35 Environmental Effects of Accidents and Malfunctions

35.1 Introduction

The KSM Project (the Project), which is proposed for development by Seabridge Gold Inc. (Seabridge or the Proponent), entails many large-scale, interrelated components that must be built and operated in isolated, glaciated, and rugged terrain approximately 65 km northwest of Stewart, BC. There are two primary areas of the Project that will be developed as described in Chapter 4: the Mine Site in the upper areas of the Sulphurets Creek watershed such as the Mitchell Valley, where mining components such as pits and rock storage facilities (RSFs) will be located; and the Processing and Tailing Management Area (PTMA) in the Teigen and Treaty Creek valleys, where the Tailing Management Facility (TMF) and milling facilities will be located. As these sites are currently inaccessible, two main roads are planned to facilitate access to the Mine Site and PTMA, and a 23 km twinned tunnel (the Mitchell-Treaty Twinned Tunnels [MTT]) will connect the two areas and enable ore transport.

Large mining projects such as the Project may involve: activities that are inherently complex or challenging; new technology; sensitive environmental, social or safety issues; and/or stringent regulatory or licensing conditions. Particular attention to risk management is therefore required. By identifying and understanding the risks, controls can be established to ensure that, if they cannot be eliminated, the risks are managed so they are as low as reasonably practicable.

The Proponent's strategy with respect to Project risk is to:

- identify risks of concern and, where elimination, avoidance or transfer is not possible, reduce the risk to as low as reasonably practicable by applying loss control and other safety strategies to the point where the impact of a failure on the environment would be negligible;
- apply due diligence by identifying and fully assessing all the material risks, taking appropriate measures to control them, and ensuring that the justification for accepting risk that remains is acceptable;
- develop risk reduction plans for identified major risks of concern; and
- provide financial security for remaining major risks, which are generally external risks beyond the Proponent's control, where the provisions become a component of the Project contingency.

As part of this strategy, Seabridge assembled a group of professionals to undertake a project-wide risk analysis for the KSM Project. This risk assessment was, in part, to satisfy requirements described in the "Application Information Requirements" (AIR) prepared by the British Columbia (BC) Environmental Assessment Office (BC EAO 2011), and comprehensive study scope of assessment documents. The Application for an Environmental Assessment Certificate / Environmental Impact Statement (Application/EIS) addresses the accidents and malfunctions that could potentially be associated with the construction, operation, closure and post-closure of the KSM Project. This component is required under Section 28 of the AIR (2011), pursuant to the BC *Environmental Assessment Act* (2002) and by the Canadian Environmental Assessment Agency (CEA Agency) pursuant to the *Canadian Environmental Assessment Act* (CEAA; 1992) for the Application/EIS associated with the proposed KSM Project.

Section 28 of the AIR (BC EAO 2011) states the following:

> *"The Application will identify the probability and potential magnitude of an accident and/or malfunction associated with the proposed Project, including a failure at the water treatment plants, water storage facility, tailing dams associated with the TMF, ore slurry and related return water pipelines, pit walls, waste rock slopes or diversion channels/tunnels, or blasting mishap, explosives factory accident or concentrate spill. In the case of a potential failure of a tailing dam, the Application will examine the likelihood and potential magnitude of the likely worst case accident or malfunction scenario through a dam break analysis. The Application will assess the probability and potential magnitude of effects of natural landslides and avalanches and glacial recession or advancement on geologic hazards, hazardous substance releases/spills and fuel spills outside of secondary containment areas. The Application will also consider potential malfunctions due to seismicity. This assessment will link and describe the outcome of accidents and/or malfunctions with a probability analysis of consequential effects to the environment. The Application will identify potential contingency plans and response options for probable accidents and/or malfunctions. Assumptions, model data sources and model outputs used for the assessment will be included in the Application."*

Under Section 16(1)(a) of CEAA (1992), accidents and malfunctions that may occur in connection with the Project require an assessment of the environmental effects. A methodical risk assessment approach was used to meet these requirements, specifically to identify the probability, potential magnitude, and likelihood of accidents and/or malfunctions associated with various components of the Project. The risk assessment methodology employed is detailed in Section 35.2.2.

Two geotechnical risk evaluations have been completed to identify failure modes and potential effects on the receiving environment.

The first was a standard Failure Modes and Effects Analysis (FMEA; McCormick 1981) covering all components of the Project as defined at that time. FMEA is a standard reliability test that assesses the likelihood of a hypothetical failure of a designed system and the potential consequences (effects) of that failure on the surrounding ecosystem (including human health and safety). This first FMEA was done during a two day session in October 2009, facilitated by Dr. Andrew Robertson P. Eng., of Robertson Geoconsultants Inc.. The risk evaluation included the identification of all potentially conceivable technical, environmental, health and safety, costs, and regulatory and public issues. The risk participants consisted of professionals in the field of environmental sciences, environmental engineering, mining, metallurgy, geotechnical engineering, geology, power transmissions, geo-hazards, road construction, tunnelling, project construction, and project operations. The composition of the 2009 evaluation team was very similar to the 2012 team. The results of the 2009 FMEA risk assessment are included in Appendix 35-A.

The second risk assessment, completed in September 2012, led by Dr. Dirk van Zyl, professor at the University of British Columbia in the Department of Mining and Mineral Processing, focused on the same potential areas and issues as the first risk assessment but with an up to date Project description. The assessment was also expanded to specifically include possible environmental consequences associated with different failure modes of major mine structures during construction, operation, and closure. The September 2012 FMEA evaluated the Project according to the latest design, and was further updated with the latest mitigations developed in December 2012 as a result of areas deemed as high risks that were identified during the September 2012 risk assessment. The consequence of a failure was addressed for each of the following:

- Biological Impacts;
- Regulatory Impacts and Censure;
- Public Concern; and
- Health and Safety.

The cost impact of each failure mode was also evaluated and, although the criticality ranking excludes the cost impact, the results are discussed within this chapter. The following sections provide the methodology of the 2009 and 2012 FMEA risk evaluations conducted for the Project. The results of the 2012 FMEA risk assessment is provided in Sections 35.2.4 to 35.2.5.

The third risk evaluation conducted for the Project addresses the potential case of catastrophic failure of the TMF tailing dams in the Treaty and Teigen valleys (which are part of the Bell-Irving River drainage system), and of the Water Storage Dam (WSD) within the Water Storage Facility (WSF) in the Mitchell Valley (which is in the local Sulphurets Creek drainage, and part of the broader Unuk River watershed). These dam failure modes have been done per standardized methodology provided in the Canadian Dam Association (CDA) *Dam Safety Guidelines* (the Guidelines; CDA 2007) for dam break and inundation studies.

In British Columbia, owners of dams are held under the authority of the *Water Act* (1996), and liable for any damage caused by the construction, operation or failure of their dam (BC MFLNRO 2013). The *British Columbia Dam Safety Regulation* (BC Reg 44/2000), under the jurisdiction of the *Water Act* (1996), will apply to the Project Proponent as it applies to all owners of licenced dams in BC. The *British Columbia Dam Safety Regulation* (BC Reg 44/2000) generally follows the dam classification and safety guidelines as set forth by the CDA Guidelines. For instance, under the *British Columbia Dam Safety Regulation* (BC Reg 44/2000), dams with failure risk classified under the CDA system as "significant, high, very high, or extreme" must prepare emergency preparedness plans for that dam, as well as follow regulatory requirements for dam safety planning, inspection and reporting.

As recommended in the Guidelines (CDA 2007), dam break and inundation studies have been done for the Mine Site WSD and PTMA TMF dams, which are the major water and tailing dams for the Project. These studies considered hypothetical failure modes of the dams (static, seismic and hydrologic), and assessed potential impacts of dam failure on areas along the receiving waters downstream of the dams relative to criteria established for dam safety in the Guidelines. The modelled impacts relative to consequence levels have been used to establish design criteria requirements for the dams. These dam break and inundation studies are also a requirement of the environmental assessment as mandated by the CEA Agency. This work was completed using a United States (US) Army Corporation of Engineers, proven state-of-the-art numeric model (HEC-GeoRAS and HEC-RAS; US Army Corps of Engineers 2012) to simulate dam failure modes. The breach failure modes considered were a dam overtopping and an internal piping failure.

In addition to the risk assessments and dam break and inundation studies summarized in this chapter, the Proponent has undertaken various detailed studies related to seismic, flood and other risks. For example, Chapter 34, Effects of the Environment on the Proposed Project, addresses the potential effects of and mitigation for storms, drought, flood, wildfire, geohazard, avalanche, seismic, and volcanic risk to the Project. The 2012 Engineering Design Update of Tailing Management Facility in Appendix 4-AC addresses seismicity and probable maximum flood risks, and contains a Ground Response and Seismic Stability Assessment (Appendix VII) for the TMF.

35.2 Geotechnical Failure Modes and Effects Analysis

35.2.1 Introduction

The AIR (BC EAO 2011) for the KSM Project Application/EIS requires a risk assessment covering the most likely mode to the most severe impact of hypothetical failure for the following Project components:

- the water treatment facilities at the Mine Site and in the PTMA;
- the Mine Site WSF and seepage recovery in the Mitchell Valley;
- tailing dams and seepage recovery associated with PTMA TMF;
- the tailing water pipeline for TMF discharge in the PTMA;
- pit wall stability in the Mine Site;
- Mine Site waste rock slopes and acid rock drainage assessment;
- water diversion channels and tunnels;
- natural landslides and avalanches;
- glacial recession or advancement;
- Mine Site explosive mishaps and explosive factory accidents;
- seismic effects on various structures;
- ore concentrate spills;
- hazardous materials spills (e.g., ammonium nitrate); and

- fuel spills outside secondary containment.

To satisfy this requirement, Seabridge initially commissioned Dr. Andrew M. Robertson, to lead an FMEA risk assessment in October 2009 for the Project (see Appendix 35-A). In September 2012, a second FMEA risk assessment was completed under the direction of Dr. Dirk van Zyl. The 2012 analysis extended to the full suite of geotechnical components in the Mitchell/Sulphurets Valley for mining, and to the PTMA, tunnels, access roads, power, fuel distribution, and explosives including:

- the PTMA, including:
  - top soil and overburden salvage and storage,
  - North and South dam embankments,
  - tailing water management,
  - carbon-in-leach (CIL) pond (Center Pond) management,
  - seepage recovery dams,
  - diversion channels,
  - closure of TMF, and
  - Treaty Process Plant site;
- the Mine Site, including:
  - top soil and overburden salvage and storage;
  - waste rock;
    - basal drain for rock storage facility (RSF) stability;
    - Mitchell and McTagg RSFs;
    - Sulphurets Pit Backfill for Kerr waste rock;
  - pits and underground development;
    - general pit slope stability;
    - Mitchell Pit;
    - Sulphurets Pit;
    - Kerr Pit;
    - Mitchell Underground Works (block caving);
    - Iron Cap Underground Works (block caving);
  - water management;
    - diversion systems;
    - acid rock drainage Water Storage Facility (WSF);

        - Water Treatment Plant (WTP);
        - sludge management;
        - Mitchell Glacier inlet and outlet works;
        - McTagg Glacier inlet and outlet works;
        - Mitchell Pit closure dam;
        - water quality in Mitchell Pit Lake;
        - water quality in Kerr Pit runoff;
- tunnels;
    - the MTT;
        - tunnels;
        - portals;
        - tunnel operations;
    - water diversion tunnels;
        - Mitchell Glacier diversion tunnel;
        - design capacity;
        - inlet operability – infiltration gallery;
        - McTagg Diversion Tunnels;
        - Mitchell Diversion Tunnel, and the Mitchell Valley Drainage Tunnel and connector to the Mitchell Diversion Tunnel;
        - Mitchell block caving underground diversion tunnel and dewatering shaft;
        - Mitchell underground access tunnel;
        - Iron Cap underground access tunnel;
- access;
    - pit access roads;
        - common to all access roads;
    - Highway 37;
    - Highway 37A;
    - Coulter Creek access road (CCAR) to the Mine Site;
    - Treaty Creek access road (TCAR) to the PTMA;
    - Treaty Saddle road;
    - Temporary Frank Mackie Glacier access route;
    - Stewart to Granduc Mine summer access road;

    - Stewart to Hyder Alaska access;
    - USA Traffic Hyder Alaska;
    - equipment laydown areas in Stewart, BC; Camp 1: Granduc Staging Camp; and Camp 2: Ted Morris Camp;
    - ice road;
- operations of temporary road;
    - adverse grades;
    - descending grades;
    - ice cracks and crevasses;
    - load capacity;
    - climatic conditions;
    - power;
- power transmission and generation;
    - Highway 37 connection;
    - power transmission to the Treaty Process Plant site;
    - power transmission through the MTT to the Mine Site;
    - power distribution at the Mine Site;
    - hydropower generation;
    - run-of-river flows for power;
    - fuel distribution;
- fuel management;
    - traffic fuel handling incident;
    - fuel spill Treaty OPC storage tank;
    - fuel spill Mitchell tank farm;
    - fuel spill highways 37 and 16;
    - distribution pipeline leak/rupture in MTT;
    - fuel spill overflow filling tanks in the field;
    - spill through containment facilities;
    - explosives;
- explosives management;
    - off-site vehicle accident with ammonium nitrate spill;
    - off-site vehicle accident with diesel fuel spill;

  - on-site vehicle accident with reagents;
  - off-site transportation accident with detonators and primers;
  - geo-hazards and avalanche along Coulter Creek access road;
  - vandalism of explosives storage facility; and
  - explosive factory leakage or equipment failure.

The objective of the 2012 FMEA was to assess the vulnerability of the Project component designs and intended construction of the various facilities to failure, taking into consideration proposed operating requirements and engineered mitigation measures.

35.2.2 Methodology

FMEA is a 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, particularly on the surrounding ecosystem, including human health and safety.

FMEA was originally developed for the United States Armed Forces in 1949, and is now widely used in reliability engineering and early on in the product lifecycle to identify and address potential issues (US Department of Defense 1949; Mikulak, McDermott, and Beauregard 2009).

The consequences considered for the Project failure modes considered consist of the hazard levels assessed for Biological Impacts, Regulatory Impacts/Censorship, Public Concern/Image, and Health and Safety Impacts. A risk profile was developed for each of these areas of concern. Once the failure modes and measures with the highest risk were identified, it was possible to consider mitigation or alternative designs to reduce risks. FMEAs will therefore be an essential part of any ongoing risk and liability reduction program.

The term “risk” combines both the likelihood of failure (the expected frequency), and the severity of the expected consequences if such events were to occur (risk = likelihood × consequence). Mines incorporate a number of structures that represent combinations of natural and engineered systems involving geology, geo-technics, hydrogeology, hydrology, geochemistry, biology, ecology, and social systems. Because of the complexity of such engineered/natural systems, no statistics of equivalent system performance or probability analyses are available to precisely determine the potential for failures. Given the lack of any established databases, the “best estimate” of the likelihood of failure is often the opinion or calculations of suitably qualified and experienced professionals. In essence, such estimates are empirical values based on the informed judgement of the appropriate expert familiar with the design, operations, and site conditions. There is uncertainty in any estimate of risk. There are also separate uncertainties associated with both the expected frequency and expected consequences. The reliability of the estimate is substantially dependent on the available information, expertise, skill, experience, and good judgement of the experts.

The following team of experts was assembled under the leadership of Dr. Dirk van Zyl for a two-day workshop to participate in this FMEA:

- University of British Columbia – Dr. Dirk van Zyl, P.Eng Professor (FMEA Facilitator)
- Seabridge – Jay Layman, President and COO
- Seabridge – Jim Smolik, Manager Technical Services
- Seabridge – Brent Murphy P.Geo, Vice President Environmental Affairs
- Seabridge – Elizabeth Miller RPBio, Manager Environmental Affairs
- Seabridge – Jessy Chaplin, Manager Permitting
- Rescan Environmental Services Ltd. (Rescan) – Clem Pelletier, Environmental Management
- Rescan – Patrick Lefebvre P.Eng, Environmental Engineering
- Rescan – Anne Currie, Vice President Regulatory and Community Affairs
- Rescan – David Luzi, Hydrologist
- Rescan – Dr. Yaming Chang P.Geo, Hydrogeology/Groundwater
- Rescan – Melissa Lesk-Winfield, Manager Environmental Assessment
- Rescan – Dr. Greg Sharam RPBio, Wildlife and Terrain Specialist
- Rescan – Dr. Kelsey Norlund, Geochemistry/Water Quality
- Rescan – Chris Burns RPBio, Fisheries Specialist
- Moose Mountain Technical Services – Jim Gray P.Eng, Mining
- Moose Mountain Technical Services – Jesse Aarsen P.Eng, Mining
- Golder Associates Ltd. – Ross Hammett P.Eng, Underground Block Cave Mining
- Golder Associates Ltd. – David Sprott P.Eng, Underground Block Cave Mining
- Klohn Crippen Berger Ltd. (KCB) – Graham Parkinson P.Geo, Geotechnical
- KCB – Harvey McLeod P.Eng, Geotechnical
- KCB – Howard Plewes P.Eng, Geotechnical
- KCB – Garry Stevenson P.Eng, Geotechnical
- Harold Bosche P.Eng, Surface Infrastructure
- Dynatec Corporation – Adrian Bodolin, Tunnelling
- Tetra Tech – Dr. John Huang P.Eng, Process Engineering
- Tetra Tech – Johan Steenkamp, Mining Infrastructure
- Tetra Tech – Kevin Jones P.Eng, Winter Ice Road Specialist
- BGC Engineering Inc. (BGC) – Dr. Iain Bruce P.Eng – Geotectechnical Specialist

- BGC – Warren Newcomen P.Eng, Geotechnical Specialist
- BGC – Dr. Derek Kinakin, Geotechnical Specialist
- BGC – Kris Holm, Geohazards Specialist
- McElhanney – Randy Ollenberger, Road Specialist
- McElhanney – Bob Parolin P.Eng, Road Engineer

The scope of the FMEA was sufficient to cover the effects of relevant modes of failure, including engineered system failures (e.g., ditches, drains, foundations, and structures) and natural failures (e.g., geo-hazards, avalanches, floods, and droughts). Factors to account for the confidence in estimates of likelihood and consequence were included to provide readers with an understanding of the group's opinion on the reliability of the estimate.

35.2.3 Failure Modes and Effects Analysis Components

The results of the FMEA (the 2009 FMEA is in Appendix 35-A, and the 2012 FMEA is presented in Sections 35.2.4 to 35.2.5) have been documented in a worksheet format that illustrates the structured approach of the methodology for identifying failure modes leading to undesired consequences. The worksheet used for the KSM Project FMEA is organised with columns that match the analysis logic as described in the following sections.

35.2.3.1 Mine Area/Component

The "Mine Area / Component" column provides a description of the area (i.e., Mine Site or PTMA) and component (e.g., seepage recovery dam) of the Project that is being evaluated.

35.2.3.2 Identification Code

This "ID" column is based on an alpha-numeric code that provides a quick reference to specific failure modes for each component by line item. The ID for each failure mode of each component can then be plotted within a Risk Matrix (Section 35.2.3.13) to provide a summary of the entire FMEA in graphical form. There are four alpha groups namely:

- Group A: PTMA
- Group B: Mine Site
- Group C: Tunnels
- Group D: Access, Power, Fuel Distribution and Explosives

The numeric identification is the orderly listing of individual failure modes under each group.

35.2.3.3 Failure Mode

The "Failure Mode" column provides a description of the manner and/or type of system failure being evaluated. A failure mode can be initiated naturally (e.g., an "act of God" such as an earthquake greater than the design event) or by the failure of one of the engineered subsystems (e.g., instability of a dam due to design limitation), or it can result from operational failure linked to ineffective or inadequate control measures (e.g., neglect to close a valve and subsequent release of contaminating liquid). Because of 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.

35.2.3.4 Effects

The "Effects" column describes the direct adverse environmental effects of the failure mode considered that may have physical, biological, or health and safety consequences. The assessment of the magnitude of the effects of specific failure modes is based on evaluations or analyses of the systems' responses following failure. It is often necessary to make first estimates of adverse direct and indirect effects based on a professional judgement of the anticipated impact of that failure. The classification of the severity of effects (i.e., the consequences) is discussed below in Section 35.2.3.7, Consequences.

35.2.3.5 Period of Interest

The "Period of Interest" column indicates the timeframe, listed as Project phases, for which the risk was considered. Some failure modes have a different likelihood of occurring, or a different consequence if they occur during construction (C), operation (O), or post-closure (PC)[1]. Some risks increase depending on the assessment period timeframe. For example, the potential of a 100-year flood is much greater during the longer post-closure phase than it is during the shorter operating life of a mine. Risk of some component failures (e.g., a spillway) may be greater post-closure when there are fewer staff to provide monitoring and maintenance. The timeframe is also important when assessing risks to human health and safety, where there are likely many more people at risk during the operation phase than during post-closure.

35.2.3.6 Likelihood

The "Likelihood" column indicates the chance that the assessed failure mode will happen. The likelihood has been classified using a five-class system, ranging from not likely to expected as outlined in Table 35.2-1. The number of classes can be adapted to best suit a specific site or engineering system. The likelihood applies to the phase being considered (5 years for construction, 51.5 years for operation, and 250 years for post-closure).

As shown in Table 35.2-1, two separate likelihood distributions have been adopted: one for safety consequences, and another for environmental, regulatory, and public concern consequences. In general, public tolerance for human safety consequences is much lower than for environmental consequences, and therefore the public acceptability of risk of a safety event compared to an environmental event is lower. For example, the probability of an environmental impact of less than 1 in 1,000 may be considered a "low" consequence, whereas an impact likely to result in a fatality would need to have a probability of 1 in 10,000 for public perception of "low" consequence.

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[1] Note that the short closure phase risks were typically considered in with the PC period, and others during operation.

Table 35.2-1. Likelihood of Failure Occurrence Criteria

Likelihood Class	Likelihood of Occurrence for Safety Consequences (events/year)	Likelihood of Occurrence for Environmental and Public Concern Consequences (events/year)
Not Likely (NL)	<0.01% chance of occurrence (1:10,000 years)	<0.1% chance of occurrence (1:1000 years)
Low (L)	0.01 - 0.1% chance of occurrence (1:10,000 - 1:1000 years)	0.1 - 1% chance of occurrence (1:1000 – 1:100 years)
Moderate (M)	0.1 - 1% chance of occurrence (1:1000 – 1:100 years)	1 - 10% chance of occurrence (1:100 – 1:10 years)
High (H)	1 - 10% chance of occurrence (1:100 – 1:10 years)	10 - 50% chance of occurrence (1:2 – 1:10 years)
Expected (E)	>10% chance of occurrence (> 1:10 years)	>50% chance of occurrence (> 1:2 years)

Since the likelihood assigned to a failure mode can vary depending on the type of consequence being evaluated, the FMEA worksheet includes two separate likelihood columns, one for the environmental, regulatory, and public concern consequences, and another for the health and safety concerns.

35.2.3.6.1 Likelihood of Failure Occurrence for Biological Impacts, Regulatory Impacts/Censorship, and Public Concern/Image

The "Bio-Reg-Pub" sub-column is a likelihood class based on the biological (i.e., environmental), regulatory, and public concern impacts likelihood of a failure mode, ranked per the right hand column of Table 35.2-1.

35.2.3.6.2 Likelihood of Failure Occurrence for Health and Safety Concerns

The "Health and Safety" sub-column is a likelihood class based on the human health and safety likelihood of a failure mode, ranked per the central column of Table 35.2-1.

35.2.3.6.3 Likelihood Comments

The "Comments" sub-column under likelihood in the FMEA worksheets, is rated A, B, C, or D based on the following criteria:

A. The likelihood of this failure mode leading to a Health and Safety risk implies that the likelihood of this event occurring must be multiplied by the likelihood of an individual being present at the location during the event. This results in a lower likelihood of occurrence, and is therefore consistent to not increasing the Health and Safety likelihood class above the Bio-Reg-Pub likelihood class.

B. Likelihood of "Expected" for all consequences (Health and Safety cannot be higher than "Expected").

C. Health and Safety driven assessment. The Health and Safety likelihood class assigned to these events occurrences are based on the Health and Safety criteria. The associated Bio-Reg-Pub likelihood class is lower by one category, as per Table 35.2-1. For example, a vehicle accident involving a fatality is driven by safety consequences, so the Bio-Reg-Pub concern impacts have been evaluated using the same likelihood criteria, which corresponds to a likelihood class descriptor lower for the Bio-Reg-Pub likelihood than for the Health and Safety likelihood.

D. Not Health and Safety driven assessment. The consequence was discussed as shown during the workshop, but the relevance or impact of the Health and Safety concern is limited. The same likelihood class was used for the Health and Safety assessment as for the Bio-Reg-Pub impact assessment. For example, the failure mode of having insufficient suitable material for the closure of the PTMA has limited potential Health and Safety risk.

35.2.3.7 Consequences

The "Consequences" column provides an indication of the severity of the failure mode, broken into sub-categories. For each failure mode, the consequence in the FMEA is assessed separately with respect to each of the five areas of concern used in this FMEA, including the cost impact:

- Biological Impacts;
- Regulatory Impacts;
- Public Concern; and
- Health and Safety.

Various scales and thresholds apply for each area of concern such as severity of injury, community well-being, environmental impact, and operational impact. Regulatory impacts have been found to have a profound influence on risk. For instance, changes in regulatory enforcement practices following failures, or perceptions of potential failures, can have severe consequences. Public concern and activism following failures have also had severe impacts, including impacts on public company share value and abilities to permit new mines.

The consequence severity scales that have been found most applicable for mine assessments are provided in Table 35.2-2. The severity ranking is typically classified using a five-class system, from negligible to extreme consequences, which has been found to be effective and intuitive. Although direct cost consequences are typically included in FMEA evaluations, as cost is considered as an internal effect on the Project, rather than an external environmental or human consequence (which is the focus of the Application/EIS), costs are not listed under the "Consequences" column in the FMEA worksheet. To be transparent, cost consequences of failure modes were assessed, as discussed in Section 35.2.3.11, but this consequence is considered secondary for the purposes of environmental assessment, and has not been included in the criticality ranking.

Table 35.2-2. Severity of Failure Effects (Consequences)

Consequence /Severity	Biological Impacts and Land Use	Regulatory Impacts and Censure	Public Concern and Image	Health and Safety
Extreme	Catastrophic impact on habitat (irreversible and large)	Unable to meet regulatory obligations; shut down or severe restriction of operations	Local, international, and non-governmental organization (NGO) outcry and demonstrations, results in large stock devaluation; severe restrictions of "licence to practice"; large compensatory payments, etc.	Fatality or multiple fatalities expected
High	Significant, irreversible impact on habitat (large but reversible)	Regularly (more than once per year) or severely fail regulatory obligations or expectations - large increasing fines and loss of regulatory trust	Local, international, or NGO activism resulting in political and financial impacts on company's "license to do business" and in major procedure or practice changes	Severe injury or disability likely; or some potential for fatality
Moderate	Significant, reversible impact on habitat	Occasionally (less than one per year) or moderately fail regulatory obligations or expectations - fined or censured	Occasional local, international, and NGO attention requiring minor procedure changes and additional public relations and communications	Lost time or injury likely; or some potential for serious injuries; or small risk of fatality
Low	Minor impact on habitat	Seldom or marginally exceed regulatory obligations or expectations; some loss of regulatory tolerance, increasing reporting	Infrequent local, international, and NGO attention addressed by normal public relations and communications	First aid required; or small risk of serious injuries
Negligible	No measurable Impact	Do not exceed regulatory obligations or expectations	No local, international, or NGO attention	No concern

35.2.3.8 Risk Ratings (Biological, Regulatory, and Public Concern, and Health and Safety)

The "Ranking by Consequence" column in the FMEA tables is broken into two sub-columns that provide a summarial ranking of the risk of a given failure mode. Two separate risk ratings have been provided in these sub-columns for each defined failure occurring: one associated with the likelihood and consequence of the highest Bio-Reg-Pub risk, and another for the risk associated with the Health and Safety likelihood and consequence. The highest consequence and likelihood combination for each failure mode is incorporated into the "Risk Rating" sub-columns.

Nine risk ratings are derived from the in the Risk Evaluation Matrix shown in Figure 35.2-1 as a result of the combination of the assessed likelihood and consequence severity of a failure mode. The risk ratings include: negligible, very low, low, moderately low, moderate, moderately high, high, very high, and critical.

35.2.3.9 Level of Confidence

Uncertainty with regard to both the likelihood of failure and the consequence estimates is associated with a number of factors, including lack of data, lack of system understanding, uncertain future operating conditions or maintenance, and potential regional development post closure. Thus, confidence in the risk estimates may range from low to high. It is useful to reviewers of the FMEA if the evaluation team provides their assessment of their own confidence in any risk rating that they conclude. The "Level of Confidence" column in the FMEA worksheet indicates this uncertainty.

A three-interval classification system of low (less than 20%), medium (20 to 80%), and high (greater than 80%) confidence in the risk ratings is usually adequate and appropriate. Where there is low confidence in a high risk assessment value, this clearly indicates a need to further evaluate the risk in order to more reliably predict the risk and identify the mitigation measures to reduce such risk.

35.2.3.10 High Concern Issue

The "High Concern Issue" column of the FMEA worksheet reflects the highest of the "Bio-Reg-Pub" or "Health and Safety" risk rankings, which has been adjusted with the level of confidence for each particular risk. For the risks evaluated with medium and high levels of confidence, the High Concern Issue is identical to the risk ranking identified previously as the highest of the Bio-Reg-Pub or Health and Safety risk rankings. Where the level of confidence in the risk assessment is low, the risk rating is manually adjusted to account for uncertainties, as appropriate.

35.2.3.11 Direct Costs

As mentioned in 35.2.3.7, cost is the fifth consequence typically considered in FMEA. Although the criticality ranking excluded the cost impacts, "Direct Costs" are still included as an FMEA worksheet column, classified following the guidelines outlined in Table 35.2-3.

Table 35.2-3. Cost Consequence Severity

Negotiable (N)	Low (L)	Moderate (M)	High (H)	Extreme (E)
< $1M	$1M - $10M	$10M - $50M	$50M - $100M	> $100M

Graphical Summary of Risk Evaluation: Typical

Likelihood		Abbv.	Consequence Severity: Negligible (N)	Low (L)	Moderate (M)	High (H)	Extreme (E)
			N	L	M	H	E
Likelihood	Expected (E)	E	Moderate	Moderately High	High	Very High	Critical
	High (H)	H	Moderately Low	Moderate	Moderately High	High	Very High
	Moderate (M)	M	Low	Moderately Low	Moderate	Moderately High	High
	Low (L)	L	Very Low	Low	Moderately Low	Moderate	Moderately High
	Not Likely (NL)	NL	Negligible	Very Low	Low	Moderately Low	Moderate

35.2.3.12 Mitigation/Comments

The final column in the FMEA worksheet is "Mitigation/Comments" which describe the applicable mitigation for the failure mode. For each of the risks of failure, safeguards that are already in place through design or operating procedures, or that could be implemented to reduce risk, are listed in this column. Safeguards act to prevent, detect, or mitigate a risk either by reducing the likelihood of occurrence or by reducing the consequences if failure should occur.

If a particular failure mode and effect was assigned a "high" or "expected" likelihood rating, and/or a "high" or "extreme" consequence rating in any of the categories evaluated, additional mitigation measures were sought to reduce the risk, and are reported in this column. In this manner, the FMEA worksheet served as a template for risk management measures or procedures.

35.2.3.13 Representation of Results

Given the likelihood and severity of a given failure mode, a risk rating can be determined and displayed by plotting the results on a two dimensional risk matrix that is colour coded to signify risk. This procedure is often referred to as "binning." A failure mode that is "expected" and that would result in an "extreme" consequence plots in the red bin. The risk ratings are indicated by colours alone, demonstrating that this is not a mathematically precise representation of risk. The level of "risk" increases moving from the bottom left to the top right. The warm colours (yellow to red) indicate failure modes with significant or higher risk ratings. These are the failure modes in most urgent need of further mitigation measures or discontinuation. The cold colours (green to dark blue) indicate the failure modes with moderate to low risk.

For ease of communication, the alpha-numeric codes in the FMEA worksheet "ID" column of the highest risk rating for each of the various failure modes have been plotted within a risk matrix, using the coding in Table 35.2-4, for each of the Project components evaluated.

Table 35.2-4. Worksheet Coding

Period of Interest	Likelihood	Consequences	Level of Confidence
C = Construction	NL = Not Likely	N = Negligible	H = High
O = Operation	L= Low	L = Low	M = Moderate
PC = Post-closure	M = Moderate	M = Moderate	L = Low
	H = High	H = High	
	E = Expected	E = Extreme	

A graphical risk presentation provides a summary and display of the ID codes with their associated risk ratings for each of the Project components that were displayed on the work sheets. The risk matrix plots for each of the Project components listed in Section 35.2.1 are included in Figures 35.2-3 to 35.2-10 at the end of Section 35.2.5, with the corresponding FMEA worksheets following the plots.

35.2.4 Risk Evaluation Summary

The FMEA risk evaluation of the KSM Project was undertaken by a team of experts (Section 35.2.2) who focused on a number of failure modes during construction, operation, and closure / post-closure of the mine. The FMEA process recognized the potential for a number of undesirable events to occur, and the possible consequences with and without mitigation. The final risk ratings are based on the assumption that identified mitigation measures will be implemented with appropriate levels of geotechnical/geohydrological/geochemical investigations and designs. The workshop used a consensus approach among the team members to provide a ranking of the risks associated with the Project.

The following risks noted in the FMEA were considered to be of sufficient concern that a mitigation plan will be required. These risks are summarized graphically in Figure 35.2-2. These risks were binned as yellow (moderately high). No light orange (very high), dark orange (highly significant), or red (critical) categories were identified. The absence of red, dark orange, or light orange level risks does not imply that there are no high hazard failure modes or potential for failures resulting in unacceptable consequences. Rather, they indicate that the level of design and the application of mitigation measures have reduced the risks to appropriately acceptable levels.

35.2.5 Yellow Moderately Significant Risks

35.2.5.1 Group A - Processing and Tailing Management Area (PTMA, Figure 35.2-3 and Worksheet Figures 35.2-4a to 35.2-4c)

A.2.2.2 Incorrect water quality predictions of TMF tailing discharge leads to permit non-compliance, and potential effects on receiving environment.

A.2.2.3 Incorrect flotation pond water quality prediction leads to poor water quality and permit non-compliance.

35.2.5.2 Group B - Mine Site (Figure 35.2-5 and Worksheet Figures 35.2-6a to 35.2-6h)

B.2.3.2 Sulphurets Pit Backfill for Kerr waste rock creates leaching and groundwater effects and leads to increase in metal loads to Sulphurets.

B.3.3.3 Fire starts, mobile accident, electrical fire, or winter traffic in Kerr underground leads to poor air quality, injury, or health issues.

B.3.4.5 Dewatering of the Mitchell Block Cave Mine exceeds the design capacity of the pumping system and leads to flooding the mine.

B.3.4.7 Fire starts, mobile accident, electrical fire, or winter traffic in Mitchell Block caving leads to poor air quality, injury, or health issues.

B.3.5.3 Fire starts, mobile accident, electrical fire, or winter traffic in the Iron Cap Block Cave Mine leads to poor air quality, injury, or health issues.

B.4.2.2 Acid rock drainage WSF inflows exceed design capacity, and lead to discharge of poor quality water to the environment.

B.4.2.6 WSF seepage collection pond efficiency is less than design criteria due to incorrect placement, and leads to increase discharge to the environment downstream of the seepage pond.

B.4.3.6 The WTP is unable to treat all elements with selected treatment methods, and leads to discharge of poor quality water to the environment for certain elements.

Likelihood	Consequence Severity: Negligible (N)	Low (L)	Moderate (M)	High (H)	Extreme (E)
Expected (E)					
High (H)			B.3.3.3, B.3.4.7 B.3.5.3, C.1.1.1 C.1.1.3, C.1.3.2 D.15.1.3, D.16.1.1		
Moderate (M)				A.2.2.2, A.2.2.3 B.2.3.2, B.3.4.5 B.4.2.2, B.4.2.6 B.4.3.6, C.2.1.10 D.1.1, D.1.11	
Low (L)					
Not Likely (NL)					
risk plots below lower threshold					

Risk Matrix - High Risks Summary

Figure 35.2-2

35.2.5.3 Group C – Tunnels (Figure 35.2-7 and Worksheet Figures 35.2-8a to 35.2-8i)

C.1.1.1 Hit major water bearing fault during the construction of the MTT, which leads to slow production, particularly with a downhill drive, and potentially to overwhelming the construction of the WTP.

C.1.1.3 More potentially acid generating (PAG) rock than predicted in the MTT leads to increased quantities of PAG rock requiring additional facilities for PAG rock.

C.1.3.2 Fire starts, mobile accident, electrical fire, or winter traffic in MTT leads to poor air quality, injury, or health issues.

C.2.1.10 Snow/rock avalanche at Mitchell Glacier diversion portals leads to blockage of the portal and to potential safety hazard.

35.2.5.4 Group D – Access, Power, Fuel Distribution, and Explosives (Figure 35.2-9 and Worksheet Figures 35.2-10a to 35.2-10h)

D.1.1 Construction accident as a result of steep terrain leads to worker injury or serious injury.

D.1.11 Loss of vehicle control on pit access roads due to road grade at select locations leads to driver injury or serious injury.

D.15.1.3 Fuel delivery (highways 37 and 16), vehicle collision, or winter conditions leads to small (less than 1 m^3) uncontrolled fuel release to the environment.

D.16.1.1 Off-site explosive components, vehicle collision, and winter conditions resulting in prill spill leads to uncontrolled release of components (i.e., ammonium nitrate) to waterbodies and to temporary highway closure.

These risks can be grouped into the following categories:

- water permit exceedance and potential effects on fishery resources due to incorrect water quality predictions and treatment design (construction, operation, and post-closure);
- water permit exceedance and potential effects on fishery resources due to Mine Site WSF capacity or seepage collection system design;
- underground mine flooding due to insufficient pumping capacity;
- poor air quality, injury, or health issues due to fire or accident underground;
- insufficient PAG facilities due to increased quantities of PAG rock;
- portal blockage due to snow/rock avalanche; and
- spill or driver injury due to vehicle accident on steep grade or during winter conditions.

Mitigations proposed to reduce these identified risks are:

1. *Incorrect water quality predictions and treatment design:*

A combination of long-term and good quality environmental data and conservative design measures provide mitigation that provides assurance against this risk.

On the Mine Site, thorough surface and groundwater modelling based on five years of field measurements and long-term historical data from Environment Canada atmospheric and hydrological information provides reasonable confidence in flow predictions (see Chapter 13). Significant geochemistry laboratory work and mass balance supports current predictions (see Chapter 10).

The WTP capacity was increased from 6.0 L/s to 7.5 L/s in response to the decision to discharge water at a rate to simulate the natural hydrograph, i.e., high stream flows, high discharge rate; low stream flow, low discharge rate. The WTP design includes significant redundancy, ensuring high availability. A high-density sludge lime treatment pilot plant was run on Mitchell Creek water spiked to simulate high predicted concentrations in the WSF (as described in Chapter 4, Appendix 4-V). The pilot plant was run in steady state conditions to produce reliable metal removal efficiency and reliable sludge consistencies. The pilot plant was run to provide design parameters to support detail design of a full scale plant. As a 7.5 m^3/s flow rate plant is deemed to be beyond proven technology, the decision was made to design seven state of the art circuits at proven capacity to reach the required throughput. These circuits can be run completely independent of each other. This will provide significant redundancy to ensure the availability and reliability of the system. Two secondary polishing ponds are included in the design to provide a second level of protection for suspended solids compliance. Filtration test work at Delkor provided good quality information to design and select proper filtration equipment. Sludge volume and handling has been carefully considered.

Selenium, as the element of principal concern from a treatment perspective and from its potential effect on the aquatic environment, was investigated in detail including speciation. Selenium in various rock types was investigated. During the pilot plant work, various methods were investigated to remove selenium including co-precipitation with iron/gypsum sludge, sulphidization, and ion exchange. It was demonstrated that selenium (IV) is effectively removed in the high-density sludge process. Selenium (VI) is not removed. The leachate from the Kerr deposit waste rock was determined to have the highest selenium (VI) concentration, and a plan was developed to isolate the Kerr waste rock from the Mitchell and McTagg RSFs. Kerr waste rock will be backfilled into the Sulphurets Pit and covered with a liner to reduce water ingress and corresponding amount of selenium leaching. The water collected from the Kerr waste rock will be directed to an Ion Exchange treatment plant. A pilot plant was run by BioteQ Environmental Technologies, which demonstrated that selenium (VI) could be reliably reduced to 1 µg/L and the regenerate from the process could be concentrated down to a management volume of elemental selenium. The limitation with this treatment is throughput limitation and costs.

The WTP requirement has been assessed for the life of the mine and for a significant post-closure of 250 years. Water flows to the WSF are based on normal annual wet and dry cycles with intermittent 200-year 24-hour events. The water treatment requirements increase to 80 Mm^3 per year at the peak year from 60 Mm^3 at the start. Long-term closure has average water treatment volume of 65 Mm^3, including variations for climate change.

Water quality at the Treaty Process Plant was determined through various test work including measurements during full pilot plant runs, kinetic tests, and column tests on the tailing and aging tests. Test work was done on rougher tails coarse and fines fraction as well as on pyrite tails. The water treatment process was determined through detailed test work at SGS Lakefield Research Ltd. The CIL precious metals recovery circuit was the primary focus on water treatment. SO_2/Air, a proven technology for cyanide destruction, was piloted for the CIL circuit. Additionally, an activated carbon circuit was added primarily to remove dissolved copper, but also for other dissolved trace metals from the SO_2/Air treatment process. The target cyanide and copper concentration to the CIL Lined Pond is 0.5 mg/L. The plan is to operate the CIL Lined Pond as a clean pond. Excess water from the CIL Lined Pond being discharged to the main flotation pond will go through a hydrogen peroxide treatment step to remove any potentially elevated metals such as copper and residual cyanide or any oxy-anions. The discharge from the flotation pond will be moderated based on stream flows in Treaty Creek from May 15 to October 15 of each year. The discharge will be through a 20 km water pipeline to the main stem of Treaty Creek. The discharge will be through a rock drain to diffuse the flow and dissipate the energy adjacent to the creek. The discharge will be fully mixed with the stream approximately 850 m downstream. The intake in the flotation pond will be through a skimmer and floating clarifier to ensure the 15 mg/L total suspended solids compliance requirement (SOR/2002-222).

2. *Mine Site insufficient WSF capacity or seepage collection system is underperforming:*

Thorough surface and groundwater modelling based on five years of field measurements and long-term historical data from Environment Canada atmospheric and hydrological information provides reasonable confidence in flow predictions. Significant freeboard is included in the WSF design for a potential avalanche or debris flow tsunami event. During significant wet years, stream dilution capacity would also be high, and the WTP throughput would be increased to cope with the additional water in the WSF.

3. *Insufficient mine dewatering at the Mitchell deposit during both open pit and underground operations:*

Mine development is progressive, and experience will provide early warning for adaptive management. Dewatering capacity can be increased, and additional diversion ditches can be added to reduce surface water entering the pits. Underground water storage capacity of 670,000 m^3 is designed for the wet year and 200-year 24-hour event. The designed pumping capacity is 4 m^3/s through four pumps that could pump the full storage in less than two days. If the system was overwhelmed, the underground would flood with no impact on the environment. The major risk is interrupted production and cost.

4. *Fire or accident underground, which would cause poor air quality and result in injury:*

Thorough and safe work practices, emergency procedures, and fire alarm systems will be implemented to reduce the likelihood and significance of these events.

5. *Insufficient PAG facilities during construction and operation:*

Conservative estimates have been included in the design. Existing PAG facilities can be readily expanded. During operation, most PAG material will be placed behind the WSF.

6. *Portal blockage due to snow/rock avalanche:*

A thorough Avalanche Management and Control Plan will be implemented to mitigate this risk. Monitoring and experience will be the primary source of control and early warning. Unstable slopes will be mined proactively. Portal access will also be protected by structures to contain or redirect snow and rock falls.

7. *Vehicle Accident*

A Traffic and Access Management Plan will be implemented to mitigate this risk both on site and off site. Safe work practices will reduce the risk of accidents, and approved contractors or Proponent employees will be trained and equipped with appropriate equipment to execute the Spill Prevention and Emergency Response Plan. Speed will be controlled through radar as well as through a Global Positioning System traffic monitoring system.

35.3 Catastrophic Dam Break Analysis

The third risk evaluation was assessing the hypothetical catastrophic failure of the TMF and the WSF. This work was completed by KCB. The detailed report on the dam break and inundation study for the Mine Site WSD is provided in Appendix 35-B and for the TMF in Appendix 35-C. This work was completed using US Army Corporation of Engineers, proven state-of-the-art numeric models (HEC-Geo RAS and HEC-RAS; US Army Corps of Engineers 2012) to simulate dam failure modes.

The dam breach failure modes considered were dam overtopping and an internal piping failure. Dam overtopping is typically caused by hydrologic events. To avoid flood-generated dam failures, as with most dam safety studies, the Project study involved a hydrologic analysis to derive an Inflow Design Flood (IDF: volume, peak, duration, shape and timing), which is usually defined as the most severe inflow flood for which a dam and its associated facilities are designed. For major dams or for those whose failure may cause significant economic losses or loss of life, the IDF is often set as the Probable Maximum Flood (PMF; Zielinski 2001).

The resulting dam overtopping flood wave predicted, given the hydrological regimes associated with the Project, would transient and is dominated by a bore (i.e., a wall of water), which would subside as the initial energy is dissipated. The crest of this wave of water is what would cause the damage downstream. The height of the crest is controlled by the rate of the initial release and by the characteristics of the stream. The timeline forms a very important component of these predictions. The level of detail provided in the two dam break and inundation studies by KCB (Appendices 35-B and 35-C) are very extensive, but the executive summaries of those two reports are summarized here to outline the potential effects of the worst case scenario of an catastrophic dam failure at the Project.

Likelihood	Negligible (N)	Low (L)	Moderate (M)	High (H)	Extreme (E)
Expected (E)	A.2.1.5				
High (H)					
Moderate (M)			A.2.1.9 A.2.5.2 A.3.3	A.2.2.2 A.2.2.3	
Low (L)		A.2.1.7 A.2.1.11 A.2.2.1 A.2.3.1 A.3.2	A.1.1, A.1.2 A.2.1.1, A.2.1.2 A.2.1.8, A.2.1.10 A.2.4.2, A.2.5.1	A.2.6.1 A.2.6.2 A.2.6.3 A.2.6.4 A.3.1	
Not Likely (NL)		A.2.3.2 A.2.3.3	A.2.3.4 A.2.4.3	A.2.3.5 A.2.4.1	A.2.1.3 A.2.1.4 A.2.1.6 A.2.1.12 A.2.2.4

Consequence Severity

risk plots below lower threshold

SEABRIDGE GOLD
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Risk Matrix - Group A: Tailing Management Area and Plant Site

Figure 35.2-3

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Processing and Tailing Management Area	A																
Top Soil and Overburden Salvage and Storage	A.1																
	A.1.1	Insufficient suitable materials	Cannot complete reclamation as planned with available material	C+O+PC	L	L	D	L	M	L	N	Moderately Low	Very Low	M	Moderately Low	M	Import material or modify design to achieve reclamation objectives if required
	A.1.2	Slope failure at soil and overburden storage sites	Diversion blockage and water overflow into TMF; sedimentation downstream; access road blockage and safety concerns	C+O+PC	L	L	A	L	M	L	L	Moderately Low	Low	H	Moderately Low	L	Monitoring and maintenance programs

A: Risk Level Requires Human Presence at time and location of the event, B: Likelihood of "Expected" for all consequences, C: H&S driven assessment, D: Not H&S Driven Assessment.

Figure 35.2-4a

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Group A, Failure Modes and Effects Analysis Worksheet

Figure 35.2-4a

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Tailings Management Facilities (TMF)	A.2																
North and South Embankments	A.2.1.1	Drain blockage	Raised water table in dam and reduced stability requiring mitigations	C	L	L	D	N	M	N	N	Moderately Low	Very Low	H	Moderately Low	M	Monitoring and maintenance programs
	A.2.1.2	ARD in borrow, fill and excavations at plant site and diversions	Release of metals to environment	C+O+PC	L	L	D	L	M	M	N	Moderately Low	Very Low	H	Moderately Low	M	ARD Management Plan to reduce any ARD
	A.2.1.3	Weak layer foundation failure; liquefaction; piping failure	Catastrophic slumping and release of up to 50% of tailings	O	NL	NL	A	E	E	E	E	Moderate	Moderate	H	Moderate	E	Monitoring and maintenance programs
	A.2.1.4	Embankment slip	Catastrophic slumping and release of up to 50% of tailings	O	NL	NL	A	E	E	E	E	Moderate	Moderate	M	Moderate	E	Monitoring and maintenance programs
	A.2.1.5	Erosion	Localized failure and repairs required	O	E	E	D	N	N	N	N	Moderate	Moderate	H	Moderate	L	Monitoring and maintenance programs
	A.2.1.6	Erosion	Dam overtopping leading to catastrophic failure and release of tailing	O	NL	NL	A	E	E	E	E	Moderate	Moderate	H	Moderate	E	Monitoring and maintenance programs
	A.2.1.7	Tailings line over land failure	Uncontained spill	O	L	L	A	L	L	L	L	Low	Low	H	Low	L	Monitoring and maintenance programs. Most tailings would spill into the tailings pond.
	A.2.1.8	ARD in cyclone dam shell	Release of metals to seepage collection	O	L	L	D	N	L	M	N	Moderately Low	Very Low	H	Moderately Low	L	Ensure flotation efficiency to remove more sulphides
	A.2.1.9	Dust from cyclone sand	Deposition of dust in the environment	O	M	M	D	L	M	M	L	Moderate	Moderately Low	H	Moderate	M	Add water sprays to surface and dam slope
	A.2.1.10	Excessive seepage past collection ponds	Losses to environment (South Teigen or North Treaty Creek)	PC	L	L	D	M	M	M	N	Moderately Low	Very Low	H	Moderately Low	M	Aquatic Effects Monitoring Program (AEMP)
	A.2.1.11	Minor Earthquake slope failure	Dam deformation less than core thickness, no tailings release	PC	L	L	A	N	L	N	L	Low	Low	H	Low	H	Dam safety monitoring and repair
	A.2.1.12	MCE Earthquake leading to slope failure	Dam failure and release of tailing	PC	NL	NL	A	E	E	E	E	Moderate	Moderate	H	Moderate	E	Dam built to Maximum Credible Earthquake (MCE).
Taillings Water Management	A.2.2.1	Discharge Structures (pipelines): Spill, pipeline rupture due to land slide, debris, etc.	Degradation of Water Quality. Damage to fisheries	O	L	L	D	L	L	L	N	Low	Very Low	H	Low	H	Pipeline directed to tailings dam with containment towards impoundment
	A.2.2.2	Incorrect water quality predictions of discharge	Exceed Permit requirements and fisheries impact	O	M	M	D	L	H	H	N	Moderately High	Low	H	Moderately High	E	Water treatment in place to mitigate any potential exceedances
	A.2.2.3	Incorrect flotation pond water quality predictions	Exceed Permit requirements, poor water quality	O	M	M	D	L	H	H	N	Moderately High	Low	H	Moderately High	E	Water treatment in place to mitigate any potential exceedances
	A.2.2.4	Discharge Structures (North and South Spillways): Blockage / rock fall / ice jam	Dam overtopping leading to dam failure and discharge of tailings to the environment	PC	NL	NL	A	E	E	H	M	Moderate	Low	H	Moderate	E	Site Maintenance and management to prevent any blockages
CIL Pond	A.2.3.1	Liner degradation beyond design criteria before development of hydraulic containment	Increased seepage through to flotation ponds	O	L	L	D	N	L	L	N	Low	Very Low	H	Low	M	Monitoring of liner and treatment of water to CIL pond
	A.2.3.2	Liner degradation beyond design criteria before development of hydraulic containment	Increased seepage to environment	O	NL	NL	D	L	L	L	N	Very Low	Negligible	H	Very Low	H	Monitoring of liner and treatment of water to CIL pond
	A.2.3.3	Liner degradation beyond design criteria before development of hydraulic containment associated to early decommissioning of the facilities row height adjusted	Increased seepage to environment	O	NL	NL	D	L	L	L	N	Very Low	Negligible	H	Very Low	H	Monitoring of liner and treatment of water to CIL pond

A: Risk Level Requires Human Presence at time and location of the event, B: Likelihood of "Expected" for all consequences, C: H&S driven assessment, D: Not H&S Driven Assessment.

Group A, Failure Modes and Effects Analysis Worksheet

MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
	A.2.3.4	CIL treatment targets not met and water discharged to CIL instead of Flotation pond	Poor water quality and increased excess water discharge in CIL ponds	O	NL	NL	D	L	M	L	N	Low	Negligible	H	Low	L	Water treatment plant modification to meet expected treatment target
	A.2.3.5	Treatment targets not met and build-up of metals and cyanide in CIL pond	Poor water quality in CIL pond and exposure of migratory birds on the pond	O	NL	NL	D	L	M	H	N	Moderately Low	Negligible	H	Moderately Low	L	Plan to treat water going to CIL pond. Design includes significant redundant treatment
Seepage Recovery Dams	A.2.4.1	Catastrophic failure of the dam	Release of stored seepage to the environmnent	O+PC	NL	NL	A	M	H	H	M	Moderately Low	Low	H	Moderately Low	M	Major clean-up exercise would be required. Dam built with significant levels of safety.
	A.2.4.2	Insufficient collection of seepage	Ground contaminating water discharge to the environment	O+PC	L	L	D	L	M	M	N	Moderately Low	Very Low	H	Moderately Low	M	Very significant modelling work and relocation of seepage dams downstream based on results of the groundwater modelling
	A.2.4.3	Insufficient Storm and seepage storage capacity, or pump failure including back-up	Overtopping releases to the environment	O+PC	NL	NL	D	M	M	M	N	Low	Negligible	H	Low	M	Very low probability. System designed to Possible Maximum Flood (PMF) resulting from a 30 day Probable Maximum Precipitation (PMP) plus 100 year snow accumulation melt
Diversions	A.2.5.1	Insufficient capacity of construction diversions	Elevated TSS, turbidity above permit limits	C	L	L	D	M	M	M	N	Moderately Low	Very Low	H	Moderately Low	L	System designed with high level of safety (200 year 24 hour peak daily flood flow)
	A.2.5.2	Avalanche / Geohazard Blockage / overtopping	Loss of fisheries maintenance flow.	C+O	M	M	D	M	L	L	L	Moderate	Moderately Low	H	Moderate	L	Avalanche Management
Closure of Tailings Management Facilities (TMF)	A.2.6.1	Reclamation - Land use Objectives not met	Water quality degradation	PC	L	L	D	M	H	M	L	Moderate	Low	H	Moderate	M	Continuous effort to meet reclamation land use objective
	A.2.6.2	Reclamation - Water Management Plan objectives not met	Inability to restore natural drainage patterns resulting in degradation in water quality and potential fisheries impact	PC	L	L	D	M	H	M	L	Moderate	Low	H	Moderate	M	More effort and management to insure Water Management Plan objective is achieved
	A.2.6.3	Reclamation - Erosion Protection Plan objectives not met	Damage to structures requiring on-going maintenance and increased sedimentation	PC	L	L	D	M	H	M	L	Moderate	Low	H	Moderate	M	Designed to high level and ongoing care and maintenane to ensure Erosion Control Plan objective is achieved
	A.2.6.4	Water Quality objectives not met	Degradation of Water Quality and potential fisheries impact	PC	L	L	D	M	H	M	L	Moderate	Low	H	Moderate	M	Water treatment available to assist meeting water quality objectives
Plant Site	A.3																
	A.3.1	Failure of containment resulting in tank farm leakage	Groundwater contamination that does not discharge to seepage pond	C+O+PC	L	L	D	M	H	M	L	Moderate	Low	M	Moderate	L	Care and maintenance of fuel containment facility and immediate clean-up if leak occurs
	A.3.2	Suspended Solids exceeding Permit requirements	Impact to receiving environment	C+O	L	L	D	L	L	L	L	Low	Low	H	Low	L	Discharge from flotation pond will be through a clarifier to ensure low Total Suspended Solids (TSS)
	A.3.3	Reagent spills past containment, fires, noxious gases beyond containment	Health and environmental effects	O	L	M		M	M	M	M	Moderately Low	Moderate	H	Moderate	L	Site management including containment facilities and control will be in place. Safety protocols will be enforced

A: Risk Level Requires Human Presence at time and location of the event, B: Likelihood of "Expected" for all consequences, C: H&S driven assessment, D: Not H&S Driven Assessment.

Likelihood	Consequence Severity: Negligible (N)	Low (L)	Moderate (M)	High (H)	Extreme (E)
Expected (E)	B.3.2.3				
High (H)	B.3.1.3	B.2.1.2	B.3.3.3 B.3.4.7 B.3.5.3		
Moderate (M)		B.1.1, B.2.2.4 B.3.3.10, B.3.3.11 B.3.4.14, B.3.4.15 B.3.5.10, B.3.5.11 B.4.1.1, B.4.1.5 B.4.1.7, B.4.2.17 B.4.2.18, B.4.2.19 B.4.7.1	B.2.5.1 B.3.1.1 B.3.1.2 B.3.1.4 B.3.4.3 B.4.1.2 B.4.1.3 B.4.1.4	B.2.3.2 B.3.4.5 B.4.2.2 B.4.2.6 B.4.3.6	
Low (L)	B.3.3.6 B.4.3.1	B.1.2, B.3.4.1 B.3.4.2, B.3.5.1 B.4.1.6, B.4.1.8 B.4.1.9, B.4.1.10 B.4.4.4, B.4.7.2	B.2.1.1, B.2.1.3, B.2.2.3 B.2.4, B.3.1.5, B.3.3.5 B.3.3.8, B.3.4.9, B.3.4.12 B.3.5.5, B.3.5.8 B.4.2.1, B.4.2.15 B.4.2.16, B.4.4.3 B.4.6, B.4.8, B.4.9	B.2.2.2, B.2.5.3 B.3.2.1, B.3.2.2 B.3.3.1, B.3.3.7 B.3.5.7, B.4.2.5 B.4.2.7, B.4.2.12 B.4.2.20, B.4.3.2 B.4.3.5, B.4.3.7, B.4.3.8 B.4.4.1, B.4.4.2, B.4.5	
Not Likely (NL)	B.3.4.10 B.3.5.6	B.3.3.9 B.3.3.12 B.3.4.13 B.3.4.16 B.3.5.9 B.3.5.12	B.2.2.1 B.3.2.5 B.4.2.3 B.4.2.4 B.4.2.14	B.2.3.1, B.2.5.2 B.3.2.4, B.3.3.4 B.3.4.4, B.3.4.8 B.3.4.11, B.3.5.4 B.4.2.8, B.4.2.9 B.4.2.11, B.4.2.13 B.4.3.3, B.4.3.4	B.3.3.2 B.3.4.6 B.3.5.2 B.4.2.10
risk plots below lower threshold					

Risk Matrix - Group B: Mine Site Area

Figure 35.2-5

MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD Of INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Mine Site Area	B																
Top Soil and Overburden Salvage and Storage	B.1																
	B.1.1	Insufficient topsoil stored for reclamation	Modifies reclamation plan and may delay vegetation growth on reclamation	PC	M	M	D	L	L	L	N	Moderately Low	Low	M	Moderately Low	L	All efforts will be placed on topsoil / till storage for reclamation
	B.1.2	Avalanche from Ted Morris buries till stockpile	Potentially loss of till material	PC	L	L	D	L	L	L	N	Low	Very Low	M	Low	L	Material would be salvaged and used

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Figure 35.2-6a

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Figure 35.2-6a

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Waste Rock	B.2																
Basal Drain (Only for Rock Storage Facility stability)	B.2.1.1	Lack of good rock for construction (5Mm³)	Reduced capacity requires more water to be diverted around waste rock dumps under extreme floods.	C	L	L	D	M	M	M	N	Moderately Low	Very Low	M	Moderately Low	L	Increase factor of safety. Install spillway and tunnel to keep pit lake level.
	B.2.1.2	Capacity reduced due to ARD precipitate or fines	Reduced internal waste rock dump drainage capacity	C	H	H	D	L	L	L	N	Moderate	Moderately Low	M	Moderate	L	Increase factor of safety. Install pump system to ensure water movement.
	B.2.1.3	Flushing of metals/metalloids to WSF	Increase in discharge concentrations to the WTP	C	L	L	D	M	M	M	N	Moderately Low	Very Low	M	Moderately Low	L	Increase in reagent cost
Mitchell Rock Storage Facility	B.2.2.1	Slope failure towards OPC area associated with lacustrine silts in Mitchell Valley	Effects on OPC	O	NL	NL	A	N	M	L	N	Low	Negligible	M	Low	H	OPC = Ore Preparation Complex Constant monitoring and evaluation. Develop mitigation plan as required.
	B.2.2.2	Slope failure towards WSF during rapid drawndown	Effects on WSF	O	L	L	D	H	H	H	L	Moderate	Low	M	Moderate	M	Constant monitoring and evaluation. Develop mitigation plan as required.
	B.2.2.3	McTagg dump failure	West failure blocks surface flows	O	L	L	A	N	M	N	N	Moderately Low	Very Low	M	Moderately Low	L	Constant monitoring and evaluation. Develop mitigation plan as required.
	B.2.2.4	Erosion of waste dump	Erosion and major sedimentation into the WSF	PC	M	M	A	L	L	L	N	Moderately Low	Low	M	Moderately Low	L	Constant monitoring and evaluation. Develop mitigation plan as required.
Sulphurets Rock Storage for Kerr waste rock	B.2.3.1	Slope faillure	Release of rock and debris to Sulphurets Creek	C	NL	NL	A	H	H	H	N	Moderately Low	Negligible	M	Moderately Low	M	Sulphurets waste rock moved to Mitchell / McTagg RSF
	B.2.3.2	Leaching and groundwater effects	Increase in metal loads to Sulphurets	O	M	M	D	H	M	M	N	Moderately High	Low	M	Moderately High	M	Sulphurets waste rock moved to Mitchell / McTagg RSF
Temporary Sulphurets Surface Dump	B.2.4	Contamination of groundwater	Potential increase in metal loads to Sulphurets Creek	O	L	L	D	M	M	M	N	Moderately Low	Very Low	M	Moderately Low	M	Sulphurets waste rock moved to Mitchell / McTagg RSF
Sulphurets Pit Backfill for Kerr Pit Waste Rock	B.2.5.1	Leaching and groundwater effects	Potential increase in metal loads to Sulphurets	O	M	M	D	M	M	M	N	Moderate	Low	M	Moderate	L	Kerr Waste Rock stored in Sulphurets Pit and lined to reduce potential point load source loading to Sulphurets Creek
	B.2.5.2	Stockpile fails	Release of solids and debris to Sulphurets Creek	O	NL	NL	D	H	H	H	N	Moderately Low	Negligible	M	Moderately Low	L	Modified plan for Kerr waste rock handling
	B.2.5.3	Collection system for contaminated water fails	Increase in metal loads to Sulphurets	O	L	L	D	M	H	L	N	Moderate	Very Low	M	Moderate	L	Modified plan for Kerr waste rock handling. Design of Sulphurets pit drainage.

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Group B, Failure Modes and Effects Analysis Worksheet

MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Pits and Underground	B.3																
General Pit Slopes	B.3.1.1	Design model for slopes at PFS level	Potential changes to slope design	O	M	M	D	N	M	L	N	Moderate	Low	M	Moderate	M	Slope design based on best proactives
	B.3.1.2	Inabiltiy to achieve slope depressurization	Potential changes to slope design	O	M	M	D	N	M	L	N	Moderate	Low	M	Moderate	L	Slope design based on best proactives
	B.3.1.3	Bench scale slope instability	Potential for minor effect	O	H	H	A	N	N	N	N	Moderately Low	Moderately Low	M	Moderately Low	L	Experience will provide information to control bench scale slope stability
	B.3.1.4	Interramp slope instability	Affects mining rate,	O	M	M	A	N	M	L	L	Moderate	Moderately Low	M	Moderate	L	Modify slope to maintain slope stability
	B.3.1.5	Overall slope instability	Delays mining	O	L	L	D	N	M	M	N	Moderately Low	Very Low	M	Moderately Low	M	Slope angles will be assured as mining progresses and appropriate adjustments will be made
Mitchell Pit	B.3.2.1	Snowfield Landslide reactivates	Potential for rock slide into the open pit	O	L	M		N	H	M	L	Moderate	Moderately Low	M	Moderate	M	Engineering mitigation to reduce likelihood of Snowfield Landslide
	B.3.2.2	Failure of Mitchell Diversion	Inflow of water into the open pit	O	L	L	D	N	H	M	N	Moderate	Very Low	M	Moderate	L	Clean up entrance and repair any damage
	B.3.2.3	Failure of pit slopes due to block caving	Deformation of pit slopes	O	E	E	B	N	N	N	N	Moderate	Moderate	M	Moderate	N	Not a problem because pit slopes will fail during block caving while no open pit mining is occurring
	B.3.2.4	Overtopping of the Mitchell Diversion	Failure of the eastern wall of the pit	O	NL	L		N	H	H	N	Moderately Low	Very Low	M	Moderately Low	L	Will require more pumping until failure is repaired
	B.3.2.5	Large slope failure into the Pit Lake	20 to 50 Mt of rock into the open pit creates a tsunami wave; erosion of mine rock. Sediment into the WSF.	PC	NL	NL	D	N	M	L	N	Low	Negligible	M	Low	L	Detailed modeling studies confirmed dam crest able to contain tsunami wave and increase sediment in WSF not a problem. WSF will be dredged on a regular basis.
Kerr Pit	B.3.3.1	Reactivation of the Kerr Landslide due to mining	Debris into Sulphurets Creek	O	L	L	D	M	H	M	N	Moderate	Very Low	M	Moderate	L	Careful monitoring of Kerr Landslide and if required buttress could be built
	B.3.3.2	Fire starts; mobile accident, electrical fire, winter traffic	Poor air quality leading to fatality	O	NL	NL	C	L	M	L	E	Low	Moderate	M	Moderate	L	Good fire protection alarm system and safety protocols
	B.3.3.3	Fire starts; mobile accident, electrical fire, winter traffic	Poor air quality leading to Injury and health issues	O	H	E		L	M	L	L	Moderately High	Moderately High	M	Moderately High	L	Good fire protection alarm system and safety protocols
	B.3.3.4	Mobile accident	Fatality	O	NL	NL	C	L	M	L	H	Low	Moderately Low	M	Moderately Low	L	Major investigation and safety improvement
	B.3.3.5	Diesel fuel pipeline break.	Drains to Mine Site	O	L	L	A	M	M	L	L	Moderately Low	Low	M	Moderately Low	M	Buried Pipeline complete with leak detection and shut-off valves. Will be contained in WSF. Will clean up of diesel fuel on and within WSF.
	B.3.3.6	Equipment contacts the power line involving physical damage to the power line	Electrical current discharge	O	NL	L		N	N	N	N	Negligible	Very Low	M	Very Low	N	Proper awareness and safety training.
	B.3.3.7	Equipment contacts the power line involving physical damage to the power line	Power outage at Mine Site area	O	NL	L		N	M	L	H	Low	Moderate	M	Moderate	L	Proper awareness and safety training.
	B.3.3.8	Rockfall or vehicle accident	Safety effect	O	NL	L	C	N	M	L	M	Low	Moderately Low	M	Moderately Low	L	Proper awareness and safety training.
	B.3.3.9	Changes to glaciation or increase in water flows	More water to the WTP	O	NL	NL	D	L	L	L	L	Very Low	Very Low	M	Very Low	L	Monitoring program will provide early warning
	B.3.3.10	Power shutdown in the tunnel	Temporary power outage	O	M	M	A	N	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	N	Most tunnel flows are by gravity, effects would be minimal
	B.3.3.11	Mechanical failure of conveyor	Economic consequence	O	M	M	A	N	N	N	L	Low	Moderately Low	M	Moderately Low	L	Maintenance response are preventative maintenance

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Figure 35.2-6c

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Group B, Failure Modes and Effects Analysis Worksheet

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
	B.3.3.12	Seismic event	Minor shaking in the tunnel	O	NL	NL	A	N	L	L	N	Very Low	Negligible	M	Very Low	N	Check for damage and general surveillance
Mitchell Underground Works (Block Caving)	B.3.4.1	Rock bursts	Safety issues	O	NL	L	C	N	L	L	L	Very Low	Low	M	Low	L	Monitoring
	B.3.4.2	Mud rushes into openings	Safety issues	O	NL	L	C	N	L	L	L	Very Low	Low	M	Low	L	Monitoring
	B.3.4.3	Flows pumped from underground in order to avoid flooding may exceed design pumping capacity to WSF for flows greater than 200 years	Flood underground works	O	L	M		N	M	M	L	Moderately Low	Moderately Low	L	Moderate	L	Ensure effectivness of the diversion ditches around the pit
	B.3.4.4	Failure of the pump system	Flood the mine	O	NL	L		N	H	H	N	Moderately Low	Very Low	M	Moderately Low	H	Ensure underground water storage is available to maximum capacity
	B.3.4.5	Exceeds design capacity of pump system	Flood the mine	O	M	H		L	H	H	N	Moderately High	Moderately Low	M	Moderately High	H	Increase capacity of dewatering system. Need diversion ditches on north wall
	B.3.4.6	Fire starts; mobile accident, electrical fire, winter traffic	Poor air quality leading to fatality	O	NL	NL	C	L	M	L	E	Low	Moderate	M	Moderate	L	Good fire protection alarm system
	B.3.4.7	Fire starts; mobile accident, electrical fire, winter traffic	Poor air quality leading to injury and health issues	O	H	E		L	M	L	L	Moderately High	Moderately High	M	Moderately High	L	Good fire protection alarm system
	B.3.4.8	Mobile accident	Fatality	O	NL	NL	C	L	M	L	H	Low	Moderately Low	M	Moderately Low	L	Major investigation and safety improvement
	B.3.4.9	Diesel fuel pipeline break.	Drains to Mine Site	O	L	L	A	M	M	L	L	Moderately Low	Low	M	Moderately Low	M	Buried pipeline complete with leak detection and shut-off valves. Will be contained in WSF. Will clean up diesel fuel on and within WSF.
	B.3.4.10	Equipment contacts the power line involving physical damage to the power line	Electrical Current discharge	O	NL	NL	C	N	N	N	N	Negligible	Negligible	M	Negligible	N	Proper awareness and safety training
	B.3.4.11	Equipment contacts the power line involving physical damage to the power line	Power outage at Mine Site area	O	NL	NL	C	N	M	L	H	Low	Moderately Low	M	Moderately Low	L	Proper awareness and safety training
	B.3.4.12	Rockfall or vehicle accident	Safety effect	O	L	L	C	N	M	L	M	Moderately Low	Moderately Low	M	Moderately Low	L	Proper awareness and safety training
	B.3.4.13	Changes to glaciation or increase in water flows	More water to the WTP	O	NL	NL	D	L	L	L	L	Very Low	Very Low	M	Very Low	L	Monitoring program will provide early warning
	B.3.4.14	Power shutdown in the tunnel	Temporary power outage	O	M	M	A	N	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	N	Most tunnel flows are by gravity, effects would be minimal
	B.3.4.15	Mechanical failure of conveyor	Economic consequence	O	M	M	A	N	N	N	L	Low	Moderately Low	M	Moderately Low	L	Maintenance response are preventative maintenance
	B.3.4.16	Seismic event	Minor shaking in the tunnel	O	NL	NL	A	N	L	L	N	Very Low	Negligible	M	Very Low	N	Check for damage and general surveillance
Iron Cap Underground Works (Block Caving)	B.3.5.1	Melting of water from the ice cap	Potential safety issue at drawpoint	O	NL	L	C	N	L	L	L	Very Low	Low	M	Low	L	Monitoring and effects would be low due to small volume of water
	B.3.5.2	Fire starts; mobile accident, electrical fire, winter traffic	Poor air quality leading to fatality	O	NL	NL	C	L	M	L	E	Low	Moderate	M	Moderate	L	Good fire protection alarm system
	B.3.5.3	Fire starts; mobile accident, electrical fire, winter traffic	Poor air quality leading to Injury and health issues	O	H	E		L	M	L	L	Moderately High	Moderately High	M	Moderately High	L	Good fire protection alarm system
	B.3.5.4	Mobile accident	Fatality	O	NL	NL	C	L	M	L	H	Low	Moderately Low	M	Moderately Low	L	Major investigation and safety improvement
	B.3.5.5	Diesel fuel pipeline break	Drains to mine area	O	L	L	A	M	M	L	L	Moderately Low	Low	M	Moderately Low	M	Buried pipeline complete with leak detection and shut-off valves. Will be contained in WSF. Will clean up diesel fuel on and within WSF.

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Group B, Failure Modes and Effects Analysis Worksheet

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	B.3.5.6	Equipment contacts the power line involving physical damage to the power line	Electrical Current discharge	O	NL	NL	C	N	N	N	N	Negligible	Negligible	M	Negligible	N	Proper awareness and safety training
	B.3.5.7	Equipment contacts the power line involving physical damage to the power line	Power outage at Mine Site area	O	NL	L		N	M	L	H	Low	Moderate	M	Moderate	L	Proper awareness and safety training
	B.3.5.8	Rockfall or vehicle accident	Safety effect	O	NL	L	C	N	M	L	M	Low	Moderately Low	M	Moderately Low	L	Proper awareness and safety training
	B.3.5.9	Changes to glaciation or increase in water flows	More water to the WTP	O	NL	NL	D	L	L	L	L	Very Low	Very Low	M	Very Low	L	Monitoring program will provide early warning
	B.3.5.10	Power shutdown in the tunnel	Temporary power outage	O	M	M	A	N	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	N	Most tunnel flows are by gravity, effects would be minimal
	B.3.5.11	Mechanical failure of conveyor	Economic consequence	O	M	M	A	N	N	N	L	Low	Moderately Low	M	Moderately Low	L	Maintenance response are preventative maintenance
	B.3.5.12	Seismic event	Minor shaking in the tunnel	O	NL	NL	A	N	L	L	N	Very Low	Negligible	M	Very Low	N	Check for damage and general surveillance

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Group B, Failure Modes and Effects Analysis Worksheet

Figure 35.2-6e

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Water Management	B.4																
Diversion Systems	B.4.1.1	Mitchell Creek pre-stripping construction diversion: Exceeding capacity of temporary diversion	Sedimentation in the environment	C	M	M	D	L	L	L	N	Moderately Low	Low	H	Moderately Low	L	Immediate response to remediate issue
	B.4.1.2	South slope diversion: Blockage of inlets to contact water diversions during peak flow period by avalanche, debris flows, rock slides, slope creep	Overtopping into clean water diversion tunnels and discharge of poor water quality	C+O+PC	M	M	D	M	M	M	N	Moderate	Low	H	Moderate	L	Water Quality Monitoring
	B.4.1.3	North wall dewatering adit: Exceeding capacity, loss of function or blockage of RSF basal drain during open pit operations	Spill into pit with risk of damage to pit and requirement to pump	O	M	M	D	N	M	M	L	Moderate	Moderately Low	M	Moderate	L	Added drainage tunnel to WSF to avoid potential with basal drain blockage System designed for predicted 200-year 24-hour rainfall plus 200-year maximum daily glacier melt
	B.4.1.4	Exceeding capacity, loss of function or blockage of RSF basal drain during Mitchell underground operations	Overtopping into clean water diversion tunnels and discharge of poor water quality to Sulphurets Creek	O	M	M	D	L	M	M	L	Moderate	Moderately Low	H	Moderate	L	Added drainage tunnel to WSF to avoid potential with basal drain blockage System designed for predicted 200-year 24-hour rainfall plus 200-year maximum daily glacier melt
	B.4.1.5	RSF perimeter and surface diversions (Mitchell): Natural hazards (avalanches and landslides)	Overtopping increasing flows to the WSF	O+PC	M	M	D	N	L	L	N	Moderately Low	Low	H	Moderately Low	L	Immediate response to remediate issue
	B.4.1.6	RSF perimeter and surface diversions (Mitchell): Exceedance of design criteria (1:200 24 hour average flow)	Overtopping increasing flows to the WSF	O+PC	L	L	D	N	L	L	N	Low	Very Low	M	Low	L	Immediate response to remediate issue. System designed for predicted 200-year 24-hour rainfall plus 200-year maximum daily glacier melt.
	B.4.1.7	RSF Perimeter and surface diversions (McTagg): Natural hazards (avalanches and landslides)	Increasing flows to the WSF	O+PC	M	M	D	N	L	L	N	Moderately Low	Low	H	Moderately Low	L	Immediate response to remediate issue
	B.4.1.8	RSF Perimeter and surface diversions (McTagg): Exceedance of design criteria (1:200 24 hour average flow)	Overtopping increasing flows to the WSF	O+PC	L	L	D	N	L	L	N	Low	Very Low	M	Low	L	Immediate response to remediate issue. System designed for predicted 200-year 24-hour rainfall plus 200-year maximum daily glacier melt.
	B.4.1.9	RSF Perimeter and Surface Diversions (Sulphurets): Flows in diversion channel above RSF exceed design criteria (1:200 24 hour average flow)	Overtopping increasing flows to the WSF	O+PC	L	L	D	N	L	L	N	Low	Very Low	M	Low	L	Immediate response to remediate issue. System designed for predicted 200-year 24-hour rainfall plus 200-year maximum daily glacier melt.
	B.4.1.10	RSF Perimeter and Surface Diversions (Sulphurets): Flows in collection channel below RSF exceed design criteria (1:200 24 hour storm peak flow)	Overtopping causing release to environment	O+PC	L	L	D	L	L	L	N	Low	Very Low	M	Low	L	Immediate response to remediate issue
Water Storage Facility (WSF)	B.4.2.1	WSD construction diversion tunnel: Blockage during operation of CDT or exceedance of design capacity	Increased sedimentation downstream and construction interruption	C	L	L	D	M	M	M	N	Moderately Low	Very Low	M	Moderately Low	L	Immediate response to remediate issue
	B.4.2.2	Inflows exceed design capacity (1:200 wet year)	Discharge of poor quality water to the environment	O+PC	M	M	D	H	H	H	N	Moderately High	Low	M	Moderately High	L	Hydrological Monitoring
	B.4.2.3	WSD reservoir: Avalanche geohazard resulting in impact wave greater than designed freeboard	Overtopping of WSD and release of water from wave to environment	O+PC	NL	NL	D	L	M	M	N	Low	Negligible	H	Low	L	Modeling does not indicate an issue. Freeboard on dam able to handle potential tsunami.
	B.4.2.4	Rockslide resulting in impact wave greater than designed freeboard	Overtopping of WSD and release of water from wave to environment and reduction of storage	O+PC	NL	NL	D	L	M	M	N	Low	Negligible	H	Low	L	Monitoring and effective remediation
	B.4.2.5	Seepage flow rates beyond design criteria due to inadequate grouting	Increased discharge to environment downstream of seepage pond	O+PC	L	L	D	H	H	H	N	Moderate	Very Low	M	Moderate	M	Monitoring and effective remediation
	B.4.2.6	Seepage collection pond efficiency less than design criteria due to incorrect placement	Increased discharge to environment downstream of seepage pond	O+PC	M	M	D	H	H	H	N	Moderately High	Low	M	Moderately High	M	Groundwater modelling does not predict issue
	B.4.2.7	Seepage paths due to foundation defects (calcareous sediments)	Increased discharge to environment downstream of seepage pond	O+PC	L	L	D	H	H	H	N	Moderate	Very Low	M	Moderate	M	Groundwater modelling does not predict issue
	B.4.2.8	Seepage flow or storm inflows to seepage pond	Overtopping of seepage dam and discharge to environment	O+PC	NL	NL	D	H	H	H	N	Moderately Low	Negligible	M	Moderately Low	M	Appropriate remediations if it happens
	B.4.2.9	Dam slope stability (seismic): Earthquake beyond design criteria	Release to environment due to crack or displacement in dam core	O+PC	NL	NL	A	H	H	H	L	Moderately Low	Very Low	H	Moderately Low	M	Dam safety monitoring
	B.4.2.10	Dam slope stability (seismic): Earthquake of sufficient magnitude to cause dam failure	Catastrophic dam failure	O+PC	NL	NL	A	E	E	E	E	Moderate	Moderate	H	Moderate	E	Design to maximum credible earthquake

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Figure 35.2-6f

SEABRIDGE GOLD
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Group B, Failure Modes and Effects Analysis Worksheet

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
	B.4.2.11	Dam slope stability (static): Dam settlement leading to core deformation	Release to environment due to crack or displacement in dam core	O+PC	NL	NL	A	H	H	H	L	Moderately Low	Very Low	H	Moderately Low	M	Dam safety monitoring
	B.4.2.12	Inadequate grouting or dissolution of grout curtain	Increased discharge to environment downstream of seepage pond	O+PC	L	L	D	H	H	H	N	Moderate	Very Low	M	Moderate	M	Monitoring and replacement of grout curtain
	B.4.2.13	Inappropriate asphalt core material (construction defects)	Increased discharge to environment downstream of seepage pond	O+PC	NL	NL	D	H	H	H	N	Moderately Low	Negligible	H	Moderately Low	H	Construction QA/QC
	B.4.2.14	Rock on downstream dam face becomes acid generating as a result of ARD from borrow source materials	Decreased water quality in seepage collection pond	O+PC	NL	NL	D	L	M	M	N	Low	Negligible	H	Low	M	Construction QA/QC
	B.4.2.15	Long term defect development in core or grout curtain	Increased flows to seepage collection pond	O+PC	L	L	D	L	M	M	N	Moderately Low	Very Low	H	Moderately Low	H	Construction QA/QC
	B.4.2.16	Decant system leakage below dam	Increased flows to seepage collection pond	O+PC	L	L	D	L	M	M	N	Moderately Low	Very Low	H	Moderately Low	M	Mitigation: Decant system replaced with pumping system. No decant.
	B.4.2.17	Blockage of decant system pipes or inlets	Requirement to pump or reduction in storage capacity of WSF	O+PC	M	M	D	N	L	L	N	Moderately Low	Low	H	Moderately Low	M	Mitigation: Decant system replaced with pumping system. No decant.
	B.4.2.18	Inability to dredge sediment pond	Reduction in storage capacity of WSF and plugging of decant structures leading to requirement to pump	O+PC	M	M	D	N	L	L	N	Moderately Low	Low	H	Moderately Low	L	Decant system replaced with pumping system. No decant.
	B.4.2.19	Inability to dewater and manage sediment	Inability to transport and safely store sediment resulting in loss of capacity in WSF	O+PC	M	M	D	N	L	L	N	Moderately Low	Low	M	Moderately Low	L	
	B.4.2.20	Leakage of construction water diversion tunnel under WSF dam	Water degradation and downstream impact	O+PC	L	L	D	H	H	M	L	Moderate	Low	H	Moderate	M	Double plug with acid resistant concrete and epoxy coating
Water Treatment Plant	B.4.3.1	Higher than estimated consumption of reagents	More sludge than anticipated and significant cost increase	C+O+PC	L	L	D	N	N	N	N	Very Low	Very Low	H	Very Low	L	Simulation studies completed based on conservative estimate
	B.4.3.2	Insufficient reagent supply at site	Discharge of poor quality water to the environment	C+O+PC	L	L	D	M	H	H	N	Moderate	Very Low	H	Moderate	L	Ensure suply on hand and ability to store water in pond
	B.4.3.3	Flooding or landslide runout	Disruption to treatment	C+O+PC	NL	NL	D	M	H	H	N	Moderately Low	Negligible	H	Moderately Low	H	Ground condition monitoring
	B.4.3.4	Capacity exceeded by direct underground inflows	Discharge of poor quality water to the environment	O+PC	NL	NL	D	H	H	H	N	Moderately Low	Negligible	M	Moderately Low	M	WTP designed with significant excess capacity. Throughput up to 7.5 m³/s.
	B.4.3.5	Capacity exceeded by inaccurate predictions of inflows including climate change	Discharge of poor quality water to the environment	O+PC	L	L	D	H	H	H	N	Moderate	Very Low	H	Moderate	H	Plant designed with significant excess capacity to match hydrograph. Climate change effects gradual - will permit adaptive management.
	B.4.3.6	Inability to treat all elements with selected treatment methods	Discharge of poor quality water to the environment for certain elements	O+PC	M	M	D	M	H	H	N	Moderately High	Low	H	Moderately High	H	Water quality predictive modelling simulation and treatment simulation studies do not indicate problem that would cause effects on receiving environment
	B.4.3.7	Not meeting discharge specifications	Discharge of poor quality water to the environment	O+PC	L	L	D	M	H	H	N	Moderate	Very Low	H	Moderate	H	Water quality predictive modelling simulation and treatment simulation studies do not indicate problem that would cause effects on receiving environment
	B.4.3.8	Inability to maintain treatment in perpetuity	Discharge of poor quality water to the environment	PC	L	L	D	H	H	H	N	Moderate	Very Low	H	Moderate	H	Ensure adequate bond in place to treat into perpetuity
Sludge Management	B.4.4.1	Secure landfill failure	Spilling of construction period sludge into downstream environment (Sulphurets Creek)	C	L	L	D	H	H	M	N	Moderate	Very Low	H	Moderate	L	Design specification to ensure stability
	B.4.4.2	Monitoring of sludge disposal in secure landfill facility not carried out	Inappropriate closure plan	C+O	L	L	D	L	H	H	N	Moderate	Very Low	H	Moderate	L	Commitment to long-term monitoring and maintenance
	B.4.4.3	Inappropriate dewatering of material conveyed to plant site and into TMF	Sludge is too wet (spills off conveyor) or too dry (dust in tunnel) leading to contamination of tunnel drainage	O	L	L	A	L	M	M	L	Moderately Low	Low	H	Moderately Low	L	Proper operation procedures with conservatively designed dewatering equipment
	B.4.4.4	Sludge leaching from secure landfill on RSF	Increased loading to WSF and treatment	PC	L	L	D	N	L	L	N	Low	Very Low	H	Low	L	Proper design with liner and monitoring procedures

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Figure 35.2-6g

SEABRIDGE GOLD
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Group B, Failure Modes and Effects Analysis Worksheet

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Figure 35.2-6g

MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Mitchell Inlet and Outlet Works	B.4.5	Plugging of the subglacial inlet	Release of water into the open pit, more water treatment	O	L	L	D	N	H	M	N	Moderate	Very Low	M	Moderate	M	Monitoring
McTagg Inlet and Outlet Works	B.4.6	Snow avalanche	Blocks inlet and increases flows to WTP	PC	L	L	A	N	M	M	N	Moderately Low	Very Low	M	Moderately Low	L	Snow removal equipment mobilized to clean area
Mitchell Pit closure dam	B.4.7.1	Differential stresses on the dam lead to leakage	Increases seepage and potential metal loading due to lower pit lake and flows into basal drain	PC	M	M	D	L	L	L	N	Moderately Low	Low	M	Moderately Low	L	Repair dam to stop leakage. Monitoring and maintenace.
	B.4.7.2	Deformations due to block caving and pit slope and caving instability	Increases seepage and potential metal loading due to lower pit lake and flows into basal drain	PC	L	L	D	L	L	L	N	Low	Very Low	M	Low	L	Dam located well beyond expected deformation zone of influence due to block cave
Pit Lake Water Quality in Mitchell Pit Lake	B.4.8	Metal leaching beyond predicted	Impact on WTP	PC	L	L	D	L	M	L	L	Moderately Low	Low	M	Moderately Low	M	Monitor water quality trend
Pit Lake Water Quality in Kerr Pit	B.4.9	Metal leaching beyond predicted	Increase metal loading with potential effect on Sulphurets Creek	PC	L	L	D	L	M	L	L	Moderately Low	Low	M	Moderately Low	M	Water from Kerr Pit pumped to WSF and treated

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Group B, Failure Modes and Effects Analysis Worksheet

Likelihood	Consequence Severity: Negligible (N)	Low (L)	Moderate (M)	High (H)	Extreme (E)
Expected (E)					
High (H)		C.2.1.4 C.2.3.3	C.1.1.1 C.1.1.3 C.1.3.2		
Moderate (M)		C.1.1.2, C.1.1.6 C.1.3.9, C.1.3.10 C.2.1.3, C.2.2.2 C.2.2.9, C.2.3.7 C.3.1.2	C.1.1.5 C.2.1.2 C.2.1.15 C.2.1.21 C.2.1.22 C.2.2.15	C.2.1.10	
Low (L)		C.2.1.1, C.2.1.5, C.2.1.7 C.2.1.8, C.2.1.11, C.2.1.12 C.2.1.13, C.2.1.19 C.2.1.20, C.2.2.1 C.2.2.11, C.2.2.12 C.2.2.13, C.2.3.1, C.2.3.2 C.2.3.4, C.3.1.1, C.3.2.1 C.3.2.2, C.3.3.1, C.3.3.4	C.1.1.4, C.1.2.1 C.1.2.3, C.1.3.4 C.1.3.7, C.2.2.7 C.2.3.6, C.3.1.5 C.3.1.6, C.3.1.7 C.3.1.8	C.1.2.2 C.1.2.4 C.1.3.6 C.2.1.9 C.2.1.14 C.2.1.16 C.2.1.17 C.2.1.18 C.2.2.14	
Not Likely (NL)	C.1.3.5	C.1.3.8 C.1.3.11 C.2.2.3 C.2.2.6 C.2.2.10 C.2.3.5	C.1.2.5, C.2.1.6 C.2.2.4, C.2.2.5 C.2.2.8, C.3.2.3 C.3.2.4, C.3.1.3 C.3.1.4, C.3.3.2 C.3.3.3	C.1.3.3	C.1.3.1 C.3.1.9
risk plots below lower threshold					

Risk Matrix - Group C: Tunnels

Figure 35.2-7

MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Tunnels	C.0																
Production (MTT) Tunnels	C.1																
Tunnels	C.1.1.1	Hit a major water bearing fault	Slows production; potentially overwhelms WTP, particulaly with a downhill drive	C	H	H	D	M	M	N	N	Moderately High	Moderately Low	M	Moderately High	L	Major water would result in diluted flow acceptable for discharge
	C.1.1.2	More poor rock than estimated	Slows production	C	M	M	D	N	L	N	N	Moderately Low	Low	M	Moderately Low	M	Monitor advancement to be ready with more rock bolting
	C.1.1.3	More PAG rock than predicted	Increased quantities of PAG rock requires additional facilities for PAG rock	C	H	H	D	L	M	N	N	Moderately High	Moderately Low	M	Moderately High	L	Expand size of pad for PAG rock
	C.1.1.4	Rockfall or accident	Injures someone	C	NL	L	C	L	M	M	M	Low	Moderately Low	M	Moderately Low	M	More rock bolting
	C.1.1.5	Water inflow for water treatment exceeds grit pond capacity	Overflow into the environment into Mitchell Creek	C	M	M	D	L	M	M	N	Moderate	Low	M	Moderate	L	Temporary bypass grit pond
	C.1.1.6	Excessive release of ammonium nitrate, metals and TSS	Increase ammonium nitrate concentrations, metals and TSS in Mitchell Creek	C	M	M	D	L	L	L	N	Moderately Low	Low	M	Moderately Low	L	Improve explosives management practices
Portals	C.1.2.1	Snow avalanche at Mitchell portal during construction	Delays; health and safety	C	NL	L	C	N	L	N	M	Very Low	Moderately Low	M	Moderately Low	L	Avalanche monitoring and control
	C.1.2.2	Rock avalanche	Blockage of portal; safety hazard	C	NL	L	C	N	L	N	H	Very Low	Moderate	M	Moderate	L	Monitoring
	C.1.2.3	Snow avalanche at saddle portals	Blockage of portal; safety hazard	C	NL	L	C	N	L	L	M	Very Low	Moderately Low	M	Moderately Low	L	Avalanche monitoring and control
	C.1.2.4	Rock fall at saddle portals; unidentified structure	Blockage of portal; safety hazard	C	NL	L	C	N	L	L	H	Very Low	Moderate	M	Moderate	L	Monitoring
	C.1.2.5	Ventilation system stops	Poor air quality	C	NL	L	C	N	M	L	L	Low	Low	H	Low	L	Monitoring ventilation system

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Operations	C.1.3.1	Fire starts; mobile accident, electrical fire, winter traffic	Poor air quality leading to fatality	O	NL	NL	C	L	M	L	E	Low	Moderate	M	Moderate	L	Good fire protection alarm system
	C.1.3.2	Fire starts; mobile accident, electrical fire, winter traffic	Poor air quality leading to injury and health issues	O	H	E		L	M	L	L	Moderately High	Moderately High	M	Moderately High	L	Good fire protection alarm system
	C.1.3.3	Mobile accident	Fatality	O	NL	NL	C	L	M	L	H	Low	Moderately Low	M	Moderately Low	L	Major investigation and safety improvement
	C.1.3.4	Diesel fuel pipeline break.	Drains to mine Site	O	L	L	A	M	M	L	L	Moderately Low	Low	M	Moderately Low	M	Buried Pipeline complete with leak detection and shut-off valves. Will collect in WSF. Diesel clean-up in WSF.
	C.1.3.5	Equipment contacts the power line involving physical damage to the power line	Electrical Current discharge	O	NL	NL	C	N	N	N	N	Negligible	Negligible	M	Negligible	N	Proper awareness and safety training
	C.1.3.6	Equipment contacts the power line involving physical damage to the power line	Power outage at Mine Site area	O	NL	L		N	M	L	H	Low	Moderate	M	Moderate	L	Proper awareness and safety training
	C.1.3.7	Rockfall or vehicle accident	Safety effect	O	NL	L	C	N	M	L	M	Low	Moderately Low	M	Moderately Low	L	Proper awareness and safety training
	C.1.3.8	Changes to glaciation or increase in water flows	More water to the WTP	O	NL	NL	D	L	L	L	L	Very Low	Very Low	M	Very Low	L	Monitoring program will provide early warning
	C.1.3.9	Power shutdown in the tunnel	Temporary power outage	O	M	M	A	N	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	N	Most tunnel flows are by gravity, effects would be minimal
	C.1.3.10	Mechanical failure of conveyor	Economic consequence	O	M	M	A	N	N	N	L	Low	Moderately Low	M	Moderately Low	L	Maintenance response are preventative maintenance
	C.1.3.11	Seismic event	Minor shaking in the tunnel	O	NL	NL	A	N	L	L	N	Very Low	Negligible	M	Very Low	N	Check for damage and general surveillance

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Figure 35.2-8b

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Group C, Failure Modes and Effects Analysis Worksheet

Figure 35.2-8b

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Diversion Tunnels	C.2																
Mitchell Glacier Diversion	C.2.1.1	Rock quality issues crossing Snowfield Landslide area to reach Mitchell Glacier	Increase support requirements and schedule delays	C	L	L	A	N	L	N	L	Low	Low	M	Low	L	Monitoring Snowfield slide area
	C.2.1.2	Hit a major water bearing fault	Slows production; potentially overwhelm temporary water treatment plant	C	M	M	A	L	M	L	L	Moderate	Moderately Low	M	Moderate	L	Monitor and control where possible
	C.2.1.3	More poor rock than estimated	Slows production	C	M	M	A	L	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	M	Monitor
	C.2.1.4	More PAG rock than predicted	Require more facilities for PAG rock and increase water treatment	C	H	H	D	L	L	L	L	Moderate	Moderate	M	Moderate	L	Expand PAG rock pad and treatment
	C.2.1.5	Hit some gas that cannot be recognized / managed	Increase ventilation - shotcrete rock, water management	C	NL	L		L	L	L	L	Very Low	Low	M	Low	L	Increase ventilation
	C.2.1.6	Rockfall or accident	Injures someone	C	NL	L	C	L	M	L	L	Low	Low	M	Low	L	Proper awareness and safety training
	C.2.1.7	Water inflow exceeds temporary construction water treatment facility	Requires larger ponds and more treatment; potential release to the environment	C	L	L	D	L	L	L	L	Low	Low	M	Low	L	Monitor and control where possible
	C.2.1.8	Snow avalanche during construction	Delays; potential health and safety hazard	C	NL	L	C	N	L	L	L	Very Low	Low	M	Low	L	Avalanche monitoring and control system
	C.2.1.9	Rock avalanche	Blockage of portal; potential safety hazard	C	NL	L	C	N	L	L	H	Very Low	Moderate	M	Moderate	L	Monitor and control system
	C.2.1.10	Snow / rock avalanche at portals (unidentified structure)	Blockage of portal; potential safety hazard	C	L	M		N	M	L	H	Moderately Low	Moderately High	M	Moderately High	L	Avalanche monitoring and control system
	C.2.1.11	Accelerated melting of glacier	Increases flows and increase to WSF and treatment	C+O	L	L	D	L	L	L	L	Low	Low	M	Low	M	Increase treatment capacity
Design Capacity	C.2.1.12	Under designed for flow conditions	More water to manage with higher TSS	C+O+PC	L	L	D	L	L	L	L	Low	Low	M	Low	L	System designed for predicted 200-year 24-hour rainfall plus 200-year maximum daily glacier melt
	C.2.1.13	Glacial advance	Decrease contact water	C+O+PC	L	L	D	L	L	L	L	Low	Low	M	Low	L	Mitigation during operation would consist of ice removal
	C.2.1.14	Diversion system flow isolation fails during maintenance	Flooding of tunnel and potential safety effect	O	NL	L	C	L	L	L	H	Very Low	Moderate	M	Moderate	L	Preventative maintenance and general monitoring
	C.2.1.15	Sediment ovewhelms sediment traps in tunnel	Increase wear on tunnel floor, potential wear on power runners and exceeds TSS in Sulphurets Creek	O	M	M	D	N	M	L	L	Moderate	Moderately Low	M	Moderate	L	Monitor sediment traps
	C.2.1.16	Groundwater inflows become acidic - contact water and requiring treatment	Discharge of poor quality water to the environment	O	L	L	D	M	H	M	L	Moderate	Low	M	Moderate	M	Increase grouting in tunnel
	C.2.1.17	Tunnel deformation due to block caving and open pit	Rockfalls and increased maintenance - increase water flows	O+PC	L	L	A	L	H	L	H	Moderate	Moderate	M	Moderate	L	Numerical modeling of tunnel location to mitigate concerns. Install monitoring system to monitor deformations
	C.2.1.18	ARD effects on concrete grouting	Reduce effect of grouting and increase water flow	O+PC	L	L	D	M	H	M	L	Moderate	Low	M	Moderate	M	Require more grouting
	C.2.1.19	Bats protection systems fail	Bats infiltration into the tunnels	O+PC	L	L	D	L	L	L	L	Low	Low	M	Low	L	Monitor bat protection system
	C.2.1.20	Water inflow from Sulphurets Pit into the diversion tunnel	Decrease water quality	O+PC	L	L	D	L	L	L	L	Low	Low	M	Low	L	Monitor water quality of tunnel discharge

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Group C, Failure Modes and Effects Analysis Worksheet

MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Inlet Operability (Infiltration Gallery)	C.2.1.21	Overflow of glacial water towards pit	More water toward WSF and more treatment	O+PC	M	M	D	L	M	L	L	Moderate	Moderately Low	M	Moderate	M	Additional inlet underneath Mitchell Glacier would be required
	C.2.1.22	Flow from Mitchell pit lake to closure tunnels	Increase contact water may require additional lining of tunnel for closure	PC	M	M	D	M	M	L	L	Moderate	Moderately Low	M	Moderate	M	Monitor system
McTagg Tunnels Pit diversion tunnels	C.2.2.1	Hit a major water bearing fault	Slows production; potentially overwhelm temporary water treatment facility; particularly with a down slope construction	C	L	L	A	N	L	L	L	Low	Low	M	Low	L	Have adequate pumping capacity
	C.2.2.2	More poor rock than estimated	Slows production	C	M	M	A	N	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	L	Monitor
	C.2.2.3	More PAG rock than predicted	Requires larger facilty for PAG rock	C	NL	NL	D	L	L	L	L	Very Low	Very Low	M	Very Low	L	Increase size of PAG rock pile, and potentially cover to control flow to water treatment
	C.2.2.4	Hit some gas that cannot be recognized / managed	Potential carbonaceous rock could produce elevated CO_2	C	NL	NL	C	L	M	L	L	Low	Very Low	M	Low	L	Increase ventilation - shotcrete rock, water management
	C.2.2.5	Rockfall or accident	Injures someone	C	NL	L	C	N	M	L	L	Low	Low	M	Low	L	Monitor tunnels and rock bolt
	C.2.2.6	Water inflow for water treatment exceeds grit pond capacity	Tunnel water discharged to environment	C	NL	NL	D	L	L	L	L	Very Low	Very Low	M	Very Low	L	Monitor flows
	C.2.2.7	Snow avalanche at inlets	Delays; potential health and safety	C	L	L	A	L	L	L	M	Low	Moderately Low	M	Moderately Low	L	Mitigation is built into the design
	C.2.2.8	Rock avalanche	Blockage of portal; potential safety hazard	C	NL	NL	A	L	L	L	M	Very Low	Low	M	Low	L	Monitor portal entrance
	C.2.2.9	High intrate levels from explosives	Water treatment non-compliance	C	L	L	D	L	L	L	L	Low	Low	L	Moderately Low	L	Explosives management underground and increase air-sparging in water treatment
	C.2.2.10	ARD effects on concrete	Maintenance	C	NL	NL	D	L	N	L	L	Very Low	Very Low	M	Very Low	L	Measure flows from input and output ends of tunnel
	C.2.2.11	Glacial advance	Require to mine glacier ice to maintain inlet	C	L	L	D	L	L	L	L	Low	Low	M	Low	L	Mine ice to maintain inlets to tunnels
	C.2.2.12	Accelerated melting of glacier	Increases flows	C	L	L	D	L	L	L	L	Low	Low	M	Low	L	Increase treatment

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Group C, Failure Modes and Effects Analysis Worksheet

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Design Capacity	C.2.2.13	Under designed for flow conditions	More water to manage with higher TSS	C+O+PC	L	L	D	L	L	L	L	Low	Low	M	Low	L	System designed for predicted 200-year 24-hour rainfall plus 200-year maximum daily glacier melt
	C.2.2.14	Diversion system fails during maintenance	Flooding of tunnel and potential safety effect	O	NL	L	C	L	M	L	H	Low	Moderate	M	Moderate	L	Surveillance of diversion during repair and general monitoring
	C.2.2.15	Sediment ovewhelms sediment traps	Increase wear on tunnel floor, potential wear on power runners	O	M	M	D	L	M	L	L	Moderate	Moderately Low	M	Moderate	L	Monitoring

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Mitchell Pit diversion tunnel and the Mitchell Valley Drainage Tunnel and connector to Mitchell Diversion Tunnel	C.2.3.1	Potential inflows are higher than expected	Increase flows to temporary water treatment facility	C	L	L	D	L	L	L	L	Low	Low	M	Low	L	Monitor and react to requirement
	C.2.3.2	Hit a major water bearing fault	Slows production; potentially overwhelm temporary water treatment facility	C	L	L	A	L	L	L	L	Low	Low	M	Low	L	Monitor and react to requirement
	C.2.3.3	Deformations in the tunnel due to the open pit	Rockfall and tunnel blockage - increase release of contact water to the WTP	C	H	H	A	L	L	L	L	Moderate	Moderate	M	Moderate	L	Monitor tunnel conditions and water flow differential from opening to exit
	C.2.3.4	Under designed for flow conditions	More water to manage with higher TSS	C+O	L	L	D	L	L	L	L	Low	Low	M	Low	L	System designed for predicted 200-year 24-hour rainfall plus 200-year maximum daily glacier melt
	C.2.3.5	Increase pit drainage due to flow through fractured rock	Necessity to drive drainholes, delays in operations	O	NL	NL	D	L	N	L	L	Very Low	Very Low	M	Very Low	L	Dewatering pipe walls to reduce inflow
	C.2.3.6	Deformations in the tunnel due to the open pit	Rockfall and tunnel blockage - increase release of contact water to the WTP	O	L	L	A	L	M	L	L	Moderately Low	Low	M	Moderately Low	L	Monitor tunnel conditions and water flow differential from opening to exit
	C.2.3.7	Deformation in the tunnel due to block caving	Rockfall and tunnel blockage - increase release of contact water to the WTP	O	M	M	A	L	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	L	Monitor tunnel conditions and water flow differential from opening to exit

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Block Caving Dewatering Tunnels and shaft	C.3.1.1	Hit a major water bearing fault	Slows production; potentially overwhelm pumping capacity; down slope construction	C	L	L	A	N	L	L	L	Low	Low	M	Low	L	Have redundent pumping capacity
	C.3.1.2	More poor rock than estimated	Slows production	C	M	M	A	N	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	M	Monitor conditions and have rock bolting equipment available
	C.3.1.3	Hit high CO_2 from calcareous rock material	Potential calcareous rock and CO_2	C	NL	NL	C	N	M	L	L	Low	Very Low	M	Low	L	Increase ventilation - shotcrete rock, water management
	C.3.1.4	Rockfall or accident	Injures someone	C	NL	L	C	N	M	L	L	Low	Low	M	Low	L	Mine safety plan, investigation, improved or changed procedures
	C.3.1.5	Increased nitrate from underground explosives and higher than predicted metals	Potential water quality issue downstream	C	L	L	D	M	M	L	L	Moderately Low	Low	M	Moderately Low	M	WTP modification
	C.3.1.6	Diversion system fails during maintenance	Flooding of tunnel and potential safety effect	O	NL	L	C	L	M	L	M	Low	Moderately Low	M	Moderately Low	M	Have pumping redundancy and standby power
	C.3.1.7	Blockage of the tunnel due to rockfalls	Lose equipment and temporary shutdown of mine due to flooding	O	NL	L	C	L	M	L	M	Low	Moderately Low	M	Moderately Low	M	Repair tunnel
	C.3.1.8	Failure of pumping system	Flooding underground works	O	NL	L	C	L	M	L	M	Low	Moderately Low	M	Moderately Low	M	Pumping redundacy with spare parts and pumps
	C.3.1.9	Failure of closure plug	Pit lake drains	PC	NL	NL	D	E	H	M	L	Moderate	Very Low	M	Moderate	H	Closure plugs will be duplicated in order to ensure complete redundancy and safety

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD Of INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Mitchell Underground AccessTunnel	C.3.2.1	Surplus water	Increased flows to WTP	O	L	L	D	N	L	L	L	Low	Low	M	Low	L	Adequate pumping capacity to handle water flows
	C.3.2.2	Power outage	Safety incident	O	NL	L	C	N	L	L	L	Very Low	Low	M	Low	L	Safety procedures adhered to
	C.3.2.3	Ventilation system interferes with MTT	Temporary influence	O	NL	L	C	N	M	L	L	Low	Low	M	Low	L	Adjustments to ventilation system
	C.3.2.4	Vehicle accident	Injury	O	NL	L	C	N	M	L	L	Low	Low	M	Low	L	Review of safety procedures, ensuring adherence to procedures, investigation, improved or changed procedures

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Figure 35.2-8h

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Figure 35.2-8h

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Iron Cap Underground Access Tunnel	C.3.3.1	Surplus water	Increase flows to WTP	O	L	L	D	N	L	L	L	Low	Low	M	Low	L	Adequate pumping capacity to handle water flows
	C.3.3.2	Ventilation system interferes with MTT	Temporary influence	O	NL	L	C	N	M	L	L	Low	Low	M	Low	L	Adjustments to ventilation system
	C.3.3.3	Vehicle accident	Injury	O	NL	L	C	N	M	L	L	Low	Low	M	Low	L	Review of safety procedures, ensuring adherence to procedures, investigation, improved or changed procedures
	C.3.3.4	Power outage	Safety incident	O	NL	L	C	N	L	L	L	Very Low	Low	M	Low	L	Review of safety procedures, ensuring adherence to procedures, investigation, improved or changed procedures

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Likelihood	Consequence Severity: Negligible (N)	Low (L)	Moderate (M)	High (H)	Extreme (E)
Expected (E)					
High (H)		D.16.1.2	D.15.1.3 D.16.1.1		
Moderate (M)	D.14.4.2 D.14.5.1	D.1.8 D.13.1 D.13.2 D.15.1.1 D.15.1.2 D.15.1.6	D.1.2, D.1.3, D.1.5 D.1.12, D.2.1.5 D.2.1.9, D.3.3, D.4.3 D.5.3, D.6.2, D.7.2 D.8.3, D.11.1 D.15.1.5, D.16.1.6	D.1.1 D.1.11	
Low (L)	D.13.6 D.13.7 D.14.2.1 D.14.5.2 D.14.5.3	D.1.9, D.2.1.2 D.2.1.6, D.2.1.10 D.2.1.13, D.4.6 D.6.3, D.7.3, D.8.6 D.9, D.12.1 D.14.4.1, D.15.1.7 D.16.1.3	D.1.4, D.1.10, D.1.14 D.2.1.3, D.2.1.7, D.2.1.8 D.2.1.11, D.3.1, D.3.2 D.3.4, D.3.5, D.3.6, D.4.1 D.4.2, D.4.4, D.4.5, D.5.1 D.5.2, D.5.4, D.5.5, D.5.6 D.6.1, D.6.4, D.6.5, D.6.6 D.7.1, D.7.4, D.8.1, D.8.2 D.8.4, D.8.5, D.10.1 D.13.4, D.15.1.8, D.16.1.5	D.1.6 D.1.7 D.2.1.4 D.13.3 D.13.5 D.15.1.4	
Not Likely (NL)	D.14.2.2	D.14.3.1 D.14.3.2 D.14.3.3	D.1.13 D.1.15 D.2.1.1 D.2.1.12 D.14.1.1 D.14.1.2 D.16.1.4		
risk plots below lower threshold					

Figure 35.2-9

Risk Matrix - Group D: Access Power, Fuel Distribution and Explosives

MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Access	D.0																
Pit Access Roads	D.1.1	Construction accidents as a result of steep terrain	Worker Injury or serious injury	C	L	M	C	N	M	L	H	Moderately Low	Moderately High	M	Moderately High	L	Work safe practices
	D.1.2	Failure of sediment control measures	Impact to fisheries habitat	C	M	M	D	M	M	M	N	Moderate	Low	H	Moderate	L	Sediment control measures monitored and repaired if requried
	D.1.3	Avalanche / geohazard occurrence	Temporary road closure	C	L	M	C	L	L	L	M	Low	Moderate	H	Moderate	L	Adherence to Traffic and Access Management Plan
	D.1.4	Landslide geohazard occurrence	Stream sedimentation in fish bearing waters	C	L	L	D	M	M	L	L	Moderately Low	Low	H	Moderately Low	L	Traffic and Access Management Plan
	D.1.5	Landslide geohazard occurrence	Temporary road closure / sedimentation	C	M	M	A	L	L	L	M	Moderately Low	Moderate	H	Moderate	L	Adherence to Traffic and Access Management Plan
	D.1.6	Major landslide geohazard occurrence in the pit area	Temporary road closure and potential environmental and health and safety impact	C+O	L	L	A	M	M	L	H	Moderately Low	Moderate	H	Moderate	L	Adherence to Traffic and Access Management Plan
	D.1.7	Major avalanche / geohazard occurrence	Road is covered by snow	C+O	L	L	A	L	L	L	H	Low	Moderate	H	Moderate	L	Snow clearing equipment to clear situation
	D.1.8	Excessive snow on the road	Mine functions compromised - large equipment access	O	M	M	A	N	N	N	L	Low	Moderately Low	H	Moderately Low	L	Mine planning modification and more snow removal equipment
	D.1.9	Wildlife collisions	Impact to wildlife populations, equipment damage, potential for injury, wildlife trapped on roadways	O	L	L	A	L	L	L	L	Low	Low	H	Low	L	Wildlife monitoring and adherence to Wildlife Management Plan
	D.1.10	Loss of communications between vehicles	Collision	O	NL	L	C	L	L	L	M	Very Low	Moderately Low	H	Moderately Low	L	Preventative maintenance and pit traffic plan modification
	D.1.11	Loss of vehicle control due to road grade at select locations	Drivers injury or serious injury	O	L	M	C	N	M	L	H	Moderately Low	Moderately High	H	Moderately High	L	Traffic and Access Management Plan
	D.1.12	Equipment accident	Injury	O	L	M	C	L	L	L	M	Low	Moderate	H	Moderate	L	Adherence to Traffic and Access Management Plan
	D.1.13	Excessive dust impairing visibility	Vehicle collision	O	NL	NL	C	L	L	L	M	Very Low	Low	H	Low	L	Adherence to Traffic and Access Management Plan with increased road dust control
	D.1.14	Goats remaining in overlap area of the UWR 02006 after mitigation	Loss of goats	O	L	L	D	M	L	M	N	Moderately Low	Very Low	H	Moderately Low	L	Adherence to Wildlife Management Plan
	D.1.15	Inadequate restoration of surface water drainage	Sedimentation in a fish bearing water course	PC	NL	NL	D	M	M	M	L	Low	Very Low	M	Low	L	Adherence to Erosion Control Plan
Access Roads	D.2																
Common to all access roads	D.2.1																
	D.2.1.1	Loss of road traffic communications	Collision / injury	C	NL	NL	C	N	N	L	M	Very Low	Low	H	Low	L	Road gated to restrict public access and strict adherence to Traffic and Access Management Plan
	D.2.1.2	Extreme weather event	Workers stranded	C	NL	L	C	N	N	L	L	Very Low	Low	H	Low	L	Traffic and Access Management Plan and Emergency Response Plan
	D.2.1.3	Construction related spill, inadequate sediment control	Sedimentation or other effects on fisheries values	C	L	L	D	M	L	L	L	Moderately Low	Low	H	Moderately Low	L	Road Erosion Control Plan
	D.2.1.4	Misidentification / acid generating rock, or failure to contain PAG	Impact on fisheries values	C	L	L	D	H	L	L	N	Moderate	Very Low	H	Moderate	L	Road Metal Leaching and Acid Rock Drainage Management Plan

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Figure 35.2-10a

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
	D.2.1.5	Road slope failure	Temporary road closure, sediment transport	O	M	M	A	M	L	L	L	Moderate	Moderately Low	H	Moderate	L	Adherence to Traffic and Access Management Plan
	D.2.1.6	Wildlife collisions	Impact to wildlife populations, equipment damage, potential for injury	O	L	L	A	L	L	L	L	Low	Low	H	Low	L	Wildlife Management Plan
	D.2.1.7	Fuel and chemical spill (reagents including lime and flocculent)	Contamination, fisheries impacts in select locations	O	L	L	A	M	L	L	L	Moderately Low	Low	H	Moderately Low	L	Strict adherence to Traffic and Access Management Plan
	D.2.1.8	Loss of vehicle control due to speeding	Injury or loss of life	O	NL	L	C	N	L	L	M	Very Low	Moderately Low	H	Moderately Low	L	Strict adherence to Traffic and Access Management Plan, including speed limits
	D.2.1.9	Snow avalanche impacting road	Road closure; accident resulting in injury; temporary road closure; sedimentation	O	L	M	C	N	L	L	M	Low	Moderate	H	Moderate	L	Strict adherence to Traffic and Access Management Plan and Avalanche Control Plan
	D.2.1.10	Controlled avalanche occurrence	Animals (goats) killed during avalanche control	O	L	L	D	L	L	L	N	Low	Very Low	H	Low	L	Strict adherence to Wildlife Management Plan
	D.2.1.11	Landslide impacting road	Damage to road / structures. Accident resulting in injury. Temporary road closure, sedimentation	O	NL	L	C	L	L	L	M	Very Low	Moderately Low	H	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.2.1.12	Excessive dust impairing visibility	Vehicle collision	O	NL	NL	C	L	L	L	M	Very Low	Low	H	Low	L	Traffic and Access Management Plan and safety procedures / protocols
	D.2.1.13	Improper closure and reclamation plan for decommissioned roads	Erosion , sedimentation	PC	L	L	D	L	L	L	L	Low	Low	M	Low	L	Proper road closure reclamation and decommissioning plan

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Figure 35.2-10b

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Figure 35.2-10b

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Highway 37	D.3																
	D.3.1	Unmanaged increase traffic	Slow public traffic and increase traffic risk	C+O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.3.2	Non-adherence to clearance / load limits	Non compliance and potential accident	C+O	L	L	A	L	M	M	L	Moderately Low	Low	M	Moderately Low	L	Adherence to Department of Transport Regulatory and internal Traffic and Access Management Plan
	D.3.3	Disrespect for Wildlife	Wildlife collision with potential injury and loss of wildlife	C+O+PC	M	M	A	M	M	L	L	Moderate	Moderately Low	M	Moderate	L	Adherence to Wildlife Management Plan and Traffic and Access Management Plan
	D.3.4	Poorly spaced ore concentrate traffic	Slow public traffic and increase traffic risk and increase in dust	O	L	L	A	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.3.5	Unmanaged reagents and supply traffic	Slow public traffic with increase traffic risk	O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.3.6	Poor emergency spill management	Major risk to environment and associated liability	O	L	L	D	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Spill Prevention and Emergency Response Plan
Coulter Creek Mine Access Road	D.4																
	D.4.1	Unmanaged increase traffic	Slow public traffic and increase traffic risk	C+O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.4.2	Non-adherence to clearance / load limits	Non compliance and potential accident	C+O	L	L	A	L	M	M	L	Moderately Low	Low	M	Moderately Low	L	Adherence to provincial regulations and internal Traffic and Access Management Plan
	D.4.3	Disrespect for wildlife	Wildlife collision with potential injury and loss of wildlife	C+O+PC	M	M	A	M	M	L	L	Moderate	Moderately Low	M	Moderate	L	Adherence to Wildlife Management Plan and Traffic and Access Management Plan
	D.4.4	Unmanaged reagents and supply traffic	Slow public traffic with increase traffic risk	O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.4.5	Poor emergency spill management	Major risk to environment and associated liability	O	L	L	D	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Spill Prevention and Emergency Response Plan
	D.4.6	Incomplete decommissioning and reclamation of road	Increased sedimentaion and erosion; access to hunters	PC	L	L	D	L	L	L	L	Low	Low	M	Low	M	Meet requirements of SUP and good reclamation standards. Safety protocols adhered to.
Highway 37 A	D.5																
	D.5.1	Unmanaged increase traffic	Slow public traffic and increase traffic risk	C+O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.5.2	Non-adherence to clearance / load limits	Non compliance and potential accident	C+O	L	L	A	L	M	M	L	Moderately Low	Low	M	Moderately Low	L	Adherence to Department of Transport Regulatory and internal Traffic and Access Management Plan
	D.5.3	Disrespect for wildlife	Wildlife collision with potential injury and loss of wildlife	C+O+PC	M	M	A	M	M	L	L	Moderate	Moderately Low	M	Moderate	L	Adherence to Wildlife Management Plan and Traffic and Access Management Plan
	D.5.4	Poorly spaced ore concentrate traffic	Slow public traffic and increase traffic risk and increase in dust	O	L	L	A	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.5.5	Unmanaged reagents and supply traffic	Slow public traffic with increase traffic risk	O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.5.6	Poor emergency spill management	Major risk to environment and associated liability	O	L	L	D	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Spill Prevention and Emergency Response Plan

A: Risk Level Requires Human Presence at time and location of the event, B: Likelihood of "Expected" for all consequences, C: H&S driven assessment, D: Not H&S Driven Assessment.

Figure 35.2-10c

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Figure 35.2-10c

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Treaty Creek Access Road	D.6																
	D.6.1	Unmanaged increase traffic	Slow public traffic and increase traffic risk	C+O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.6.2	Disrespect for Wildlife	Wildlife collision with potential injury and loss of wildlife	C+O+PC	M	M	A	M	M	L	L	Moderate	Moderately Low	M	Moderate	L	Adherence to Wildlife Management Plan and Traffic and Access Management Plan
	D.6.3	Incomplete decommissioning and reclamation of road	Increased sedimentaion and erosion; access to hunters	PC	L	L	D	L	L	L	L	Low	Low	M	Low	M	Meet requirements of SUP and good reclamation standards
	D.6.4	Poorly spaced ore concentrate traffic	Slow public traffic and increase traffic risk and increase in dust	O	L	L	A	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.6.5	Unmanaged reagents and supply traffic	Slow public traffic with increase traffic risk	O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.6.6	Poor emergency spill management	Major risk to environment and associated liability	O	L	L	D	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Spill Prevention and Emergency Response Plan
Treaty Saddle Road	D.7																
	D.7.1	Unmanaged increase traffic	Slow public traffic and increase traffic risk	C+O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.7.2	Disrespect for wildlife	Wildlife collision with potential injury and loss of wildlife	C+O+PC	M	M	A	M	M	L	L	Moderate	Moderately Low	M	Moderate	L	Adherence to Wildlife Management Plan and Traffic and Access Management Plan
	D.7.3	Incomplete decommissioning and reclamation of road	Increased sedimentaion and erosion; access to hunters	PC	L	L	D	L	L	L	L	Low	Low	M	Low	M	Meet requirements of SUP and good reclamation standards
	D.7.4	Poor emergency spill management	Major risk to environment and associated liability	O	L	L	D	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Emergency Spill Response Plan
Temporary Frank Mackie Glacier access route	D.8																
	D.8.1	Unmanaged increase traffic	Slow public traffic and increase traffic risk	C+O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.8.2	Non-adherence to clearance / load limits	Non compliance and potential accident	C+O	L	L	A	L	M	M	L	Moderately Low	Low	M	Moderately Low	L	Adherence to Department of Transport Regulatory and internal Traffic and Access Management Plan
	D.8.3	Disrespect for wildlife	Wildlife collision with potential injury and loss of wildlife	C+O+PC	M	M	A	M	M	L	L	Moderate	Moderately Low	M	Moderate	L	Adherence to Wildlife Management Plan and Traffic and Access Management Plan
	D.8.4	Unmannaged reagents and supply traffic	Slow public traffic with increase traffic risk	O	L	L	A	L	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Traffic and Access Management Plan
	D.8.5	Poor emergency spill management	Major risk to environment and associated liability	O	L	L	D	M	M	M	M	Moderately Low	Moderately Low	M	Moderately Low	L	Adherence to Emergency Spill Response Plan
	D.8.6	Incomplete decommissioning and reclamation of road	Increased sedimentaion and erosion; access to hunters	PC	L	L	D	L	L	L	L	Low	Low	M	Low	M	Meet requirements of SUP and good reclamation standards
Stewart to former Granduc Mine Site (Summer Season)	D.9	Snow avalanche and rock slides	Road blockage delays project	C	L	L	A	L	L	L	L	Low	Low	M	Low	L	Active Avalanche Management Plan; Traffic and Access Management Plan
Stewart / Hyder, Alaska	D.10.1	Trans-border Issues	Traffic delay, import restriction, etc.	C	L	L	D	N	M	L	L	Moderately Low	Low	M	Moderately Low	L	Meeeting trans-border issues
US Traffic Hyder, Alaska	D.11.1	Traffic Management (Hyder)	Traffic through Hyder noise and dust issues	C	M	M	D	N	M	M	L	Moderate	Moderately Low	M	Moderate	L	Traffic and Access Management Plan
Equipment Laydown Areas (3 Areas - Stewart, Granduc and Ted Morris Camp)	D.12.1	Avalanche, debris flow, broken containers, etc.	Damaged goods, supplies and equipment; potential contamination	C+PC	L	L	A	L	L	L	L	Low	Low	M	Low	L	Proper Management Plan and monitoring

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Figure 35.2-10d

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Figure 35.2-10d

MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Ice Road over Frank Mackie Glacier	D.13.1	Glacier cracks, ice melting, approach issues	Transporation disruption and access issues	C+PC	M	M	D	L	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	M	Surveillance of glacier conditions
	D.13.2	Adverse grade at both approaches to glacier	Access problem to adverse slope	C	M	M	D	L	L	L	L	Moderately Low	Moderately Low	M	Moderately Low	L	Modification to glacier approaches to moderate slope
	D.13.3	Loss of vehicle control in descending grade of up to 30%	Worst case - loss of life	C	L	L	A	N	L	L	H	Low	Moderate	H	Moderate	L	Modification to glacier approaches to moderate slope
	D.13.4	Falling into unexpected ice cracks and crevasses along route	Damage to vehicles, injury	C	L	L	A	N	N	L	M	Low	Moderately Low	H	Moderately Low	L	Glacier surveillance
	D.13.5	Falling into unexpected ice cracks and crevasses along route	Contaminant spills into glacier crevasses	C	L	L	D	M	M	H	N	Moderate	Very Low	H	Moderate	M	Glacier surveillance
	D.13.6	Load capacity subject to climatic conditions	Ice road not avaialble due to melt conditions	C	L	L	D	N	N	N	N	Very Low	Very Low	H	Very Low	M	Glacier surveillance
	D.13.7	Road not avaiable due to climatic conditions / seasonal	Significant impact on project startup	C	L	L	D	N	N	N	N	Very Low	Very Low	H	Very Low	M	Glacier surveillance

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Figure 35.2-10e

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Group D, Failure Modes and Effects Analysis Worksheet

Figure 35.2-10e

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD: BIO-REG-PUB	LIKELIHOOD: HEALTH & SAFETY	LIKELIHOOD: COMMENTS	CONSEQUENCES: BIOLOGICAL IMPACT	CONSEQUENCES: REGULATORY IMPACT	CONSEQUENCES: PUBLIC CONCERNS	CONSEQUENCES: HEALTH & SAFETY	RANKING BY CONSEQUENCE: BIO-REG-PUB RISK RATING	RANKING BY CONSEQUENCE: H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Power	D.14																
Highway 37 Connection	D.14.1.1	Powerline down, i.e., accident	Energy on the highway and no power to the Project	C+O	NL	NL	A	L	L	L	M	Very Low	Low	H	Low	M	Emergency power, power generated on site not affected, implement plant operation procedures for power isolation and to restart after outage. Avalanche Mangement and Control Plan and Traffic and Access Management Plan
	D.14.1.2	Aircraft hits powerline	No power to the Project and injury to the aircraft occupants	C+O	NL	NL	C	L	L	L	M	Very Low	Low	H	Low	M	Safety Protocols and Traffic and Access Management Plan
Power Transmission to Plant Site	D.14.2.1	Tree falll, high wind, ice load, lightning etc. causing line damage	No power to the Project	C+O	L	L	A	N	N	N	N	Very Low	Very Low	H	Very Low	M	Emergency power, power generated on site not affected, implement plant operation procedures for power isolation and to restart after outage. Powerline design includes significant loads for wind, ice and earthquake.
	D.14.2.2	Avalanche takes out a pole / structure	No power to the Project	C+O	NL	NL	A	N	N	N	N	Negligible	Negligible	H	Negligible	M	Active Avalanche Management Plan
Power Transmission to Mine Site through Tunnel	D.14.3.1	Accidental physical damage to the cable	Lose power to the Mine Site and energy discharge	O	NL	NL	A	N	N	N	L	Negligible	Very Low	H	Very Low	M	Standard Procedures for Tunnel Traffic and Safety Protocols
	D.14.3.2	Accidental physical damage to the drive stations	Lose power to the Mine Site and energy discharge	O	NL	NL	A	N	N	N	L	Negligible	Very Low	H	Very Low	M	Emergency power, power generated on site not affected, implement plant operation procedures for power isolation and to restart after outage.
	D.14.3.3	Rock fall Interruptions in the MTT resulting in power outage	No power to the Mine Site	O	NL	NL	A	N	N	N	L	Negligible	Very Low	H	Very Low	M	Standard Procedures for Tunnel Traffic and Safety Protocols
Power Distribution at Mine Site	D.14.4.1	Avalanche takes out a pole / structure	The circuit power is interupted to specific areas	O	L	L	A	N	N	N	L	Very Low	Low	H	Low	L	Active Avalanche Management Plan
	D.14.4.2	Blasting fly rock hits a power transformer or line	The circuit power is interupted to specific areas	O	M	M	D	N	N	N	N	Low	Low	H	Low	L	Blasting Prodecures and Safety Protocols
Power Generation	D.14.5.1	Mechanical / piping system failure to power generation system to WTP	No hydro backup power to the WTP, for 2-3 days	O+PC	M	M	D	N	N	N	N	Low	Low	H	Low	L	Water diverted to WSF. Repair power source as fast as possible
	D.14.5.2	Mechanical / piping system failure and/or hit by avalanche on surface penstocks	Short-term distruption to the power generation	O+PC	L	L	D	N	N	N	N	Very Low	Very Low	H	Very Low	L	Water diverted to WSF. Repair power source as fast as possible
Flow Estimates	D.14.5.3	Low water flows	Reduction or loss of hydropower production	O+PC	L	L	D	N	N	N	N	Very Low	Very Low	M	Very Low	L	Minimize power consumption to essential services such as water treatment

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Group D, Failure Modes and Effects Analysis Worksheet

					LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE					
MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING	LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
Fuel Distribution	D.15																
Fuel Management	D.15.1.1	On-site fuel handlling incidents (truck traffic, air traffic and fuel transfers)	Spills to the receiving environment and effect on environment	C+O	M	M	A	L	L	L	L	Moderately Low	Moderately Low	H	Moderately Low	M	Truck Loading areas have containment in place
	D.15.1.2	On-site fuel handlling incidents (Treaty OPC storage tanks, Mitchell Fuel Storage and refuelling areas)	Spills to the mine site contained environment	C+O	M	M	A	L	L	L	L	Moderately Low	Moderately Low	H	Moderately Low	L	Fuel truck offloading areas will have fuel containment in place
	D.15.1.3	Fuel delivery (Hwy 37 / 16), vehicle collisions, winter conditions	Small (<1 m³) uncontrolled release to the environment	C+O	H	H	A	M	M	M	M	Moderately High	Moderately High	H	Moderately High	L	Small fuel loss minimal clean-up cost. Spill Prevention and Emergency Response Plan
	D.15.1.4	Fuel Delivery (Hwy 37 / 16), vehicle collisions, winter conditions	Large (100,000 l) uncontrolled release to the environment	C+O	L	L	A	M	M	H	M	Moderate	Moderately Low	H	Moderate	M	Large fuel loss major clean-up cost. Spill Prevention and Emergency Response Plan
	D.15.1.5	Emergency spill management of tank farm or small fuel depot	Groundwater contamination	C+O	M	M	A	L	M	L	L	Moderate	Moderately Low	M	Moderate	L	Spill Prevention and Emergency Response Plan
	D.15.1.6	Distribution pipeline in MTT leak / rupture (maximum loss of 1,000 L)	Loss to groundwater in MTT; fuel mixed with water flow to Mitchell RSF drainage; effect on water treatment	O	M	M	D	N	L	N	N	Moderately Low	Low	H	Moderately Low	L	Dangerous Goods and Hazardous Materials (Fuel) Management Plan and Emergency Response Plan
	D.15.1.7	Overflow while filling tanks in the field	Small leak on the ground; small effect on environment	O	L	L	D	L	L	L	L	Low	Low	H	Low	L	Dangerous Goods and Hazardous Materials (Fuel) Management Plan
	D.15.1.8	Spill under containment facility noted on decommissioning and closure	Groundwater contamination	PC	L	L	D	L	M	L	L	Moderately Low	Low	M	Moderately Low	L	Spill Prevention and Emergency Response Plan

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Figure 35.2-10g

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MINE AREA / COMPONENT	ID	FAILURE MODE	EFFECTS	PERIOD OF INTEREST	LIKELIHOOD			CONSEQUENCES				RANKING BY CONSEQUENCE		LEVEL OF CONFIDENCE	HIGH CONCERN ISSUE	DIRECT COSTS	MITIGATION / COMMENTS
					BIO-REG-PUB	HEALTH & SAFETY	COMMENTS	BIOLOGICAL IMPACT	REGULATORY IMPACT	PUBLIC CONCERNS	HEALTH & SAFETY	BIO-REG-PUB RISK RATING	H&S RISK RATING				
Explosives	D.16																
	D.16.1.1	Off-site transportation: Vehicle collisions, winter conditions resulting in prill spill	Uncontrolled release of components (amonium nitrates) to water bodies and temporary highway closure	C+O	H	H	A	M	M	M	M	Moderately High	Moderately High	H	Moderately High	L	Likelihood of annual event low, life of mine event higher. Traffic and Access Management Plan, Emergency Response Plan and Spill Contingency Plan
	D.16.1.2	Off-site transportation: Vehicle collisions, winter conditions resulting in a minor fuel spill	Temporary highway closure	C+O	H	H	A	L	L	L	L	Moderate	Moderate	H	Moderate	L	Spill Prevention and Emergency Response Plan
	D.16.1.3	On-site transportation: Vehicle collisions resulting in a spill	Uncontrolled release of ammonium nitrate and fuel to water bodies	C+O	L	L	A	L	L	L	L	Low	Low	H	Low	L	Spill Prevention and Emergency Response Plan
	D.16.1.4	Explosives Storage facility vandalism	Stolen Explosives	C+O	NL	NL	D	L	M	M	L	Low	Very Low	M	Low	L	Adherence to Canada Explosive Act Management Requirements
	D.16.1.5	Explosives Factory failure or leakage	Uncontrolled release of ammonium nitrate and fuel to water bodies	C+O	L	L	D	L	M	L	L	Moderately Low	Low	M	Moderately Low	L	Adherence to Canada Explosive Act Management Requirements
	D.16.1.6	Off-site transportation (detonators and primers - Bell II / Coulter Creek Access Road): Vehicle incidents or geohazard / avalanche impact, winter conditions resulting in a spill	Exposure of explosive material	O	M	M	A	L	M	M	M	Moderate	Moderate	H	Moderate	L	Emergency Response Plan and Traffic and Access Management Plan

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Figure 35.2-10h

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35.3.1 Tailing Management Facility Dams

The proposed TMF (illustrated in Figures 4.5-82 to 4.5-84) is located on the divide between the South Teigen Creek and North Treaty Creek catchments, and will ultimately consist of four dams impounding three cells: the North Cell, South Cell, and the interior lined CIL, Cell. The North dam and Splitter dam will impound the North Cell during the first phase (Years 0 to 25). The Southeast dam and the Saddle dam will impound the South Cell during the second phase (Years 26 to 52). The Saddle dam and Splitter dam will impound the CIL Cell, located centrally between the North and South cells. The CIL Cell would be operational from Year 0 to Year 52.

A failure of the Splitter dam would have no external consequences because the Saddle and North dams would further contain the tailing. A failure of the Saddle dam during the first phase would release CIL tailing. A failure of the Saddle dam during the second phase would not release CIL tailing because the Southeast dam would retain the tailing. A failure of the North or Southeast dam at any phase would release only non-sulphide bearing flotation tailing solids and water into downstream waters.

Failure of the North dam or the Southeast dam would result in a larger flood than a failure of the Saddle dam because the North and South ponds have the potential to contain more water than the CIL Lined Pond.

The flood route downstream of the North dam consists of the following: 12 km along Teigen Creek; 5 km east along Snowbank Creek; 81 km southeast along the Bell-Irving River; and 200 km along the Nass River. The Nass River discharges into the Portland Inlet on the Pacific Ocean. The flood route downstream of the Southeast dam consists of the following: approximately 2 km along North Treaty Creek, which discharges into Treaty Creek; about 18 km along Treaty Creek up to the Bell-Irving River; about 60 km along the Bell-Irving River; and 200 km along the Nass River to its mouth.

The area downstream of the North dam, up to the Nass River, is relatively undeveloped. Bell 2 Lodge is located on the south bank of the Bell-Irving River, about 3.4 km upstream of the Snow Bank Creek/Bell-Irving River confluence. The lodge is visited by tourists during the summer via Highway 37 and the lodge is used for heli-skiing in the winter. The Proponent is proposing to construct an access road (TCAR) along Treaty Creek from Highway 37 to the mill facilities and the TMF in the PTMA. Highway 37 follows Snowbank Creek and the Bell-Irving River to a point just downstream of Bowser River. The highway crosses the Bell-Irving River at two locations within this reach. Most of the area along the Nass River downstream of the Bell-Irving River is also relatively undeveloped and sparsely populated.

The largest population centres downstream of the TMF include Vandyke Camp, and the villages of New Aiyansh, Gitwinksihlkw (Canyon City), Laxgalts'ap (Greenville), and Gingolx (Kincolith). The populations of the villages range between 200 and 800. The village of Laxgalts'ap and the site of the old village of Aiyansh have historically been subject to flooding from the Nass River.

The proposed dams are designed as compacted cyclone sand embankments constructed by the centreline method with crest widths of 20 m and a downstream slope of 3H:1V. Ultimate heights of the North and Southeast dams would be approximately 215 m and 239 m, respectively. A vertical till core, with a minimum width of 20 m, is provided in each dam to restrict seepage; in addition, the Splitter and Saddle dams incorporate geomembrane liners to isolate the CIL residue tailing. Given their size and storage capacity, the North, Saddle, and Southeast dams were assigned the "Extreme" consequence classification, which is the highest classification provided in the CDA *Dam Safety Guidelines* (2007), and the seismic and flood design criteria for the dams were set accordingly. The internal Splitter dam was assigned the "Significant" consequence classification based on repair costs because no foreseeable downstream impact or loss of life would be anticipated.

Two failure conditions were considered for the conventional dam break analysis: overtopping failure of the dam due to an extreme flood; and a "sunny-day" dam failure (e.g., piping without concurrent flooding). Sensitivity analyses were conducted by varying the assumed dam breach parameters such as breach formation time, volume of tailing released and Manning's roughness coefficient (n) for the downstream flood route. The HEC-RAS hydrodynamic computer model, developed by the US Army Corporation of Engineers, was used with the geographic information system ARC-GIS to simulate dam failures and to estimate flood inundation limits along streams and rivers downstream of the dams.

The conclusions reached by KCB were based on the results of the dam break and inundation study (Appendix 35-C) and can be summarized as follows:

- The dam break and inundation analyses completed for the TMF are based on hypothetical modes of failure under extreme and highly unlikely events. For example, for a dam to be overtopped, not only would the flood storage capacity provided for the probable maximum flood (PMF) and the freeboard have to be used up, but the overflow spillway would also have to be non-functional at the same time (in the closure case). The results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dams.
- The discharge rate at the dam resulting from a dam failure is sensitive to the assumed breach formation time. The shorter the breach formation time, the higher the dam breach peak discharge. The influence of the selected breach formation time is larger at the dam and becomes less significant as the flood moves further downstream and attenuates.
- The attenuation of the flood as it travels downstream is dependent on the assumed Manning's roughness coefficient (n). The larger the roughness coefficient, the larger the attenuation. The influence of the selected roughness coefficient is small at the dam site, but becomes more significant with respect to flood depth and flood arrival times as the wave moves further downstream.
- Existing and/or proposed facilities that would be affected by a failure of the Southeast dam based on the model's outputs include:
  - Several sections of Highway 37 would be temporarily flooded along the Bell-Irving River and the Nass River.

  - Sections of Highway 113 between New Aiyansh and Laxgalts'ap would be flooded.
  - Some of the bridges along Highway 37 and other roads that cross the Bell-Irving and Nass rivers could be overtopped.
  - Existing cabins and outfitter/guide facilities located on riverbanks, floodplains, or close to natural floodplains could be flooded.
  - An overtopping failure of the dam resulting from the PMF or similar event would not cause additional flooding at the downstream villages over and above, which might occur during a naturally occurring PMF. The wave resulting from the dam failure would be fully attenuated before it reaches the downstream villages.
  - A piping failure of the dam would not cause flooding in the downstream villages but a relatively small flood depth above the mean annual flow would be apparent.
  - Sections of TCAR along Treaty Creek, which provides access to the mill facilities and the TMF, could be damaged.
- Existing and/or proposed facilities that would be affected by a failure of the North dam include the affected facilities listed above for the Southeast dam plus the following:
  - Bell 2 Lodge would be flooded; however, the difference in flooding at Bell 2 Lodge between a dam breach coincident with a PMF, and a PMF event alone, is expected to be relatively small.
  - Highway 37, north of Bell 2 Lodge and at some local areas upstream of the confluence of Bell-Irving River and Teigen Creek, would be affected.

The rate of rise is a critical factor and is determined as the change in elevation divided by the time between the initiation of the flood wave and when the peak of the flood wave occurs. The rate of rise for the piping failure mode is typically higher than for the overtopping mode because there is less water in the river during average conditions than during the flood condition, so the incremental raise is more pronounced. The rate of rise for the piping failure mode for the midlife Splitter/Saddle dam is higher due to the presence of more water (North Cell and CIL Cell), although this condition is temporary as the dams are ultimately buttressed by the South Cell (Table 35.3-1).

Table 35.3-1. Summary of Rate of Flood Rise

Dam Break Mode	Dam	Rate of Flood Rise (m/h)	
		Bell-Irving / Nass confluence	**Nass River at Gitwinksihlkw (Canyon City)**
Overtopping Failure	Ultimate North Dam	0.9	0.02
	Midlife Splitter/Saddle Dam	2	0.04
	Ultimate Southeast Dam	1.9	0.1
Piping Failure	Ultimate North Dam	1.5	0.1
	Midlife Splitter/Saddle Dam	5	0.01
	Ultimate Southeast Dam	2.9	0.3

35.3.2 Water Storage Dam Break

The dam break and inundation report summarizes the assessment of hypothetical failures of the proposed Water Storage dam (WSD) located on Mitchell Creek at the Mine Site of the KSM Project. The purpose of the WSD is to collect runoff from the mine RSFs for treatment prior to discharge. The dam will be a 166 m (545 ft) high zoned rockfill structure with a central asphalt/earth fill impervious core. The dam will have an upstream slope of 2.5H:1V and a downstream slope of 2H:1V.

The WSD is located on Mitchell Creek within the Sulphurets and Unuk River watershed. Releases from the dam would flow down Mitchell Creek, Sulphurets Creek, and Unuk River and eventually discharge into Burroughs Bay (Alaska) approximately 77 km downstream of the dam. The lower 40 km of the Unuk River is located within the State of Alaska.

Flood inundation limits presented are based on hypothetical failures of the WSD under highly unlikely scenarios, particularly the overtopping mode of failure which would have the largest downstream impact. The rockfill dam is robust against overtopping failures and has been provided with sufficient capacity to store a 200-year wet year runoff, plus 8 m of freeboard above the 200-year water level to accommodate potential avalanche or landslide induced waves and 10 m freeboard over the spillway invert to manage the PMF flows and waves. Since the majority of large avalanches typically occur prior to the freshet period, available freeboard will be larger during the higher risk freshet period. Therefore, overtopping of the dam is a highly unlikely scenario. For the dam to be overtopped, not only would the flood storage capacity and the freeboard have to be used up, but the water treatment rate would have to be exceeded and the overflow spillway would also have to be not functioning. The results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dam.

The purpose of the dam break and inundation study is to assess the consequences of dam failures as defined in the Canadian *Dam Safety Guidelines* (2007). The proposed WSD has been designed in accordance with the CDA's 2007 Canadian *Dam Safety Guidelines*, and a comparison of the Canadian and the Alaska guidelines is presented in Table 35.3-2 for information purposes.

Table 35.3-2. Comparison of Canadian and Alaska Dam Design Criteria

	Design Criteria		
Description	**Alaska Guidelines**	**CDA Guidelines**	**Selected for Design**
Consequence Classification	I (High)	Very High	Extreme
Avalanche for setting wave freeboard	-	-	300-year avalanche (equivalent to the maximum probable avalanche)
Inflow Design Flood	200 year	2/3 between 1000 year event and PMF, with snowmelt	PMF, with snowmelt
Operating Basis Earthquake	150 to >250 year	-	-
Maximum Design Earthquake	2,500 year return period to the MCE	5,000 year return period	Maximum Credible Earthquake

Note: MCE = Maximum Credible Earthquake; PMF = Probable Maximum Flood

As specified by these guidelines, the inflow design flood selected for the dam is the PMF with snowmelt, which is more conservative than the inflow design flood resulting from a 1 in 200-year event according to the Alaska guidelines. The WSD has also been designed to attenuate the excess volume resulting from the 1 in 200-year annual runoff (i.e., the 1 in 200-year wet year) to minimize discharge of untreated water.

The area downstream of the WSD, along Sulphurets Creek and Unuk River up to Burroughs Bay, is relatively undeveloped. The downstream reach of the Unuk River through Alaska is within the Ketchikan Misty Fiords Ranger District Tongass National Forest that is used for recreational purposes. The area also has a small number of guided use and hunting and trap line cabins.

Several failure conditions were considered, including flood-induced dam failure (e.g., overtopping of the dam); sunny-day dam failure (e.g., piping); sunny-day dam failure during winter conditions where ice jam formation is possible; and failure induced by failure of an upstream structure.

The HEC-RAS hydrodynamic computer model, developed by the US Army Corporation of Engineers (2012), was used to simulate the dam failure and to estimate flood inundation limits along streams and rivers downstream of the dam. The model covered the entire reach from the dam to Burroughs Bay.

The conclusions based on the results of the dam break and inundation study (Appendix 35-B) are as follows:

- The dam break and inundation analyses are based on hypothetical modes of failure under extreme and highly unlikely events. For example, for the dam to be overtopped, not only would the flood storage capacity and the large freeboard have to be used up, but the overflow spillway would also have to be not functioning and the treatment rate overwhelmed. The results of the analyses presented herein in no way reflect upon the structural integrity or safety of the dam.
- The dam break analyses presented here include both normal pond and worst case (i.e., 200-year wet year, plus snow avalanche - full pond, and spillway blockage).
- Existing and/or proposed facilities that would be affected by a failure of the WSD include:
  - the KSM WTP located at the confluence of Mitchell Creek and Sulphurets Creek;
  - the proposed KSM Mine Site Access Road (the Coulter Creek access road), including the bridge across Mitchell Creek;
  - the proposed KSM McTagg Power Plant located at the confluence of Mitchell Creek and Sulphurets Creek;
  - the proposed KSM Upper Sulphurets Power Plant located near Sulphurets Lake; and,
  - existing cabins and outfitter/guide locations in BC and Alaska that are either located on the riverbanks, on floodplains, or close to the river within the natural 200-year flood extents.

The dam breach would lead to a flood wave that would move downstream, decreasing in elevation change. The main facilities downstream include:

- within 10 km of the mine: the KSM facilities, which include the WTP, small hydro-plants, the access road, and a bridge at the Mitchell/Unuk confluence; and
- downstream of the Canada/USA border: existing cabins and outfitter/guide sites that are located on the on the river banks, on floodplains, or close to natural floodplains.

The modelling consequences of a dam breach are summarized as follows:

- Overtopping of the dam during a 200-year flood (Rainy-day Dam Break) results in a flood wave that varies from approximately 9 m high at the Mitchell/Unuk confluence to 3.5 m high at the Canada/USA border, decreasing to near zero at Burroughs Inlet. The extent of the flood wave is similar to the 200-year flood levels in the Unuk. The incremental consequence of a rainy-day overtopping failure in terms of life safety and potential damage to property along the lower reaches of the Unuk River (i.e., through Alaska), as defined in the CDA *Dam Safety Guidelines* (2007), is considered to be negligible in terms of the extent of flooding.
- Piping failure of the dam during normal operations (Sunny-day Dam Break) results in a flood wave that varies from approximately 8.5 m high at the Mitchell/Unuk confluence to 2 m high at the Canada/USA border, decreasing to zero at Burroughs Inlet. Except for a few outfitter/guide locations, a sunny-day failure of the dam would flood the same facilities as those listed for the rainy-day failure although the flood depths may be smaller. A sunny-day failure of the dam may have more noticeable incremental consequences as it could include flooding slightly above annual average levels, and as a result, some cabins and outfitter/guide locations could be flooded, and there could also be some loss of life.

To put the variation in consequence of the dam break water level rise in perspective for locations along the downstream reaches, the rate of rise of the water at a location near the dam is estimated to be about 20 m/hour. The rate of rise along the lower reaches of the Unuk River, where most of the cabins and outfitter/guide facilities are located, is indicated by the model to be on the order of 2 m/hour to 4 m/hour.

35.4 Conclusion

The Project has paid particular attention to risk management by incorporating the FMEA process into the Application/EIS and by developing mitigations associated to the risks identified until only an acceptable level of risk remains. Relevant dam break analysis have also been performed to understand the significance of such an event, although appropriate design measures have been applied to limit the eventuality of such an unlikely event occurring.

Although risks are an inevitable component of mining projects such as the KSM Project, the potentially larger risks have been identified, and mitigations have been included in the design or mitigation plans will be put in place to reduce the remaining higher potential risks.

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