around a horizontal axis.

<u>Option 2: One-Stage Crushing and SABC Circuit</u>

This option includes one stage of crushing followed by a semi-autogenous grinding (SAG) mill / ball mill grinding / pebble crushing grinding circuit, otherwise known as a semi-autogenous-ball milling-crushing (SABC) circuit. This option will reduce the ore discharged from the underground crusher using one SAG mill and one ball mill. A pebble-crushing circuit will be incorporated into the SAG mill circuit to improve the efficiency of the circuit. SAG mills have rotating drums, containing the crushed ore, which throw larger ore rocks into a cascading motion causing both impact breakage of larger rocks as well as compressive grinding of finer particles.

4.4.2.3 Alternatives Comparison

The alternative methods for ore comminution characteristics were compared against the four performance objectives as summarized in (Table 4.4-3).

<u>Technical and Project Economic Considerations</u>

The mill for the Project would have to process material with a relatively high moisture content that would also need to accommodate handling material during freezing winter conditions. The primary technical factors considered for the ore comminution assessment for the Project included size of footprint, ease of operation, maintenance, and potential issues with handling of material.

Option 1 (three stage crushing and two stage ball mill grinding) would have lower annual processing capabilities, likely leading to lower production rates, though this method is associated with higher nugget gold recovery due to having two stages of gravity concentration. Option 1 is slightly more energy efficient than Option 2; however, Option 1 (with three-stage crushing that involves more equipment pieces) requires a higher level of maintenance than Option 2. Coupled with the cold climate, the relatively high moisture content of the mill feed means that Option 1 would require more heating and face more issues for material handling compared to Option 2. Due to less dust produced with the one step crushing used in Option 2, the SABC option will also require less dust control mitigation measures compared to the three-stage crushing option crushing option (Tetra Tech 2012).

Overall, the simpler SABC circuit (Option 2) is preferred technically due to easier operation, smaller footprint, less maintenance, and less material handling issues. Economically, Option 1 was determined to have a slightly lower operating cost (around 5%) but a slightly higher capital cost (around 7%) compared to Option 2. The total cost difference between the two options over the life of the Project is insignificant (Tetra Tech 2012).

Environmental and Social Considerations

The primary intermediate components and receptor VCs, including their sub-component indicators, which would be subject to differential potential effects (therefore being relevant and comparable attributes) from the Project ore comminution alternatives were identified for the environmental and human environments, as listed in Table 4.4-4. A summary of the potential differential effects on these primary intermediate components and receptor VCs of the ore comminution alternatives are provided in Table 4.4-3 and in the text below.

Option 2 will have a slightly smaller footprint than Option 1, though this may not lead to an environmental advantage due to the site being located within the generally cleared mine area footprint. Option 2 will require slightly more electric power from the provincial grid to operate. Due to having more crushing stages, more fugitive dust emissions will be generated from Option 1. Water requirements would also be higher for Option 1 if wet grinding will be used. Overall, Option 2 is preferred environmentally as it reduces the required footprint and related fugitive dust, and water usage that will likely require mitigation.

There are few differential considerations regarding social aspects, with OH&S effects from fugitive dust expected to be higher for Option 1 due to the three-stage crushing and associated higher dust generation, although BMP dust mitigation measures would be applied for either method that would bring levels within BC air quality guidelines. From a labour perspective, Option 1 would likely slightly increase jobs generated from additional operational stages (e.g., three crushing stages). Overall, largely due to the reduced OH&S effects from Option 2, this option is preferred socially.

4.4.2.4 Selected Alternative

Based on the technical, economic, environmental, and social attributes considered, Option 2—one-stage crushing and SABC circuit—was selected as the preferred option primarily due to easier operation, fewer maintenance requirements, and lower dust control requirements. This conventional SABC circuit has been widely used in various mineral processing plants for mining and is a proven circuit to operate.

Table 4.4-3. Evaluation of Brucejack Gold Mine Project Alternative Methods for Ore Comminution

Alternative	ATTRIBUTE RATINGS AGAINST FOUR PERFORMANCE OBJECTIVES								FINAL RATING
	Environmental Attributes		Social Attributes		Technical Attributes		Project Economic Attributes		
OPTION 1: Three Stage Crushing and Two Stage Ball Mill Grinding	☒ More ambient fugitive dust emissions from three stages of crushing ☒ Higher water supply needs	Acceptable	☒ Higher dust-related OH&S risks, though can be mitigated using BMPs ☑ More operators required to run the three crushers, resulting in an increased number of jobs	Acceptable	☑ Better nugget gold recovery likely due to two stages of gravity concentration ☒ More maintenance requirements due to additional equipment and processing stages ☒ Higher dust control requirements due to three stages of crushing ☒ Due to high moisture content in the mill feed and the cold climate, more heating energy required to remain operational	Acceptable	☑ Slightly lower operating cost compared to Option 2 (about 5% difference) ☒ Slightly higher capital costs than Option 2 (about 7% difference) ☑ Total cost difference between the two options over the life of the mine is insignificant	Acceptable	ACCEPTABLE
OPTION 2: One Stage Crushing and SABC Circuit	☑ Significantly reduced ambient fugitive dust emissions ☑ Lower water supply needs	Preferred	☑ Minimizes dust-related OH&S risks requiring mitigation ☒ Fewer operators required, reducing number of jobs	Acceptable	☒ Reduced nugget gold recovery compared to Option 1 ☑ Easier to operate and maintain ☑ Fewer material handling issues, especially during winter ☑ Lower dust control requirements due to only one crushing stage	Preferred	☒ Slightly higher operating cost compared to Option 1 (about 5% difference) ☑ Slightly lower capital costs than Option 1 (about 7% difference) ☑ Total cost difference between the two options over the life of the mine is "very insignificant"	Acceptable	PREFERRED

Notes:
☑ = Preferred, ☒ ☑ = Acceptable, ☒ = Challenging, ☒ = Unfeasible; ✓ in the box indicates a relative advantage; ✗ in the box indicates a relative disadvantage. See Section 4.2.2 for description of attribute ranking methodology.
OH&S = occupational health and safety; BMP = best management practice

Table 4.4-4. Valued Component Attributes Compared for Ore Comminution Alternatives

Assessment Theme	Identified Component[1]	Compared Attributes[2]
Atmospheric Environment	• Air quality	• Fugitive dust emissions
Freshwater Environment	• Surface water quantity	• Relative water requirements
Human Environment	• Labour and income • Occupational Health & Safety (OH&S)[3]	• Relative number of jobs created • Safety risks from fugitive dust

[1] *Components listed include "subject area" and "sub-components" of VCs (see Chapter 6, Table 6.4-4)*
[2] *Attributes are linked to "indicators" of VCs (see Chapter 6, Table 6.4-4)*
[3] *Occupation Health and Safety is not within the scope of the Application/EIS, but considered here as an important consideration of Project alternatives*

4.4.3 Location of Final Flotation Concentrate Processing into Gold-Silver Doré

4.4.3.1 Purpose and Background

Following the ore comminution process (Section 4.4.3) the selected method to process the ore for the Project will involve conventional bulk sulphide flotation and gravity concentration to recover gold and silver from the ore. A flotation plant at the Brucejack Mine Site will produce bulk gold-silver flotation concentrate as well as gravity concentrate. To process the flotation concentrate into gold-silver doré, the flotation concentrate requires final processing. Hard rock gold mines typically utilize cyanidation as a standard practice to increase gold recovery. Using cyanide introduces management considerations and potential issues such as spill and contamination risks. To minimize environmental risks for the Project, Pretivm has investigated processing the final flotation concentrate off-site as an alternative to on-site.

4.4.3.2 Alternatives Identification

Two economically and technically feasible alternative locations were screened into the assessment (Table 4.3-1) for concentrate processing, as described below.

<u>On-site Concentrate Processing</u>

This alternative would involve the proponent processing the gold-silver bearing concentrate into doré, likely through cyanidation, in a leach facility situated at the Project site near Highway 37 between the Bell-Irving River and Bowser Lake (Figure 4.4-1) prior to selling the final gold and silver doré product. This option would also require adding a tailings storage facility (TSF) situated near the leach plant in order to accommodate the additional tailings produced by this final ore processing step.

<u>Off-site Concentrate Processing</u>

This alternative would involve selling the gold-silver bearing concentrate to a third party, resulting in transport of the concentrate for final processing to the third-party's off-site location via haul trucks from the Project site to a location to be determined based on a contract bidding process.

4.4.3.3 Alternatives Comparison

The two alternatives for final flotation concentrate processing into gold-silver doré were compared against the four performance objectives as summarized in Table 4.4-5.

<u>Technical and Project Economic Considerations</u>

On-site processing of the flotation concentrate would require the construction of an on-site leach plant (Figure 4.4-1), which would also require the design, permitting, and development of a TSF, as well as increase the power and water requirements for the Project. This alternative would involve processing the concentrate in a cyanide leach plant (cyanidation and recovery) at the Project site, likely near Highway 37 due to Brucejack Mine Site space constraints. Concentrate haul trucks and specialized vehicles for glacier travel would transport concentrate from the Brucejack Mine Site at Brucejack Lake east to the leach plant, approximately 70 km. This alternative would be more technically challenging from a construction, operation, and maintenance perspective; it would require construction and maintenance of the plant, along with the storage and management of cyanide and the waste generated in the TSF, in addition to potential delays or issues due to permitting and regulatory risk. Off-site processing would utilize existing facilities, owned, operated, and already permitted for industrial use by a third party, although this alternative would require the long-haul transport of the flotation concentrate, resulting in technical challenges such as shipment disruptions.

If the concentrate were shipped internationally, import restrictions, depending on destination, could either limit shipping options or require additional process requirements (e.g., reducing arsenic concentrations in the ore concentrate through dilution). Considering the above technical considerations overall, off-site processing is preferred as it reduces the technical issues of siting, permitting, constructing, operating, and maintaining a new leach plant facility and associated cyanide tailing management for the Project.

Economically, building an on-site leach plant would increase initial capital costs for the Project, as well as incurring additional closure costs. Although building a leach plant would increase initial capital cost and closure cost, on-site processing would likely generate better gold and silver sales values (assuming that both options use cyanidation to extract gold and silver). Also, on-site processing would likely have the advantages of: 1) no expensive shipping costs to an off-site smelter; 2) no potential concentrate shipment disruption issues; and 3) faster cash turnover. From an economic perspective overall, operational costs and lower payable gold and silver from off-site processing, means on-site processing is preferred, with off-site processing being acceptable.

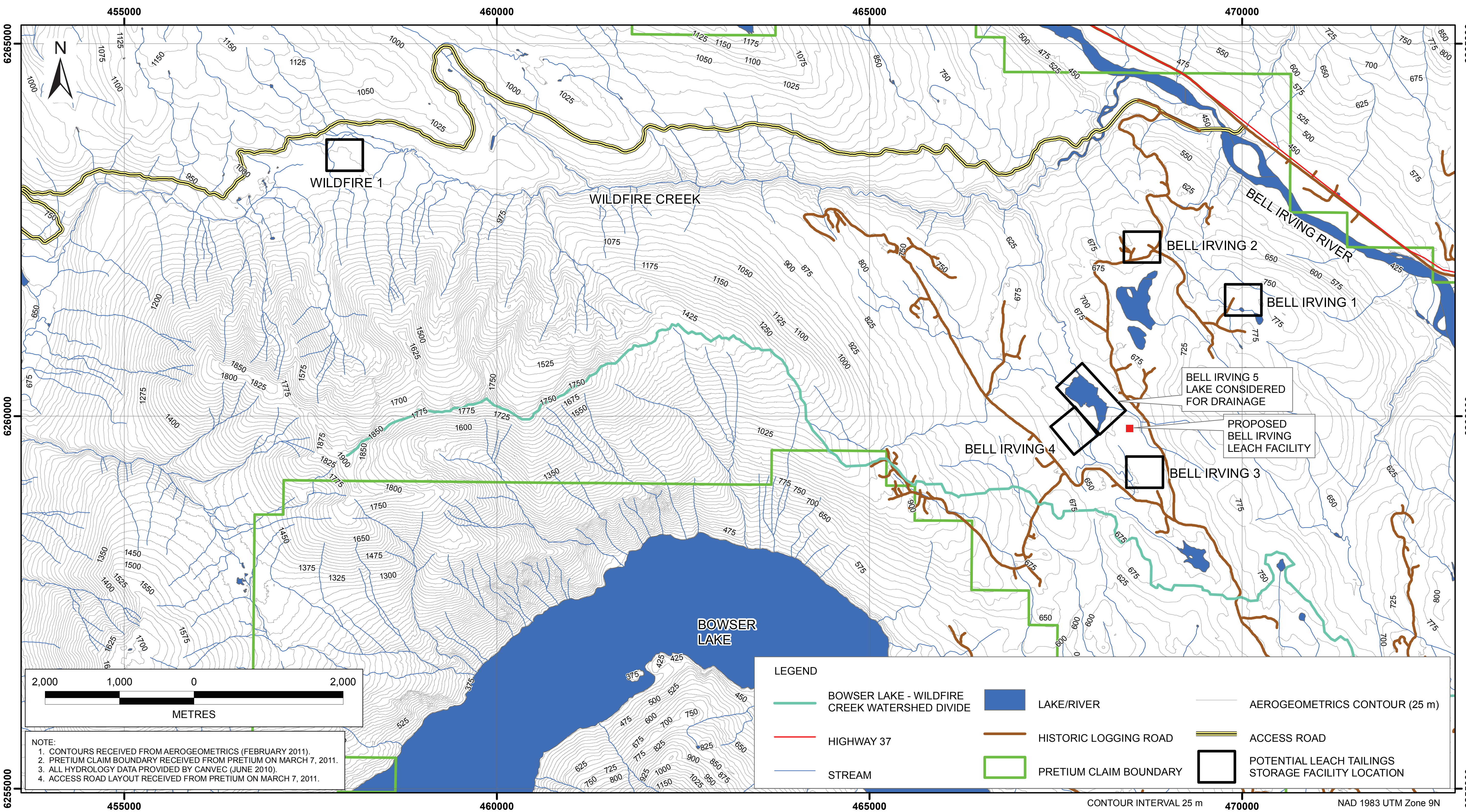
Environmental and Social Considerations

The primary intermediate components and receptor VCs which would be subject to differential potential effects (therefore being relevant and comparable attributes) from the Project ore flotation concentrate processing alternatives, were identified for the environmental and human environments, as listed in Table 4.4-6. A summary of the potential differential effects on these intermediate components and receptor VCs of the final flotation concentrate processing alternatives is provided in Table 4.4-5 and in the sections below.

Conducting final concentrate processing on-site would lead to greater facility-level air quality CAC and GHG emissions for the Project from constructing and operating the leach plant and associated TSF near Highway 37, though less off-site transport emissions by third-party haul truck contractors. Though levels would be mitigated to air quality objectives, on-site processing could lead to effects on local air quality. On-site final processing would have higher surface water requirements to operate the plant and TSF, affecting water quantity. Water quality would also potentially be affected by on-site processing, in particular from the TSF; risk of on-site accidental discharge would increase and need to be managed as well. Comparatively, off-site processing would minimize potential effects to local water quality; though increase risks of spills during transport. Though BMP mitigation measures would be used to mitigate effects to water quality and on-site risks associated with cyanide management and transport, this would add considerable extra management burden to the Project, and increase the chance for potential downstream effects on aquatic plankton, invertebrates and fish. Off-site processing would eliminate the on-site spill risks; there would be risks of ore concentrate spills during transport but these could be mitigated through following regulations set out by Transport Canada. On-site concentrate processing would result in a larger Project footprint from the site requirements for the processing plant and associated TSF development near the plant location (Figure 4.4-1); the larger footprint for the site, TSF and ancillary infrastructure would lead to increased habitat disturbance that may affect soil, plants, wetlands and wildlife in the area. Off-site floatation concentrate processing would utilize existing facilities, with no additional local footprint disturbance.

Environmentally, off-site processing is rated preferred overall as it avoids or minimizes most potential environmental effects on intermediate components and receptor VCs in the Project area. While environmental risks are higher with on-site processing, this approach is still considered environmentally acceptable assuming relevant BMPs are followed for mitigation, which bring potential adverse effects to acceptable levels.

Figure 4.4-1
Proposed Off-site Leach Facility and Potential Leach Tailings Facility Locations



Source: BGC Engineering Inc. (2013).

Table 4.4-5. Evaluation of Brucejack Gold Mine Project Alternatives for Location of Final Processing of Gold-Silver Flotation Concentrate into Doré

Alternative	ATTRIBUTE RATINGS AGAINST FOUR PERFORMANCE OBJECTIVES								FINAL RATING
	Environmental Attributes		Social Attributes		Technical Attributes		Project Economic Attributes		
On-site Processing by Proponent	☒ Adding Project mill and TSF facility increases GHG & CAC emissions from land clearing and operations ☒ Reduced local air quality from higher CAC production from process plant and associated TSF; though could be mitigated with BMPs ☑ No GHG and CAC emissions from transport of ore concentrate ☒ Would involve on-site effluent discharge to local surface water; water quality effects could be mitigated with BMPs, but would require more risk management considerations than the off-site ore concentrate transport alternative ☒ Increased soil and terrestrial habitat loss ☒ Increased potential effects from habitat loss/ alteration, disruption, disturbance, attractants and chemical hazards on wildlife from plant and TSF presence and operation	Acceptable	☑ Higher economic benefits and diversification related to higher on-site job creation; though less transport driver jobs ☒ Land will be used for process plant and TSF, which will make it permanently unavailable for other use, although post closure reclamation will provide some mitigation ☒ Expansion in land use for the Project may affect current use of lands and resources for traditional purposes in the area ☒ Increased risks of accidental spills (i.e., from the TSF and related reagent transport), that may affect downstream water quality in the nearby Bell-Irving River, increasing risk to fisheries or human health ☑ Removes off-site risk of concentrate transport spills ☒ Increased OH&S risks from cyanide transportation and handling (thought manageable to acceptable levels with BMPs)	Acceptable	☑ No long-distance transport of concentrate, reducing potential concentrate shipment disruption ☒ Would require construction of an on-site leach plant and TSF that may be challenging given on-site space constraints ☒ Greater permit requirements and potential regulatory risk to Project for leach facility and associated TSF ☒ Increased power requirements in the Project area that may require an extra power line or diesel generators ☒ Increased management required for safe handling of reagents such as cyanide, and long term management of the TSF	Challenging	☑ Overall, on-site processing would yield the most beneficial Project economics ☑ Faster recuperation of operating costs ☒ Increased initial capital costs for access roads, the leach plant, a diesel electrical power plant, a leach residue management facility, and ancillary facilities (camp and services) ☑ Reduced operating costs for shipping ☒ Additional reclamation and waste management costs	Preferred	CHALLENIGING
Off-site Processing by Third Party	☑ Eliminates on-site mill and TSF facility so minimizes associated GHG and CAC emissions ☑ Improved local air quality at Project site ☒ Increased third-party contractor transport GHG and CAC emissions for ore concentrate ☑ No discharge of mill and TSF effluent in the Project area, minimizing local water quality effects and spill risks; BMPS would manage ore concentrate transport related spill risks ☑ Reduced potential effects on aquatic species, including fish, from effluent and potential spills ☑ Reduced soil and terrestrial habitat loss ☑ Minimizes effects on wildlife from habitat loss or alteration, disruption, disturbance, attractants and chemical hazards	Preferred	☒ Fewer economic benefits and diversification related to lower on-site job creation; though higher transport driver jobs ☑ Reduces industrial land use without the requirement to site a mill and permanent TSF ☑ Removes additional local effects to current land use as mill and TSF will not require local site ☑ Removes the risk of local spills from ore processing and TSF reducing risk to downstream fish or human health ☒ Increased risks of ore concentrate spills off-site (i.e., along Highway 37 which may affect country foods along travel route); mitigated to acceptable levels by following Transport Canada regulations ☑ Reduced on-site OH&S risks of cyanide handling (though manageable to acceptable levels with BMPs)	Preferred	☑ Third-party smelters could produce better gold and silver recoveries ☑ Off-site facilities are extant, with this option reducing the technical issues of siting, construction, operating, and maintaining a new leach plant facility in an isolated location ☑ No permit requirements for leach facility and leach residue storage facility ☒ Destination import restrictions could either limit shipping options, or require additional process requirements ☒ Potential disputes with smelters on metal recovery, grade, and tonnage ☒ Less control on final product sale	Preferred	☒ Overall, less economically beneficial than on-site processing ☑ Lower initial capital cost, since this option does not require a leach plant or TSF	Acceptable	PREFERRED

Notes:

☑ = Preferred, ☒ ☑ = Acceptable, ☒ = Challenging, ☒ = Unfeasible; ✓ in the box indicates a relative advantage; ✗ in the box indicates a relative disadvantage. See Section 4.2.2 for description of attribute ranking methodology.
CAC = criteria air contaminant; GHG = greenhouse gas; TSF = tailing storage facility; BMPs = best management practices

Table 4.4-6. Valued Component Attributes Compared for Final Ore Concentrate Processing

Assessment Theme	Identified Component[1]	Compared Attributes[2]
Atmospheric Environment	• Climate • Air quality	• GHG emissions • Fugitive dust emissions
Freshwater Environment	• Surface water quality • Surface water quantity • Primary and secondary producers • Fish habitat • Fish	• Concentrations of water contaminants (i.e., dissolved metals and sediment) • Project water requirements • Abundance and diversity of plankton and invertebrate species • Habitat loss and alteration • Water quality degradation and mortality
Terrestrial Environment	• Soil quantity • Plants • Ecosystems (parkland, riparian, forested) • Wildlife	• Soil loss levels • Potential removal of rare or economically / culturally important plants • Changes in ecosystem function and extent • Habitat loss or alteration, disruption of movements, sensory disturbance, attractants, and chemical hazards
Human Environment	• Labour and income • Economic activity • Commercial land use • Non-commercial land use • Drinking water quality • Non-commercial land use • Occupational Health & Safety (OH&S)[3]	• Relative number of jobs created, changes in tax revenues • Economic activity level and diversification • Changes in access to land and resource use • Changes in access to traditional land and resource use related to hunting and fishing, changes to visual quality • Concentrations of water contaminants (i.e., dissolved metals and sediment) from processing as well as accidental spills • Changes in access to current land and resource use, changes to visual quality • Safety risks from fugitive dust, air quality contaminants, and accidental leaks and spills at facility and in transit

[1] Components listed include "subject area" and "sub-components" of VCs (see Chapter 6, Table 6.4-4)
[2] Attributes are linked to "indicators" of VCs (see Chapter 6, Table 6.4-4)
[3] Occupation Health and Safety is not within the scope of the Application/EIS, but considered here as an important consideration of Project alternatives

From a social perspective, off-site processing will lead to fewer local economic benefits due to no extra jobs to construct and operate a concentrate processing plant and associated TSF, though the need for haul truck contractors would increase. The converse is the case for the on-site alternative. Industrial land use for the Project would be lower with the off-site alternative, which reduces potential effects on current land use in the area of the potential leach plant and TSF. Off-site processing will also reduce OH&S risks to Project personnel from handling cyanide (though manageable to acceptable levels using BMPs). Off-site processing would also reduce any potential risks to downstream waterways from accidental spills; this reduces potential risks to fisheries and human health. There would be increased risk of concentrate spill during transport for the off-site option; however this risk would be less potentially hazardous and simpler to manage through the use of practices set out under Transport Canada transportation regulations. Overall, off-site processing is preferred from a social perspective due mainly to no on-site use of cyanide. In terms of social benefits associated with the extra labour utilization, on-site processing is acceptable assuming relevant mitigation and management measures are put in place to address social risks.

4.4.3.4 Selected Alternative

Off-site processing of the concentrate has been selected based on the preferred ratings for environmental, social, and technical attributes. The final concentrate will be dewatered and loaded in 2-tonne bags. The bags will be transported in containers via properly equipped vehicles to the proposed Knipple Transfer Area, where the containers will then be transferred to B-train trucks for shipment off-site.

It is currently assumed that the concentrate will be shipped to the Horne Smelter in Noranda, Québec. For this option, concentrate will be transported south along Highway 37, and then Highway 16 to Terrace, a one-way distance of about 310 km. The concentrate bags will be received in Terrace, inventoried, and loaded into open top gondola cars. The estimated transit time from Terrace to the Horne Smelter is 13 days. As a contingency, a second option for concentrate transport would be to transport the concentrate via B-train truck south along Highway 37 and then west on Highway 37A to Stewart. At the Port of Stewart, the concentrate would be offloaded for transfer to deep sea freighters for shipment to offshore smelters. Total one-way distance travelled by each truck originating from the Project to Stewart will be 175 km on the Brucejack Access Road, Highway 37, and Highway 37A (Chapter 5, Project Description).

4.4.4 Tailings Disposal Method

4.4.4.1 Purpose and Background

The Project is expected to produce ore at a rate of 2,700 tonnes per day over the 22-year Operation phase. The ore will be processed through a conventional sulphide flotation and gravity concentration circuit, generating approximately 16 Mt of tailings that will require safe and effective disposal. The gold-silver flotation concentrate will be dewatered and trucked off-site for final processing (Section 4.4.4), which will substantially reduce the total tailings for the Project with related environmental benefits (Section 4.6). The flotation tailings are not anticipated to be acid generating, and will be predominantly clay- and silt-sized fraction, with approximately 80% by dry weight passing the No. 200 sieve (74 microns; BGC Engineering Inc. 2013a).

Identifying suitable tailings disposal locations for the Project required consideration of key factors including minimizing habitat disturbance and loss, preventing and minimizing water quality impacts, minimizing transport distances, and finding a sufficiently large area to contain the tailings. Disposal of tailings for the Project is also associated with the decision for waste rock disposal (Section 4.4.5) as similar methods are considered for both and capacity is limited in underground stopes; however, the sections of this assessment have been separated out to increase clarity regarding their specific differences. Appendices 4-A and 4-B provide more detail on some aspects of the alternatives considered for tailings and waste rock.

4.4.4.2 Alternatives Identification

During the screening step, four tailings disposal methods were assessed, including paste backfill into stopes of the underground mine; subaqueous deposition into Brucejack Lake; deposition as conventional slurry into a TSF; and dry stacking of filtered tailings. The screening led to TSF and dry stacking options being discarded (Table 4.3-1). Multiple TSF sites were investigated by Pretivm at an earlier design stage (Figure 4.4-1), but were deemed to be technically unfeasible to develop at the Brucejack Mine Site due to inadequate storage capacity and challenging topography, meaning a site would have to be developed somewhere near Highway 37 (Section 4.4.4). In addition, due to the relatively small size of the mine, TSF storage would not be cost effective. The proposed TSF sites that were discarded are illustrated in Figure 4.4-2, as well as in the report by BGC Engineering Inc. provided in Appendix 4-B, Brucejack Project - Tailings Alternatives Assessment (DWG No. 04). Dry stacking was rejected since—given the wet climate (unsuitable for dry stacking), difficult mine site access, and inadequate storage capacity—this method was determined to be technically unfeasible. As a result, the two tailings disposal methods discussed below were screened into the detailed assessment.

Tailings Paste Backfilling

Backfilling is required for the Project to achieve stability and grade control. Unclassified mill tailings from initial ore flotation processing (Section 4.3.4) will be directed to a paste plant and mixed with adequate cementitious binder to form paste backfill that will meet the strength requirements of re-exposure to adjacent mining. Stopes that will not be re-exposed may be backfilled with unconsolidated waste rock and/or by paste fill with sufficient binder to remove any risk of future liquefaction (low-strength paste fill). The paste fill distribution system will transport the paste from the surface plant to the underground stopes through a pipeline system based on a dual pumping system. A positive displacement pump in the paste fill plant will provide paste to the underground mine. High-strength paste fill will be required in the lower portion of all primary and secondary stopes that will be undercut by sill extraction from below. Estimates of volumes of paste backfill required include 139,000 m^3 of high-strength paste, 4,166,000 m^3 of regular paste, and 1,714,000 m^3 of low-strength paste. The amount of binder required to create these volumes is estimated at 286,000 tonnes. Waste rock will also be required for use to consume stope voids that might otherwise receive mill tailings in the form of paste fill where strength specifications of the waste rock are suitable. On closure, the mine will be flooded and the backfill will become saturated with water, minimizing the potential for acid rock drainage (Tetra Tech 2013; Chapter 5, Project Description).

Subaqueous Deposition of Tailings

Brucejack Lake has been used for the disposal of mine waste in the past (Section 4.4.6). For subaqueous disposal of tailings into Brucejack Lake using a fluidized mound at the outfall, tailings slurry would be discharged from a pipe extending along the bottom of the lake to a sand filter located near the deepest part of the lake (85 m). An agitated mixing tank downstream of the thickener used in the mill process would ensure that the tailings slurry at the pipe discharge will have about 35% solids by weight. The discharge point of the pipeline may be raised from time to time to address the backpressure in the pipeline caused by the weight of the overlying tailings. Subaqueous discharge of tailings through a sand filter has been used successfully at other locations to minimize the release of suspended solids into the overlying water body (Tetra Tech 2013; Chapter 5, Project Description).

A second subaqueous deposition option in which thickened tailings would be discharged at depth into the lake is currently under investigation. This option would use similar equipment to the paste backfill alternative.

4.4.4.3 Alternatives Comparison

The alternative tailings disposal attribute characteristics were compared against the four performance objectives as summarized in Table 4.4-7.

Technical and Project Economic Considerations

Approximately 16 Mt of tailings will be produced throughout the life of the mine (LOM). The use of backfill is considered integral to the mine plan to maximize both orebody recovery and mining productivity (Tetra Tech 2013). The backfilling of the mining voids will be accomplished with a combination of paste backfill (composed of thickened tailings and a cementitious binder) and waste rock, each of which has different strength characteristics that will direct where and how they will be applied. It is estimated that about 8 Mt of tailings can be stored underground in paste backfill over the life of the mine. During the Construction phase and the first three years of the Operation phase, there will not be sufficient void space underground for the storage of tailings in paste backfill. During this time, an alternative tailings storage method is required. In addition, during the LOM, the underground disposal of tailings will be limited ultimately by available stope space. Accordingly, a total of approximately 8 Mt of tailings will not be able to be stored underground, leaving subaqueous disposal as the only technically/economically feasible option for these tailings.

Brucejack Lake is 1,200 m long, 600 m wide (782,000 m^2), up to 85 m deep, and has a total volume of 30.4 Mm^3 (Rescan 2013b; Chapter 5, Project Description), which provides enough capacity to store all the tailings not used as backfill (totalling approximately 8 Mt or 6.3 Mm^3). Assuming a flat-line tailings surface, there will be approximately 40 m (maximum height) of tailings on the lake bottom. No dams are required to impound this volume of tailings for this approach.

Disposing tailings as backfill will require a paste plant and ancillary piping and equipment to distribute tailings in the stopes while disposing tailings in Brucejack Lake to a fluidized mound would require an agitated mixing tank and ancillary piping and equipment to pump tailings into the lake. Disposal of thickened tailings to the lake would require similar equipment as the paste backfill alternative. It is assumed that the construction and operational complexity, as well as power and water requirements for these two options are roughly equivalent.

Since the use of tailings in paste backfill is integral to the mine plan and provides stable permanent storage for tailings, this technically feasible and suitable alternative is rated as being preferred technically, while subaqueous disposal of tailings in Brucejack Lake is rated acceptable.

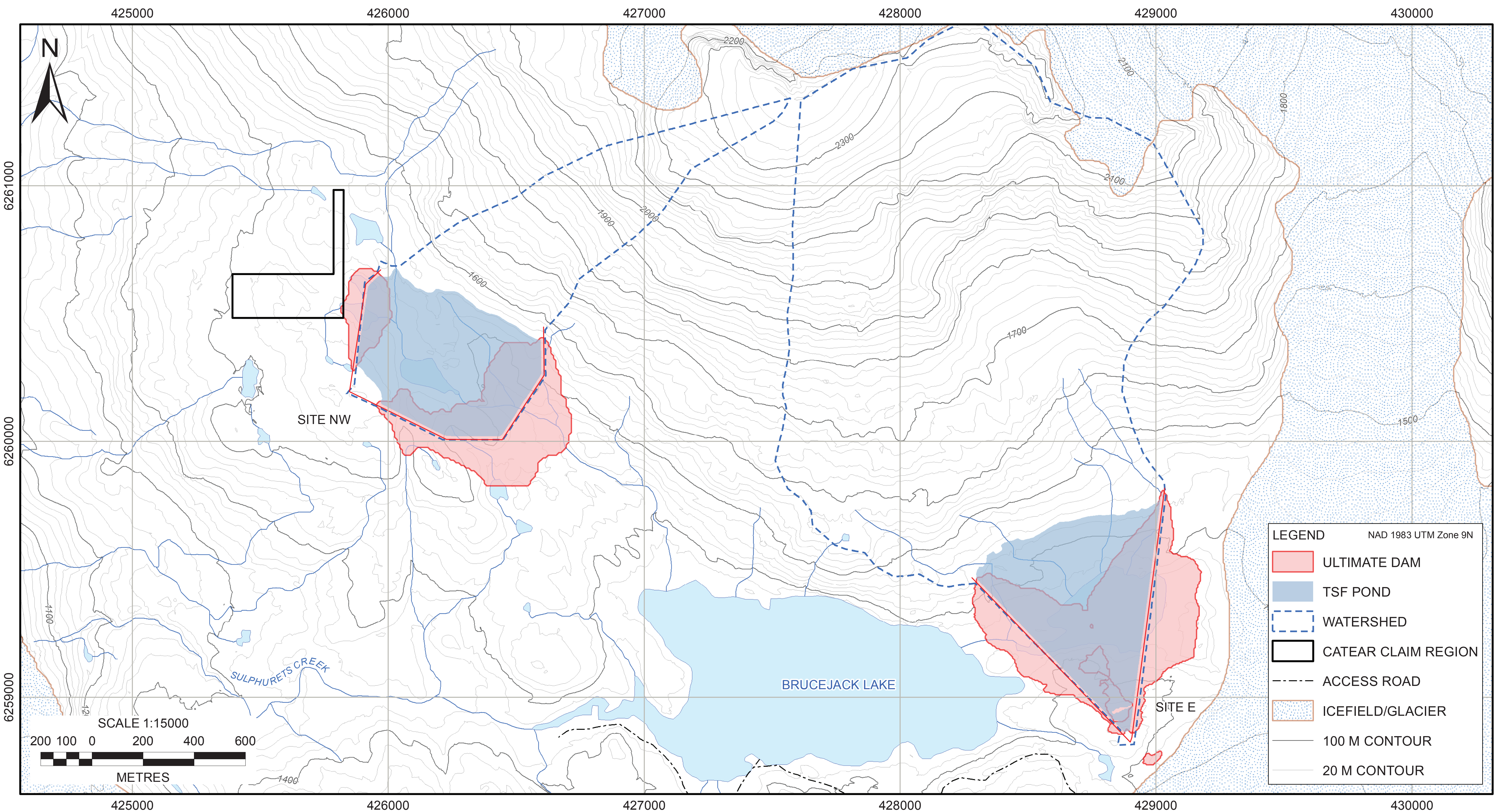
From an economic perspective, paste backfilling minimizes expenses compared to lake disposal as it helps maximize orebody recovery and mining productivity. Accordingly, backfill of tailings is rated as being economically preferred, with subaqueous disposal of the tailings rated acceptable.

Environmental and Social Considerations

The primary intermediate components and receptor VCs that would be subject to differential potential effects (therefore being relevant and comparable attributes) from the Project tailings disposal methods were identified for the environmental and human environments, as listed in Table 4.4-8. A summary of the potential differential effects on these intermediate components and receptor VCs of the tailings disposal method alternatives is provided in in Table 4.4-7 and in the text below.

For subaqueous disposal, tailings will be placed at the bottom of Brucejack Lake using mitigation methods to protect water quality through minimizing TSS concentrations, such as a sand filter at the discharge point that will act to trap fine tailings particles, reducing suspended solids in the overlying water. The tailings will accumulate at the pipeline terminus, effectively increasing the size of the sand filter as discharge proceeds. Depositing tailings at the east end of the lake will maximize the depth of deposition and the distance from the lake outlet, which will further minimize the potential for suspended solids discharge from the lake.

Figure 4.4-2
Brucejack Project Tailing Storage Facility Alternatives Considered



Source: BGC Engineering Inc. (2013).

Table 4.4-7. Evaluation of Brucejack Gold Mine Project Alternatives for Tailings Disposal Method

Alternative	ATTRIBUTE RATINGS AGAINST FOUR PERFORMANCE OBJECTIVES								FINAL RATING
	Environmental Attributes		Social Attributes		Technical Attributes		Project Economic Attributes		
Tailings paste backfill into underground stopes	☑ Avoids changing surface water quality in Brucejack Lake and Brucejack Creek ☑ Minimizes potential adverse effects on aquatic resources (i.e., phytoplankton, zooplankton and sediment quality) in Brucejack Lake and Brucejack Creek	Preferred	☑ Employs more workers for operation of paste plant	Preferred	☑ Lower monitoring and mitigation needs ☑ Maximizes both orebody recovery and mining productivity as tailings are an available and convenient source of backfill	Preferred	☑ Lowest capital and operating expenses due to minimized distance and infrastructure needed compared to transporting tailings to Brucejack Lake ☑ Economically the most cost effective to use paste to maximize mining efficiency	Preferred	PREFERRED
Subaqueous disposal into Brucejack Lake	☒ Will alter water quality in Brucejack Lake and its outlet, Brucejack Creek ☒ Water quality changes will increase effects to aquatic resources in Brucejack Lake and Brucejack Creek (i.e., phytoplankton, zooplankton and sediment quality) in Brucejack Lake and Brucejack Creek)	Acceptable	☒ Lower number of new jobs created	Acceptable	☒ Higher need for monitoring and mitigation measures (i.e., for TSS measures) ☒ Still need to backfill, need to use another source of backfill material if tailings not used ☒ Cannot use 100% of the tailings as paste so have to dispose of the remainder as tailings into lake	Acceptable	☒ Higher capital and operating expenses to transport tailings extra distance to Brucejack Lake	Acceptable	ACCEPTABLE

Notes:
☑ *= Preferred,* ☒ ☑ *= Acceptable,* ☒ *= Challenging,* ☒ *= Unfeasible;* ✓ *in the box indicates a relative advantage;* ✗ *in the box indicates a relative disadvantage.*

Table 4.4-8. Valued Component Attributes Compared for Tailings Disposal Alternatives

Assessment Theme	Identified Component[1]	Compared Attributes[2]
Freshwater Environment	• Surface water quality	• Concentrations of total and dissolved metals, nutrients, turbidity, TSS, temperature in Brucejack Lake and Brucejack Creek
	• Aquatic resources: primary and secondary producers	• Abundance and diversity of periphyton, phytoplankton, benthic invertebrates, and zooplankton; changes in sediment quality in Brucejack Lake and Brucejack Creek
Human Environment	• Labour and income	• Relative number of jobs created

[1] *Components listed include "subject area" and "sub-components" of VCs (see Chapter 6, Table 6.4-4)*
[2] *Attributes are linked to "indicators" of VCs (see Chapter 6, Table 6.4-4)*

The alternative of deposition of thickened tailings into the lake is still being investigated, but is thought to result in less potential for release of sediments into the water column.

In addition, tailings are not anticipated to be acid generating, thereby minimizing risk of water quality issues associated with disposal in the lake (Chapter 5, Project Description).

Any potential residual effects on sediment and surface water quality from disposal of tailings and other activities are expected to be localized. Brucejack Lake and Brucejack Creek are not fish-bearing, with the closest fish habitat (at the confluence of Sulphurets Creek and the Unuk River) approximately 20 km downstream of the Project. Due to this considerable distance, and because effects on surface water quality are anticipated to be restricted to the local receiving environment, the Project is not predicted to cause adverse effects on fish and fish habitat in Sulphurets Creek or the Unuk River. The potential for any transboundary effects (in the Unuk River across the BC/Alaska border) to occur (i.e., degraded water quality 45 km downstream of the discharge pipeline) is considered extremely unlikely (Chapter 5, Project Description). Although considered unlikely to cause significant environmental effects, a long-term monitoring program (Section 29.3, Aquatic Effects Management Plan) will be undertaken to ensure the water cover is maintained and to monitor the water quality of the lake and downstream areas.

Underground disposal of tailings will utilize paste fill with sufficient binder to remove any risk of future liquefaction (Tetra Tech 2013). Environmentally, this approach is preferred as it minimizes risk of tailings leaching, while keeping a significant portion of tailings away from surface water bodies (Chapter 5, Project Description).

There are no major differences in the social effects between the different tailing disposal methods. Paste backfilling will lead to more skilled labour being required to spread the paste in the underground stopes. Due to reduced potential environmental effects overall associated with paste backfilling tailings, this method is rated as preferred, while subaqueous disposal is rated as acceptable, and the best alternative environmentally and socially when paste backfilling is not feasible for use.

4.4.4.4 Selected Alternative

Underground disposal of tailings utilizing stope voids and paste backfilling is the preferred method of tailings disposal due to the technical and economic benefits, and reduced environmental risks.

Due to limitation of the paste backfilling method (i.e., there is nowhere to put tailings underground while the underground mine is being constructed, as well as ultimate underground space limitations), subaqueous disposal into Brucejack Lake was deemed the best option for disposal of the remaining 8 Mt of tailings.

4.4.5 Waste Rock Disposal Method

4.4.5.1 Purpose and Background

Determining the location and method of waste rock disposal is one of the key decisions for metal mines. Waste rock at the Project will consist of overburden and other rock materials (i.e., soil and fine sand to large boulders) excavated in order to create foundation pads for surface facilities and rock excavated from underground to develop underground access to ore zones, ventilation raises, haul roads, and other infrastructure. Waste rock can be barren of precious metals or have concentrations below cut-off grades, so what is originally classified as waste may change over a project lifetime based on metal prices.

Historically at the site, previous owner Newhawk Gold Mines Ltd. stored waste rock and low-grade ore (from 5.3 km of excavated underground workings) in piles or pads at the surface of the site. After abandoning production plans at the site in 1990, Newhawk Gold Mines Ltd. reclaimed the property in 1998/1999, including the removal of all waste rock and ore above the water table. With the assistance of the British Columbia Ministry of Energy and Mines (BC MEM), a qualitative assessment of waste rock disposal methods was conducted and a decision made to dispose approximately 60,890 m^3 of waste rock and ore into Brucejack Lake in 1999. The BC MEM concluded that "if the water quality impacts resulting from the dissolution of built-up weathering products could be shown to be insignificant, disposal of waste rock in Brucejack Lake would result in the lowest liability and environmental risk" (MEND 2005).. Since late 2012, Pretivm has been subaqueously disposing of waste rock generated from bulk sample collection at the VOK into the southwest corner of Brucejack Lake, with Ministry approval.

Over the LOM, the Project will generate about 5 Mt of waste rock from general construction activities (e.g., cut-and-fill required for the mill building pad area) and extraction activities from underground mining (BGC Engineering Inc. 2013b). Waste rock volumes have been significantly reduced through the selection of underground mining rather than open-pit mining for the Project.

Identifying suitable waste rock disposal locations for the Project requires careful consideration of key factors including: minimizing habitat disturbance and loss, preventing and minimizing potential metal leaching (ML) and acid rock drainage (ARD), minimizing haul distances, and finding a sufficiently large area to contain the waste rock in a stable configuration. A significant portion of the waste rock will be potentially acid generating (PAG), which will require mitigation to prevent ML/ARD. AMC Mining Consultants (Canada) Ltd. have estimated that about 1.1 million tonnes (531,000 m^3) of PAG rock will be produced from the underground mine during the construction stage, and approximately 1.64 Mm^3 of waste rock during operation (AMC 2013). Waste rock disposal is also linked to the disposal of tailings for the Project (Section 4.4.5) due to similar options available for disposal of these two waste streams.

4.4.5.2 Alternatives Identification

The two waste rock disposal methods described below were deemed potentially feasible based on basic technical and economic criteria (Table 4.3-1), and screened into the detailed assessment.

Subaqueous Deposition into Brucejack Lake

This alternative would involve deposition of waste rock for disposal in Brucejack Lake. This kind of subaqueous disposal is regarded as "generally the most effective means of preventing ARD and reducing metal leaching" since the water acts as an oxygen barrier that prevents sulphide oxidation (Price 1998). Deposition into Brucejack Lake would be possible from the Construction phase onwards.

Backfill into Stopes of the Underground Mine

This alternative would involve backfilling waste rock into the stopes (open spaces left after excavation of ore) in the underground mine. Backfilling into voids in underground mines helps to improve the stability of the rock mass around the stopes and reduce mine waste requiring disposal at surface (Li 2009). In BC it is recognized that for many mines, "the best waste disposal strategy in terms of limiting liability, risk, and land use, is the backfilling of wastes into existing excavations" (Price 1998); this is partially due to the ability of this method to prevent the formation of ML/ARD from PAG rock, especially when the chamber is effectively flooded as well. The option of backfilling into voids will not be available until such time that appropriate voids become available, and would be done in conjunction with paste backfill to optimize stability and other technical requirements (Section 4.4.5).

4.4.5.3 Alternatives Comparison

The alternative waste rock disposal attribute characteristics were compared against the four performance objectives as summarized in Table 4.4-9.

Technical and Project Economic Considerations

Technical criteria used in choosing between the two waste rock disposal alternatives involved considerations for Project scheduling, capacity, and site conditions, among other factors. During the first three years of operations, waste rock generated (approximately 2 Mt) cannot be stored underground as there will be nowhere to put it until sufficient underground stopes are opened up (BGC Engineering Inc. 2013b). Therefore, subaqueous disposal of the waste rock is the only technically feasible option for this first 2 Mt of generated waste rock.

As stated previously, Brucejack Lake has been used to deposit small volumes of waste rock in the past and is currently authorized to be used to dispose of waste rock (BGC Engineering Inc. 2013b). From a technical perspective, Brucejack Lake provides enough capacity to store all the generated waste rock. Subaqueous disposal does require the development of additional infrastructure including a platform/causeway of not-PAG waste rock out into Brucejack Lake to enable disposal in the appropriate locations in the lake (i.e., in a location ensuring a minimum depth of submersion of one metre). In addition, an aerator may be required to keep a channel in Brucejack Lake ice-free during winter to allow continued waste rock deposition. This extra infrastructure and equipment will increase the technical requirements to operate this disposal method compared to backfilling as well as increase capital and operating expenses.

For the remainder of the waste rock (3 Mt), both waste rock disposal alternatives are technically feasible and suitable for the Project. Backfill of waste rock will be the most technically efficient method to dispose of waste rock, and is also considered to be integral to the mine plan to maximize both orebody recovery and mining productivity (Tetra Tech 2013). The underground stopes have a limited capacity to store waste rock and/or tailings paste since rock volume expands once excavated and broken, which limits this option as being the sole alternative for disposal of all waste rock for the Project. Although limited by capacity and temporal constraints, backfill of waste rock is rated as being preferred, with subaqueous disposal of the waste rock rated as acceptable for the remainder of waste rock that cannot be disposed of through backfilling.

From an economic perspective, backfilling stope voids underground is the most economically feasible alternative as it reduces the labour and transport required to move waste rock to the surface and dispose of it in Brucejack Lake, while also helping maximize orebody recovery and mining productivity. For these reasons, backfill of waste rock is rated as being preferred, with subaqueous disposal of the waste rock rated as acceptable.

Environmental and Social Considerations

The primary intermediate and receptor VCs (including their sub-component indicators), with relevant and comparable attributes due to differential potential effects from the Project waste rock disposal alternatives, were identified for the environmental and human environments, as listed in Table 4.4-10. A summary of the potential differential effects on these primary intermediate and receptor VCs of the waste rock disposal alternatives is provided in in Table 4.4-9 and in the text below.

As discussed in Section 4.4.5.2, both backfilling in stopes and subaqueous disposal in Brucejack Lake are methods of disposing of waste rock that will reduce the potential for ML/ARD and related environmental effects compared to other disposal methods such as rock storage dumps. Backfilling is considered a best practices method of waste rock disposal as it can help to prevent ML/ARD as well as provide required stability to underground stopes, thereby also helping to minimize subsidence (caving in of the ground surface into underground voids) risk and extent. Flooding of the underground workings at closure will also help to prevent long term ML/ARD formation for this method. Brucejack Lake emerged as the preferred alternative for subaqueous disposal in the area in a study conducted by the BC MEM in the late 1990s, and has since been successfully used and managed by Pretivm for disposing of waste rock generated from bulk sample collection. Historic disposal of waste rock in Brucejack Lake has not been found to have led to significant effects on Brucejack Lake water quality; however, backfilling waste rock into the underground stopes would minimize any changes to water quality compared to deposition in the lake.

Brucejack Lake and Brucejack Creek are not fish-bearing, with the closest fish habitat (confluence of Sulphurets Creek and the Unuk River) approximately 20 km downstream of the Project. Brucejack Lake is typically stratified, which will promote retention of TSS in the deep, dense hypolimnion. Water quality (including TSS) effects monitoring will be required in Brucejack Lake and Brucejack Creek and TSS effects may require addition of flocculant to the lake or other mitigation measures. However, it is not anticipated that there will be water quality effects beyond Brucejack Lake and Brucejack Creek, so fish are not anticipated to be adversely affected by waste rock disposal in the lake. Aquatic life, such as phytoplankton and zooplankton, is anticipated to be affected by any significant changes to the water quality resulting from waste rock disposal in the lake.

Disposal of waste rock into Brucejack Lake will need to be timely to prevent oxidation of the PAG rock. As part of the mitigation strategy associated with this waste rock disposal method, similar to the reclamation work that occurred in the 1990s, a platform will be constructed out into the lake topped with non-acid-generating waste rock so that trucks can dump rock at greater depths and to ensure that sufficient water cover (over 1 m) is maintained over the waste rock to prevent oxidation, which is a contributory factor to the formation of acid rock drainage.

There are no major differences in the social effects between the different waste rock disposal methods. Due to the presence of geohazards and potential geotechnical instability of the platform, there will be increased OH&S risks to personnel on the platform to Brucejack Lake, but these will be mitigated to acceptable levels using BMPs such as implementing monitoring and management plans for crew on the causeway. Underground disposal of waste rock poses less risks for personnel, but there is insufficient room underground for the anticipated volume of waste rock.

Due to reduced environmental effects overall associated with backfilling the waste rock, this method is rated as preferred, while subaqueous disposal is rated as an acceptable alternative environmentally and socially when backfilling is not available.

4.4.5.4 Selected Alternative

Underground disposal of waste rock through backfilling into stope voids is the preferred method of waste rock disposal due to the technical and economic benefits and reduced environmental risks.

Due to limitation of the backfilling method (i.e., there is nowhere to put waste rock underground while the underground mine is being constructed during the first two years), subaqueous disposal into Brucejack Lake was deemed the most suitable option for disposal of the initial approximately 2 Mt of waste rock due to it being demonstrated as technically, economically, and environmentally acceptable in the past, as well as it offering the best solution to managing PAG waste rock and ML/ARD. Furthermore, there will not be sufficient volume for underground disposal of all of the waste rock and tailings, so some waste rock will continue to be disposed of in Brucejack Lake throughout the LOM.

Table 4.4-9. Evaluation of Brucejack Gold Mine Project Alternatives for Waste Rock Disposal Method

Alternative	ATTRIBUTE RATINGS AGAINST FOUR PERFORMANCE OBJECTIVES								FINAL RATING
	Environmental Attributes		Social Attributes		Technical Attributes		Project Economic Attributes		
Backfill into Mine Stopes	☑ Minimizes GHG and air quality emissions and noise levels ☑ Avoids changes to surface water quality in Brucejack Lake and Brucejack Creek ☑ Minimizes effects to aquatic life (i.e., phytoplankton, zooplankton and sediment quality) in Brucejack Lake and Brucejack Creek ☑ Minimizes fugitive dust effects on local plants ☑ Minimizes ecosystem disturbance ☑ Minimizes wildlife disruption and disturbance	Preferred	☑ Reduced OH&S risks underground compared to dumping from causeway into Brucejack Lake	Preferred	☑ Maximizes both orebody recovery and mining productivity as technically less demanding than hauling rock out of mine to Brucejack Lake ☑ More reliable method in inclement weather ☑ Lower ongoing monitoring and mitigation requirements ☒ Waste generated before the start of secondary mining must be hauled to surface given that it is unsuitable for backfilling primary voids without a cement binder ☒ Limited capacity of stope volumes ☒ Requires a cement plant, with power and water requirements	Preferred	☑ Lowest capital and operating costs due to minimized distance and infrastructure needed compared to hauling rock to deposit in lake ☒ Extra expenses associated with construction and operating plant for cement binder	P{referred	PREFERRED
Subaqueous into Brucejack Lake	☒ Waste rock transport to Brucejack Lake will increase GHG, CAC, dust, and noise emissions ☒ Will alter surface water quality in Brucejack Lake Brucejack Creek; however, subaqueous placement of waste rock is a preferred disposal method that prevents ML/ARD ☒ Increased potential effects on aquatic life in in Brucejack Lake and Brucejack Creek from water quality changes ☒ Increased potential dust deposition effects on local plants along haul route ☒ Increased potential ecosystem disturbance effects along haul route ☒ Increased potential for effects to disruption and sensory disturbance of wildlife from causeway	Acceptable	☒ Geohazard and OH&S risks associated with utilizing the waste rock causeway for offloading waste rock into Brucejack Lake (e.g., foundation failures); mitigated to acceptable levels using BMPs	Acceptable	☒ Lower productivity as requires hauling rock up and out of mine to Brucejack Lake, as well as additional technical requirements, such as a causeway and aerator in the lake ☒ During adverse weather, the waste rock causeway will not be accessible requiring waste rock be temporarily stored in the ore storage facility, potentially competing for space with ore prior to mill start up ☒ Requires coordination with subaqueous tailings disposal as waste rock should not be disposed of on top of tailings for stability reasons ☒ Ongoing TSS and water quality monitoring and mitigation (e.g. adding flocculant) may be required, adding management burden ☑ Doesn't require cement plant and no dams are required for lake containment either ☑ Has sufficient capacity to store all waste rock	Acceptable	☒ Higher capital and operating expenses than for backfill as rock has to be hauled to surface and lake ☒ Extra expenses for construction and operation of causeway, haul trucks, and additional water monitoring	Acceptable	ACCEPTABLE

Notes:

☑ = Preferred, ☒ ☑ = Acceptable, ☒ = Challenging, ☒ = Unfeasible; ✓ in the box indicates a relative advantage; ✗ in the box indicates a relative disadvantage. See Section 4.2.2 for description of attribute ranking methodology.

$CaCO_3$ = calcium carbonate; ML/ARD = metal leaching and acid rock drainage; OH&S = occupational health and safety; BMPs = best management practices; TSS = total suspended solids

Table 4.4-10. Valued Component Attributes Compared for Waste Rock Disposal Alternatives

Assessment Theme	Identified Component[1]	Compared Attributes[2]
Atmospheric Environment	• Air quality	• Criteria air contaminant (CAC) emissions and fugitive dust
	• Climate	• GHG emissions
	• Noise	• Relative noise emissions
Freshwater Environment	• Water quality	• Concentrations of total and dissolved metals, nutrients, turbidity, TSS, temperature
	• Aquatic resources: primary and secondary producers	• Abundance and diversity of periphyton, phytoplankton, benthic invertebrates, and zooplankton; changes in sediment quality
Human Environment	• Occupational Health and Safety (OH&S)[3]	• Safety during transit

[1] *Components listed include "subject area" and "sub-components" of VCs (see Chapter 6, Table 6.4-4)*
[2] *Attributes are linked to "indicators" of VCs (see Chapter 6, Table 6.4-4)*
[3] *Occupation Health and Safety is not within the scope of the Application/EIS, but considered here as an important consideration of Project alternatives*

As mentioned (Section 4.4.5), waste rock will be used to consume stope voids that might otherwise receive mill tailings in the form of paste fill. Table 4.4-11 tabulates the approximate volumes of waste to be generated from milled ore and development headings, and the destination of these volumes over time. Over the life of the mine, 54% of development waste and 46% of tailings generated from milled ore will be placed back underground. The balance will be disposed of in Brucejack Lake as detailed in Table 4.4-11.

Table 4.4-11. Life of Mine Backfilling – Waste Rock and Mill Tailings

Year	Ore Tonnes ('000 t)	Total Tailings ('000 t)	Waste Rock Tonnes ('000 t)	Waste Rock Fill Volume (m^3)	Paste Fill Volume (m^3)	Tailings Underground ('000 t)
-2	5	-	575	-	-	-
-1	241	-	492	-	-	-
1	566	771	442	6,000	192,000	272
2	937	894	292	65,000	252,000	358
3	979	929	291	96,000	256,000	377
4	981	938	294	81,000	246,000	349
5	983	939	266	114,000	286,000	406
6	986	943	251	108,000	207,000	294
7	985	945	108	46,000	321,000	456
8	985	945	336	119,000	299,000	425
9	980	942	278	119,000	265,000	376
10	991	951	147	63,000	308,000	436
11	978	936	151	65,000	305,000	433
12	979	930	142	61,000	282,000	400
13	982	936	105	45,000	286,000	406
14	987	946	74	32,000	364,000	517

(continued)

Table 4.4-11. Life of Mine Backfilling – Waste Rock and Mill Tailings (completed)

Year	Ore Tonnes ('000 t)	Total Tailings ('000 t)	Waste Rock Tonnes ('000 t)	Waste Rock Fill Volume (m^3)	Paste Fill Volume (m^3)	Tailings Underground ('000 t)
15	987	937	33	14,000	373,000	530
16	979	934	15	7,000	371,000	527
17	982	928	25	11,000	394,000	560
18	949	886	16	7,000	383,000	544
19	501	466	10	4,000	190,000	269
20	495	462	18	8,000	174,000	248
21	404	379	6	2,000	202,000	286
22	144	135	3	1,000	55,000	78
Total	**18,986**	**18,072**	**4,369**	**1,074,000**	**6,019,000**	**8,548**

Source: Chapter 5, Project Description

4.4.6 Controlling Sediment Release from the Lake

4.4.6.1 Purpose and Background

There is a risk of release of very fine rock particles, or sediment, to the water column when waste rock and tailings are deposited in Brucejack Lake. The sediment may remain suspended and be transported with the flow of runoff from the lake into Brucejack Creek and eventually to Sulphurets Creek and the Unuk River. The sediments may have elevated metals content, which could have adverse effects on aquatic life downstream.

The preferred tailings disposal method has been specifically selected to reduce the release of suspended sediments. Additional mitigation may be of benefit to address unexpected events or malfunctions of the proposed deposition method.

Historically no additional mitigation has been applied for control of sediment during waste rock disposal in the lake. Pretivm is proposing mitigation to improve on historical procedures and avoid adverse effects from disposal of much larger quantities of waste rock in the lake.

4.4.6.2 Alternatives Identification

During the screening step, six sediment control methods were assessed, including washing waste rock prior to deposition in the lake, the preferred tailings disposal method, installation of a turbidity curtain at the lake outlet, installation of a turbidity curtain around the waste rock disposal area, construction of an outlet control structure to retain water in the lake when suspended sediment levels are high, and flocculation of the whole lake. During the screening process the washing of waste rock and flocculation of the lake were found to be unfeasible and were deleted. The preferred tailings disposal method is discussed elsewhere and will not be further addressed here.

Turbidity Curtain at the Lake Outlet

Turbidity curtains are proven technology and have been used successfully to reduce the release of suspended sediments from construction sites. A turbidity curtain across the outlet of Brucejack Lake would reduce the level of suspended sediments generated from tailings and waste rock deposition in the lake that might accompany runoff flows from the lake to Brucejack Creek. The curtain would be suspended from a cable supported by floats, with weights at the bottom of the curtain to maintain a vertical orientation.

Turbidity Curtain Around the Waste Rock Disposal Area

A turbidity curtain installed around the perimeter of the waste rock disposal area would contain suspended sediments generated by the rock dumping of waste rock into the water. It would be similar to the lake outlet turbidity curtain, but would be held in place by anchors as it would not be a “shore-to-shore” configuration.

Outlet Control Structure

The outlet control structure would in effect be a dam across the lake outlet that would retain lake water to allow suspended sediments to settle before water is released. The structure would be classified as a major dam under the criteria defined in the Health, Safety and Reclamation Code for Mines in British Columbia due to its height and the volume of water that it would retain. Construction would require a significant volume of rock, some of which could be PAG waste rock from the mining operation. All rock placed above the low water level would have to be non-PAG rock from the quarry, increasing the size of the quarry. The soft sediment on the bottom of the lake creates challenging foundations for a dam. Due to the small size of the lake there would not be much capacity for retention, particularly for spring freshet, without significant dam height.

4.4.6.3 Alternatives Comparison

The alternative sediment control attribute characteristics were compared against the four performance objectives as summarized in Table 4.4-12.

Technical and Project Economic Considerations

Technical criteria involved in choosing between the three sediment control alternatives involved considerations for scheduling, capacity and site conditions, among other factors.

From a scheduling perspective, both of the turbidity curtain alternatives can be constructed quickly with little or no preparation required. Site conditions are not a significant consideration. The turbidity curtain configuration can be flexible, allowing adaptations over time if required. The turbidity curtain alternatives are not mutually exclusive and both can be built without adverse effects on the other. Installing both turbidity curtains could have cumulative positive effects.

The outlet control structure would require an extended construction period. It would have limited retention capacity unless constructed to considerable height. Retaining flows to allow time for sediment to settle would raise the level of the lake, which could flood the waste rock dumping platforms. The laydown area and related facilities would have to be raised to avoid flooding, requiring the excavation and placement of more non-PAG rock from the quarry. There would be considerable cost to constructing and maintaining this structure. At closure the structure would have to either be breeched or a plan and funding put in place for ongoing inspection and maintenance.

Environmental and Social Considerations

The Outlet Control Structure would trade off release of sediment-laden water against reduction of flows to Brucejack Creek, both of which may have adverse effects on the aquatic environment. Neither of the turbidity curtain alternatives would affect flows in Brucejack Creek, and both could improve water quality downstream.

The Outlet Control Structure would require an increase in the volume and distance of haul truck traffic to place waste rock and non-PAG quarry rock in the lake, increasing potential GHG and noise effects. It could also change the level of Brucejack Lake, with related increased effects footprint.

The Outlet Control Structure would create more jobs for the hauling and placement of waste rock and non-PAG quarry rock. There would be some weather related and geotechnical OH&S risk involved in placing these materials into the water. Conversely, installation of the turbidity curtains would require personnel working from boats and potentially in the water using diving gear, but the installation period would be very short compared to the construction of the Control Structure.

4.4.6.4 Selected Alternative

The installation of turbidity curtains is the preferred alternative. Both turbidity curtains can be installed with cumulative positive effects.

4.4.7 Solid Waste Disposal Method for Non-hazardous Waste

4.4.7.1 Purpose and Background

Solid wastes are defined as solid non-hazardous domestic and industrial wastes. The types of solid non-hazardous waste that will typically be generated during Construction, Operation, Closure, and Post-closure of the Project are listed in Table 4.4-13. Hazardous wastes will be shipped off-site by licensed carriers to appropriate licensed facilities according to regulatory requirements, and are not considered here.

Identifying suitable waste disposal locations for the Project requires consideration of key criteria including minimizing habitat disturbance and loss, preventing and minimizing water quality impacts, minimizing transport distances, and finding sufficient disposal areas to accept the different types of generated waste.

4.4.7.2 Alternatives Identification

Three main solid waste disposal methods—on-site landfill, off-site disposal, and incineration—were assessed during the screening stage. On-site landfill was discarded with there not being sufficient space with suitable geotechnical and ecological criteria on-site to cater for a landfill for the LOM. In addition, an on-site landfill would have generated significant environmental and social impacts at the site, including runoff, seepage, and attraction of wildlife. Waste reduction, reuse, and recycling will be practised to the extent practicable for all solid waste generated; however, in and of themselves, these strategies are supportive of the above alternatives rather than being feasible alternatives. Both off-site disposal and incineration options, described below, were retained for further detailed evaluation.

<u>Off-site Disposal</u>

Existing off-site landfills in the region that could handle Project non-hazardous solid wastes are located at Stewart, Iskut, and Meziadin. The landfill in Stewart is operated by the Town of Stewart; the facilities in Iskut and Meziadin are operated by the Regional District of Kitimat-Stikine.

<u>Incineration</u>

Incineration involves the burning of selected wastes at very high temperatures, with the ash to be deposited within an off-site landfill or underground.

4.4.7.3 Alternatives Comparison

The alternative waste disposal attribute characteristics were compared against the four performance objectives as summarized in Table 4.4-14.

Table 4.4-12. Evaluation of Brucejack Gold Mine Project Alternatives for Sediment Control Method

Alternative	ATTRIBUTE RATINGS AGAINST FOUR PERFORMANCE OBJECTIVES								FINAL RATING
	Environmental Attributes		Social Attributes		Technical Attributes		Project Economic Attributes		
Turbidity Curtain at the Lake Outlet	☑ Minimizes GHG and air quality emissions and noise levels ☑ Reduces changes to surface water quality in Brucejack Creek ☑ Minimizes effects to aquatic life (i.e., phytoplankton, zooplankton and sediment quality) in Brucejack Creek ☑ Minimizes ecosystem disturbance ☑ Minimizes wildlife disruption and disturbance	Preferred	☒ Fewer jobs created than hauling rock from the quarry to create the Outlet Control Structure and raise the laydown area ☒ Requires people to work on the water for installation and maintenance, with attendant risks	Preferred	☑ Proven track record elsewhere ☑ Simple to decommission at Closure ☑ Readily adaptable if conditions change	Preferred	☑ Lowest capital and operating costs	P[referred	PREFERRED
Turbidity Curtain Around the Waste Rock Disposal Area	☑ Minimizes GHG and air quality emissions and noise levels ☑ Reduces changes to surface water quality in Brucejack Creek ☑ Minimizes effects to aquatic life (i.e., phytoplankton, zooplankton and sediment quality) in Brucejack Creek ☑ Minimizes ecosystem disturbance ☑ Minimizes wildlife disruption and disturbance	Preferred	☒ Fewer jobs created than hauling rock from the quarry to create the Outlet Control Structure and raise the laydown area ☒ Requires people to work on the water for installation and maintenance, with attendant risks	Preferred	☑ Proven track record elsewhere ☑ Simple to decommission at Closure ☑ Readily adaptable if conditions change	Preferred	☑ Lowest capital and operating costs	Preferred	PREFERRED
Outlet Control Structure	☒ More truck traffic, therefore more GHG and air quality emissions and noise levels ☑ Reduces changes to surface water quality in Brucejack Creek ☒ May create periods of reduced flows in Brucejack Creek	Acceptable	☑ More jobs created due to hauling rock from the quarry to create the Outlet Control Structure and raise the laydown area ☒ Requires people to work near the water for construction and maintenance, with attendant risks	Acceptable	☒ Foundations may present geotechnical challenges ☒ Limited retention time during freshet ☑ Readily adaptable if conditions change	Challenging	☒ Highest capital costs ☒ Highest Closure costs	Challenging	CHALLENGING

Notes:

☑ = Preferred, ☒ ☑ = Acceptable, ☒ = Challenging, ☒ = Unfeasible; ✓ in the box indicates a relative advantage; ✕ in the box indicates a relative disadvantage. See Section 4.2.2 for description of attribute ranking methodology.

$CaCO_3$ = calcium carbonate; ML/ARD = metal leaching and acid rock drainage; OH&S = occupational health and safety; BMPs = best management practices; TSS = total suspended solids

Table 4.4-13. Typical Solid Non-hazardous Waste Generated at the Brucejack Gold Mine Project

Type of Waste	Example of Waste	Phase Generated			
		C	O	Cl	PC
Domestic Waste	Aluminum cans and glass	X	X	X	X
	Domestic garbage	X	X	X	X
	Paper materials	X	X	X	X
	Plastics	X	X	X	X
	Putrescible food waste	X	X	X	X
Industrial Waste	Aerosols	X	X		
	Batteries	X	X	X	X
	Building materials and bulk debris	X	X	X	
	Cement	X	X	X	
	Conveyor belts		X	X	
	Culvert pieces	X	X	X	
	Fluorescent light ballasts	X	X	X	X
	Glass	X	X	X	X
	Incinerator ash	X	X	X	X
	Insulation material scraps	X	X	X	
	Packaging	X	X	X	X
	Rebar	X	X	X	
	Scrap metal	X	X	X	
	Scrap wood	X	X	X	
	Steel balls		X		
	Tires	X	X	X	
	Transformers	X	X	X	
	Vehicles	X	X	X	
	Wiring	X	X	X	

Source: (Chapter 29.17, Waste Management Plan)
C - Closure, O -Operation, Cl - Closure, PC - Post-closure

Table 4.4-14. Valued Component Attributes Compared for Solid Waste Disposal Alternatives

Assessment Theme	Identified Component[1]	Compared Attributes[2]
Atmospheric Environment	• Air quality • Climate	• Criteria air contaminant (CAC) emissions • Greenhouse gas (GHG) emissions
Terrestrial Environment	• Wildlife (general)	• Attractants
Human Environment	• Labour and income • Health • Occupational Health & Safety (OH&S) • Non-commercial land use	• Relative number of jobs created • Potential dust deposition on country foods harvested along corridor • Safety during transit • Changes in quality and quantity of currently used wildlife and fishery resources

[1] *Components listed include "subject area" and "sub-components" of VCs (see Chapter 6, Table 6.4-4)*
[2] *Attributes are linked to "indicators" of VCs (see Chapter 6, Table 6.4-4)*

Technical and Project Economic Considerations

The primary benefit of off-site disposal means a reduction in on-site management of waste, along with reduced monitoring and management associated with on-site waste disposal. This option would require, however, that solid waste be shipped to one of the offsite e landfill facilities, creating extra hauling requirements.

Due to limitations of the incineration process, inert materials such as plastics, rubber, metals, and glass would need to be crushed, shredded, or otherwise packaged as appropriate for disposal in an off-site landfill or recycling site. An incinerator would also require additional technical requirements including installation of an incinerator, use of fuels to run the incinerator, and the requirement to monitor and manage air emissions. The primary benefits of incineration include volume reduction and permanent disposal of waste (with the exception of ash and items mentioned above).

Off-site disposal of solid waste at a landfill/recycling facility is a standard approach to solid waste management and is reliable and predictably effective for the management of non-hazardous solid waste. Incinerators are also effective and can reduce waste volumes; however they can be more difficult to operate to consistently achieve end-of-stack emissions air quality standards, in addition to the fact that they cannot manage all waste types generated on-site. Disposal of solid waste off-site was therefore preferred from a technical applicability and system reliability performance perspective, and use of an on-site incinerator was rated as acceptable.

Incineration of solid waste is considered the most cost-effective alternative, with off-site disposal associated with higher costs due to transportation requirements. Incineration was therefore preferred from a cost-effectiveness perspective, and off-site disposal was rated as acceptable.

Environmental and Social Considerations

The primary intermediate components and receptor VCs that would be subject to differential potential effects (therefore being relevant and comparable attributes) from the Project solid waste disposal alternatives were identified for the environmental and human environments, as listed in Table 4.4-15. A summary of the potential differential effects on these intermediate components and receptor VCs of the solid waste disposal alternatives is provided in Table 4.4-14 and in the text below.

Disposal by off-site landfill or incineration will require the solid waste collected on-site to be managed in collection areas on-site, with relevant waste segregated for recycling/reuse and removal. The waste collection areas would be designed to adequately and safely store a sufficient quantity of waste over a prescribed time limit of one to three months.

Incineration leads to atmospheric emissions of air quality contaminants and GHGs, the net emissions of which are likely to be higher than those associated with transport of solid waste to a landfill via haul trucks. Incineration generates immediate GHG emissions, but the gradual long-term breakdown of landfill wastes generates methane, which is a stronger GHG. Incineration would minimize on-site direct interference with wildlife, as the incineration of food wastes reduces the attraction of wildlife to the waste collection areas for the landfill alternative, thereby minimizing related personnel/bear safety issues. Increased road traffic associated with waste transport to landfill would also increase the chance of wildlife collisions, though the increase would be minimal.

Incineration would reduce the potential for the importing of invasive species on-site, though mitigation measures would bring this risk to acceptable levels for haul trucks to and from the landfill.

Table 4.4-15. Evaluation of Brucejack Gold Mine Project Alternatives for Solid Waste Disposal Method for Non-hazardous Materials

Alternative	ATTRIBUTE RATINGS AGAINST FOUR PERFORMANCE OBJECTIVES								FINAL RATING
	Environmental Attributes		Social Attributes		Technical Attributes		Project Economic Attributes		
Off-site Landfill	☑ Minimizes atmospheric emissions (criteria air contaminants [CACs] and GHGs) of Project compared to incineration (although increased emissions from hauling that are outside Project scope) ☒ Higher local potential attraction of wildlife to stored waste prior to hauling off-site; risks mitigated with BMPs	Acceptable	☒ Off-site disposal will result in minor additional traffic and associated risk on the roads ☑ Slightly higher potential driving contractor job creation	Acceptable	☒ Slightly increased trucking requirements and traffic management ☑ Would be able to accommodate all materials, so not require separate handling ☑ Reduction in on-site management of waste, along with reduced monitoring and management associated with on-site waste disposal	Preferred	☒ Increased costs associated with transportation and off-site disposal of waste ☑ Reduced capital expenses	Acceptable	PREFERRED
Incineration	☒ Increased stack air emissions (CACs and GHGs) generated from the incineration process would slightly alter local air quality compared to hauling waste off-site; effects would likely be negligible to low ☑ Minimizes potential for interference with wildlife, as minimizes attraction of wildlife (i.e., bears) and associated risks that would require mitigation	Acceptable	☑ Incineration will reduce traffic and associated risks associated with hauling waste off-site for disposal ☒ Slightly lower driving contractor job creation	Preferred	☑ Reduced trucking requirements and traffic management ☒ Due to limitations of the incineration process, inert materials such as plastics, rubber, etc. would not be able to be incinerated and still require management ☒ Additional equipment management and maintenance, as well as additional monitoring of air quality needed	Acceptable	☑ Reduction haul truck contractor and fuel transport expenses during operation to landfill. ☒ Additional equipment costs for incinerator increases capital expenses	Acceptable	ACCEPTABLE

Notes:

☑ *= Preferred,* ☒ ☑ *= Acceptable,* ☒ *= Challenging,* ☒ *= Unfeasible;* ✓ *in the box indicates a relative advantage;* ✗ *in the box indicates a relative disadvantage. See Section 4.2.2 for description of attribute ranking methodology.*

CAC = criteria air contaminant; GHG = greenhouse gas; BMPs = best management practices

With proper controls, either of the two solid waste disposal options is capable of providing the required level of environmental protection. Accordingly, both alternatives were rated as acceptable from an environmental and social perspective.

4.4.7.4 Selected Alternative

A combination of off-site landfill and on-site incineration has been selected for the Project to dispose of non-hazardous solid waste.

An incinerator at Brucejack Camp will be used to dispose of all waste that is a wildlife attractant, including food waste and food-related products. Food waste is a prime wildlife attractant and will therefore be incinerated in a timely manner, thus leaving no trace of attractants for wildlife. All appropriate kitchen, dining room, office, and accommodation waste will be incinerated to reduce the potential of attracting wildlife. All resultant incinerator ash will be hauled for off-site disposal in a permitted landfill, disposed underground or mixed with tailings for subaqueous disposal. Electric fencing will be used to deter bears from entering the incinerator facility.

The remaining solid waste will be collected and stored in the waste collection areas until it is processed further or disposed of off-site by hauling via public roads to licensed recycling facilities, disposal facilities, or landfill. The waste collection areas will be designed to adequately and safely store waste. Where required, the waste collection areas will be covered and fenced to prevent attraction of wildlife and to provide protection from weather.

4.5 SUMMARY OF ALTERNATIVES ASSESSMENTS

This chapter has described the decision-making rationale behind all the Project components recommended for assessment in the CEA Agency (2013a) EIS Guidelines and the BC EAO (2014) AIR document, as well as several more. For this assessment, Pretivm has undertaken to transparently demonstrate that the decision-making rationale behind the selected alternative for each of the Project components addressed has been conducted in a systematic, reasonable, and defensible manner—balancing technical and economic Project criteria with minimizing potential adverse effects on surrounding environmental and human systems.

Table 4.5-1 presents a summary of the entire alternatives assessment carried out for the Project and Figure 4.5-1 illustrates the final Brucejack Mine Site design. More detail on the development of selected Project alternatives is provided in Chapter 5, Project Description.

4.6 PROJECT DESIGN CHANGES

Throughout the Project planning process, Pretivm has made decisions on the Project design that, in aggregate, minimize potential environmental and related social effects to Aboriginal people and the public. Table 4.6-1 provides a list of the key design changes that have led to significant reductions in predicted environmental and social adverse effects for the Project.

Figure 4.5-1
Brucejack Gold Mine Project Final Mine Area Plan

ERM

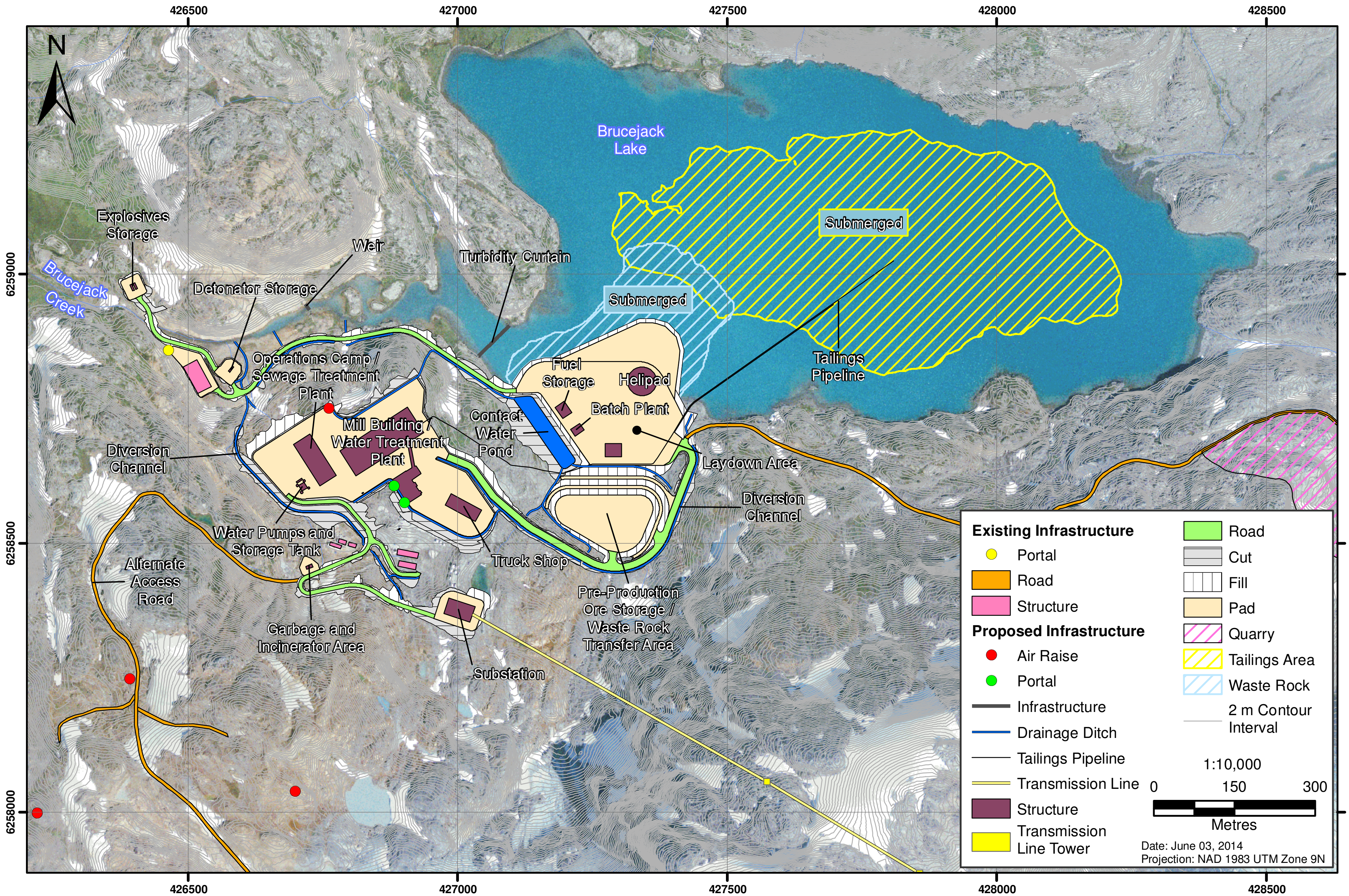


Table 4.5-1. Summary of Project Alternatives Evaluation

Major Component of Project	Sub-Component	Alternative	Performance Objective Attribute Ratings					Project Decision
			Environmental	Social	Technical	Economic	OVERALL RATING	
Project Access and Transport	Personnel Transport Method to Knipple Transfer Area	Fixed-wing air from major centres	Preferred	Unfeasible (In Poor Weather)	Unfeasible (In Poor Weather)	Acceptable	**Unfeasible (In Poor Weather)**	**Fly in good weather, and use bus in poor weather**
				Preferred (In Good Weather)	Preferred (In Good Weather)		**Preferred (In Good Weather)**	
		Land via private vehicle from Highway 37	Acceptable	Challenging	Challenging	Acceptable	**Challenging**	
		Land via bus from Highway 37	Acceptable	Preferred (In Poor Weather)	Preferred (In Poor Weather)	Preferred	**Preferred (In Poor Weather)**	
				Acceptable (In Good Weather)	Acceptable (In Good Weather)		**Acceptable (In Good Weather)**	
Ore Processing	Ore Comminution	Option 1: three stages of crushing and two stages of ball mill grinding	Acceptable	Acceptable	Acceptable	Acceptable	**Acceptable**	**Use SABC Circuit (Option 2)**
		Option 2: one stage of crushing and grinding in a SAG mill grinding/ball mill grinding/ pebble crushing (SABC) circuit	Preferred	Acceptable	Preferred	Acceptable	**Preferred**	
	Location of Final Flotation Concentrate Processing into Gold-silver Doré	On-site by Proponent	Acceptable	Acceptable	Challenging	Preferred	**Challenging**	**Process Final Flotation Concentrate Off-site by Third Party**
		Off-site by third party	Preferred	Preferred	Preferred	Acceptable	**Preferred**	
Solid Waste Disposal	Tailings Disposal Method	Backfill as paste into stopes of underground mine	Preferred	Preferred	Preferred	Preferred	**Preferred**	**Backfill as paste when feasible; otherwise deposit in Brucejack Lake**
		Subaqueous deposition into Brucejack Lake	Acceptable	Acceptable	Acceptable	Acceptable	**Acceptable**	
	Waste Rock Disposal Method	Backfill into stopes of underground mine	Preferred	Preferred	Preferred	Preferred	**Preferred**	**Backfill into stopes where feasible; otherwise deposit in Brucejack Lake**
		Subaqueous deposition into Brucejack Lake	Acceptable	Acceptable	Acceptable	Acceptable	**Acceptable**	
	Sediment Control	Turbidity curtain at the outlet of Brucejack Lake	Preferred	Preferred	Preferred	Preferred	**Preferred**	**Install turbidity curtains at the outlet or Brucejack Lake and around the waste rock disposal site in the lake**
		Turbidity curtain around the waste rock disposal area	Preferred	Preferred	Preferred	Preferred	**Preferred**	
		Outlet control structure at the outlet of Brucejack Lake	Challenging	Acceptable	Challenging	Challenging	**Challenging**	
	Solid Waste Disposal Method for Non-hazardous Waste	Off-site landfill	Preferred	Acceptable	Preferred	Acceptable	**Preferred**	**Food waste will be incinerated and other waste disposed in off-site landfill**
		Incineration, and disposal in off-site existing landfill	Acceptable	Preferred	Acceptable	Preferred	**Acceptable**	

Table 4.6-1. Key Brucejack Gold Mine Project Design Changes and Related Environmental and Social Benefits

Redesigned Project Component	Description	Benefits of Changes to the Environment	Benefits of Changes to Aboriginal Peoples	Benefits of Changes to the Public
Mining method	The original mine proposal included an underground mine plus up to four open pits, generating 8.7 Mt of waste rock in total. This waste rock would have been deposited in the underground workings and in two separate areas of Brucejack Lake. The current mine plan does not include open pits and will generate only 4.5 Mt of waste rock, to be deposited underground and in one area of Brucejack Lake.	• Smaller Project footprint • Less waste rock to manage and haul • Fewer waste rock deposit areas • Simpler water management • Reduced acid rock drainage concerns	• Reduced area of disturbance • Reduced environmental risk	• Reduced environmental risk
Ore processing method	The original Project proposal included two process plants: a conventional flotation concentrator at the mine site to produce bulk gold-silver flotation concentrate/gravity concentrate, and a cyanide leach plant located near Bell-Irving River to produce gold-silver doré, each with its own tailings storage area. Tailings from the flotation plant would have been disposed in Brucejack Lake, while the leach plant would have required a lined side-hill tailings storage facility with a capacity of 2.4 Mt. The current Project proposal does not include a leach plant and associated tailings storage facility. Concentrate will be transported to an off-site smelter for further processing.	• Reduced area of disturbance and ultimate tailings volume to be managed • Elimination of use of cyanide • Reduced long term water management concerns • Reduced electric power consumption	• Reduced area of disturbance • Improved safety with elimination of cyanide transportation, storage and use • Reduced environmental risks	• Improved safety with elimination of cyanide transportation, storage and use • Reduced environmental risks • Reduced electric power consumption
Layout of surface facilities	The original Project proposal incorporated separate buildings for the mill, crusher, warehouse and truck shop, and a trailer-style mine camp. The current Project proposal consolidates the mill, crusher and warehouse in a single building, and uses a more compact mine camp.	• Reduced area of disturbance • Reduced construction phase waste rock to be managed • Reduced electric power consumption	• Reduced area of disturbance • Safer for mine employees	• Reduced electric power consumption • Safer for mine employees
Employee transportation	The original Project proposal for employee transportation was by road to and from the site along the access road from Highway 37. The current proposal incorporates the Bowser Aerodrome, a re-establishment and expansion of an historical airstrip at the head of Bowser Lake.	• Potential benefits for wildlife and fisheries	• Reduced traffic on Hwy 37 and the access road • Protection of wildlife and fisheries	• Reduced traffic on Hwy 37 and the access road
Glacier travel	The original Project proposal did not consider the implications of transporting supplies and concentrate over the glacier. The current proposal incorporates the Knipple Transfer Area as a staging area for the use of specially equipped vehicles for glacier travel, as well as detailed management plans for this travel.	• Reduced environmental risk from accidents	• Increased safety for glacier travel	• Increased safety for glacier travel
Water treatment	The original Project proposal recognized that surface water treatment would be required, but gave little detail. Treatment of surplus underground water was not considered to be necessary. Subsequent analysis has demonstrated that underground water may exceed allowable metal concentrations for discharge. The current proposal includes details of facilities for treatment of excess groundwater pumped from the underground operations, and surface contact water. The proposed treatment facilities will allow the Project to operate in a manner consistent with the Metal Mining Effluent Regulations (SOR/2002-222) and *Environmental Management Act* (2003) standards with regards to effluent waters.	• Project discharges consistent with the *Metal Mining Effluent Regulations* and *Environmental Management Act* standards with regards to effluent waters	• Water quality protected	• Water quality protected
Tailings disposal	Originally, the pipeline for tailings would have discharged at a depth of 70 m directly into Brucejack Lake. This location was efficient and inexpensive. The current plan is for initial discharge at a depth of 80 m, with the discharge passing through a sand filter mound on the lake bottom. The sand filter will reduce the release of suspended sediments into the lake. As backpressure in the tailings pipeline increases as a result of the build-up of tailings above the mound, a second outfall will be established at about 60 m depth with the same type of sand filter.	• Containment of tailings fines to the bottom of the lake, keeping them out of the water column where they could potentially be more mobile • Improving certainty of achieving regulatory discharge standards	• Potentially reduced adverse downstream effects on water quality and fisheries	• Potentially reduced adverse downstream effects on water quality and fisheries
Turbidity curtain	In order to address the potential for the release of increased total suspended solids (TSS) from Brucejack Lake to Brucejack Creek, Pretivm has proposed the introduction of turbidity curtains near the outlet of the lake and around the waste rock disposal area in the lake. These turbidity curtains would capture excess TSS. TSS may be generated by the dumping of waste rock in to the lake, tailings that could be disturbed by the semi-annual turnover of the lake water column, or by malfunction of the tailings discharge sand filter.	• Restriction of excess TSS flowing to Brucejack Creek, thereby avoiding adverse effects on the aquatic environment and water quality • Improving certainty of achieving regulatory discharge standards	• Potentially reduced adverse downstream effects on water quality and fisheries	• Potentially reduced adverse downstream effects on water quality and fisheries

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