TECHNICAL MEMORANDUM

DATE January 08, 2021 **Reference No.** 20351262-823-TM-Rev0

TO Michel Groleau and Jamie Quesnel
Agnico Eagle Mines Limited

CC Colleen Prather (Agnico Eagle); Jen Range (Golder)

FROM Lasha Young (Golder) **EMAIL lyoung@golder.com**

CIRNAC-TRC-07: RATIONALE FOR CLASSIFICATIONS OF SALINE WATER SPILL TO ICE-RICH SOILS IN FMEA WATERLINE ADDENDUM

In the response to the Technical Comments, Agnico Eagle provided a Failure Modes and Effects Analysis (FMEA) in Attachment TC-01, which was completed by Agnico Eagle and supporting subject matter experts. An assessment of risks to permafrost from the construction and operation of the waterline was also provided as Attachment TC-03. CIRNAC had questions related to how the conclusion that a "worst" case scenario would have "low" environmental, health & safety, and societal impacts. CIRNAC recommended that Agnico Eagle present more information on the conclusion of low potential impacts, based on the FMEA, of a spill on terrestrial environment (per CIRNAC-TRC-06) and its associated mitigation measures before it decides if this TRC is resolved.

Subsequently, additional information on the rationale for the environmental impact classification used in the FMEA for failure modes causing a spill is provided herein.

Approach Used in the FMEA

The FMEA was designed to identify all the ways in which a failure mode could occur, with multiple failure modes potentially resulting in the same outcome (i.e., a spill). The FMEA did the following:

- Identify all the various ways that a system can fail ("failure modes")
- Assess the various consequences of each of those failure modes (if they occur)
- Assess the probability of each failure mode (as defined by its consequences) occurring during the operational period
- Combine the probability of occurrence and all the consequences into a single metric (i.e., "severity") for each failure mode
- Prioritize the failure modes based on their severity to guide additional mitigation planning
- Environmental impacts were defined as the area/degree/duration of water and land contamination, and damage/loss to habitat/wildlife, relative to a defined "worst case scenario" (i.e., via a rating of 0 for no impact to 100 for worst case scenario).

For the purposes of the FMEA, spills were compared between the various types of locations where a spill could occur. The classification considered the context of the consequence relative to the various location types and management actions available at those locations. As described in the FMEA, spills on the tundra could be contained to a local area on the tundra and wildlife could be deterred from the area, resulting in much less impact (1%) on the terrestrial wildlife, resulting in a small fraction (0.01% to 0.1%) of the defined worst case environmental impact (Golder 2020a).

Appendix A (Golder 2020b) describes the consequences to areas of ice rich soils as provided in CIRNAC TRC-07. The conclusion of a "low" environmental impact was based on the definitions in the FMEA taking into account the scale of potential environmental consequences between the various types of locations where a spill could occur as well as taking into account the potential management actions under these scenarios.

The definition of failure mode consequence ratings is provided in Table 1. Table 2 provides the definition of failure mode probability ratings in terms of the probability of the failure mode occurring over the operational period. The "severity" is the "expected" (probability-weighted) value of combined consequences (not just environmental impacts) using the relative-weighted sum of the various types of consequences. In this case, one fatality was assessed to be 100 times more important than the defined worst case scenarios for environmental impacts and for social impacts, which in turn were assessed to be approximately equivalent, which is subsequently discussed separately.

Table 1: Definition of Consequence Ratings

Consequence	Ratings[a] (order of magnitude)					
	None	Very Low (VL)	Low (L)	Moderate (M)	High (H)	Very High (VH)
Environmental (scenarios, rating 0-100)	no impact {rating=0.0}	0.01%scen. {rating=0.01}	0.1%scen. {rating=0.1}	1%scen. rating=1}	10%scen. {rating=10}	100%scn. {rating=100}

[a] Ratings of environment and societal impacts, which are scenario based, are expressed numerically relative to a defined "worst" (100%) impact scenario, which is assigned a rating of 100.

Table 2: Definition of Probability Ratings

	Ratings (order of magnitude)						
	None	Very Low (VL)	Low (L)	Moderate (M)	High (H)	Very High (VH)	Given
Probability for operations	0.0%	0.01%	0.1%	1%	10%	100%	

Environmental Assessment Classification

In the request from CIRNAC, Agnico Eagle was asked to classify the outcomes of a large spill. It should be noted that Agnico Eagle has designed the Project to avoid a large spill through using two waterlines to reduce the volume of water in each line and to install a leak detection system and does not consider a large spill a likely scenario, but rather a substantial accident and malfunction in which the design and mitigations have been put in place to avoid.

In the environmental assessment, residual impact classification were completed using direction, magnitude, geographic extent, duration, frequency, reversibility, and likelihood. Table 3 provides a summary of the potential impacts of a large spill (i.e., an accident or malfunction) on terrain and permafrost using these same criteria.

Table 3: Summary of Impact Classification on Terrain and Permafrost

Effects Pathway	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood
Terrestrial Environment							
Accidental release of treated groundwater effluent from an unknown location along the discharge pipe effecting terrain and permafrost.	Negative	Low to moderate	Local	Permanent	Isolated	Irreversible	Unlikely

It is anticipated that if a large spill were to occur along the All-Weather Access Road on the tundra, it would have a negative impact on terrain and permafrost as there could be localized loss of permafrost and there is the potential for sloughing. The magnitude was defined as low to moderate because an outcome would be dependent on where the spill occurred and the level of ponding. The geographic extent was considered local because the maximum area impacted would be 10 acres adjacent to the All-Weather Access Road, while the duration of the spill would be considered short, the duration of the localized impact would last into perpetuity and be irreversible, as it is not anticipated that the terrain or permafrost would re-establish after the spill. The impact would be considered isolated as a spill would be confined to a specific discrete period. Based on the current mitigations in place and the design of the waterline the likelihood of a worst case or large spill is unlikely and has a less than 1% chance of occurring over the life of the Project (an unlikely impact, as defined in the 2014 FEIS (Agnico Eagle 2014), is the impact that is likely to occur less than one time in 100 years).

It should be noted that the terrain analysis completed as part of Agnico Eagle 2014 and briefly summarized in Appendix A (Golder 2020b), indicates relatively low potential for differential movement related to geohazards to occur during the short summer season when the waterline is operational. This assessment is supported by site experience. For example, the mine operator has indicated that there has been little to no change in the grade of the All-Weather Access Road over 7 years of operation, which suggests that even in the high-risk areas ground conditions are relatively insensitive to thawing (Long 2000 pers. comm.). In addition, the mine has operated 4 km pipeline discharge to Meliadine Lake over the last 3 years with no signs of degradation to the tundra.

Closure

We trust the above meets your needs.

Golder Associates Ltd.

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Lasha Young, MSc.F., PMP
Associate

Corey De La Mare, P.Biol.
Principal, Senior Ecologist

LY/CDLM/BR/jr

Appendices: A- Waterline Permafrost Impacts

https://golderassociates.sharepoint.com/sites/132380/project files/5 technical work/03_technical_meeting/06_classification fmea/20351262-823-tm-classificationrationalefmea-rev0.docx

References

Agnico Eagle. 2014. Final Environmental Impact Statement (FEIS) - Meliadine Gold Project, Nunavut from: ftp://ftp.nirb.ca/02-REVIEWS/ACTIVE%20REVIEWS/11MN034-Agnico Eagle%20MELIADINE/2-REVIEW/09-FINAL%20EIS/FEIS.

Golder (Golder Associates Ltd.). 2020a. Meliadine Waterline – Failure Modes and Effects Analysis. Dated November 20, 2020. Ref No. 20351262-805-TM-Rev0.

Golder. 2020b. Meliadine Mine Response to NIRB-IR-016, Geotechnical Hazards NIRB-IR-016 Waterline Permafrost Impacts. Dated November 20, 2020. Ref No. 20351262-810-TM-Rev0.

Long M. 2020. Construction superintendent, Agnico Eagle Mines Limited. All weather Access Road grad during operations. FMEA workshop with Agnico Eagle and Subject Matter Experts. 4 November 2020.

APPENDIX A

Waterline Permafrost Impacts

GOLDER

TRANSMITTAL

DATE 20 November 2020 — 20351262-810-TM-Rev0

TO Michel Groleau
Agnico Eagle Mines Limited

CC Jamie Quesnel

FROM Jen Range — **EMAIL jrange@golder.com**

MELIADINE MINE RESPONSE TO NIRB-IR-016, GEOTECHNICAL HAZARDS NIRB-IR-016 WATERLINE PERMAFROST IMPACTS

Michel,

Please find enclosed technical memorandum *Meliadine Mine Response to NIRB-IR-016, Geotechnical Hazards NIRB-IR-016 Waterline Permafrost Impacts*. The technical memorandum has been prepared and reviewed by our sub-consultant Golder Associates Inc.

Please contact the undersigned if you require any clarifications.

Sincerely,

GOLDER ASSOCIATES LTD.

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Jen Range
Project Manager

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Lasha Young
Associate

JR/LY/jr

https://golderassociates.sharepoint.com/sites/132380/project files/5 technical work/01_information_requests/03_ir commitments/2310_terrainpermafrost/20351262-810-coverletter.docx

GOLDER

TECHNICAL MEMORANDUM

DATE 20 November 2020 20351262-810-TM-Rev0

TO Jen Range and Lasha Young
Golder Associates Ltd.

CC

FROM Mark Musial, Andrew Garrigus, and Eric Cannon **EMAIL mmusial@golder.com**

MELIADINE MINE RESPONSE TO NIRB-IR-016, GEOTECHNICAL HAZARDS NIRB-IR-016 WATERLINE PERMAFROST IMPACTS

The NIRB identified the following issue related to geotechnical hazards and their impact on the planned water pipeline in Information Request #NIRB-IR-016.

- **Issue/Concern**: *The IS Addendum states that the occurrence of geotechnical hazards to the project proposal related to climate change is low. The NIRB notes that the scope of activities include the burial of up to 90 percent of the waterlines. No discussion is provided on potential impacts to the waterline from the environment from natural weathering processes (e.g., will the waterline be subject to freeze/thaw, frost heave, subsidence, etc.).*
- **Request**: *Provide a discussion on the impacts of potential hazards to the waterline that could contribute to the long-term performance of the materials.*

1.0 CONDITIONS ALONG ALIGNMENT

Terrain and geohazards along the alignment are described in *Volume 6.0 Terrestrial Environment and Impact Assessment, Final Environmental Impact Statement (FEIS) – Meliadine Gold Project, Nunavut* (Agnico Eagle 2014). Permafrost terrain types and conditions (e.g., ground ice and active layer processes) along the waterline alignment are summarized in *Table 6.3-A, Terrain Unit Descriptions and Interpretations,* with additional description and mapping presented in Appendices B-D (Agnico Eagle 2014). This mapping covers about 25 km from the mine site toward Rankin Inlet. Approximately 8 km from Rankin Inlet to the end of the mapping crosses areas where 20%-40% of the terrain may contain ground ice based on inspection of recent imagery. However, the relative content of ground ice and hazard in these areas is expected to be similar to the mapping.

There are 10 different terrain types present along the alignment. In addition, the waterlines will pass above or around a few shallow lakes/streams and cross three bridges. Typical active layer processes were expected to include frost heave, frost creep, thaw settlement, frost jacking, frost sorting, and frost wedging. Approximately 24% of the alignment (6.2 km) are in terrain types 2E, 3D, 4D, 5D, 5E, and 12C, which are rated as having a potentially high to very high hazard for thaw or freeze inducted displacement. The distribution of these higher hazard areas is shown in Figure 1. However, the bulk of these areas (5.1 km) are in two terrain types, 5E and 5F, which consist of blankets and/or veneers of marine washed, gravelly to lesser sandy till, or marine sands and/or gravels overlying till.

Figure 1: Risk of Thaw or Subsidence along Pipeline Route (Red is rated as High to Very High (H to VH) as discussed in text)

Approximately 0.4% of the waterline (96 m) crosses areas mapped as lakes (i.e., small streams and/or standing water). Most of these are dry in more recent imagery, but new areas of ponded water are present. These new areas commonly develop adjacent to roads in permafrost terrain and represent areas where ice-rich soils are thawing or the surface drainage has been interrupted by the road embankment. The waterline will either go above or around areas with the potential for water (i.e., small streams and/or standing water).

2.0 WATERLINE IMPACTS

The waterline will be built in one of seven typical configurations shown in Figure 2. In these configurations the waterline will be subjected to freezing temperatures when it is empty in the winter and seasonal movements as the ground refreezes after summer operations. The line will only be operational for a few months during summer, and it will be empty the rest of the year. During summer operations the water will be slightly saline and have a temperature of approximately 4ºC. Some additional thawing should be anticipated in permafrost near the waterlines, but the potential thaw and associated settlement will be mitigated to some degree by the fill placed below the waterlines, as indicated in Figure 2. Natural thawing associated with climate change is expected to be much greater that any thawing associated with waterline operations, potentially increasing by 2 to 4 m during the life of mine operations (Volume 6, Section 6.3.4.4).

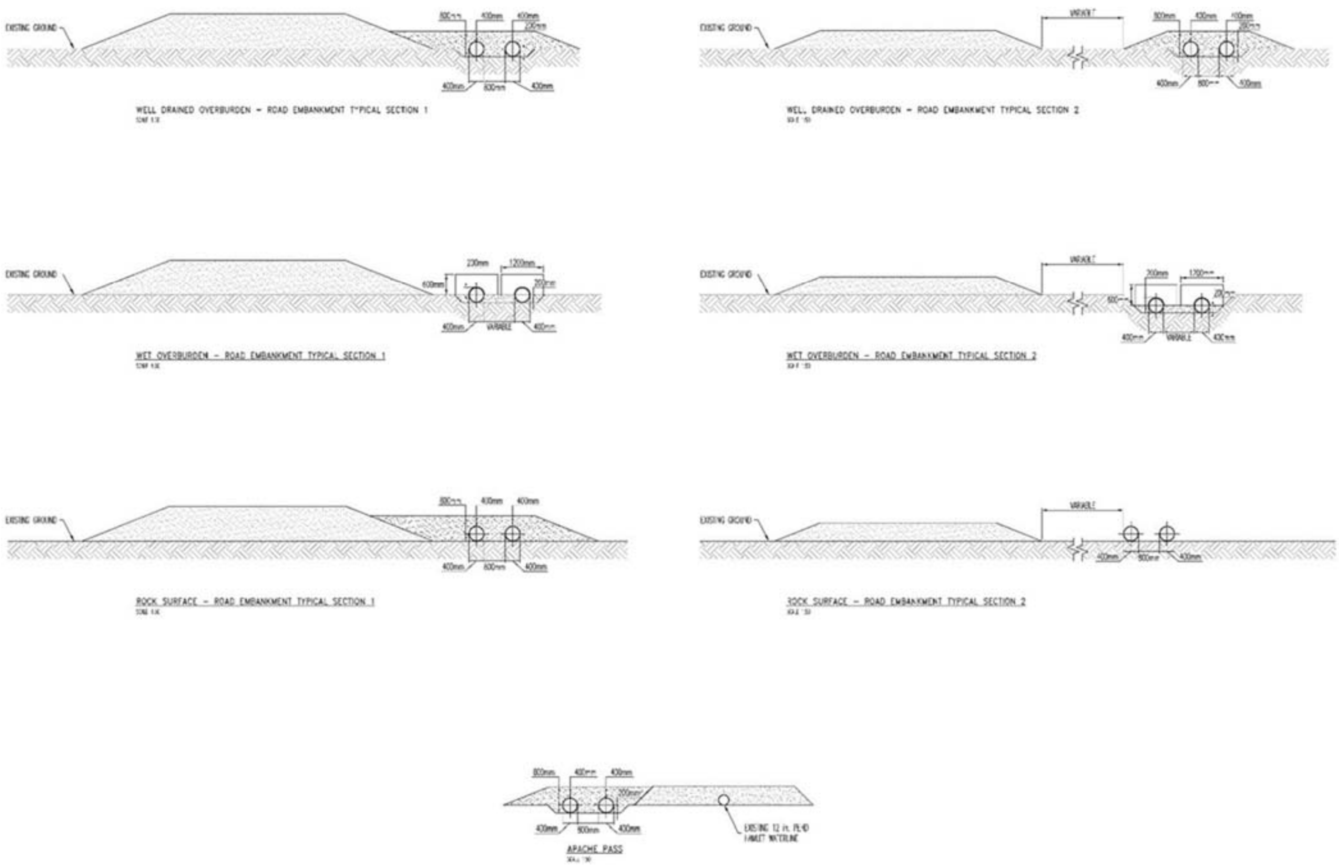

Figure 2: Typical Waterline Configurations

Waterlines and other linear infrastructure are most at risk from geohazards where differential movement occurs such as where the waterline changes from below ground to aboveground modes. These movements could be due to freezing and thawing process or mass wasting. The terrain analysis discussed in Section 1 indicates relatively low potential for differential movement related to geohazards to occur during the relatively short summer season when the waterline is operations. This assessment is also supported by experience at the site. For example, the mine operator has indicated that there has been little or no change in the grade of the All-Weather Access Road over 7 years of operations, which suggests that even in the high risk areas ground conditions are relatively insensitive to thawing and that significant thermokarst that could lead to unsupported segments and over-stressing of the waterline has not developed along the All-Weather Access Road or Bypass Road (Long 2020, pers. comm.). In addition, the mine has operated a 4 km pipeline discharge to Meliadine Lake that is similar to those planned (16 inch diameter HDPE pipe) over the last 3 years with no signs of degradation to the tundra nor signs of distress to the pipe itself.

The waterlines will only be operated in the summer and subject to monitoring for leaks. If leaks were to occur, water discharge will cause erosion or localized degradation of the permafrost in areas where the slightly saline water can pond, as well as causing vegetation damage and potentially impacting fish habitat (i.e., over bridge crossings). The worst-case spill of saline water identified in the Failure Modes and Effects Analysis (FMEA) is 5,000 m^3. This water is expected to spread to a maximum area of 10 acres at an average of 10 cm deep. Surface water or interstitial water in thawed overburden would dilute the salinity and it would be further diluted as it melts ground ice it contacts. If water remains ponded, surface conditions will be changed and there will be a longer term degradation of permafrost conditions. However, potential impacts to the waterline caused by the spill will depend on the ice content of the soil in the spill area. As indicated above, the available data suggests that the impacts are likely to be minor.

3.0 SUMMARY

Most of the waterline length will be in areas where there is low to moderate risk of thaw or freezing induced displacements occurring and where the waterlines will move with seasonal changes in the ground from frozen to thawed or where the waterlines are in lakes and become encased in ice during the winter. The approximately 6.2 km segments crossing terrain with higher hazard of freezing or thawing induced displacements will have higher potential for differential movement, but evidence from performance of the existing All-Weather Access Road indicates that significant thermokarst features that could lead to unsupported and more highly stressed sections of pipe are unlikely to develop. In addition, performance of an existing 16-inch diameter HDPE pipe with discharge to Meliadine Lake has reportedly performed well over 3 seasons of operations.

4.0 CLOSURE

Please do not hesitate to contact the undersigned with any questions.

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Andrew Garrigus, PE (AK)
Senior Geotechnical Engineer

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Mark R. Musial, PE (AK)
Principal, Senior Geotechnical-Permafrost Engineer

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References

Agnico Eagle. 2014. Final Environmental Impact Statement (FEIS) - Meliadine Gold Project, Nunavut from: ftp://ftp.nirb.ca/02-REVIEWS/ACTIVE%20REVIEWS/11MN034-Agnico Eagle%20MELIADINE/2-REVIEW/09-FINAL%20EIS/FEIS.

Long M. 2020. Construction Superintendent, Agnico Eagle Mines Limited. All-weather Access Road grade during operations. FMEA workshop with Agnico Eagle and Subject Matter Experts. 4 November 2020.