31. Accidents and Malfunctions

31.1 BACKGROUND

The proposed Pretium Resources Inc. (Pretivm) Brucejack Gold Mine Project (the Project) in northwestern British Columbia (BC), 65 km north-northwest of Stewart, will be located above the tree line in a mountainous area at an elevation of about 1,400 metres (m) with glaciers located to the north, south, and east of the mine.

Ore will be extracted via a decline ramp system from long-hole open stopes using conventional rubber-tired, diesel and electric powered mobile equipment. Ore will be processed on site. The processing plant, water treatment plant, camp, substation, and related facilities will be located close to the mine portals. Waste rock and tailings that cannot be backfilled will be stored underwater in Brucejack Lake. Access to the Project will be via the existing 75-kilometre (km) exploration access road off Highway 37. Pretivm will upgrade the exploration access road and construct a transfer area at Knipple Lake for the transfer of personnel and materials to vehicles specialized for glacier travel over the westernmost 12-km section of the exploration access road. The provincial electricity grid—via a new 55-km-long transmission line from the Long Lake Hydro Project near Stewart, BC—supplies electrical power for the Project. The Project requires a 2-year construction period and will operate for a minimum of 22 years once commissioned.

The Project design includes difficult access conditions in remote areas, potentially acid-generating ore, handling of large quantities of waste rock and tailings, limited space to locate infrastructure, operation of large machinery, and potentially adverse environmental conditions.

The management of risks and preparedness for unplanned events such as accidents and malfunctions are important elements within Pretivm's corporate policies. These policies and their subsequent management plans form the backbone in identifying causal mechanisms, and eliminating or minimizing risk and consequences of accidents and malfunctions. The broad approach adopted by Pretivm with respect to Project risk is as follows:

- proactively identify major risks of concern starting at the design phase and continuing through all Project phases;
- fully assess all material risks using a methodological analysis, including estimating the probability, potential magnitude, and consequence(s) of accidents and/or malfunctions associated with the Project;
- develop management plans, training, and education, and facilitate a culture of risk awareness designed to prevent accidents and/or malfunctions associated with the Project;
- develop and maintain emergency preparedness plans and other management plans to ensure the protection of the environment, workers, and public in case of accidents and/or malfunctions associated with the Project;
- where elimination, avoidance, or transfer of risk is not possible, reduce the risk to as low as reasonably practicable by applying loss control and other strategies to minimize the effect on the environment, workers, and public; and
- employ adaptive management techniques to ensure continual appraisal and improvement for all risk awareness, management, mitigation and response plans, and training associated with the Project.

To accomplish these objectives, a large complex project requires a systematic approach to the identification and assessment of risk.

31.2 SCOPE

The Accidents and Malfunctions Chapter, in part, satisfies requirements described in the Application Information Requirements (AIR) prepared for the British Columbia Environmental Assessment Office (BC EAO; 2014) and the Environmental Impact Statement (EIS) Guidelines prepared by the Canadian Environmental Assessment Agency. The Application for an Environmental Assessment Certificate (Application)/EIS addresses the accidents and malfunctions that could potentially affect the environment and would be associated with the Construction, Operation, Closure, and Post-closure phases of the Project.

Section 21 of the AIR (BC EAO 2014) states the following:

The Application/EIS will identify the probability of potential accidents and malfunctions related to the Project, including an explanation of how those events were identified, potential consequences (including environmental effects and mitigation), the worst-case scenarios, and the effects of these scenarios. At minimum, the following accidents and malfunctions will be assessed:

- failure of tailings pipeline;
- failure of water treatment plant;
- failure of water diversion channels;
- failure of underground mine stability;
- concentrate spills;
- fuel spills outside secondary containment;
- hazardous spills; and
- explosives mishap.

As per Section 21 of the AIR (BC EAO 2014), the Application/EIS also includes the following:

- the spatial and temporal boundaries for the assessment of accidents and malfunctions;
- the methodology for assessing potential risks;
- definitions of assessment characterization criteria (e.g., likelihood, magnitude);
- identification of the magnitude of the accident and/or malfunction, including the quantity, mechanism, rate, form, and characteristics of the contaminants and other materials likely to be released into the environment during the accident and malfunction events;
- identification of the likelihood of the accident and/or malfunction occurring;
- identification of the safeguards that have been established to protect against such occurrences;
- detailed contingency/emergency response procedures and plans that will be in place if accidents and/or malfunctions do occur; and
- conclusions on the potential risk of the accident or malfunction.

31.3 APPROACH

The overall approach examines the accidents and malfunctions identified in Section 21 of the AIR (BC EAO 2014) and supplements these with an independent review of the Project using a Failure Mode and Effects Analysis (FMEA) methodology. FMEA is a comprehensive risk analysis that screens accidents and malfunctions, i.e., failure modes, that may have an effect(s) on intermediate and receptor Valued Components (VC) identified for the Project (Table 6.4-4). The intermediate and receptor VCs then undergo an assessment to determine the significance of residual effects after mitigation. Through FMEA and reviewing environmental management plans, a total of 430 failure modes were identified and analyzed. In many cases, further investigation indicated that broader categories listed above should be subcategorized for effective analysis and reporting. The methodology and results of the FMEA are detailed in Section 31.4.

In addition to the assessments presented in this chapter, the Application/EIS describes potential effects to the Project related to seismic, climatic, and other risks associated with the natural environment. To this end, Chapter 32, Effects of the Environment on the Project, addresses the potential effects of and mitigation for extreme weather, climate change, fire, seismic events, geohazards (including avalanche), and glaciers to the Project. Appendix 11-A, *Brucejack Gold Mine Project Geohazard and Risk Assessment*, as well as the Appendix 11-C, *Preliminary Assessment of Subsidence Potential for the Brucejack Gold Mine Project,* address elements of these potential risks.

31.4 FAILURE MODE AND EFFECTS ANALYSIS

FMEA was originally developed for the United States Armed Forces in 1949, and is now widely used in reliability engineering and early in the product life cycle to identify and address potential issues, i.e., risks (US Department of Defense, 1949; Mikulak, McDermott, and Beauregard 2009). FMEA is a semi-qualitative methodology that provides a structured and transparent analysis of:

- the likelihood of hypothetical failure of structures, equipment, or processes, and variation from assumptions made during design and estimates; and
- the effects or consequences of such failures on external systems.

For the purposes of this chapter, the term “failure mode” is synonymous with “accidents and malfunctions.” These terms are applied interchangeably.

Applied to this Project, FMEA assessed the likelihood of a hypothetical failure of the designed system and the potential consequences (effects) of that failure in five areas:

- safety and health;
- environment;
- production;
- costs; and
- reputation.

The FMEA methodology applied in this Application/EIS has three distinct phases;

1. Data input.
2. Summarizing risks in risk matrices.
3. Environmental effects assessment.

31.5 DATA INPUT

FMEA is based on inductive reasoning (forward logic) single point of failure analysis. Analysis is grounded on experience with similar products and processes with inputs by experts in the field (McCormick 1981). To this end, the Project assembled a team of experts under the facilitation of Dave Ireland of Tetra Tech for a two-day workshop to participate in this FMEA, April 8, 2013 and April 9, 2013 (Table 31.5-1). The first day addressed underground activities and the second day addressed surface activities. In both cases, the participants reviewed the latest Project design. The participants in the workshop consisted of professionals in the fields of environmental sciences, environmental engineering, mining, metallurgy, geotechnical engineering, geology, power transmission, geohazards, road construction, project construction, and project operations.

Table 31.5-1. FMEA Workshop Participants

Name	Company	Expertise/Role	2013/04/08 Underground	2013/04/09 Surface
D. Ireland	Tetra Tech	FMEA Facilitator/Mechanical Engineer	✓	✓
I. Chang	Pretivm	Proponent	✓	✓
G. Grewal	Pretivm	Proponent	✓	✓
K. Torpy	Pretivm	Proponent	✓	✓
W.J. Witte	Pretivm	Proponent	✓	✓
M. Chin	Tetra Tech	Civil Engineer		✓
A. Farah	Tetra Tech	Mechanical Engineer		✓
P. Guest	Tetra Tech	Project management/Engineer	✓	
J. Huang	Tetra Tech	Metallurgical/Process Engineer		✓
M. Rutherford	Tetra Tech	Facilitation support	✓	✓
W. Scott	Tetra Tech	Electrical Engineer		✓
P. St. Pierre	Tetra Tech	Construction logistics/Engineer		✓
R. Yokome	Tetra Tech	Project management/Engineer	✓	✓
G. Norton	ERM Rescan	Environmental Scientist		✓
G. McKillop	ERM Rescan	Environmental Scientist		✓
C. Keogh	AMC Consultants	Mining Engineer	✓	✓
C. McVicar	AMC Consultants	Mining Engineer	✓	
M. Molavi	AMC Consultants	Mining Engineer	✓	
G. Zazzi	AMC Consultants	Mining Engineer	✓	
C. Banton	BGC Engineering	Geotechnical Engineer	✓	
K. Halisheff	BGC Engineering	Geotechnical Engineer		✓
B. McAfee	BGC Engineering	Geotechnical Engineer		✓
B. Gould	Avalanche Services	Avalanche specialist/Engineer		✓
M. Wise	Valard	Transmission specialist/Engineer		✓

The basis for FMEA data gathering and input is a worksheet that uses a structured approach to capture risk and risk control information. The FMEA worksheet used for the Project is organized with column headings that match the analysis logic described in the following sections. For reference purposes, Table 31.5-2 provides a synopsis of the column headings of the worksheet.

Table 31.5-2. FMEA Worksheet Column Heading Synopsis

				Life of Mine					Existing Controls and Contributing Factors					Impact Categories	Residual Risk				Inherent Risk (no controls)				Recommended Action
Component Category: 1. Major 2. Area 3. Sub-area/Item	Activity/Step/Area or Category	Hazard/Aspect or Threat	Unwanted Event	Exploration	Study	Construction	Operation	Closure	Current Controls	Type of Control	Effectiveness of Control	Total Effectiveness of Controls	Why Controls Effective or <u>Not</u>	Safety & Health/ Environment/Production/ Costs/Reputation	Likelihood	Severity	Level (H, M, L)	Rank (1 to 25)	Likelihood	Severity	Level (H, M, L)	Rank (1 to 25)	Improve existing controls/ implement new controls

31.5.1 Component Categories

The “Component Category” column of the FMEA worksheet is a numeric identifier for each potential failure mode per specific Project component. Each major category has a number of areas, and within each area there are sub-areas/items. As an example, General Development (11) was subdivided into nine areas (e.g., site roads), and this was further divided into sub-areas (e.g., construction). The numeric system provides an orderly listing and cataloguing of individual failure modes under each category.

The major categories areas within which failures may occur are:

- general development (Brucejack Mine Site);
- mine underground;
- mine site process;
- mine site utilities;
- mine site facilities;
- mine site tailings (Brucejack Lake);
- mine site temporary facilities;
- mine site (surface) mobility equipment;
- off-site infrastructure; and
- proponent costs.

31.5.2 Activity/Step/Area or Category

The “Activity/Step/Area or Category” column of the FMEA worksheet provides a description of the activity, (e.g., construction), location (e.g., mining underground), or component (e.g., lateral development) under evaluation.

31.5.3 Hazard/Aspect or Threat

The “Hazard/Aspect or Threat” column of the FMEA worksheet provides a description of the manner and/or type of system failure under evaluation. A failure mode can be initiated naturally (e.g., avalanche causing access road closure), by the failure of one of the engineered subsystems (e.g., inadequacy of a diversion channel due to a design limitation), or it can result from operational failure linked to ineffective or inadequate control measures (e.g., neglect to close a valve and the subsequent release of contaminating liquid). Due to the large number of potential failure modes that could be included in an FMEA, it is often necessary to confine evaluations to those that represent the most significant and realistic risks.

31.5.4 Unwanted Event

The “Unwanted Event” column of the FMEA worksheet describes the direct adverse effects of the failure mode considered that may have safety and health, environment, production, cost, and reputational consequences. These are first estimates of adverse direct and indirect effects based on a professional judgement of the anticipated result of that failure.

31.5.5 Life of Mine

The five “Life of Mine” columns of the FMEA worksheet indicate the timeframe for the risk including; preliminary activities (exploration and study) and Project phases (Construction, Operation, and Closure/Post-closure). The scope of this EA will focus on the Project phases. Some failure modes have different likelihoods of occurring, or different consequences if they occur during Construction, Operation, or Closure/Post-closure. Some risks increase depending on the assessment period timeframe. For example, the risk of some component (e.g., a diversion channel) failures may be greater Post-closure when there are fewer staff to provide monitoring and maintenance.

31.5.6 Existing Controls and Contributing Factors

The five columns that address "Existing Controls and Contributing Factors" of the FMEA worksheet provide information on:

- those measures currently envisaged to exert control over the Project effects;
- the type of control, i.e., administrative, elimination, engineering, protective equipment, separation, response plan, and substitution;
- the effectiveness of control, i.e., whether the control is effective, limited, or partial;
- an aggregation of the effectiveness ratings; and
- the reasons for why the controls are or are not effective.

31.5.7 Impact Categories

The "Impact Categories" column of the FMEA worksheet reflects the impact categories or areas of concern referred to previously, as follows:

- safety and health;
- environment;
- production;
- costs; and
- reputation.

31.5.8 Residual and Inherent Risks

The "Residual and Inherent Risks" columns define the types of risk associated with each "Hazard/Aspect or Threat." The FMEA addresses two forms of risk; residual and inherent risk. Residual risk is the amount of risk remaining after the application of controls. Inherent risk is the risk associated with an event for which no controls are available. The final risk associated with a failure mode will either be the residual or inherent risk depending on whether controls are available.

All risk, whether inherent or residual, combines at least two fundamental concepts; the likelihood (the expected frequency), and the severity (the expected consequences) of a failure mode.

$$Risk = f(likelihood, severity)$$

Mines incorporate a number of structures that represent combinations of natural and engineered systems involving geology, geotechnics, hydrogeology, hydrology, geochemistry, biology, ecology, and social systems. Due to the complexity of such engineered/natural systems, no statistics of equivalent system performance or probability analyses are available to precisely and mathematically determine the potential for failures. Given the lack of any established databases, the judgement and experiences of suitably qualified and experienced professionals provides the "best estimate" of the severity and, more importantly, likelihood. This is the norm for many industrial, engineering, financial, economic, and social management systems that employ FMEA methodologies (Carbone and Tippett 2004).

In most cases, as with this Application/EIS, the FMEA uses a semi-quantitative method to estimate the likelihood and severity of a failure mode. Appropriate experts familiar with the design, operations, and site conditions assigned quantitative values for likelihood and severity. For this Project, the FMEA uses a five-category ordinal scale to describe likelihood and severity. A key description guides the categorization of the failure mode within each scale. This properly set the scale for each category and provided consistency, repeatability, and transparency in the methods.

31.5.8.1 Likelihood

Likelihood is the chance that the assessed failure mode will occur for each of the impact categories. The likelihood ranges from “almost certain” to “rare,” for the period being evaluated (Table 31.5-3). Codes A to E define the likelihood ratings, respectively.

Table 31.5-3. Criteria for Likelihood of Failure Modes

	Code	Description	Definition
Likelihood Ratings	A	Almost Certain - The event will occur.	90 to 100%
	B	Expected - The event will probably occur in most circumstances.	55 to 90%
	C	Likely - The event could occur at some time.	30 to 55%
	D	Unlikely - The event may occur at some time.	5 to 30%
	E	Rare - The event may occur only in exceptional circumstances.	< 5%

31.5.8.2 Severity

Severity is the degree of consequence for a failure mode. The nature of accidents and malfunctions is that the consequence is increasingly negative with increasing severity. For each failure mode, the FMEA assesses severity separately with respect to each impact category. Table 31.5-4 is a severity scale appropriate to mine assessment and applied to this Project. A five-category system uses codes 1 to 5 to represent “limited” to “severe,” respectively.

31.5.9 Rank and Risk Level

Rank and risk level are derived values associated with the likelihood and severity categories. Using a procedure known as “binning,” each combination of likelihood and severity assigns a rank ranging from 1 to 25 (Table 31.5-5). The greater the likelihood and/or severity, the lower the rank. Smaller values represent a greater risk. As an example, a failure mode that is “almost certain” (A) and that would result in a “severe” (5) consequence is considered the greatest rank, i.e., rank = 1.

The risk level is based on ordering of the 25 ranks into three risk management categories; low, medium, and high (Table 31.5-5). This matrix has two values in each cell. The first is whether the failure mode is low (L, green), medium (M, yellow), or high (H, red), and secondly the rank is the numeric value attached to each cell of the matrix.

The high-risk level (red; ranks 1 to 9) indicates failure modes with significant risk ratings and will be failure modes in most urgent need of further mitigation measures or discontinuation. In general, these failure modes have severe consequences greater than 3, with likely to expected frequency. The medium risk level (yellow; ranks 10 to 17) indicates failure modes with a broad range of likelihoods, expected to rare and severity consequences ranging from 2 to 4. In these cases, the combination of preventative, response, and contingency measures would be generally effective in dealing with these failure modes. Lastly, the low-risk level (green; ranks 18 to 25) has a broad range of likelihoods, expected to rare but low severity (1 and 2). Again these would be dealt with through the combination of preventative, response, and contingency measures.

Table 31.5-4. Criteria for Severity of Failure Modes

Severity Rating	1	2	3	4	5
Production Variance (i.e., Au -ounce Cu - pound, etc.)	< 1%	1 to 2%	2 to 5%	5 to 10%	> 10%
Cost Variance (relative to budget)	< 1%	1 to 2%	2 to 5 %	5 to 10%	> 10%
Safety and Health	First aid case or minor reversible health effect(s) of no concern.	Medical treatment case or reversible health effect(s) of concern, no disability.	Lost time injury/illness or severe, reversible health effect(s) resulting from acute, short-term exposure or progressive chronic condition, infectious disease.	Single fatality, permanent disability, or exposures resulting in irreversible health effect(s) of concern.	Multiple fatalities or health effect(s) resulting in multiple disabling illnesses leading to early mortality.
Environment	Limited environmental effect(s), no regulatory reporting, potential minor delays for 1 to 2 years.	Minor on-site environmental effect(s), reportable to regulators, potential delays for 3 to 6 years.	Moderate environmental effect(s), extending beyond site boundary, regulatory violations with fines, significant potential delays of 6 to 10 years.	Serious medium-term environmental effect(s), major regulatory violations, potential long-term delays for >10 years.	Severe long-term environmental effect(s), severe breach of regulations with operation suspended, potential for closure.
Stakeholder Relations and Reputation	No effect(s) on stakeholder confidence in management of the company.	Limited effect(s) on stakeholder confidence in management of the company.	Medium effect(s) on stakeholder confidence in management of the company.	High effect(s) on stakeholder confidence in management of the company.	Loss of stakeholder confidence in management of the company.

Table 31.5-5. Criteria for Overall Risk Matrix

		Severity				
		1	2	3	4	5
Likelihood	A	L_{18}	M_{11}	H_6	H_3	H_1
	B	L_{20}	M_{14}	M_{10}	H_4	H_2
	C	L_{22}	L_{19}	M_{12}	H_7	H_5
	D	L_{24}	L_{21}	M_{15}	M_{13}	H_8
	E	L_{25}	L_{23}	M_{17}	M_{16}	H_9

31.5.10 Recommended Action

The final "Recommended Action" column of the FMEA worksheet provides for recording of information about possible improvements to existing controls or the implementation of new controls, for each failure mode. The list of Recommended Actions was compared to Chapter 5, Project Description, and Chapter 29, Environmental Management and Monitoring Plans. The Project addresses all Recommended Actions.

31.6 RISK REGISTERS AND RISK MATRICES

31.6.1 Risk across All Impact Categories

Table 31.6-1 presents a summary of the entire risk matrix for all impact categories. Across the five impact categories, there are 430 potential failure modes. Forty-nine (11%) of these are high risk, 135 (32%) medium risk, and 246 (57%) low risk.

Table 31.6-1. Summary of Risk Ranks

		Severity				
		1	2	3	4	5
Likelihood	A	0	4	0	0	0
	B	3	4	19	14	1
	C	21	24	28	20	0
	D	117	43	33	22	1
	E	30	8	12	13	13

Summary of the risk categories indicates that the medium and high risk categories are largely due to potential impact of failure modes on production (47), costs (49), reputation (24), and health and safety categories (55), whereas only nine medium-risk and no high-risk failure modes were associated with the environment (Table 31.6-2).

Table 31.6-2. Risk Level by Impact Category

Impact Category	Low Risk	Medium Risk	High Risk	Total
Cost	113 (26 %)	36 (8 %)	13 (3 %)	**162 (38%)**
Environment	25 (6 %)	9 (2 %)	0 (0 %)	**34 (8%)**
Production	66 (15 %)	39 (9 %)	8 (2 %)	**113 (26%)**
Reputation	10 (2 %)	15 (8 %)	9 (2 %)	**34 (8%)**
Safety and Health	32 (7 %)	36 (8 %)	19 (4 %)	**87 (20%)**
Total	**246 (57%)**	**135 (31%)**	**49 (11%)**	**430**

While Pretivm recognizes the importance of all impact categories, particularly health and safety, the remainder of this chapter, with the exception of the discussion on explosives mishap below, will focus on the potential environmental effects of accidents and malfunctions as per the requirements of the AIR and EIS Guidelines.

Explosives Mishap

Section 21 of the AIR (EAO 2014) stipulates that the Application must provide an “evaluation of the worst-case scenario” for an explosives mishap.

Explosives of the type proposed for use at the Project are very common and are used every day by mining and construction companies throughout Canada. If proper procedures are followed, the risks of accidents and malfunctions are extremely rare. Pretivm has a primary focus on safety and will ensure that appropriate procedures are in place and are strictly followed. As a consequence, the likelihood of the failure mode for an accident or malfunction related to explosives has been assessed as "rare."

For the purpose of addressing the AIR, the worst-case scenario for explosives is considered to be the detonation of a full Operation phase explosives magazine. The explosives magazine will be located north of Brucejack Creek, northwest of and across the creek from the exploration adit. It will be located at distances from other facilities prescribed by federal regulations to ensure the safety of personnel and facilities in the extremely unlikely event of an accident or malfunction.

In a worst-case scenario the principal effects will be health and safety related. It is expected that a worst-case scenario would result in one or more fatalities as an accident or malfunction is most likely to be human-caused. The worst-case scenario would then have a red failure mode of H_9.

An Emergency Response Plan (Section 29.6) will be in place to address explosives-related incidents. The Project will have comprehensive first aid facilities and qualified first aid attendants equipped to handle major incidents. There will be an ambulance and access to a helicopter for transportation of injured persons.

31.6.2 Evaluation of Environmental Failure Modes

To evaluate the environmental risks, the following steps were taken:

- filtering from the FMEA worksheet those failure modes exclusive to the “Environment” category;
- selecting from the array of “Environment” those failure modes whose risk rankings (both residual and inherent) place them in the high- or medium-risk levels, i.e., in the yellow or red sectors of the risk matrix; and
- documenting the rationale behind their rank and subsequent risk level assignment.

Filtering the “Environment” impact category from the FMEA worksheet produced a total of 34 failure modes. Twenty-five of these failure modes are within the low-risk (green) level and nine of them are within the medium-risk (yellow) level. No environmentally related failure modes are in the high-risk (red) levels of the risk matrix (Table 31.6-3).

31.6.3 Low Environmental Risks

Twenty-five failure modes are low environmental risks. Twenty of the failure modes have a combination of being “rare” or “unlikely” and a low severity rating of 1 or 2. Three failure modes are “likely” with a severity rating of 2. A single failure mode is “expected” over the life of the mine. This failure mode is the contamination of the underground sump water with debris and contaminants. The sump gathers the excess water in the underground mine and its contamination is “expected” to occur one or more times sometime over 22 years of Operation. There are no other “expected” or “almost certain,” or “moderate” severity (severity code = 3) or greater failure modes.

Table 31.6-3. Summary of Identified Environmental Risks

		Severity				
		1	2	3	4	5
Likelihood	A	0	0	0	0	0
	B	1	1	1	0	0
	C	0	3	1	0	0
	D	12	6	5	0	0
	E	3	0	1	0	0

Table 31.6-4 summarizes the Failure Mode, Description/Consequence, Area of Impact, Phase, Severity, Likelihood, Risk Level/Rank, and Controls and Applicable Management and Monitoring Plans for low environmental risk failure modes through the FMEA process. Two accidents and malfunctions identified for examination in Section 21 of the AIR (BC EAO 2014) were registered as low risk by the FMEA process (Table 31.6-4). These were the failure of the tailings pipeline and failure of the water diversion channels.

31.6.4 Medium Environmental Risks

Nine failure modes are medium environmental risks. Of these, five have their spatial boundary within the underground environment. Hence, they have negligible effects on the intermediate or receptor VCs. The five failure modes identified for the underground environment will be briefly discussed in the next section; the focus of the assessment will be on the intermediate or receptor VCs potentially affected by the other four failure modes identified as having medium environmental risk. Table 31.6-5 summarizes the Failure Mode, Area of Impact, Phase, Severity, Likelihood, Risk Level/Rank, and Relevant Management Plans for the failure modes with medium environmental risk. An additional failure mode identified by Section 21 of the AIR (BC EAO 2014), explosives mishap, is considered a medium environmental risk but was not identified in the FMEA process as an Environmental impact. Rather it is considered a Health and Safety impact and as such is not included in the Medium Risk Registry developed from the FMEA (Table 31.6-5). In reviewing the Risk Registry, this is an erroneous omission. This chapter will include a description of preventative and contingency measures and an environmental assessment for explosives mishap.

31.6.4.1 Medium Environmental Risks – Underground Failure Modes

Five of the medium failure modes are associated with the underground works. While an Application/EIS process focuses on effects assessment, the FMEA process focuses on identifying all potential failures, in terms of likelihood and severity. Underground failure modes are serious in nature; however, the receiving environment is isolated such that there are negligible interactions with the designated intermediate and receptor VCs. One these medium risks, inadequate capacity of the water treatment plant and failure of underground mine stability, is also listed in the requirements of Section 21 of the AIR (BC EAO 2014). The FMEA recognized failure of underground mine stability under a number of impact categories including: Health and Safety, Production, Costs, and Reputation. Environment was not one of those categories. Nonetheless, this section describes failure of underground mine stability as an environmental risk.

Table 31.6-4. Risk Register – Low Environmental Risks

Failure Mode	Description/ Consequence	Area of Impact	Phase	Severity	Likelihood	Risk Level/ Rank	Controls and Applicable Management and Monitoring Plans
Pipeline breakage/ release of tailings discharge[1]	Uncontrolled release of tailings onto land and into lake	Tailings - Tailing Delivery System	Operation	Level 2	Unlikely	L21	Design and Standard Operating Procedures (SOPs); Emergency Response Plan; Spill Prevention and Response Plan; Tailings Management Plan
Overflow of control structures[1]	Flooding and washout resulting in overland flows of water particularly during freshet runoff	General Development - Site Drainage	Construction, Operation, Closure	Level 2	Unlikely	L21	Design, and Procedural (inspection, and maintenance); Ecosystem Management Plan; Soils Environmental Management and Monitoring Plan
Blasting/general construction creating runoff	Acid rock drainage/ metal leaching	General Development - Bulk Earthworks/ Site Preparation	Construction, Operation	Level 2	Likely	L19	This is not a true failure mode as this is a drilling program undertaken to develop an understanding of the location of PAG material so that where possible disturbance of PAG material could be avoided during Operations, Drilling program, lab analysis, and field testing (ongoing); ML/ARD Management and Monitoring Plan
Vehicle accidents/ building strikes	Spills of fuels or loads	Off-site Infrastructure - Knipple Transfer Area	Construction, Operation, Closure	Level 2	Likely	L19	Design and SOPs; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan; Transportation and Access Management Plan
Spills/waste oil handling and storage	Spills of fuels	Utilities - Waste Disposal - Solid Waste Disposal (General)	Exploration, Construction, Operation, Closure	Level 2	Likely	L19	Design and SOPs; Environmental permits/authorizations (Hazardous waste regulations); Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan
Contamination of sump water with debris and other fluids (e.g., oil and fuel)	Release of contaminants into tailings discharge	Underground Mining Infrastructure - Pump Station	Operation	Level 1	Expected	L20	Oil-water separator in design, containment of fuel storage, and spill kits available for equipment; Environmental permits/authorizations (Hazardous waste regulations); Hazardous Materials Management Plan; Spill Prevention and Response Plan; Waste Management Plan

(continued)

Table 31.6-4. Risk Register – Low Environmental Risks (continued)

Failure Mode	Description/ Consequence	Area of Impact	Phase	Severity	Likelihood	Risk Level/ Rank	Controls and Applicable Management and Monitoring Plans
Spills/contamination (as well as blasting residue)	Spills of contaminants and sediment	General Development - Bulk Earthworks/ Site Preparation	Construction, Operation	Level 2	Unlikely	L21	Design, Procedures to mitigate spills, and contact water collection pond; Environmental permits/authorizations (Hazardous waste regulations); Hazardous Materials Management Plan; Soils Spill Prevention and Response Plan
Spills	Contamination of underground environment. Potential for contaminants to reach aboveground environment	Underground Mining Infrastructure - Explosive Magazine	Operation	Level 2	Unlikely	L21	Design and SOPs; *Mines Act* (1996) and federal *Explosives Act* (1985); Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan
Plugging of sand filter at the discharge terminus	Decrease in water quality with potential secondary effect(s) on aquatic resources and sediment chemistry, and downstream effect(s)	Tailings - Tailing Delivery System	Operation	Level 2	Unlikely	L21	Design - upstream treatment, design - treatment in situ, Brucejack Lake discharge monitoring procedures, water quality monitoring and SOPs; Tailings Management Plan; Waste Rock Management Plan
General failure of road network caused by receding glacier	Road closures, increased chance of vehicle accidents resulting in spillage of fuels and loads	Off-site Infrastructure - Off-site Access Road	Exploration, Construction, Operation, Closure	Level 2	Unlikely	L21	Maintenance Procedures; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan; Transportation and Access Management Plan
General failure of sedimentation and erosion measures	Erosion of soils and increased sediment transport from runoff	General Development - Bulk Earthworks/ Site Preparation	Construction, Operation, Closure	Level 1	Unlikely	L24	Design and SOPs; Ecosystem Management Plan; Soils Transportation and Access Management Plan; Waste Rock Management Plan
Failure of dust control measures on roads	Decrease in air quality, increased sediment in receiving environment	General Development - Site Roads	Construction, Operation	Level 1	Unlikely	L24	Design and SOPs; Air Quality Management Plan; Ecosystem Management Plan; Rare Plants and Lichens Management Plan; Soils Waste Rock Management Plan

(continued)

Table 31.6-4. Risk Register – Low Environmental Risks (continued)

Failure Mode	Description/ Consequence	Area of Impact	Phase	Severity	Likelihood	Risk Level/ Rank	Controls and Applicable Management and Monitoring Plans
Equipment fires	Direct effect(s) on air quality in underground environment. Potential decrease in air quality upon venting to aboveground environment.	Underground Mining Equipment - Mobile Equipment	Operation	Level 1	Unlikely	L24	Emergency response plans in place, and fire suppression is specified on all mobile equipment; Air Quality Management Plan; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan
Equipment fires	Direct effect(s) on air quality in underground environment. Potential decrease in air quality upon venting to aboveground environment.	Underground Mining Equipment - Fixed Equipment	Operation	Level 1	Unlikely	L24	Emergency response plans in place; Air Quality Management Plan; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan
Spills and pipe failures (e.g., fuels, grease, and solvents)	Cleanup in the underground environment. Minimal effect(s) to aboveground environment.	Underground Mining Infrastructure - Underground Fuel Storage and Distribution	Operation	Level 1	Unlikely	L24	Design, and SOPs; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan
Spills (in loading bay, assay lab)	Cleanup within buildings environment. Minimal effect(s) to outside environment.	Ancillary Facilities - Buildings General	Construction, Operation	Level 1	Unlikely	L24	Design and SOPs; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan
Failure of collection pond for runoff	Runoff creating overland flows and potential erosion and sediment transport.	Temporary Facilities - General Temporary Facilities	Operation	Level 1	Unlikely	L24	Design and SOPs; Spill Prevention and Response Plan; Wetland Ecosystem Monitoring Plan
Instability of temporary waste rock dump	Slumping of waste rock pile causing discharges of sediment into the surrounding area.	Temporary Facilities - General Temporary Facilities	Operation	Level 1	Unlikely	L24	Design, scheduling, and monitoring of temporary storage facility; Soils Waste Rock Management Plan

(continued)

Table 31.6-4. Risk Register – Low Environmental Risks (completed)

Failure Mode	Description/ Consequence	Area of Impact	Phase	Severity	Likelihood	Risk Level/ Rank	Controls and Applicable Management and Monitoring Plans
Equipment fires	Health and safety incidents, delay to schedule, equipment damage, spills, and air quality	Surface Mobile Equipment - Surface Mobile Equipment	Exploration, Construction, Operation, Closure	Level 1	Unlikely	L24	Emergency response plans in place, and fire suppression is specified on all mobile equipment; Air Quality Management Plan; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan
Inadequate emergency response planning	Could potentially affect responses to all environmental emergencies	Mine-wide	Exploration, Construction, Operation, Closure	Level 1	Unlikely	L24	Existing emergency plan and *Mines Act* (1996) and regulations; Emergency Response Plan; all specific environmental sector management plans
Spills	Potential fuel spills and other contaminants to soil and water bodies	Utilities - Fuel, Storage, & Distribution - (General)	Exploration, Construction, Operation	Level 1	Unlikely	L24	Design and SOPs; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan; Transportation and Access Management Plan
Inadequate solid waste storage	Attraction of wildlife to Mine Site, wildlife-human interactions	Utilities - Waste Disposal - Solid Waste Disposal (General)	Exploration, Construction, Operation	Level 1	Unlikely	L24	Design and SOPs; Environmental Management Plan and Reporting; Waste Management Plan
Inadequate sewage holding tank	Potential for contaminant spills including raw sewage to soil and water bodies	Ancillary Facilities - Buildings General	Construction, Operation	Level 1	Rare	L25	Design and SOPs; Spill Prevention and Response Plan; Waste Management Plan
Disruption of wildlife and fish habitat created by culvert and bridge failures	Disruption of Ungulate corridors, fish habitat and streams, environmental permitting	Off-site Infrastructure - Off-site Power Transmission	Construction, Operation, Closure	Level 1	Rare	L25	Design and Procedural Controls
Inadequate sewage treatment capacity	Low plant performance from increased flow; and environmental non-compliance	Utilities - Waste Disposal - Solid Waste Disposal (General)	Construction, Operation	Level 1	Rare	L25	Design and SOPs; Environmental Management Plan and Reporting

[1] *These were also noted in Section 21 of the AIR (BC EAO 2014).*

Table 31.6-5. Risk Register – Medium Environmental Risks

Failure Mode	Area of Impact	Phase	Severity	Likelihood	Risk Level/ Rank	Relevant Management Plans
Water inflow to underground works	Mining Underground - Vertical Development	Operation	Level 4	Expected	M14	Emergency Response Plan; Water Management Plan
Vehicle collisions/ congestion - underground	Underground Mining Equipment - Mobile Equipment	Operation	Level 3	Unlikely	M15	Emergency Response Plan; Underground Access/Traffic Management Plan
Vehicle collisions, water damage, and ground failure	Underground Mining Equipment - Fixed Equipment	Operation	Level 3	Unlikely	M15	Emergency Response Plan; Underground Access/Traffic Management Plan
Existing exploration borehole openings allowing access to the underground works	Mining Underground - Vertical Development	Exploration, Construction, Operation, Closure	Level 3	Likely	M17	Emergency Response Plan
Inadequate capacity of the water treatment plant	Utilities - Water Systems - Distribution System General	Operation	Level 3	Unlikely	M15	Water Management Plan
General failure of tailings discharge systems and waste rock placement and storage creating sediment	Tailings - Tailing Delivery System, Waste Rock Placement and Storage	Operation	Level 3	Expected	M10	Tailings Management Plan; Waste Rock Management Plan
Spills	Off-site Infrastructure - Off-site Access Road	Exploration, Construction, Operation, Closure	Level 3	Likely	M12	Avalanche Management Plan; Ecosystem Management Plan; Emergency Response Plan; Hazardous Materials Management Plan; Spill Prevention and Response Plan; Transportation and Access Management Plan
Vehicle collisions/congestion - surface	Surface Mobile Equipment - Surface Mobile Equipment	Exploration, Construction, Operation, Closure	Level 3	Unlikely	M15	Emergency Response Plan; Transportation and Access Management Plan
Loss of vehicles on the glacier	Off-site Infrastructure - Off-site Access Road	Exploration, Construction, Operation, Closure	Level 3	Unlikely	M15	Avalanche Management Plan; Emergency Response Plan; Transportation and Access Management Plan

Failure of the Water Treatment Plant

Due to equipment failure, the capacity at the water treatment plant could be potentially overwhelmed creating the potential for water not being removed from the underground mine. The water treatment plant receives contact water from two sources; groundwater seepage into the underground workings, and contact surface water that would report to the collection pond. In the event of a failure of the water treatment plant, water would remain in the collection pond while underground inputs would cease. There would be no release of water to the surface environment; hence, there will be no environmental effects on intermediate or receptor VCs.

Preventive measures focus on building capacity within the treatment plant system to handle larger volumes or failure of the system. The design of the plant will be modular with two or three identical treatment modules, ensuring at least one module will work, allowing some treatment to continue. The design capacity of the water treatment plant exceeds inputs. The capacity of the water treatment plant during years 0 to 12 has 7,440 m^3/d of mine water needing to be treated. In Year 13, this will increase to 11,160 m^3/d. Design capacity of the collection pond exceeds typical inputs. Capacity for the collection pond is based on a 24-hour, 200-year return period rainfall event. Assuming a runoff co-efficient of 0.9, the required storage volume is 15,000 m^3. Design capacity of pumps exceeds inputs. Capacity for the pumping system will have a maximum inflow of 139 L/s. Total inflows are estimated to be approximately 100 L/s. The pipe capacity will match the maximum inflow. In a worst-case scenario of a complete failure of the water treatment plant, dewatering of underground facilities would cease to limit total inflow until repairs are completed. Forecasting and monitoring of extreme precipitation events and snow pack melting allows for treatment and to pre-empty the collection pond.

Water Inflow into Underground Works

Water inflow into mining works is a part of the normal operations of an underground mine. This has the potential of degrading the air and water quality in the underground environment but these effects, while of concern for health and safety, production, and costs, have no effects on the intermediate and receptor VCs. Proper design and effective management and monitoring of water ingress into the underground works will provide preventative measures. An array of preventative, mitigation, and management measures encompassed by the various policies, plans, monitoring procedures, and SOPs for the entire mine operation will maintain the underground quality of air and water.

Existing Exploration Borehole Openings

Borehole openings allow water ingress into underground works. Similar to Water Inflow into Underground Works, there are no predicted effect(s) on the intermediate and receptor VCs. Borehole openings will be plugged to limit water ingress.

Vehicle Collisions/Congestion - Underground

A residual risk exists with underground mobile equipment in that collisions or congestion increase the risk of spills of potentially hazardous materials. The location of these accidents confines these spills to the underground location; hence, there will be no effect(s) on intermediate and receptor VCs. A Spill Prevention and Response Plan (Section 29.14) is in place for the Project.

Failure of Underground Mine Stability

The FMEA analysis identified four failure modes associated with underground mine emergencies including roof fall. These were associated with potential impacts to health and safety, production, cost, and reputation. The FMEA identified no environmental impacts. However, intermediate and receptor VCs may be affected by an underground collapse through subsidence of the terrain above the mine.

This has the potential to change surface water and groundwater flows, terrestrial ecosystems, and the subsequent changes to aquatic resources, fish and fish habitats, and wildlife and wildlife habitats.

Appendix 11-C, *Preliminary Assessment of Subsidence Potential for the Brucejack Gold Mine Project*, assesses the underlying geology of the Project, mine plan, and other site-specific conditions. The potential for subsidence at the Project indicates a very low probability that significant subsidence will occur.

31.6.4.2 Medium Environmental Risks – Surface Failure Modes

Table 31.6-6 identifies and describes the mechanisms and conditions associated with medium environmental risk failure modes and their prevention, mitigation, and follow-up monitoring. Additional management plan details for each topic are presented in Chapter 28, Environmental Management System, and Chapter 29, Environmental Management and Monitoring Plans. The management of risk and assessment of environmental effects for spills are further subdivided. In particular, the management and assessment for spills depends on the load (fuel, concentrate, or other hazardous materials) and the receiving environment (land or water). This section includes requirements for Section 21 of the AIR (BC EAO 2104) with descriptions and assessments for:

- concentrate spills;
- fuel spills outside secondary containment;
- hazardous spills; and
- explosives mishap.

31.7 ASSESSMENT OF POTENTIAL ENVIRONMENTAL EFFECTS

Five medium risk failure modes identified for the Project were advanced for environmental assessment. Following precautionary and emergency preparedness management principles, assessment is based on realistic worst-case scenarios. As an example, spills of any magnitude due to accidents were considered “likely”, reflecting the probability of a road accident over the 22 years of mine life. However, the magnitude of spills can vary from the losses from a personal vehicle to the 20,000-L haul trucks used to supply gasoline and diesel fuel. For the following assessment, a worst-case scenario would involve a fuel spill involving a 20,000-L fuel haul truck, which is considered to have a frequency of “rare.” Although spills were considered a single mode, the prevention, mitigation, and follow-up as well as potential effects on VCs, are likely to be different depending on the vehicle type, trip frequency, substance spilled, and receiving environment. Thus, failure mode for spills was divided into four categories.

The following failure modes were considered for environmental assessment:

1. Sediment in Tailings Discharge and Waste Rock. The release of suspended solids and metals into Brucejack Lake potentially entering Brucejack Creek and downstream to the receiving environment above permitted levels.

2a. Spill/Fuel – Land. 20,000-L fuel supply (gasoline or diesel) truck overturns and releases load onto adjacent soil.

2b. Spill/Fuel – Water. 20,000-L fuel supply (gasoline or diesel) truck overturns and releases load onto adjacent water bodies.

2c. Spill/Concentrate – Land. Concentrate haul truck (40 tonne tandem) overturns and releases load onto adjacent soil.

2d. Spill/Concentrate – Water. Concentrate haul truck (40 tonne tandem) overturns and releases load into adjacent water bodies

3. Vehicle Collisions/Congestion – Surface. A vehicle collision occurs causing a loss of load or spill of hazardous materials other than fuel or concentrate.
4. Loss of Vehicles on the Glacier and to Avalanche – Spills of fuel, concentrate, or hazardous materials on the glaciers or as the result of avalanche.
5. Explosives Mishap – Detonation of the explosives magazine during the Operation phase.

31.7.1 Identification of Potential Interactions between Failure Modes with Intermediate and Receptor Valued Components

Thirteen intermediate and receptor VCs were considered for an initial screening on the environmental effects of failure modes. The failure modes described in Table 31.6-6 were examined across an interaction matrix with subject areas including climate, noise, air, hydrology, hydrogeology, surface water quality, aquatic resources, fish and fish habitat, terrain and soil, terrestrial ecology, wetlands, wildlife and wildlife habitat, heritage, traditional land use, and commercial and non-commercial land use. Interactions between failure modes and intermediate and receptor VCs within the subject areas were ranked in a similar manner as the interaction between key Project effects and intermediate and receptor VCs for the primary effects assessment as described in Chapter 6, Assessment Methodology. The interactions were ranked as follows:

- Hollow (0) — no interaction anticipated.
- Green (1) — negligible to minor adverse effect(s) expected and discussed; no monitoring required and will not be carried forward in the formal assessment.
- Yellow (2) — potential for moderate adverse effect(s); these are often the secondary or tertiary receptor(s) along a chain of consequences emanating from a failure mode – effect(s) pathway; warrants further consideration and will be carried forward in the assessment.
- Red (3) — key interaction resulting in potential significant major adverse effect(s) or concern(s); warrants further consideration and will be carried forward in the assessment.

Table 31.7-1 summarizes the interaction ranks between failure modes and subject areas.

Interactions considered to have the potential for moderate to major adverse effects (rated as yellow or red in Table 31.7-1) are considered in more detail and are assessed using similar characteristics as was used for the residual effects assessments described in Chapter 6, Assessment Methodology. However, the scope of the accidents and malfunctions are both spatially and temporally often much more limited. Environmental effect(s) are only likely to manifest at the location of the accident or malfunction and a single short-term effect. The formal analysis provides transparency on assessments and provides important information for mitigation and follow-up monitoring and management of consequences. Table 31.7-2 summarizes the assessment characteristics and their descriptors, and significance levels.

Table 31.6-6. Description, Prevention, and Responses to Potential Medium Environmental Risk Failure Modes

Potential Failure Mode	Potential Environmental Effect(s)	Preventative Procedures	Response and Contingency Procedures	Follow-up Monitoring
1. General Failure of Tailings Discharge Systems and Waste Rock Placement and Storage-Creating Sediment. A worst-case scenario would result from a malfunction of the tailings discharge system, damage to turbidity curtains, or slumping of submerged waste rock pile. Tailings with a maximum concentration of 35% w/w solids will be discharged at a constant rate of 77 L/s (corresponding to a flow rate of 278 m^3/h). During Construction 531,000 m^3 of waste rock will be deposited in the Brucejack Lake. During Operation, 1.18 Mm^3 of waste rock will be deposited in the Brucejack Lake. Waste rock deposition in Brucejack Lake decreases after year 5 of operations with a small planned increase in year 9. Thereafter waste rock deposition will decrease until mine closure at year 22.	1. Potential primary effect(s) on surface water (total suspended sediments and elevated metals). 2. Potential secondary effect(s) on aquatic resources and fish and fish habitat.	• Proper design, engineering, construction, and operation of the tailing discharge system; • Monitor, review and assess the recent deposition of waste rock and tailings discharge system; • Deposition of tailings at depth and to bottom of a coarse sand or gravel over the pipeline terminus to filter the slurry being discharged and prevent transport of the tailings solids toward the upper layers of the lake; • Air valves on tailings pipeline to release trapped air and prevent suspension of sediments in air bubbles; • Continuous flow of tailings through tailings mound; • Twinning of pipeline for tailings discharge to provide for pipeline maintenance and emergency shutdown; • Monitoring and adjusting the composition and flow rates of tailings discharges; • Monitoring and response to any deformation of the waste rock pile is critical to maintaining its stability. Limiting the rate of advancement of the crest line will also prevent waste rock from being deposited too rapidly onto the lake bottom sediments and creating bottom sediment dispersal events; • Use of a turbidity curtain placed across outlet of Brucejack Lake to prevent sediments from escaping the deposition area; and • Runoff from temporarily stored waste rock will be collected in a collection channel and will not be allowed to flow to adjacent water bodies.	• Conduct initial response and notification (Environmental Manager, Mine Manager); • Initiate assessment of potential health, safety, and environmental effect(s); • It is unlikely that water of unsuitable quality will be released to downstream environments; however, if it is, conduct initial response and notification (Mine Manager, MOE, EC, MMER) following the Emergency Response Plan, including downstream users; activate emergency response groups; and, initiate immediate monitoring and assessment procedure; • Back-up turbidity curtains available for immediate replacement of any damaged or failed curtains; • Contingency for fines "escaping" from tailings area would be to stop discharge of tailings and allow only water to flow through the pipe; and • If pipeline becomes blocked or fails, transition flow to second pipeline.	• Implement enhanced monitoring of water quality particularly total metals, turbidity, and downstream sediment quality, if applicable.
2a. Spill/Fuel – Land 2b. Spill/Fuel – Water 2c. Spill/Concentrate – Land 2d. Spill/Concentrate – Water A vehicle travelling on an off-site road has an accident and releases fuel or concentrate onto adjacent environment. Gasoline and diesel fuel, which contain hydrocarbons, heavy metals, increased nutrient and salt loads, and toxic compounds, including benzene, toluene, and hexavalent chromium are released. The concentrate is not considered a dangerous good or hazardous material. The primary effect(s) would be physical smothering of soil with potential secondary effect(s) including; an increase in airborne particulate matter and reaction with water to produce metal leachates. Vehicles on access roads will range from ATVs to large fuel supply trucks (gasoline or diesel) with up to 20,000 L capacity. A worst-case scenario would be an accident and spill from a 20,000 L fuel truck. Fuel trucks will make 20 to 25 trips a month during Operations.	Land 1. Potential primary effect(s) on soils with diesel and gasoline or concentrate contamination. 2. Potential secondary effect(s) of concentrate on air quality. Water 1. Potential primary effect(s) on surface water quality with diesel and gasoline or concentrate contamination. 2. Potential secondary effect(s) on aquatic resources, fish and fish habitat, wetlands, and terrain and soil (riparian).	• Fuel trucks will meet all regulatory standards for the safe transport and handling of fuels; • Design, construct, and maintain Project site and access roads are designed to Mines Act standards so that they are safe for designated uses including the use of guard rails and berms to prevent over turning and/or capture load loss; • Prevent site and access roads from becoming wildlife attractants to avoid wildlife vehicle collisions; • Controlling access along the Project roads, with the ultimate objective of zero unauthorized use; • Controlling excessive speed on access roads to the speed limit or less depending on environmental conditions, promoting, and ensuring safe driving practices; • Regular inspection, maintenance (including an up-to-date maintenance plan and log), and equipping (including radio contact capability, and emergency spill materials) of mine and contractor vehicles; • Convoying traffic at times of poor visibility; • Ensure training of mine personnel and contractors for safe driving and emergency response and spill contingency procedures; and • Implement haul supervision and monitoring (check-in, check-out), and driver feedback to evaluate and report road conditions.	• Response protocol for spills: o identification and control of immediate dangers to human life or health; o identification and control of spill source; o elimination of additional potential spill sources; o containment of spill; o notification of authorities, as appropriate; o recovery and cleanup; and o incident investigation and reporting. • Initial Response o the safety of the site for all personnel and the public will be ensured; o immediate hazards associated with the spill material or near the spill (e.g., aromatic substances, flammable material, or ignition sources) will be mitigated; o responsible Environmental Manager and Health and Safety representative will be notified; and o the spill material and source of the spill will be identified. • If safe to do so: o measures will be taken to stop the flow; o barriers will be constructed with available materials (e.g., snow, earth, or absorbent pads) to prevent the spread of material; in particular, to prevent the spill from entering any watercourse; and o if the material or circumstance is unsafe, the relevant Environmental Manager and Health and Safety representative will be notified that an emergency response team is required.	• Implement enhanced soil and groundwater monitoring procedures to assess requirement for additional soil cleanup and disposal, if required; and • Implement enhanced water quality monitoring procedures to assess requirement for additional cleanup.

(continued)

Table 31.6-6. Description, Prevention, and Responses to Potential Medium Environmental Risk Failure Modes (continued)

Potential Failure Mode	Potential Environmental Effect(s)	Preventative Procedures	Response and Contingency Procedures	Follow-up Monitoring
2. *(cont'd)* Concentrate is moved in 40 tonne tandem haul trucks. A worst-case scenario would be a spill from one of these vehicles. Concentrate haul trucks will make 100 to 130 trips a month during Operations. The length of the access road is 75 km. Water bodies adjacent to the access road include the glacier, Bowser River, Scott Creek, and tributaries of Wildfire Creek. Also, the wetlands at the junction of the Todd Creek, Bowser River, and Bowser Lake.			• Secondary Response o Once the initial response has been undertaken, possibly affected environmental receptors will be identified and protected, particularly surface water bodies; o Mobilizing appropriate cleanup methods including using absorbents (e.g., oil booms or pads). Small spills of fuel and glycol or battery acids can be buried to prevent wildlife attraction. Large spills may require hydro-vacuuming or soil removal and disposal, where appropriate; o Statutory reporting of spills of more than 100 L of fuel to provincial authorities. Spill Report needs to be submitted within 24 hours to the BC Provincial Emergency Program at 1-800-663-3456; and • Reporting potential effect(s) to fish and fish habitats to Fisheries and Oceans Canada, if appropriate.	
3. Vehicle Collisions/Congestion – Surface A vehicle collision occurs causing a loss of load or spill of hazardous material other than fuel or concentrate (discussed above 2a, 2b, 2c, 2d). The volume of traffic from Highway 37 to the Knipple Transfer Area during Construction will be 2,075 to 2,175 trips per year, and during Operation 2,695 to 3,105 trips per year.	1. Potential primary effect(s) on surface water, and terrain and soils depending on receiving environment. Collisions with wildlife can affect wildlife populations. 2. Potential secondary effect(s) on aquatic resources, wetlands, and fish and fish habitat.	• Fuel trucks will meet all regulatory standards for the safe transport and handling of fuels; • Design, construct, and maintain Project site and access roads are designed to Mines Act standards so that they are safe for designated uses including the use of guard rails and berms to prevent over turning and/or capture load loss; • Prevent site and access roads from becoming wildlife attractants to avoid wildlife vehicle collisions; • Controlling access along the Project roads, with the ultimate objective of zero unauthorized use; • Controlling excessive speed on access roads to the speed limit or less depending on environmental conditions, promoting, and ensuring safe driving practices; • Regular inspection, maintenance (including an up-to-date maintenance plan and log), and equipping (including radio contact capability, and emergency spill materials) of mine and contractor vehicles; • Convoying traffic at times of poor visibility; • Ensure training of mine personnel and contractors for safe driving and emergency response and spill contingency procedures; and • Implement haul supervision and monitoring (check-in, check-out), and driver feedback to evaluate and report road conditions.	• Response protocol for spills: o identification and control of immediate dangers to human life or health; o identification and control of spill source; o elimination of additional potential spill sources; o containment of spill; o notification of authorities, as appropriate; o recovery and cleanup; and o incident investigation and reporting. • Initial Response o the safety of the site for all personnel and the public will be ensured; o immediate hazards associated with the spill material or near the spill (e.g., aromatic substances, flammable material, or ignition sources) will be mitigated; o responsible Environmental Manager and Health and Safety representative will be notified; and o the spill material and source of the spill will be identified. • If safe to do so: o measures will be taken to stop the flow; o barriers will be constructed with available materials (e.g., snow, earth, or absorbent pads) to prevent the spread of material; in particular, to prevent the spill from entering any watercourse; and o if the material or circumstance is unsafe, the relevant Environmental Manager and Health and Safety representative will be notified that an emergency response team is required. • Secondary Response o Once the initial response has been undertaken, possibly affected environmental receptors will be identified and protected, particularly surface water bodies; o Mobilizing appropriate cleanup methods including using absorbents (e.g., oil booms or pads). Small spills of fuel and glycol or battery acids can be buried to prevent wildlife attraction. Large spills may require hydro-vacuuming or soil removal and disposal, where appropriate; o Statutory reporting of spills of more than 100 L of fuel to provincial authorities. Spill Report needs to be submitted within 24 hours to the BC Provincial Emergency Program at 1-800-663-3456; and o Reporting potential effect(s) to fish and fish habitats to Fisheries and Oceans Canada, if appropriate.	• Implement enhanced soil and groundwater monitoring procedures to assess requirement for additional soil cleanup and disposal, if required; • Implement enhanced water quality monitoring procedures to assess requirement for additional cleanup; and • Implement enhanced wildlife monitoring if required.

(continued)

Table 31.6-6. Description, Prevention, and Responses to Potential Medium Environmental Risk Failure Modes (completed)

Potential Failure Mode	Potential Environmental Effect(s)	Preventative Procedures	Response and Contingency Procedures	Follow-up Monitoring
4. Loss of Vehicles on the Glacier and to Avalanche[1]. Traversing the glacier segment of the access road will have a higher risk than travel along other site roads and the other sections of the access road. Crevasses, changing location of the active driving surface, often poor visibility, fog, and inclement weather increase the risks of travel along the glacier. The length of road to the south of Brucejack Lake between the Knipple Glacier and the Mine Site has a high potential for avalanches. Thirty five other avalanche areas are identified. With both travel on the glacier and avalanches, the worst-case scenario would be loss of a vehicle and its load. The volume of traffic over the glacier would be 6,681 to 8,201 trips per year.	1. Potential primary effect(s) on surface water (snow and ice) fuel, concentrates, other materials. 2. Potential secondary effect(s) on aquatic resources.	Preventative measures discussed in 2a, 2b, 2c, 2d, and 4 apply. Further points specific to glacier and avalanche travel include: • specific training for vehicle travel along the glacier and within avalanche zones; • routine monitoring and reporting weather, road condition, and avalanche hazard; • check-in/check-out procedures; • vehicles hauling on the glacier will travel in convoys during periods of particularly poor visibility; • glacier haul equipment will have Global Positioning System navigation devices and will remain in radio communication with other haul equipment and the camps; • The road route will be demarcated with closely spaced, high-visibility bamboo stakes that will provide a visual reference for operators at night and in low-visibility weather; • road signage for these areas should be high visibility and provide with content including recommended travel speeds, avalanche hazard areas, glacier road hazard areas, and rescue equipment cache locations; • the glacier road route will be regularly inspected during the summer months and altered to avoid particularly large hazards as needed; • crevasse surveys will be completed each summer so that a safe route can be planned for the winter when crevasse hazards are obscured by snow bridging; • during periods when it is unsafe to travel on Lakeshore Drive due to high avalanche hazard, an alternate snow route over the Valley of the Kings will be used; • increased communications via VHF radio or satellite phones on the glacier road; and • the use of explosives to reduce road or worksite closures during periods of high avalanche hazard. Regulations, protocols, and standards relevant to the use of explosives are also listed in the Avalanche Management Plan (Section 29.4).	• Follow measures outlined in the Emergency Response Plan after an accident including the action plans in the event of a traffic accident referencing firefighting, road closures, and evacuation, if required. • Vehicles traversing the glacier and avalanche zone are equipped with location GPS tracking devices and transreceivers; personnel working outside vehicles are equipped with personal transreceivers. • Rescue caches will be located at the Mine Site (mine rescue training room), the Knipple Transfer Area, the Bowser Aerodrome, and in each Snowcat. • A systematic approach to dealing with avalanche rescues is described, comprising three plans for immediate action by directly involved personnel, for the site rescue leader, and for base personnel. These plans are described in the Avalanche Management Plan (Section 29.4). • Follow the spill response protocol (see above), if applicable: o identification and control of immediate dangers to human life or health; o identification and control of spill source; specific guidelines for managing specific substances are given in the Spill Prevention and Response Plan, and the Hazardous Materials Management Plan. o elimination of additional potential spill sources; o containment of spill; o notification of authorities, as appropriate; required reporting guidelines for different substances are available in the Spill Prevention and Response Plan and the Hazardous Materials Management Plan. o recovery and cleanup; and o incident investigation and reporting.	• Implement snow monitoring procedures to assess requirement for additional snow cleanup and disposal; and • Enhanced monitoring of nearby water bodies if runoff contamination is a possibility.
5. Explosives Mishap Explosives on site include: • ammonium nitrate-based products, such as the Senatel™; • a range of bulk emulsion explosives; • packaged stick explosives are also likely to be used where emulsion is not appropriate; and • ignition systems will include detonating cords, boosters, detonators, and connectors. A worst-case scenario would be the detonation of a full Operation phase explosives magazine. During the Construction phase the existing exploration explosives magazines will continue to be used for the development of the underground works. During Operations, explosives consumption at full production is estimated to be 2.7 t/d of bulk emulsion. Two emulsion bays will each contain two 6,000-L storage tanks and a storage area. Consumption will average three tanks per week.	1. Potential primary effect(s) on terrain and soils and aquatic resources. 2. Potential secondary effect(s) on air quality, surface water quality, and fish and fish habitat.	• The design criteria for all manufacturing and storage facilities for explosives will conform with the requirements of the *Explosives Act* (1985), Ammonium Nitrate Storage Facilities Regulations (CRC, c 1145), Transportation of Dangerous Goods Regulations (SOR/2001-286), Guidelines for Bulk Explosives Facilities (NRCan 2010), and the Health, Safety and Reclamation Code for Mines in British Columbia (BC MEMPR 2008). • Explosives will be stored in licensed magazines located in accordance with the *Explosives Act* (1985) and criteria established by the NRCan Explosives Regulatory Division. The explosive magazine will be located north of Brucejack Creek, northwest of and across the creek from the exploration adit. It will be located at distances from other facilities prescribed by federal regulations to ensure the safety of personnel and facilities in the extremely unlikely event of an accident or malfunction. • Explosives will be transported to the Knipple Transfer Area in highway trucks by qualified contractors following the strict requirements of the federal *Explosives Act* (1985) and the *Transportation of Dangerous Goods Act* (1992) and the Transportation of Dangerous Goods Regulations (SOR/2001-286). • Transportation will take place as soon as possible, again in a manner consistent with the *Transportation of Dangerous Goods Act* (1992) and related regulations, and stored in designated and licensed explosives magazines. The magazines will be designed and operated in a manner consistent with the *Explosives Act* (1985), the Ammonium Nitrate Storage Facilities Regulations (CRC, c. 1145), and Natural Resources Canada's Guidelines for Bulk Explosives Facilities. The transportation, storage, handling, and use of explosives on the Project will also be consistent with the requirements of the *Mines Act* (1996).	• An explosion mishap will trigger the Emergency Response Plan (Section 29.6) and Spill Prevention and Response Plan (Section 29.14) that will provide specific information concerning compatibility groups, emergency plans for various classes of explosive materials, criteria for initiation of emergency and evacuation plans, resources, detailed contact lists, reviews, and testing plan.	• Depending on the receiving environment and environmental effect(s), implementation of enhanced monitoring may be required.

[1] *Avalanches were not noted in the original FMEA but comes off the glacier to link the Knipple Transfer Area and the Brucejack Mine Site.*

Table 31.7-1. Interaction of Potential Project Failure Modes with Intermediate and Receptor Valued Component Subject Areas

Description of Failure Mode	Air	Climate	Noise	Groundwater	Surface Water	Aquatic Resources	Fish and Fish Habitat	Terrain and Soil	Terrestrial Ecology	Wildlife and Wildlife Habitat	Wetlands	Heritage	Traditional Land Use	Commercial and Non-Commercial Land Use
1. Sediment in tailings discharge and waste rock					3	3	1							
2a. Spill/Fuel - land								3						
2b. Spill/Fuel - water					3	3	2	1			2			
2c. Spill/Concentrate - land	1							2						
2d. Spill/Concentrate - water					3	3	2				2			
3. Vehicle collisions/Congestion - surface					2	1	1	2		2	1			
4. Loss of vehicles on the glacier/avalanches					2	1								

Table 31.7-2. Characteristics and Descriptors for Environmental Assessment

Characteristic and General Definition	Descriptors
Magnitude: This refers to the expected magnitude or severity of the residual effect after response to the failure mode.	*Low*: differing from the average value for baseline conditions to a small degree, but within the range of natural variation and well below a guideline or threshold value. *Moderate*: differing from the average value for baseline conditions and approaching the limits of natural variation, but below or equal to a guideline or threshold value. *High*: differing from baseline conditions and exceeding guideline or threshold values so that there will be a detectable change beyond the range of natural variation (i.e., change of state from baseline conditions).
Duration: This refers to the length of time the effect persists.	*Short Term*: an effect that lasts approximately 1 to 5 years. *Medium Term*: an effect that lasts between 6 to 25 years. *Long Term*: an effect that lasts between 26 and 50 years. *Far Future*: an effect that lasts more than 50 years.
Likelihood: This refers to the probability of occurrence for the failure mode. These descriptors follow those used in the FMEA and differ (by an additional level) from those in the Environmental Assessment Methodology in Section 6.7.	*Almost Certain:* the event will occur. *Expected:* the event will probably occur in most circumstances. *Likely*: the event could occur at some time. *Unlikely*: the event may occur at some time. *Rare*: the event may occur only in exceptional circumstances.
Geographic Extent: This refers to the spatial scale over which the residual effect is expected to occur.	*Local*: an effect is limited to the Project footprint. *Landscape*: an effect extends beyond the Project footprint to a broader area. *Regional*: an effect extends across the regional study area. *Beyond Regional*: an effect that extends possibly across or beyond the province of BC.
Reversibility: This refers to the degree to which the effect is reversible.	*Reversible Short Term*: an effect that can be reversed relatively quickly. *Reversible Long Term*: an effect that can be reversed after many years. *Irreversible*: an effect that cannot be reversed (i.e., is permanent).
Resiliency: This refers to the capacity of an intermediate component or receptor VC to resist or recover from major changes in structure and function following disturbance from a failure mode.	*Low*: the component is considered to be of low resiliency following the failure mode. *Moderate*: the component is considered to be moderately resilient following the failure mode. *High*: the component is considered to be highly resilient following the failure mode.
Ecological or Social Context: This refers to the current condition of the intermediate component or receptor VC and its sensitivity.	*Low*: the component is considered to have little to no unique attributes. *Neutral*: the component is considered to have some unique attributes. *High*: the component is considered to be unique.

(continued)

Table 31.7-2. Characteristics and Descriptors for Environmental Assessment (completed)

Characteristic and General Definition	Descriptors
Significance of Residual Effects: Based on a comparison of the current receptor VC with the predicted state of the receptor VC after the failure mode and subsequent mitigation measures have been taken.	*Not significant:* Residual effects have low or moderate magnitude, local to regional geographic extent, short- or medium-term duration, could occur at any frequency, and are reversible in either the short- or long-term. The effects on the receptor VC (e.g., at a species or local population level) are either indistinguishable from background conditions (i.e., occur within the range of natural variation as influenced by physical, chemical, and biological processes), or distinguishable at the individual level. Land and resource management plan objectives will likely be met, but some management objectives may be impaired. There is a medium to high level of confidence in the analyses. Follow-up monitoring of these effects may be required if the magnitude is medium. *Significant*: Residual effects have high magnitude, have regional or beyond regional geographic extent, duration is long-term or far future, and occur at all frequencies. Residual effects on receptor VCs are consequential (i.e., structural and functional changes in populations, communities, and ecosystems are predicted) and are irreversible. The ability to meet land and resource management objectives is impaired.

31.7.2 Spatial and Temporal Boundaries

The chapter uses the same spatial and temporal boundaries as are defined for the Predictive Studies (Part B) and Assessment of Potential Effects, Mitigation, and Significance of Residual Effects – Biophysical Environment (Part C). The assessment for each of the eight subject areas identified by the Potential Project Failure Modes with Intermediate and Receptor VC Subject Areas matrix (Table 31.7-1) will use the same spatial boundaries as the broader assessment.

The spatial boundaries are described in detail in the respective chapters and are not repeated here:

- Chapter 7, Air Quality Predictive Study;
- Chapter 11, Terrain and Soils Predictive Study;
- Chapter 13, Assessment of Potential Surface Water Quality Effects;
- Chapter 14, Assessment of Potential Aquatic Resources Effects;
- Chapter 15, Assessment of Potential Fish and Fish Habitat Effects;
- Chapter 16, Assessment of Potential Terrestrial Ecology Effects;
- Chapter 17, Assessment of Potential Wetlands Effects; and
- Chapter 18, Assessment of Potential Wildlife Effects.

Boundaries described in chapters are the maximum limit within which the effects assessment and supporting studies (i.e., predictive studies) are conducted. Effects from accidents and malfunctions are likely to be localized as a point source from the location of the failure mode. Also, the receiving environment in the vicinity of Project activities and facilities are more at risk than other areas. If applicable, these areas are identified in the discussion of each failure mode.

Similarly, the temporal boundaries follow the effects assessment and supporting studies (i.e., predictive studies). Potential effects will be considered for each phase of the Project (where relevant), which are:

- Construction phase: 2 years;
- Operation phase: 22 years;
- Closure phase: 2 years; and
- Post-closure phase: minimum of 3 years.

31.7.3 Summary of Assessments for the Medium Environmental Risks

Table 31.7-3 summarizes the assessments of the medium environmental risks that can affect intermediate and receptor VCs. The analysis predicts that the residual effect(s) of these accidents and malfunctions will be "not significant." Detailed descriptions of the analyses follow in subsequent sections.

31.7.4 Sediment in Tailings Discharge and Waste Rock

As described in Table 31.6-6, fine materials from the tailings discharge and waste rock could produce an increase of total suspended solids and metals transported out of Brucejack Lake and into Brucejack Creek and onward to downstream receiving environments. A worst-case scenario would result from a malfunction of the tailings discharge system, damage to turbidity curtains, and/or slumping of submerged waste rock pile.

Screening of potential interactions indicates that receptor VCs in the following subject areas will be potentially affected by elevated levels of TSS from Brucejack Lake.

Potential for major (red) adverse effect(s):

- surface water quality; and
- aquatic resources.

Potential for negligible to minor (green) adverse effect(s):

- fish and fish habitat.

31.7.4.1 Surface Water Quality

The potential effect(s) on water quality will be directly due to increased concentrations of total suspended solids (TSS) and total metals above anticipated permitted discharge limits in the water column of, and outflow from, Brucejack Lake. The magnitude of effect on water quality will be "high" as concentrations of TSS and total metals would likely exceed permit limits and the range of natural variability. The geographic extent will be "landscape," limited to the near-field receiving environment of Brucejack Creek. Brucejack Lake outflow provides the majority of flow in Brucejack Creek until the confluence with Sulphurets Creek under the Sulphurets Glacier, approximately 2 km downstream of Brucejack Lake. It is expected that elevated TSS and total metal concentrations would persist along the length of Brucejack Creek until the confluence with Sulphurets Creek. Once Brucejack Creek confluences with Sulphurets Creek, it is expected that elevated TSS and total metals in Brucejack Creek would become indistinguishable from the background TSS load originating from the Sulphurets Glacier.

Table 31.7-3. Assessment of Intermediate Risks on Intermediate Receptor Valued Components

Subject Area	Evaluation Criteria							Significance of Failure Mode Producing Residual Effects *(not significant; significant)*
	Magnitude *(low, moderate, high)*	**Duration** *(short, medium, long, far future)*	**Likelihood** *(rare, unlikely, likely, expected, almost certain)*	**Geographic Extent** *(local, landscape, regional, beyond regional)*	**Reversibility** *(reversible short term; reversible long term; irreversible)*	**Resiliency** *(low, moderate, high)*	**Context** *(low, neutral, high)*	
Sediments from Tailings Discharge and Waste Rock								
Surface Water Quality (red)	high	short	expected	landscape	reversible short term	moderate	low	not significant
Aquatic Resources (yellow)	high	short	expected	landscape	reversible short term	high	low	not significant
Fuel Spills on Land								
Terrain and Soil (red)	minor	short	rare	local	reversible short term	low to high[1]	low	not significant
Fuel Spills on Water								
Surface Water Quality (red)	high	medium	rare	landscape	reversible short term	low	low	not significant
Aquatic Resources (yellow)	high	short to medium	rare	landscape	reversible short term	moderate	low	not significant
Fish and Fish Habitat (yellow)	moderate	short	rare	landscape	reversible short term	high	high	not significant
Wetlands (yellow)	minor	short	rare	local	reversible long term	low	low	not significant
Terrain and Soil (yellow)	minor	short	rare	local	reversible short term	low to high[1]	low	not significant
Concentrate Spills on Land								
Terrain and Soil (yellow)	minor	short	rare	local	reversible short term	high	low	not significant
Concentrate Spills on Water								
Surface Water Quality (red)	high	short	rare	landscape	reversible short term	moderate	low	not significant
Aquatic Resources (yellow)	high	short	rare	landscape	reversible short term	high	low	not significant

(continued)

Table 31.7-3. Assessment of Intermediate Risks on Intermediate Receptor Valued Components (completed)

Subject Area	Evaluation Criteria							Significance of Failure Mode Producing Residual Effects *(not significant; significant)*
	Magnitude *(low, moderate, high)*	**Duration** *(short, medium, long, far future)*	**Likelihood** *(rare, unlikely, likely, expected, almost certain)*	**Geographic Extent** *(local, landscape, regional, beyond regional)*	**Reversibility** *(reversible short term; reversible long term; irreversible)*	**Resiliency** *(low, moderate, high)*	**Context** *(low, neutral, high)*	
Concentrate Spills on Water ***(cont'd)***								
Fish and Fish Habitat (yellow)	moderate	short	rare	landscape	reversible short term	high	high	not significant
Wetlands (yellow)	minor	short	rare	local	reversible short term	high	low	not significant
Vehicle Collisions/Congestion - Spills of Hazardous Materials								
Terrain and Soil (yellow)	minor	short	likely	local	reversible short term	low to high[2]	low	not significant
Surface Water Quality (yellow)	low to high[2]	short	likely	landscape	reversible short term	low to high[2]	low	not significant
Wetland (yellow)	minor	short	unlikely	local	reversible long term	low to high[2]	low	not significant
Wildlife and Wildlife Habitat (yellow)	minor	short to medium[3]	likely	local to landscape[2]	reversible short term to reversible long term[2]	low to high[3]	high	not significant
Loss of Vehicles on the Glacier/Avalanches Spills of Fuels, Concentrate, and Hazardous Materials								
Surface Water Quality (yellow)	low to high[2]	short	rare	landscape	Reversible short term	low to high[2]	low	not significant
Explosive Mishap								
Terrain and Soil (yellow)	moderate	short	rare	local	reversible long term	low	low	not significant
Surface Water Quality	moderate	short	rare	landscape	reversible short term	low	low	not significant
Aquatic Resources (yellow)	moderate	short	rare	landscape	reversible short term	high	low	not significant

[1] *Depending on volume released onto soils.*
[2] *Depending on material released.*
[3] *Depending on the generation time of the species.*

Discharge from the Sulphurets Glacier is approximately six times greater than the discharge from Brucejack Lake based on relative watershed area, and has a median TSS concentration of 110 mg/L compared to the anticipated permit limit for discharge from Brucejack Lake of 15 to 30 mg/L. Approximately 1.5 km downstream from the Sulphurets Glacier, Sulphurets Creek flows into Sulphurets Lake, which is a natural depositional area for suspended solids including those originating from Brucejack Lake. Downstream of Sulphurets Lake, Sulphurets Creek receives contributions from other major tributaries that are also relatively high in stream flow, TSS, and metal concentrations compared to Brucejack Lake such as Ted Morris Creek and Mitchell Creek. Thus, any measurable influence on downstream water quality as a result of this failure mode is expected to be limited to Brucejack Creek upstream of Sulphurets Creek. The likelihood of this failure mode is “expected” over the life of the mine. The design of the tailings discharge system, and procedures and mitigation measures associated with waste rock discharge will prevent or minimize sediment release during a failure mode; however, deployment of some mitigation measures (e.g., turbidity curtains) will be limited during winter. A tailings system malfunction would be readily detected and detection of elevated TSS will be rapid because of the daily monitoring of outflow water quality, and will allow contingency measures to be put in place within a short timeframe. The duration of any single failure mode will be "short." Once contingency measures are implemented, it is expected that TSS and total metals concentrations would return to typical operating levels within days, thus the effect will be “reversible short-term.” Due to the dynamic hydrologic regime of the area, with large seasonal and inter-annual variability, water quality in the receiving environment also displays a relatively high degree of natural variation. Thus the receiving environment is considered to have a “moderate” resiliency to short-term changes in water quality. Ecological context is considered to be “low” as Brucejack Lake and Brucejack Creek are considered to have little to no unique attributes.

Based on the above criteria, the overall assessment for the effects of elevated sediment release from Brucejack Lake will be “not significant.”

31.7.4.2 Aquatic Resources

The primary potential effects on aquatic resources from increased loading of sediments and metals into Brucejack Creek from Brucejack Lake are direct and indirect effects from sediment and toxic effects from increased metal concentrations. Increased sediment loads can smother aquatic organisms, interfere with light availability for aquatic primary production, inhibit oxygen diffusion in the benthic environment, increase scour in stream habitats, and change sediment particle size composition. Increased metal concentrations from tailings discharge can have acutely and chronic toxic effects on aquatic organisms. In the advent of a significant failure in the tailings management system, the effects on aquatic resources could be greater than the range of natural variation and the magnitude of the effect would be considered “high.” As previously mentioned, the likelihood of this failure mode is “expected” over the lifetime of the mine. The geographic extent will be “landscape” because the effects would be restricted to Brucejack Creek and would not extend beyond the Sulphurets Glacier. Since the duration of elevated sediments and metals will be “short,” the effects to aquatic resources will also be “short.” Aquatic resources have short generation times and are resilient to environmental variability in sediment loading and metal concentrations, and the effects from a tailings discharge failure mode are predicted to be “reversible short-term.” The resiliency is considered “high” because of the high reproductive rates and the natural adaptations of aquatic organisms in the alpine environment to natural changes in sediment loading and metal concentrations. Brucejack Creek is a typical low-productivity aquatic environment for aquatic resources; hence, its ecological context is “low.”

Based on the above rationale, the overall assessment for the effects of a failure mode in tailings discharge and waste rock deposition in Brucejack Lake on aquatic resources will be “not significant.”

31.7.4.3 Fish and Fish Habitat

The effect(s) on fish and fish habitat will be negligible as the nearest fish population is in the lower reach of Sulphurets Creek (downstream of the cascade) and in the Unuk River. Any increase in suspended solids or metals from Brucejack Lake are not expected to be distinguishable from other background sources of suspended solids beyond Sulphurets Lake, which is approximately 13 km upstream of the nearest fish-bearing waters in the lower reach of Sulphurets Creek. No further assessment is made on potential effect(s) on fish and fish habitat.

31.7.5 Spill/Fuel – Land, Water

Although all vehicles will have fuel, a worst-case scenario will involve an accident with a 20,000-L fuel truck causing a rupture of the fuel tank superstructure resulting in a spill of gasoline or diesel fuel load onto the adjacent environment. With the FMEA, the likelihood of an accident on the access road over the life of the mine was rated as “likely.” However, the lower traffic, greater regulations/restrictions, and the safety features of fuel trucks reduce the likelihood of a worst-case scenario accident to “rare.”

The likely locations for this failure mode will be terrestrial or aquatic environments adjacent to the 75-km access road. Adjacent waters include the Bowser River, Knipple Lake, Bowser Lake, Scott Creek, Wildfire Creek, and/or Bell-Irving River, as well as smaller order tributaries of these systems. A number of these systems are fish-bearing streams including Knipple Lake, Bowser River, Bowser Lake, the proximal reach of Scott Creek to Bowser Lake, Todedada Creek, the proximal reach of Wildfire Creek to Bell-Irving River, and Bell-Irving River (Figure 15.3-3). Wetlands located adjacent to the access road could also be affected by fuel spills. There are substantial roadside wetlands found near the Bowser River and tributaries of Scott and Wildfire creeks (Figure 17.4-1).

For a land-based worst-case fuel spill, the screening of potential interactions indicated that intermediate components in the following subject areas could potentially be affected.

Potential for major (red) adverse effect(s):

- terrain and soil.

For a spill in water or runoff from land into waters, the screening of potential interactions indicated that intermediate components in the following subject areas would be affected by a large fuel spill.

Potential for major (red) adverse effect(s):

- surface water quality; and
- aquatic resources.

Potential for moderate (yellow) adverse effect(s):

- fish and fish habitat;
- wetlands; and
- terrain and soil (riparian).

All other intermediate and receptor VCs will show negligible or minor effects. Table 31.7-3 presents a summary of the formal assessments.

31.7.5.1 Terrain and Soil

The effects on terrain and soil will be direct as it involves the potential increase in metal concentrations, changes in electrical conductivity, and changes in soil pH, as well as the introduction of diesel fuel and gasoline, and their associated additives to the spill location. The magnitude will be "minor" as the spill of fuels will be managed by containment and rapid recovery of materials with spill kits and other absorbents. In the event of a large-scale spill, contaminated soils will be removed and appropriately disposed. Detection of the spilled fuel will be immediate at the time of the accident followed by an immediate response; hence, the duration of a spill will be "short." The likelihood of a fuel truck getting in an accident and discharging will be "rare." The geographic extent of a spill will be "local," i.e., the area of the accident. While the condition of the affected soil will require time to recover, its removal means that the site conditions can be "reversible short-term" very shortly after the accident. For small spills, the resiliency of the soil is relatively "high"; however, the resiliency decreases with volume of fuel spilled. For a full spill of 20,000 L, the capacity of the soil would be overwhelmed, therefore, in that case a "low" resiliency. Again in this instance, contaminated soils would be removed to restore site conditions. However, the ecological context of the likely spill areas (access road sides, staging areas, general mine site area) do not have unique features and would already be considered a disturbed area, hence, the ecological context is "low."

Based on the above rationale, the overall assessment for the effect(s) of a fuel spill from fuel transport on land will be "not significant."

31.7.5.2 Surface Water Quality

The potential effects on surface water quality will be direct as various hydrocarbon compounds from the fuel spill are immediately introduced to the watercourse. The magnitude of a 20,000-L fuel spill is assessed as "high." Lighter fuel components will remain on the surface of the water where they will be subject to volatilization and dilution. Fuel components such as benzene, toluene, ethylbenzene, and xylenes volatilize relatively rapidly. Additives such as methyl tertiary butyl ether will dissolve into the water but will continue to evaporate from surfaces. In general, lighter fuels such as gasoline will volatize quicker than heavier diesel fuels, which tend to persist in the environment. Lastly, some compounds such as polyaromatic hydrocarbons will be persistent requiring several years to degrade. Although detection of the spilled fuel will be immediate at the time of the accident followed by an immediate spill response, due to the potential for persistence of some fuel constituents the duration of the effect is assessed as "medium." The likelihood of a fuel truck spill is "rare." The geographic extent of the spill will be "landscape" since fuel spills on water have the opportunity to spread prior to containment. Containment would be through booms and temporary diversions for small waterways and rapid recovery of materials with spill kits and other absorbents. With the implementation of the spill response procedures, natural degradation and dilution, and volatilization, the effect is considered to be "reversible short-term." Resiliency of water quality will be "low" due to the immediate and direct effect of fuel on water quality. Ecological context is considered to be "low" as watercourses adjacent to the access road are considered to have little to no unique attributes.

Based on the above rationale, the overall assessment for the effect(s) of a fuel spill on surface waters will be "not significant."

31.7.5.3 Aquatic Resources

The potential effects on aquatic resources are direct toxicity from the hydrocarbon components of the fuel and the accumulation of hydrocarbons in the sediments. The magnitude of effects depends on the environmental conditions and is confounded by the different environmental fates of fuel constituents. Mixing processes from stream flow or waves can increase the exposure of aquatic organisms and consequently increase the magnitude of toxic effects. Furthermore, the persistence of the fuel constituents depends on environmental and biological factors including temperature, oxygen concentration, and microbial activity. For this worst-case assessment, the magnitude of effects on aquatic resources is predicted to be “high” to account for these confounding factors. Spill response efforts and volatilization will minimize the exposure of aquatic resources to the majority of the spilled fuel. However, some fuel constituents can be persistent in alpine environments and accumulate in the benthic environment of streams and lakes, so the duration of the effect is predicted to be “short to medium.” The likelihood of a fuel truck spill is “rare.” The geographic extent of a spill on aquatic resources will be likely to be “landscape” as discussed in the assessment of fuel spills effects on surface water quality. Aquatic organisms have short generation times and with the removal of fuel constituents, the effects are predicted to be “reversible short-term.” The resiliency is considered “moderate” because of the confounding factors for the detoxification and persistence of fuel constituents in the aquatic environment. The ecological context is “low” because no unique aquatic resources have been observed adjacent to the access road.

Based on the above rationale, the overall assessment for the effect(s) of a fuel spill on aquatic resources will be “not significant.”

31.7.5.4 Fish and Fish Habitat

The effects on fish and fish habitat will be through direct toxicity of the water column, physical effects of contact with spilled fuels, and ingestion of primary and secondary producers. The magnitude will be “moderate” as most petroleum products are toxic to fish and aquatic organisms. They may cause mortality at high concentrations and reduced health or altered behaviour at sublethal levels. The toxicity of these products occurs through their water-soluble constituents and emulsions, and toxicity increases when dissolved oxygen levels are low. Behavioural changes in fish after sublethal exposure to spilled petroleum products typically are responses to the physiological changes caused by the toxins. This means that fish can avoid or leave affected areas to escape direct contact with fuels. The duration of the effect will be “short” as spill detection would be immediate followed by spill response, and sublethal effects would not last beyond the life history stage of the fish species. The likelihood of a fuel truck getting in an accident and discharging its load will be “rare.” The geographic extent of the spill on fish and fish habitat will be “landscape.” Fuels may produce a measureable effect(s) on fish populations and habitats further downstream; however, spill detection would be immediate followed by spill response. Effects on fish populations by a fuel spill will be “reversible short-term” as fish are mobile and re-population is possible from individuals from upstream and downstream reaches. Resiliency is considered “high” because of the location of fish habitat on stream and lake bottoms and the ability of fish populations to move away from areas with undesirable water quality and eventually re-stock these areas after water quality has recovered. The fish bearing water bodies adjacent to roads have salmon (Chapter 15, Assessment of Potential Fish and Fish Habitat Effects). Also, Bowser Lake is of significance to local Aboriginal groups and Nisga’a, hence, their ecological context is “high.”

Based on the above rationale with an emphasis on the magnitude, extent, likelihood, and spill response, the overall assessment for the effect(s) of a fuel spill on fish and fish habitat will be “not significant.”

31.7.5.5 Wetlands

Fuels directly spilled into their waters or received from contaminated inflows from other water bodies will affect wetlands. Since wetlands have water quality, aquatic resources, and fish and fish habitat, environmental assessments that apply to those subject areas also apply to wetlands. However, wetlands have additional ecological functions that make them unique. In general, spills of fuels (or any material) will be more difficult to clean up since emergent vegetation makes skimming and use of absorbent materials challenging.

As with other water bodies, the magnitude will be considered "moderate." Detection of the spilled fuel will be immediate at the time of the accident followed by an immediate response; hence, the duration of a spill will be "short." The likelihood of a fuel truck getting in an accident and discharging its load is "rare." The geographic extent of a spill in a wetland is "local" as the slower flows and the coating of the emergent vegetation will prevent it from the same pattern of spread as would occur in open waters. The greater difficulty in the containment of the spill and removal of affected waters, particularly the recovery of fuels that may require removal of vegetation, will mean that site conditions may take a longer time to recover than open waters, i.e., "reversible long-term." Resiliency of water quality will be "low" to the type of chemical and physical change created by fuels. The roadside environment has no unique features and is by its nature a disturbed area; hence, the ecological context is "low."

Based on the above rationale, the overall assessment for the effect of a fuel spill on wetlands will be considered "not significant."

31.7.5.6 Terrain and Soils (Riparian)

The property of fuels to float on surface waters means that soils on the shoreline of water bodies have a potential to become contaminated. In this case, the assessment will be the same as the fuel spill on land (Section 31.7.5.1) with an overall assessment of "not significant."

31.7.6 Spill/Concentrate – Land, Water

This failure mode considers a concentrate haul truck (40 tonne tandem) that is involved in an accident and releases its load onto the adjacent land. Concentrate will be packed into 2-tonne bags and then loaded into enclosed containers. These bags and containers will be secured and sealed during transit until they reach their destination for further shipment; either at a railhead at Terrace, BC or port facilities in Stewart, BC. For the following assessment a worst-case scenario of a complete release of a concentrate load is considered. With the FMEA, the likelihood of an accident on the access road over the life of the mine was rated as "likely." However, the lower traffic, greater regulations/restrictions, and the safety features of concentrate haul trucks lower the likelihood of a worst-case scenario accident to "rare."

As with the fuel spill, the likely locations for this failure mode will be terrestrial or aquatic environments adjacent to the 75-km access road. Adjacent waters include the Bowser River, Knipple Lake, Bowser Lake, Scott Creek, Wildfire Creek, and/or Bell-Irving River, as well as smaller order tributaries of these systems. A number of these systems are fish-bearing streams including Knipple Lake, Bowser River, Bowser Lake, the proximal reach of Scott Creek to Bowser Lake, Todedada Creek, the proximal reach of Wildfire Creek to Bell-Irving River, and Bell-Irving River (Figure 15.3-3). Wetlands located adjacent to the access road could also be affected by fuel spills. There are substantial roadside wetlands found near the Bowser River and tributaries of Scott and Wildfire creeks (Figure 17.4-1).

For a land-based worst-case concentrate spill, the screening of potential interactions indicated that intermediate components in the following subject areas could potentially be affected.

Potential for moderate (yellow) adverse effect(s):

- terrain and soil.

Potential for negligible to minor (green) adverse effect(s):

- air.

For a water-based worst-case concentrate spill, the screening of potential interactions indicated that intermediate components in the following subject areas could potentially be affected.

Potential for major (red) adverse effect(s):

- surface water quality.

Potential for moderate (yellow) adverse effect(s):

- aquatic resources;
- fish and fish habitat; and
- wetlands.

All other intermediate and receptor VCs will show negligible or minor effects. Table 31.7-3 presents a summary of the formal assessments.

31.7.6.1 Terrain and Soil

The effect(s) on terrain and soil will be direct as it involves a smothering of the soil surface with concentrate. The magnitude will be "minor" as the concentrate is not acutely toxic, though precautions should be taken as with any fine dust. Any spill will remain on the soil surface and will not become incorporated into the soil with prompt cleanup. Recovery of any spilled concentrate will be immediate. Detection of the spill will be immediate at the time of the accident followed by immediate response; hence, the duration of a spill will be "short." The geographical scale of a spill will be confined the area of the accident, hence, it will be "local." Removal of contact soils is likely with the removal of the concentrate, site conditions will return to pre-accident conditions in the short-term, i.e., "reversible short-term." While the concentrate is of a different physical and chemical composition than soils with prompt response and cleanup there will be no time for significant digenesis of the concentrate. Soil resiliency to change from concentrate spill will be "high." A possible mitigation action will be to replace the removed soil with soil salvaged from another location if large quantities need to be removed during concentrate recovery. The ecological context of the roadside environment has no unique features and is by its nature a disturbed area; hence, the ecological context is "low."

Based on the above rationale, the overall assessment for the effect(s) of a concentrate spill from transport on terrain and soils will be "not significant."

31.7.6.2 Air

There is a potential for effect(s) on local air quality at the site of the accident if the windy conditions occur between the release of concentrate and its containment and recovery. Concentrate is composed of fine particles with 80% passing through a 70 µm sieve, hence, the finer particles could contribute to an increase in PM_{10} and $PM_{2.5}$. Chapter 7, Air Quality Predictive Study, reviews wind conditions in detail. In general, strong winds occur during all seasons at high elevations, blowing from the northeast, east, and southeast during cold months and from the south, southwest, and west during warmer months. However, wind speeds near roads are greatly influenced by the surrounding forest. Correcting for vegetation effects, the roadside winds along Scott Creek Road average from 0 to 4.32 km per hour per day with a maximum gust of 17.3 km per hour. Wind speeds greater than 4 km per hour occur less than 2.4% of the time. Under the rare extreme wind conditions, travel on roads would be restricted; hence, the coincidence of high winds and a concentrate spill generating accident is greatly reduced. The environmental assessment of this risk will be minor or negligible as the quantities lost through a spill and re-deposited by winds are not likely to be great. Already settled material would have to be scoured by winds to re-suspend particles. No further assessment was made on air quality.

31.7.6.3 Surface Water Quality

The potential effects on surface water quality will be direct as TSS, metals, and process chemicals from the concentrate release are immediately introduced to the watercourse. Concentrates are composed of fine particles and a significant portion will initially form a layer on the surface then remain suspended in the water column for relatively long periods of time prior to settling on the bottom. The magnitude is considered “high” because the potential increase in sediment load and metal concentrations would be beyond the range of natural variation. The geographical extent will be “landscape” as suspended particulate material may move downstream prior to containment. As detection would be immediate after an accident, spill containment and recovery would be immediate. Hence, the duration of any effect(s) will be “short”. As already discussed, the frequency of an accident with a release concentrate into water will be “rare.” The effect to surface water quality will be “reversible short-term” as containment and mitigation measures will remove deposited concentrate and the remaining material will be dispersed downstream or entrained in stream bed sediments. The resiliency to the impact of concentrate input at the point of release is “low.” Ecological context is considered to be "low" as watercourses adjacent to the access road are considered to have little to no unique attributes.

Based on the above rationale, the overall assessment for the effect(s) of a concentrate spill in water to surface water quality will be “not significant.”

31.7.6.4 Aquatic Resources

The primary potential effects from a concentrate spill on aquatic resources would be direct and indirect from increased sediment loads and toxic effects from increased metal concentrations. Increased sediment loads can smother aquatic organisms, interfere with light availability for photosynthesis and aquatic primary production, interfere with oxygen diffusion in the benthic environment, increase scour in stream habitats, and change sediment particle size composition. Increased metal concentrations from a concentrate spill can have acutely and chronic toxic effects on aquatic organisms. This assessment covers changes to stream sediments and only if the concentrate deposited in the stream cannot be recovered. Flows will dilute concentrates transported downstream. The magnitude is considered “high” because the potential increase in sediment load and metal concentrations would be beyond the range of natural variation. The geographic extent would likely be “local” because of the limited quantity of concentrate spilled and low likelihood of dispersion on the landscape scale. The duration of the spill will be “short” because the effects will be short-term for any particular location due to dilution and downstream movement of released concentrates and affected waters. As already discussed, the frequency of an accident with a release concentrate into water would be “rare.” Aquatic resources have short generation times and are resilient to environmental variability in sediment loading and metal concentrations, and the effects from a concentrate spill are predicted to be “reversible short-term.” The resiliency is considered “high” because of the high reproductive rates and the natural adaptations of aquatic organisms in the alpine environment to natural changes in sediment loading and metal concentrations. The ecological context is “low” because no unique aquatic resources have been observed adjacent to the access road.

Based on the above rationale, the overall assessment for the effect(s) of a concentrate spill in water on aquatic resources will be “not significant.”

31.7.6.5 Fish and Fish Habitat

The effect(s) on fish and fish habitat would be through turbidity in the water column, intake of metals in the concentrate, or indirect changes in the primary and secondary producers. Also depending on the location of the spill, fish habitat could be affected if the concentrate is deposited on critical habitat such as spawning areas. The majority of the effects of a concentrate spill would be highly localized. Low-moisture concentrate would not quickly mobilize and could be cleaned up relatively easily. Direct mortality would result if the concentrate enters the watercourse and crushes or smothers fish or aquatic organisms. Mortality may also occur if metal concentrations in the water around the spill increase above toxicity levels. These levels vary by species, water chemistry, and water temperature. Sublethal effects occur when metal accumulation in the gills of fish cause a stress response that can lead to behavioural changes. Sublethal effects can lead to physiological changes in fish. The magnitude will be “moderate” as there may be a prerequisite sustained change in water quality and/or abundance and community structure of the primary and secondary producers to affect the fish populations. The duration of the effect will be "short" as spill detection would be immediate followed by spill response; and sublethal effects would not last beyond the life history stage of the fish species. As already discussed, the frequency of an accident with a release of concentrate into water will be “rare.” The effect(s) will be “landscape” as the spill would primarily affect the fish at the spill site, but may produce a measureable effect(s) on fish populations and habitats further downstream; however as spill detection would be immediate followed by spill response. The mobility of fish and their ability to escape prolonged exposure and return when pre-accident conditions return suggests that changes to fish communities will be “reversible short-term” and resiliency is “high.” The fish-bearing water bodies adjacent to roads have salmon (Chapter 15, Assessment of Potential Fish and Fish Habitat Effects). Also Bowser Lake is of significance to local Aboriginal groups and Nisga’a, hence, their ecological context is “high.”

Based on the above rationale with an emphasis on consideration of the magnitude, extent, likelihood, and spill response the overall assessment for the effect(s) of a concentrate spill in water on fish and fish habitat will be “not significant.”

31.7.6.6 Wetlands

Wetlands will be affected if concentrates are spilled directly into their waters or if they receive contaminated waters from a spill. Since wetlands have water quality, aquatic resources, and fish and fish habitat, and terrestrial ecology, environmental assessments that apply to those subject areas also apply to wetlands. However, a spill of concentrate (or any material) is more difficult to clean up since emergent vegetation and wet margins makes access for containment and recovery more difficult.

The magnitude will be “minor.” Concentrate is not acutely toxic and its effects are largely physical with changes in turbidity and total suspended sediments. Detection of the spilled concentrate would be immediate at the time of the accident followed by an immediate response; hence, the duration of a spill will be “short.” As already discussed, the frequency of an accident with a release of concentrate into water will be “rare” and even rarer for wetlands because of their lesser abundance. The slower moving waters within wetlands will mean the spill will probably stay in the area of the accident creating “local” effects. The greater difficulty in the containment and removal of the spill may mean removal of vegetation and greater site disturbance leading to a longer time required for the re-growth of vegetation, i.e., “reversible long-term.” Resiliency of wetlands to a concentrate spill is “high” as the potential chemical and physical changes are not great. The ecological context of wetlands alongside roads is “low” with no ecologically unique features.

Based on the above rationale, the overall assessment for the effect(s) of a concentrate spill on wetlands will be “not significant.”

31.7.7 Vehicle Collisions/Congestion – Surface

This assessment covers all environmental risks generated by vehicle collisions, other than those already discussed, and congestion on surface roads. The main environmental effects are the spill of other hazardous materials (excluding fuels and concentrate) and collisions with wildlife. Other substances to be transported on the access road are listed in the Spill Prevention and Response Plan (Section 29.14), Hazardous Materials Management Plan (Section 29.7), and Waste Management Plan (Section 29.17). A list of these materials includes:

- lubricants and greases;
- ethylene glycol;
- hydraulic fluids;
- batteries;
- solvents;
- surfactants;
- propane;
- H_2SO_4;
- process reagents (lime, potassium amyl xanthate [PAX], methyl isobutyl carbinol [MIBC], flocculants, antiscalant and flux, possibly borax [$Na_2B_4O_2$], sodium nitrate [$NaNO_3$], silica [SiO_2], and fluorspar [CaF_2]);
- water treatment sludge;
- radioactive equipment;
- explosives;
- domestic waste; and
- industrial waste.

These same management plans specify the safe handling, storage, transport and disposal of these materials. Along with the Emergency Management Plan (Section 29.6), these plans outline appropriate responses in case of a release into the environment.

Wildlife collisions by vehicles are a potential causal factor in vehicle collisions. In 2007, 1 out of 25 vehicle accidents in BC were caused by collisions with wildlife.[1] Aside from the obvious health and safety concerns, there are two potential environmental effects. Firstly, a spill may occur from the damaged vehicle. Secondly, vehicle collisions are potentially a significant source of wildlife mortality. From 1996 to 2007, the British Columbia Ministry of Transportation and Infrastructure estimated that more than 200,000 animals were killed in collisions.

A spill on the Brucejack Access Road as the result of a vehicle accident presents a potential residual risk to surface waters, aquatic resources, and fish and fish habitat at or in proximity to stream crossings being contaminated. A roadside spill could affect Knipple Lake, Bowser River, Bowser Lake, Scott Creek, Wildfire Creek, and Bell-Irving River. A number of fish-bearing water bodies are adjacent to roads. These include

[1] http://www.wildlifecollisions.ca/thefacts.htm

Knipple Lake, Bowser River, Bowser Lake, the proximal reach of Scott Creek to Bowser Lake, Todedada Creek, the proximal reach of Wildfire Creek to Bell-Irving River, and Bell-Irving River (Figure 15.3-3). Spills adjacent to these water bodies have the potential of affecting fish and fish habitat. Significant roadside wetlands occur near the Bowser River and tributaries of Scott and Wildfire creeks (Figure 17.4-1).

The access roads pass through greenfield areas, hence, wildlife can be expected along their entire length; however, areas of particular note to specific species are:

- Moose: high-quality winter habitat along the access road adjacent to Bowser River (Figure 18.3-2);
- Mountain goats: high-quality winter and summer habitat along the access road adjacent to Bowser River (Figures 18.3-3 and 18.3-4);
- Grizzly bear: high-quality winter and summer habitat along all of the access road except the Knipple Glacier section (Figure 18.3-5);
- American marten: high-quality habitat along the access road adjacent to Scott and Wildfire creeks (Figure 18.3-8); and
- Western toad and Columbia spotted frog: breeding sites in wetlands adjacent to the access road near Scott and Wildfire creeks (Figure 18.3-16).

Screening of potential interactions indicated that intermediate and receptor VCs in the following subject areas could be potentially affected by vehicle collisions and congestion. This assessment covers the effects to both land and water.

Potential for moderate (yellow) adverse effect(s):

- terrain and soil;
- surface water quality;
- wetlands; and
- wildlife and wildlife habitat.

Potential for negligible to minor (green) adverse effect(s):

- aquatic resources; and
- fish and fish habitat.

All other intermediate and receptor valued components will show negligible or minor effects. Table 31.7-3 presents a summary of the formal assessments.

31.7.7.1 Terrain and Soil

The effect(s) on terrain and soil will be dependent upon the materials released into the environment. Extremely hazardous materials such as chemical reagents and explosives are packaged in such a manner that a spill due to a traffic accident would be rare. Of the remaining compounds, their quantities during shipping are relatively small or they are relatively of low toxicity. Hence, the magnitude of a spill will be “minor.” Detection of a spill will be immediate at the time of the accident followed by immediate response; hence, the duration of a spill will be “short.” Given the predicted traffic to the Mine Site over the mine life, a vehicle accident creating a spill is a “likely” event. The geographic extent of the spill will be “local.” Depending on the spilled material, the affected soil may require removal and disposal for recovery; however, rapid removal of the material means that site conditions will be restored very shortly after the accident, i.e., “short-term reversible.” For small spills, the resiliency of the soil is relatively “high”; however, this potentially decreases with volume of material spilled and for liquid spills. Hence, resiliency could vary from “low to high.” In general, liquids that are able to infiltrate the soil are more likely to have a sustained presence and greater effects on soils. The ecological context of the roadside environment has no unique features and is by its nature a disturbed area; hence, the ecological context is “low.”

Based on the above rationale, the overall assessment for the effect(s) of a spill from a vehicle collision on terrain and soils will be “not significant.”

31.7.7.2 Surface Water Quality

The potential effect(s) on water quality are dependent on the quantity and physical and chemical properties of the materials released into the environment. Spills into water have the ability to rapidly disperse, particularly in streams. Light hydrocarbons, other liquids that are less dense than water, or floating debris can be contained and recovered using booms and absorbents. Other material would have to be evaluated and an appropriate spill response applied. Management plans will provide guidelines for such events. The magnitude will be “low to high” as the other materials are shipped in relatively small quantities; however, the magnitude is dependent on the specific volume released. The duration of the effect(s) of a spill will be “short” given the almost immediate detection and emergency response plans in place. Given the predicted traffic to the Brucejack Mine Site over the mine life, a vehicle collision creating a spill is a “likely” event. Extremely hazardous materials such as some chemical reagents and explosives are packaged in such a manner that a spill due to a traffic accident would be “rare.” Due to the ability of spills in flowing water to disperse, the geographic extent of the spill will be potentially “landscape,” i.e., watershed. Spills will be “reversible short-term” given the range of materials likely to be spilled, the amount, their rapid detection, containment, and recovery. Resiliency to a change will depend on the compound released. In general, surface waters will have a “low” resiliency to liquids as these are more readily mixed, whereas resiliency to solids, mainly large particulate matter, will be “high.” Ecological context is considered to be “low” as watercourses adjacent to the access road are considered to have little to no unique attributes.

Based on the above rationale, the overall assessment for the effect(s) of a spill from a vehicle collision on surface waters will be “not significant.”

31.7.7.3 Wetlands

Wetlands have surface waters, aquatic resources, fish and fish habitat, and terrain and soils. Assessments that apply to those subject areas also apply to wetlands. However, spills in wetlands are more difficult to clean up since emergent vegetation makes skimming and use of absorbent materials more difficult. Also, access to wetlands for containment and recovery is often difficult. Hydrocarbons other than fuels and lighter-than-water liquids or floating debris can be contained and recovered using booms and absorbents. Other materials, including solids, would require an on-site evaluation and development of an appropriate response, which will be addressed in the management plans. Extremely hazardous materials such as chemical reagents and explosives are packaged in such a manner that a spill due to a traffic accident will be “rare.” The magnitude will be “minor” due to small quantities of materials or their low toxicity. The effects of a spill are likely to be “short” given the almost immediate detection and emergency response plans in place. Given the relatively small area of wetlands adjacent to roads, an accident creating a spill will be an “unlikely” event. The spill will be potentially “local” to “landscape” depending on the nature of the material. Water soluble and dispersive materials flow to the greater watershed. The inherent difficulties with containment and recovery in wetlands, particularly the ability to access and potential for removal of vegetation, indicate that effects will be potentially “reversible long-term.” Resiliency to a change will depend on the compound released. In general, wetlands will have a "low" resiliency to liquids as these are more readily mixed, whereas resiliency to solids, particularly large particulate matter will be "high." The ecological context of the roadside environment has no unique features and is by its nature a disturbed area; hence, the ecological context is "low."

Based on the above rationale, the overall assessment for the effects of a spill from a vehicle collision to wetlands will be "not significant."

31.7.7.4 Wildlife and Wildlife Habitat

This section assesses the environmental effects on wildlife by vehicle collisions. Five receptor VCs are potentially affected by vehicle collisions: moose, mountain goats, grizzly bear, American marten, and western toad.

The magnitude of this effect(s) on wildlife populations will be "minor." Control measures to prevent roads from becoming attractants include avoiding the use of road salts, reduction of browse in roadside habitats using mechanical means, re-vegetation with plant species not attractive to wildlife, especially to moose, mountain goats, and black bears, minimizing pooling of water in ditches and culverts, and removal of roadside carrion. The effect(s) on a species will depend on the consequence of mortality on the population, likely related to the species generation time and reproductive rates. Species with longer generation times and/or lower reproductive rates will be more affected by the death of individuals. For the species listed, the effect will vary from "short" to "medium." The frequency of vehicles striking animals will be "likely" over the mine life. The effect(s) on the population of species will be "local" in the case of amphibians, "landscape" for moose, mountain goats, and American marten, and "regional" for grizzly bears. The geographical area reflects the home range size of the wildlife species. The generation time and reproductive rates determines the reversibility of effects. Species with a relatively high turnover rate, such as amphibians, will be "reversible short-term," whereas species such as grizzly bears will be "reversible long-term." The resiliency to change again will depend on the species. Those with shorter generation times, high reproductive capacity, and fairly high mobility will have "high" resiliency, e.g., moose, whereas populations with restricted ability to move across the landscape, e.g., amphibians, or low reproductive rates, e.g., grizzly bears, will have a "low" resiliency. In the absence of specific population and movement models, the ability to predict the likelihood of vehicle impact and animal mortality on populations is "medium." The ecological context of these species is "high." Moose, mountain goat, grizzly bear, and American marten were identified by Aboriginal groups, government (except American marten), public/stakeholder groups, and the effects matrix as important (Table 18.4-1). Western toad is a Species of Special Concern under Schedule 1 of the *Species at Risk Act* (2002).

Based on the above rationale with an emphasis on consideration of the magnitude, extent, and likelihood the overall assessment for the effect(s) of vehicle collisions on wildlife will be "not significant."

31.7.7.5 Aquatic Resources and Fish and Fish Habitats

The effect(s) on aquatic resources, and fish and fish habitat can either be direct through changes to water quality or indirect such as effects through the food chain or intermediate components. Extremely hazardous materials, e.g., some chemical reagents and explosives, would be transported under very secure conditions such that their release into the environment would be rare. All other materials are relatively small in volume or not acutely hazardous. Their discharge into the environment would require a relatively widespread and sustained presence in surface waters and wetlands to produce an effect(s). As described in the assessments on surface waters (Section 31.7.7.2) and wetlands (Section 31.7.7.3), the magnitude of these spills will be "low to high" depending on the specific volume of material released into the aquatic environment and the duration "short." As such, there will be a low potential for these subject areas and their respective receptor VCs to be affected by spills from vehicle accidents other than those with fuels or concentrate. No further assessment was made of aquatic resources and fish and fish habitat.

31.7.8 Loss of Vehicles on the Glacier/Avalanche Zones

The regular transport of goods and personnel across a glacier or through an avalanche zone represents a unique risk that requires a separate assessment. At the southeast end of the Knipple Glacier, a constructed ramp allows tracked vehicles to access the glacier, which is traversed for about 12 km to the proposed Brucejack Mine Site. Detailed examination of topography and natural features from available mapping and imagery resulted in avalanche paths and hazard areas being identified, and these were confirmed by ground-truthing reconnaissance in the field. This reconnaissance indicated that Project infrastructure or access roads may potentially be affected in 36 locations by avalanche paths or hazard areas. The Avalanche Safety Plan BJ-042 estimates that many of these locations may be affected on an annual basis. In particular, the length of road to the south of Brucejack Lake, known as Lakeshore Drive, between the Knipple Glacier and the Brucejack Mine Site often has a high avalanche risk. When the avalanche risk is high alternative routes of travel are possible.

This failure mode was recognized in the FMEA and is addressed by the Avalanche Management Plan (Section 29.4), Transportation and Access Management Plan (Section 29.16), and other management plans (Table 31.3-5). The primary failure mechanism is the loss of a vehicle and its load either through damage and burial in an avalanche or in a crevasse on the glacier. With avalanches, vehicle recovery is possible; however, it is likely not to be possible to recover a vehicle lost in a crevasse. In either case, the immediate or delayed release of materials from the vehicle itself or its load can create environmental effects.

The worst-case scenario would be the loss and rupturing of the tank of a fully loaded fuel truck upon burial by the avalanche or after falling into a crevasse. In these cases, containment and recovery near the spill would be difficult or not possible. Instead, the fuel spill would have to be tracked until it appears in a location where it can be logistically contained and recovered.

Screening of potential interactions indicated that intermediate and receptor VCs in the following subject area could be potentially affected by the loss of a vehicle. Though the surface medium for both spills is snow and ice, the assessment on surface waters seems appropriate as the fuel is likely to end up in the surface waters. Gasoline and diesel fuel contain hydrocarbons, heavy metals, increased nutrient and salt loads, and other compounds, including benzene, toluene, and hexavalent chromium.

Potential for major (red) adverse effect(s):

- surface water quality.

Depending on the eventual receiving environments of the spill, other subject areas and components may be affected. A summary of the formal assessment is listed in Table 31.7-3. The specific assessments of spills on intermediate and receptor VCs other than surface water quality is considered sufficient to cover the loss of vehicles on glaciers failure mode, and no further assessment of effects for those intermediate and receptor VCs is considered (Sections 31.7.5, 31.7.6, and 31.7.7).

31.7.8.1 Surface Water Quality

The potential effects on surface water quality will be direct as the spill must travel to a watercourse from the glacier or avalanche area. The western section of the Knipple Glacier drains into East Lake, which is located upstream and approximately 500 m east of Brucejack Lake (Section 10.3.3.1).

A vehicle lost on Lakeshore Drive, which has a particularly high avalanche hazard, would likely drain fuel into Brucejack Lake. For the other avalanche locations, the same assessment for fuel spills into water would apply (Section 30.6.5).

The magnitude would vary from "low" for a small spill in a recoverable area to "high" for a spill on the glacier. A spill on the glacier is not likely to be contained and detection may occur months after the time of the accident. Spills due to avalanches will vary in magnitude depending on the amount of fuel spilled and the ability to contain and recover the fuel. The duration of the spill will still be considered "short" (Table 31.5-12). There are strictly enforced guidelines for travel on the glacier (*Procedures and Guidelines Glacier and Travel in Spring/Summer* (Mine Site Procedure BJ-031, May 25, 2013). Avalanche prevention procedures including monitoring and active triggering to reduce snow loads are in place to ensure safe travel through those areas. The likelihood of a large-scale fuel spill due to a loss on the glacier or avalanche is "rare." The geographic extent is "landscape," i.e., watershed, particularly if containment and recovery are delayed and fuel enters a water body. Reversibility is "reversible short-term," i.e., less than five years if the fuel leaks from the tanks and is contained and recovered in that time period. Resiliency of surface water is "low" to the type of chemical and physical change created by fuels. Ecological context is considered to be "low" as watercourses adjacent to the access road and Brucejack Lake are considered to have little to no unique attributes.

Based on the above rationale, the overall assessment for the effects of a fuel spill from fuel transport on glaciers and through avalanches are "not significant."

31.8 CONCLUSIONS

The assessment of the risk of accidents and malfunctions, i.e., failure modes, for the Project has been formally addressed by means of an FMEA. None of the failure modes of relevance to the environment identified during the FMEA fall into the high-risk category. Twenty-five environmental failure modes were assessed to be low risk while nine environmental failure modes were classified as medium risk. Four of these failure modes pertain to the underground environment and do not affect the designated intermediate components or receptor VCs of this Project (Table 6.4-4). These failure modes included water ingress underground, underground vehicle collisions/congestion between vehicles, underground vehicle collisions with fixed infrastructure, and risks associated with existing exploration borehole openings.

Five failure modes of medium risk could potentially affect the intermediate components or receptor VCs of this Project. These include sediment in tailings discharge and waste rock, spills on land and water of fuel and concentrate, inadequate capacity or failure of the water treatment plant, surface vehicle collisions/congestion, and vehicles loss on the glacier or in avalanche zones.

It is clear from the FMEA analysis, which examined 430 potential failure modes, that vehicle travel represented the greatest potential risk to the environment. The Project takes place in a rugged and challenging area of BC. The access is especially challenging including travel across a glacier and through high-risk avalanche areas. These risks have been recognized and Pretivm has responded with precautionary mine and infrastructure designs (Chapter 7, Air Quality Predictive Study) and management plans (Chapter 29, Environmental Management and Monitoring Plans) that prevent and mitigate failure modes and their consequences.

Overall, the residual effects of failure modes were assessed to be not significant, in all cases. The confidence in the result ranged from medium to high for all intermediate components or receptor VCs, except for the impact of vehicle collisions on wildlife. In this case, the lack of data and modelling on influence of mortality on species limited the confidence in the assessment. However, ongoing monitoring will fill these data gaps in the future (Chapter 29.21, Wildlife Management and Monitoring

Plan). Given that the most common failure mode involved a spill of materials into water or on land, the most commonly affected sub-components were surface water quality and/or soil quality. The second most common sub-components were wetlands, aquatic resources, and fish and fish habitat. The key management measures were safe travel routes, vehicle maintenance, and driver training, and mitigation including rapid detection, containment, and recovery of spilled materials.

By undertaking the FMEA process as part of the Application/EIS and incorporating the outcomes into the consideration of environmental risk effects, an evaluation of their implications for the viability of the Project has been possible. It is believed that the environmental risks of relevance to decision-making have been demonstrated to be of an acceptably low level.

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