Appendix 17.6-A

Summary of Failure Mode and Effects Analysis (FMEA) Workshop, February 2015

Memorandum

Date: November 1, 2015

To: Kate Parsons, Nicola Banton, KAM

From: Jason Rempel, ERM

Cc: Derek Chubb, ERM

Subject: **Addendum to Ajax Failure Mode and Effects Analysis (FMEA) Workshop**

1. INTRODUCTION

This memorandum is an addendum to ERM's March 12, 2015 memorandum: *Summary of Failure Mode and Effects Analysis (FMEA) Workshop held February 19th and 20th, 2015, Kamloops, British Columbia*; it provides discussion related to two additional potential failure modes that were identified and evaluated subsequent to the FMEA workshop:

1. Failure of the SMRSF into the TSF, generating an induced wave; and
2. Rupture of the natural gas supply pipeline.

2. SMRSF FAILURE

Norwest Engineers have evaluated the potential for a failure of the SMRSF into the TSF, including the potential for generation of an induced wave, and have provided the following response:

> "The development of the TSF embankment has been integrated with the placement of rock in the SWRSF. During the initial years of operations, the dyke crest and rock pile are raised at the same rate. Once the rock lifts exceed the elevation of the ultimate dyke crest (approx. 1,056 m), the rock is placed in low lifts (20-25 m) at an overall slope of 2.5H:1V and the stability of the overall rock fill slope meets or exceeds design criteria.
>
> In addition, the presence of the TSF dyke and favourably dipping bedrock foundation all interact to increase the stability of the rock pile slopes and mitigate failures which would affect the tailings dyke and the tailings deposition area.
>
> The configuration, sequencing and overall slope of the SWRSF above the 1,075 m elevation mitigate the risk of flowslides above the TSF basin."

Based on this evaluation, no credible failure mode is identified and further risk assessment of this scenario is not warranted. [Note: two other potential failure modes associated with the SMRSF were previously evaluated.]

3. NATURAL GAS PIPELINE

Rupture of the natural gas pipeline has been identified as a potential failure mode. The length of the pipeline is approximately 5.3 km, with a start point near Knutsford and end point to the west of the proposed truck shop. The natural gas will be used for building heating and emergency back-up electricity generation. The main supply pipeline will be owned and operated by Fortis, while the distribution lines within the mine site will be owned and operated by KAM.

Buried natural gas pipelines are common on the landscape; burial protects the pipes from most potential means of rupture. Regular inspection and maintenance will be performed on all gas lines to minimize the potential for rupture resulting from processes such as external corrosion or stress corrosion cracking. It is possible that the pipeline could potentially be ruptured during on-site earth moving and excavation activities associated with Construction, or maintenance activities during other Project phases. This would occur as a result of a break-down in subsurface clearance protcols.

Natural gas is highly flammable and ruptures commonly ignite. A rupture that releases natural gas to the soil and atmosphere but does not ignite is considered a lower bound scenario. A worst case scenario is a rupture resulting in an explosion followed by a large fire. Using the US EPA's RMP*Comp tool and based on a vapour cloud explosion of 1,000 kg of methane, blast overpressures at a level that could result in minor property damage or personal injury (6.9 kPa) would be confined to a distance of 200 m from the source. Therefore, damage to on-site infrastructure may occur, but off-site effects to local residents or the public from an on-site explosion are not expected. Similarly, while smoke will travel further and may result in short-term poor air quality for the surrounding area, the heat related effects of the fire will be confined to the immediate vicinity.

Based on the above background information, Table 1 summarizes the risk rating for a natural gas pipeline rupture failure mode. Overall risk is considered low, because of the limited spatial and temporal extent of potential environmental effects, and the rare likelihood of occurrence.

Table 1. Accidents and Malfunctions – FMEA Risk Register

			Consequence				Controls				
Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
Natural Gas Pipeline	Rupture of natural gas pipeline, resulting in an explosion followed by a large fire	Construction, Operation, Decommissioning and Closure	Potential damage to site infrastructure (estimated within 200 m radius of blast); smoke from resulting fire influences local air quality	Serious	Minor	Minor	• Regular monitoring and maintenance of pipeline infrastructure; • Call-before-you-dig procedures for on-site and off-site Project activities.	• Engage emergency shut-offs to stop natural gas flow; • Fire fighting response; • Emergency response plan.	Rare	Low	Continued discussion/ planning with Fortis

Memorandum

Date:	March 12, 2015
To:	Kate Parsons, KAM
From:	Mireille Busque, ERM
Cc:	Derek Chubb, Elizabeth Sherlock, Jason Rempel, Rebecca D'Onofrio, ERM
Subject:	**Summary of Failure Mode and Effects Analysis (FMEA) Workshop held February 19th and 20th, 2015, Kamloops, British Columbia**

CONTEXT SETTING

KGHM Ajax Mining Inc. (KAM) plans to develop the Ajax Project (the Project), an open pit copper and gold mine located south of the city of Kamloops, BC. The primary components supporting the open pit mine include: mine rock management facilities; processing facility and truck maintenance facility; process water intake and line; and tailings storage facility. The key infrastructure will be located outside of the Kamloops city limits, largely on private land owned by KAM, with some utilization of Crown land. Engineering design of the Project is currently underway, and details of the design are subject to change as work continues. However, the primary components and activities of the Project are well developed.

The Project is subject to regulatory review under the *British Columbia Environmental Assessment Act* (BCEAA; 2002) and is also subject to regulatory review under the former *Canadian Environmental Assessment Act* (CEAA; 1992) as a comprehensive study. While the *Canadian Environmental Assessment Act, 2012* (CEAA 2012) came into force on July 6, 2012, the Project was already underway when the new legislation came into force, and therefore it is subject to the transition provisions as set out in CEAA 2012 and it will continue to be assessed under the former Act as if the former Act had not been repealed.

Following the principles of the *Canada-BC Agreement for Environmental Assessment Cooperation (2004)*, a single joint coordinated environmental assessment (EA) review process is being carried out for the Project. Under the coordinated process, a joint Application Requirements and Environmental Impact Statement Guidelines (AIR/EISg) specifies the information that is needed to conduct an EA that meets both provincial and federal requirements.

WORKSHOP

A workshop was held on February 19th and 20th, 2015 (8:30 – 16:00 each day) to support, in part, the requirements of the AIR/EISg to qualitatively identify and assess potential accidents, malfunctions, and unplanned events (Event) that could occur during any phase of the Project.

The workshop was based on a Failure Modes and Effect Analysis (FMEA) approach in accordance with the requirements of the AIR/EISg.

The workshop was attended by a multi-disciplinary team of KAM and its consultants. Workshop participants are listed in Table 1 and were selected based on their knowledge of the Project and technical expertise. The workshop was facilitated by Mireille Busque of ERM, a trained facilitator for qualitative and semi-quantitative risks assessments.

Table 1 : Workshop participants

Participant Information			2015/02/19		2015/02/20	
Name	**Organization**	**Role**	**AM**	**PM**	**AM**	**PM**
Mireille Busque	ERM	Facilitator	x	x	x	x
Rebecca D'Onofrio	ERM	Scribe	x	x	x	x
Kate Parsons	KGHM	Environmental Manager	x	x	x	x
Nicola Banton	KGHM	EA and Permitting Manager	x	x	x	x
Dene McGunigle	KGHM	Safety Superintendent	x	x	x	x
Carlos Penunuri Yepiz	KGHM	Health and Safety Manager	x	x	x	x
Clyde Gillespie	KGHM	Project Development Manager	x	x	x	x
Wayne Fong	KGHM	Process Manager	x	x	x	x
Yves Lacasse	KGHM	External Affairs Manager	x	x		
Sheila Kluck	KGHM	Manager Geotechnical Engineering	x	x		
Michal Wypych	KGHM	Chief Mine Engineer	x	x	x	
Daniel Lefebvre	KGHM	Manager of Engineering	x	x	x	x
Les Galbraith	Knight Piesold	Geotechnical Engineering	x	x	x	x
Mediha Hodzic	Knight Piesold	Water Management	x	x		
Trevor Crozier	BGC	Groundwater, Water Management	x	x	x	
Mark Bietting	KCB	Hydrogeology	x	x	x	
Derek Chubb	ERM	EA	x	x	x	x
Elizabeth Sherlock	ERM	EA	x	x	x	x
Jason Rempel	ERM	EA	x	x		
Chris Klassen	Norwest	Geotechnical Engineering	x	x	x	
Bruce Mattson	Lorax	Geochemisty			x	

The methodology undertaken was for workshop participants to brainstorm on potential failure modes associated with each of the primary Project components. As per the AIR/EISg, the failure modes considered included:

- Fire;
- Pit failure;
- Contamination of soils and/or water due to spill, leaks, etc. (e.g., fuel spills, reagents);
- Failure of seepage collection and runoff ponds;
- Leakage from seepage collection and runoff ponds;
- Failure of the waste rock storage facilities;
- Kinder Morgan Pipeline leakage or failure;
- Accidental leakage of effluent;
- Power outages;
- Flying rock from blasting;
- Motor vehicle/transportation accidents;
- Flooding, erosion and/or burial due to containment structure failures;
- ML/ARD;
- Sediment transport into watercourses; and
- Accidental explosion.

KAM is not responsible for the portion of the Kinder Morgan Pipeline that runs through the Project site. However, as infrastructure located on the Project site, it was included in the scope of the workshop. The Kinder Morgan Pipeline is proposed to be relocated to facilitate the Project and it is the relocated pipeline that was assessed.

An assessment of accidents, malfunctions, and unplanned events associated with the tailings storage facility (TSF) was excluded from the scope of this specific workshop. The TSF is the subject of detailed stand-alone assessment as required under the AIR/EISg.

For each of the failure modes identified, the team then:

1. Specified the project phase in which the failure could occur;
2. Evaluated the consequences of the failure;
3. Evaluated the severity of the consequences:
4. Identified the preventive controls;
5. Identified the mitigating controls;
6. Estimated the likelihood on the consequences;
7. Ranked the environmental risk using the risk assessment matrix; and
8. Formulated recommendations for all high risk and medium risk that could be further mitigated.

Preventive controls are intended to prevent an Event from happening. Mitigating controls are intended to reduce the potential severity of the Event if it occurs. It is important to note that the likelihood of an Event was rated based on its potential environmental consequences.

Risk was ranked using the risk provided in Table 2 below and is based on current industry practices. The likelihood was defined in order to be able to discriminate events with very low frequencies, which is typically used in such assessments.

Table 2 : Risk matrix

	Consequence Severity				
Likelihood	Minor	Moderate	Serious	Major	Catastrophic
Almost Certain (1/year)	Low	Medium	High	High	High
Likely (1/10 years)	Low	Medium	Medium	High	High
Possible (1/100 years)	Low	Low	Medium	High	High
Unlikely (1/1000 years)	Low	Low	Medium	Medium	High
Rare (1/10000 years)	Low	Low	Medium	Medium	High

High risks are considered intolerable and need to be further mitigated to a tolerable level. Medium risks either need to be further mitigated or monitored closely to prevent them from occurring. Low risks are considered acceptable and typically no recommendations are made.

The consequence definitions used for this analysis are presented in Table 3.

The workshop discussions were recorded in a Risk Register (Excel based worksheet in the Appendix 1). All failure modes, as per the AIR/EISg, were considered. As a screening to focus the workshop, only the failure modes that had a potential material impact in nature were carried forward to be documented in the Risk Register. The focus of the assessment was the major events that have the potential to jeopardize the success of the project as a result of environmental consequences. Events that are controlled by good management and standard operating practices were not documented as part of the FMEA workshop. The Project will undergo detailed risk assessments as part of the normal course of basic and subsequent engineering phases of development. The outputs from this workshop will serve as a key input into the accidents and malfunctions chapter of the EIS required under the AIR/EISg.

Table 3: Consequence definition

Severity Definitions					
	Minor (1)	Moderate (2)	Serious (3)	Major (4)	Catastrophic (5)
Environment	Events with no negative impact on the environment in the local study area	Events with small reversible impact on the environment in the local study area	Events causing reversible damage outside of the local study area but not dysfunction of ecosystems.	Events causing reversible damage to the environment and temporary dysfunction of ecosystems	Events causing irreversible damage to the environment and permanent dysfunction of ecosystems
Community	Tangible expressions of mistrust among a handful of community members with no influence on public opinion and decision-makers.	Tangible expressions of mistrust among a few community members with some influence on public opinion and decision-makers.	Tangible expressions of mistrust among some community members with moderate influence on public opinion and decision-makers.	Tangible expressions of mistrust among most community members with significant influence on decision-makers.	Widespread loss of trust across the community setting the agenda for decision-makers and key stakeholders.
Health and Safety	First aid required.	Lost time injuries.	Disabling injuries.	Single fatality.	Multiple fatalities.

RESULTS

A total of 37 failure modes were carried forward and captured in the Risk Register consisting of 2 high risks, 23 medium risks and 12 low risks. Table 4 presents the environmental risk distribution within the risk matrix used for the assessment.

Table 4: Environmental Risk Distribution Within the Assessment Risk Matrix.

	Consequence Severity				
Likelihood	Minor	Moderate	Serious	Major	Catastrophic
Almost Certain (1/year)	0	0	0	0	0
Likely (1/10 years)	2	0	0	0	0
Possible (1/100 years)	2	2	1	0	0
Unlikely (1/1000 years)	1	4	8	8	0
Rare (1/10000 years)	0	1	1	5	2

Excluding considerations related to tailings management (TSF will be a separate detailed assessment and not covered in the FMEA workshop), the open pit mine, mine rock management and the water management structures were identified as the components that pose the highest threats to the environment. Most of the failure modes identified relate to the geotechnical risks of the physical stability of infrastructure. Table 4 shows the distribution of the risks per project component.

Table 4: Risk distribution per project component

Project Component	Risk Level			
	High	Medium	Low	Total
Open Pit Mine	2	4	1	7
Processing Facitity	0	1	2	3
Mine Rock Management	0	6	0	6
Water Management Structures	0	5	0	5
Access Roads	0	3	1	4
Transmission line	0	0	1	1
Explosive storage facility (prefered location)	0	0	2	2
Explosive storage facility (alternative location)	0	0	2	2
Potable water system including intake to Kamloops Lake	0	0	0	0
Concentrate Storage and shipping area	0	0	0	0
Concentrate transportation	0	0	0	0
General	0	4	2	6
Kinder- Morgan Pipeline	0	0	1	1
Total	2	23	12	37

CONCLUSIONS

An FMEA workshop was held in Kamloops, B.C. on February 19th and 20th, 2015. A multi-disciplinary team was assembled to identify and assess accidents and malfunctions that could occur at the KAM Ajax Project. Through the course of this workshop, a total of 37 failure modes were documented, 2 of which were rated as high risk events requiring further mitigation. Each of the workshop attendees have reviewed this memorandum including the associated Risk Register, confirming that the output is an accurate reflection of the workshop findings and captures key risks for the Project.

The information collected through the course of the workshop serves as a key input into the accidents and malfunctions chapter required by the AIR/EISg.

APPENDIX 1

Workshop Risk Register

KGHM Ajax Mining Inc.

Accidents and malfunctions - FMEA Workshop AIR/EISg

				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
01	Open Pit Mine	Highwall failure that propagates into Jacko lake resulting in a significant volume of water transferring into the mine pit	Operation	Loss of fish and wildlife habitat (extending downstream of the lake); Potential of loss of life (fishermen on the lake, workers in the pit); Loss of recreational and cultural value.	Catastrophic	Catastrophic	Catastrophic	Geotechnical investigation and design (provides a 1.6 factor of safety minimum); De-pressurization of wall; Monitoring of stability with proper reaction to observations (reinforcement of wall, evacuation of pit, evacuation of Jacko Lake); Mine plan will be continuously optimized and refined to ensure long-term stability.	Re-establishment of lake;	Rare	High	1. Re-evaluate magnitude of consequences based on the distance between pit crest and the cut-off wall considering the most likely pit failure plane; 2. Ensure that pit slope stability analysis and design incorporates conservative information (voids); 3. Consider having a third-party geotechnical expert review the slope design; 4. Ensure that the monitoring program of the high wall stability is robust and that the area close to Jacko lake is subject to more stringent review;
02	Open Pit Mine	Highwall failure that propagates into Jacko lake resulting in a significant volume of water transferring into the mine pit	Post Closure	Loss of fish and wildlife habitat (extending downstream of the lake); Potential of loss of life fishermen on the lake; Loss of recreational and cultural value.	Minor	Catastrophic	Catastrophic	Geotechnical investigation and design (2.0 factor of safety minimum); Back-fill; Closure plan will be continuously re-evaluated and optimized to ensure long-term stability.	Re-establishment of lake;	Rare	High	1. Re-evaluate magnitude of consequences based on the distance between pit crest and the cut-off wall considering the most likely pit failure plane; 2. Ensure that pit slope stability analysis and design incorporates conservative information (voids); 3. Consider having an third-party geotechnical expert review the slope design;
03	Open Pit Mine	Over-loading blast holes projecting rocks further than expected.	Operation	Injuries due to fly rock employees and members of the community; Noise, vibrations and dust impact on local community; Distress to fish due to noise and vibration.	Major	Serious	Major	Blasting procedures; QC of blast loads; Clearing people from the safety blast radius.	Emergency response plan (for injuries), including extended search zones; Aquatic and wildlife habitat assessment.	Unlikely	Medium	N/a

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Accidents and malfunctions - FMEA Workshop AIR/EISg

				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
04	Open Pit Mine	Incorrect delineation of Peterson Creek aquifer extent increasing groundwater flow to the pit.	Operation	Reduce ground water flow to Peterson Creek aquifer impacting wildlife and aquatic system.	Minor	Major	Serious	Water level monitoring in Peterson Creek aquifer; Continue site characterization of underlying material and update models.	Consolidation grouting or interception wells to cut off groundwater flow into the pit; Supplement water from Kamloops Lake to compensate the loss to Peterson Creek.	Unlikely	Medium	4. Conduct additional surveys to understand hydraulic conductivity using geophysic methods to increase confidence of distance between the open pit and Peterson Creek aquifer.
05	Open Pit Mine	Groundwater seepage from open pit to local aquifer	Post Closure	Release of potentially contaminated pit-lake water to groundwater and downstream receiving environment	Minor	Major	Major	Monitor water level in the pit and compare to pit infill model to validate that calculated pit filling are being realized; Monitor groundwater levels; Monitor water quality; Identify fracture patterns and distribution during operations and adjust closure plan as needed.	Remediation	Unlikely	Medium	5. Further validate water model and adapt the water management plan as required (for example: fault mapping during pit operations).
06	Open Pit Mine	Failure in water-retention from Jacko Lake progressively filling the pit.	Operation and Post Closure	Loss of fish and wildlife habitat; Effect on downstream water users;	Minor	Major	Major	Geotechnical investigation and design of the dam; Performance monitoring of the dam. Third-party review and inspection in accordance with established guidelines.	Re-establishment of lake	Unlikely	Medium	6. Consider having a third party expert review the dam design basis and engineering design.

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Accidents and malfunctions - FMEA Workshop AIR/EISg

				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
07	Open Pit Mine	Break in dewatering pipeline causing a discharge in the environment	Operation	Potential effects on surface and ground water quality downstream; Erosional damage to roads and access (on site);	Minor	Moderate	Moderate	Controlled drainage; Low-flow alarms to operator that can shutoff the pumps; Preventive maintenance on pipeline; Pipeline protected by berms along access roads	Controlled drainage; Shut pumps down; Replace pipe; pill response plan	Possible	Low	Low - N/a
08	Mine Rock Management	Slope Failure of SMRSF	Operation	Potential rupture of the Tailings and Reclaimed pipelines which would naturally drain to Humphreys Creek.	Minor	Major	Serious	Geotechnical investigation and conservative design; Monitoring of slope movement of the SMRSF.	Pumps can be shutdown by operator on low flow or low pressure alarms; Spill contingency plan; Remediation	Unlikely	Medium	7. Evaluate means to protect the pipelines from a potential slope failure if the SMRSF.
09	Mine Rock Management	Slope Failure of SMRSF	Operation	Potential impact to Plant site with potential loss of life and causing environmental damage due to the chemicals used in that area.	Catastrophic	Major	Major	Geotechnical investigation and conservative design; Monitoring of slope movement	Spill contingency plan; Remediation	Rare	Medium	8. Further investigate the likelihood that a slope failure from the SMRSF would result in catastrophic impacts at the Plant site; (i.e. validate the spatial extent of the slope failure.
10	Mine Rock Management	Slope Failure of West MRSF	Operation	Potential impact to Kinder-Morgan pipeline releasing hydrocarbons in the environment; Potential impact to Lac Le Jeune and mine roads; Potential impact on Jacko Lake.	Minor	Major	Major	Geotechnical investigation and conservative design; Monitoring of slope movement; Pipeline is buried.	Spill contingency plan; Remediation	Rare	Medium	9. Evaluate if a slope failure of the WMRSF can reach the pipeline, Lac Le Jeune Lake or Jacko Lake.

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Accidents and malfunctions - FMEA Workshop AIR/EISg

				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
11	Mine Rock Management	Slope Failure of EMRSF (50m height)	Operation	Loss of containment of EMRSF water management pond with potential impact on Peterson Creek due to poor quality of the water released.	Minor	Major	Major	Geotechnical investigation and conservative design; Monitoring of slope movement; Placement of NPAG material only in this pile.	Spill contingency plan; Remediation	Rare	Medium	10. Evaluate if the slope failure of the EMRSF can reach Peterson Creek if the height is limited to 50m.
12	Mine Rock Management	Slope Failure of SMRSF or West MRSF (PAG material)	Post Closure	Soil erosion and sedimentation in the downstream environment with potential impact on aquifer and surface water due to acid generation and metals leaching.	Minor	Major	Major	Geotechnical investigation and conservative design; Revegetation; Monitoring surface and ground water quality during closure and the period of post-closure monitoring; Updating and revising source terms during the life of the project.	Re-cap areas that have eroded and remediation of the impacted ecosystems;	Rare	Medium	N/a
13	Mine Rock Management	Failure in mine rock management (inappropriate placement of mine rock)	Operation	Poor water quality exceeding guidelines in the receiving environment during operations or post-closure.	Minor	Major	Major	Operational MLARD monitoring and management plan; Implementation of Environmental monitoring plan; Haul truck Fleet management system; Run-off and seepage collection ponds.	Cover systems; Collect and pump to the tailings pond (or to the pit post-closure); Remediation; Removal of material to proper storage area.	Unlikely	Medium	11. Revisit the consequence rating once the water quality modeling has been done; 12. Revisit the water balance for the pit at closure (to consider a pump scenario for the Peterson Creek aquifer).

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Accidents and malfunctions - FMEA Workshop AIR/EISg

				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
14	Processing Facility	Containment failure of the tailings or reclaim pipeline.	Operation	Tailings and reclaim water released to Humphreys Creek and Plant Site.	Minor	Major	Serious	Maintenance on pipeline (MAC TSM compliance);	Pressure sensors at strategic locations on pipeline will allow operations to detect leakage and act; Containment ditching along the pipeline; Spill contingency plan; Remediation.	Unlikely	Medium	13. Investigate means of automating pump shutdown on tailing and reclaim lined if leakage is detected using the process parameters; 14. Quantify potential volume of discharge in case of a pipeline failure.
15	Processing Facility	Hazardous material release	Operation	Within limits of the plant, no environmental consequence. Could have environmental impact during unloading activities, exposing workers to the substance. Worst-case consequence is an explosion within the plant because of xanthate in mixing area.	Catastrophic	Moderate	Serious	Explosion-proof walls in mixing area; Xanthate mixing electrical classification; Ventilation systems for exposure to hazardous materials; Restricted area.	Dedicated concrete pad for unloading transfer areas; Secondary containment for all hazardous materials; Emergency response plan;	Unlikely	Low	N/a
16	Processing Facility	Fire in the plant	Operation	Visible smoke; Exposure of workers to smoke (potentially toxic); Localized air quality impact of short duration.	Serious	Minor	Minor	Hot-work permit; NFP compliant/Electrical-code compliant (Division classification).	Fire-fighting capabilities; All run-off water is contained in the plant site; Fire protection and detection systems in the plant site.	Possible	Low	N/a

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Accidents and malfunctions - FMEA Workshop AIR/EISg

				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
17	Access Roads	Concentrate Truck Accident/Spill	Operation	Concentrate in the environment (Peterson Creek into downstream pond and localised soil contamination); Potential fatality due to truck accident.	Major	Serious	Serious	Traffic Management Plan (including speed limits and seat belts); Vehicle inspection prior to accessing site; Road maintenance; Safety berms on the road at portion adjacent to Peterson Creek	Spill response plan; Emergency response plan; Remediation activities for the spill	Unlikely	Medium	N/a
18	Access Roads	Fuel Truck Accident/Spill	Operation	Fuel in the environment (Jacko Lake, localized soil contamination); Potential fatality (truck driver)	Major	Major	Major	Traffic Management Plan (including speed limits and seat belts); Vehicle inspection prior to accessing site; Road maintenance.	Spill response plan; Emergency response plan; Remediation activities for the spill	Unlikely	Medium	15. Add berms and ditching along road near Jacko Lake; 16. Extend Traffic Management to Lac le Jeune Road for all suppliers and employees.
19	Access Roads	Hazardous Goods Truck Accident/Spill	Operation	Hazardous material (ammonium nitrate) in the environment with the potential for the material to reach Jacko Lake during a rain event; Potential fatality (truck driver).	Major	Major	Major	Traffic Management Plan (including speed limits and seat belts); Vehicle inspection prior to accessing site; Road maintenance; TDG requirements;	Spill response plan; Emergency response plan; Remediation activities for the spill	Rare	Medium	15. Add berms and ditching along road near Jacko Lake; 16. Extend Traffic Management to Lac le Jeune Road for all suppliers and employees.
20	Transmission line and transformer upgrade	Power Failure	Operation	Discharge of material within the process plant site.	Minor	Minor	Minor	Maintenance on transmission line.	Emergency generators on critical systems; Emergency response plan; Process plant self-contained.	Likely	Low	N/a

				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
21	Explosive storage facility (preferred location)	Accidental explosion at the manufacturing facility (explosive capacity designed to meet 30,000T/year).	Operation	Visible smoke; Impact on the community from noise and vibration; Potential injuries and loss of life; Potential spills; Potential local environmental impact from material spill.	Catastrophic	Moderate	Major	Explosives and Blasting Safety Procedure; Minimizing the stored quantities of explosive materials; Fenced secure site with controlled access.	Building location (on a hill); Building design (explosion panels); Emergency response plan; Spill response plan.	Unlikely	Low	17. Further H&S planning to reduce over-all risk on people.
22	Explosive storage facility (alternative location)	Accidental explosion at the manufacturing facility (explosive capacity designed to meet 30,000T/year).	Operation	Visible smoke; Impact on the community from noise and vibration; Potential injuries and loss of life; Potential spills; Potential local environmental impact from material spill.	Catastrophic	Moderate	Major	Explosives and Blasting Safety Procedure; Minimizing the stored quantities of explosive materials; Fenced secure site with controlled access.	Building location (on a hill); Building design (explosion panels); Emergency response plan; Spill response plan.	Unlikely	Low	18. Ensure that the road is outside of the offset distance of the explosion plant if located at the alternative location.
23	Explosive storage facility (preferred location)	Ammonium Nitrate emulsion spill.	Operation	Potential soil contamination;	Minor	Moderate	Minor	Explosives and Blasting Safety Procedure; à Minimizing the stored quantities of explosive materials; Product transfer done inside the building on adequate flooring surface.	Building design (secondary containment); Spill response plan.	Possible	Low	N/a
24	Explosive storage facility (alternative location)	Ammonium Nitrate emulsion spill.	Operation	Potential soil contamination;	Minor	Moderate	Minor	Explosives and Blasting Safety Procedure; à Minimizing the stored quantities of explosive materials; Product transfer done inside the building on adequate flooring surface.	Building design (secondary containment); Spill response plan.	Possible	Low	N/a

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Accidents and malfunctions - FMEA Workshop AIR/EISg

				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
25	Access Roads	Accident/Spill of truck transporting Ammonium Nitrate emulsion (alternative location)	Operation	Hazardous material (ammonium nitrate emulsion) in the environment, soil contamination; Potential fatality (truck driver).	Major	Moderate	Moderate	Traffic Management Plan (including speed limits and seat belts); Vehicle inspection prior to accessing site; Road maintenance; Federal transportation requirements; TDG requirements	Spill response plan; Emergency response plan; Remediation activities for the spill.	Unlikely	Low	N/a
26	Water Management Structures	Structural failure of one of the seepage and collection ponds upgradient of Jacko Lake.	Operation	Potential release of contact water into Jacko Lake;	Minor	Serious	Serious	Geotechnical investigation and design; Monitoring of the structure.	Re-build the dam; Additional water quality monitoring; Potential fishing restrictions at Jacko Lake; Aquatic habitat assessment.	Unlikely	Medium	N/a
27	Water Management Structures	Leakage from one of the seepage and collection ponds upgradient of Jacko Lake.	Operation and Post Closure	Potential leakage into the groundwater reaching Jacko Lake	Minor	Serious	Serious	Lined facility (natural or synthetic); Pond level control (during operations); Environmental monitoring plan; Closure and reclamation plan (post-closure)	Additional water monitoring; Potential fishing restrictions at Jacko Lake; Temporary suspension of pumping from Jacko Lake; Aquatic habitat assessment; Repair leak in liner.	Unlikely	Medium	N/a
28	Water Management Structures	Failure of the Central Collection pond liner.	Operation	Release of contact water into Peter Creek and Peterson Creek aquifer.	Minor	Serious	Moderate	Pond level control; Environmental monitoring plan.	Groundwater and surface water quality monitoring; Aquatic habitat assessment; Repair leak in liner.	Unlikely	Medium	19. Revisit the consequence description once the groundwater modeling flow-path assessment is complete.

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				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
29	Water Management Structures	Failure of the EMR collection pond liner	Operation and Post Closure	Release of contact water into Peterson Creek and Peterson Creek aquifer.	Minor	Serious	Moderate	Pond level control (during operations); Environmental monitoring plan; Closure and reclamation plan (post-closure)	Groundwater and surface water quality monitoring; Temporary suspension of pumping from Jacko Lake; Aquatic habitat assessment; Repair leak in liner	Unlikely	Medium	N/a
30	Water Management Structures	Structural failure of the EMR collection pond	Operation and Post Closure	Impact to Peterson Creek and Peterson Creek aquifer;	Minor	Serious	Moderate	Geotechnical investigation and conservative design; Monitoring of slope movement; Placement of NPAG material only in this pile;	Spill contingency plan; Remediation; Re-build the dam	Unlikely	Medium	N/a
31	Water Management Structures	Failure of the down-stream pond dam (5m height)	Operation and Post Closure	Silting and erosion downstream of Peterson Creek into the City of Kamloops due to the unexpected waterflow.	Minor	Serious	Major	Site investigation and detail design; Performance monitoring of the dam. Third-party review and inspection in accordance with established guidelines.	Re-build the dam; Repair creek and associated infrastructure	Rare	Medium	23. Consider having a third party expert review the dam design basis and engineering design.
32	General	Grass land / Forest Fire (ex. by cigarette or road incident)	Operation	Fire starts on site and extends to Aberdeen or Knutsford potential impact on the community because of smoke and poor air quality.	Moderate	Major	Serious	Smoking policies (ex. no smoking in company vehicles, designated smoking areas).	On-site fire department; BC forestry service fire department; Municipal fire department	Unlikely	Medium	20. Conduct an annual review of fire-safety to minimize the likelihood of such an event.
33	General	Equipment fire	Operation	Smoke locally and short-term air quality; Possible employee injury; Potential fuel spill	Serious	Minor	Minor	Equipment maintenance program; Operator training (proper equipment use); Speed limits.	Fire suppression systems and/or Fire extinguishers; Emergency response plan.	Likely	Low	N/a

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				Consequence				Controls				
ID	Area	Failure Description	Period of interest	Description	H & S	Environment	Community	Prevention Pre-Event	Mitigation Post-Event	ENV Likelihood	ENV Risk Ranking	Recommendation
34	General	Fuel spill at the truck shop fuel storage location (20,000L spill) due to tank and associated equipment failure.	Operation	Potential soil contamination; Potential contamination of Peterson Creek; Potential groundwater contamination; Potential fire; Potential employee injury.	Moderate	Serious	Moderate	Berm around facility; Tank inspection and monitoring; Fueling procedures; Fuel management plan; Physical protection of pump and tanks (protection from impact).	Secondary containment around the tanks; Emergency response plan; Fire suppression systems; Censors; Spill response plan; Spill response kit	Unlikely	Medium	N/a
35	General	Fuel spill at the haul truck fueling station due to tank and associated equipment failure (100,000L)	Operation	Potential soil contamination towards pit; Potential employee injury; Potential contamination of pit de-watering water	Minor	Minor	Minor	Berm around facility; Tank inspection and monitoring; Fueling procedures; Fuel management plan; Physical protection of pump and tanks (protection from impact).	Secondary containment around the tanks; Emergency response plan; Censors; Spill response plan;	Unlikely	Low	N/a
36	General	Repetitive small leaks from fueling stations over the life-time of the project.	Operation	Potential Soil contamination; Potential groundwater contamination.	Minor	Serious	Serious	Secondary containment; Use of spill trays during fueling activities and unloading. Standard operating procedures.	Groundwater monitoring; Remediation; Spill response plan	Possible	Medium	21. Conduct periodic soil sampling around fueling stations to identify hydrocarbon contamination early.
37	Kinder- Morgan Pipeline	Failure of Kinder-Morgan pipeline near Jacko Lake	Operation	Large release of hydrocarbons in Jacko Lake or Peterson Creek that KGHM will pump through the Peterson Creek diversion to the downstream pond (suction pumps are 2m below the lake water surface) soil contamination, water contamination.	Minor	Moderate	Major	Kinder-Morgan informs KGHM that there has been a release in proximity of Jacko Lake; Prevention of the release is Kinder-Morgan's responsibility	Stop pumping from Jacko Lake; Assist Kinder-Morgan in responding to spill	Rare	Medium	22. The likelihood of this event is rare as it would require a series of events to occur. This includes failure of the Kinder Morgan Pipeline in the area of Jacko Lake/access road to occur undetected and no response, the material spilling into Jacko Lake a distance of ~1km and hilly and water (also undetected and no response) before reaching water intake location, and because the water intake on Jacko Lake is located on the lake bed and fuel floats, it would take a significant lake drawdown to occur undetected for the fuel to be withdrawn from Jacko Lake and discharged downstream to Petersen Creek.