# Appendix B2

# Meadowbank Dike Review Board Reports

November 10th, 2017

Mr. Luc Chouinard
General Manager
Agnico–Eagle Mines, Meadowbank Division
Baker Lake Office

Email: luc.chouinard@agnico-eagle.com

Dear Mr. Chouinard,

Report No 20
Meadowbank Mine Dike Review Board
Conference call March 23rd, 2017

## 1.0 INTRODUCTION

A Webex conference was held on March 23rd, 2017 to bring the Board members up to date on two issues, namely:

1. Update on Central Dike Assessment;
2. Stormwater Dike Assessment.

PowerPoint presentations were prepared and given by Golder personnel.

In the interest of permitting appropriate and timely action on the two issues, the Board transmitted preliminary comments by way of a note prepared and transmitted on March 29th, 2017, as requested by Agnico Eagle Mines (AEM).

Subsequently, Golder Associates Limited (GAL) completed and issued the reports entitled:

*Central Dike, Seepage and Performance Assessment Update, August 2017, and;*

*Stormwater Dike, Geotechnical Field Investigation and Performance Report, June 26, 2017.*

There have also been presentations and discussion on the latest situation at these structures during the on-site meeting of September 2017.

AEM has provided the Board with written responses to the earlier preliminary comments. The present document constitutes the official report of the Board for meeting #20 and notes the responses. However, subsequent discussions and presentations can be found in the report of the meeting #22.

## 2.0 CENTRAL DIKE

The Board is pleased to note the excellent work done in integrating the available data to create a 3-D appreciation of the geological conditions.

It would be useful to include the probable permafrost boundaries on the graphical presentations where applicable.

Seepage modeling has been refined using the latest data but is essentially based on a single cross-section through the series of instruments located at Stn. 0+650, as were the analyses carried out for the feasibility studies and for detailed engineering.

The stratigraphic units have been modeled as homogeneous and isotropic. Parameters were based on testing and typical values, and the model has been calibrated to match the seepage rates currently recorded. Unit values of flow are extrapolated over a distance of 300 m to arrive at total flow rates.

The Board expresses some unease with these simplified assumptions as local high conductivity pathways have been indicated by Willowstick geophysical survey, by geotechnical drilling and by observations made during construction.

When the unit flow values are extrapolated over shorter distances to simulate the high conductivity zones identified by Willowstick, the necessary values for permeability to arrive at the measured flows exceed the values obtained by in-situ testing. However, it is suggested by AEM that the possibility exists that the limits of pump capacity was reached when the tests were conducted.

The Board is concerned that large conductors such as the cavities apparently shown in the acoustic televiewer surveys may indeed provide pathways for the migration of tailings under pressure. The hypothesis of a complete tailings coverage over the floor of the basin would then be no longer valid and seepage quantities would continue to rise in proportion to the pond level and may overwhelm the transfer pump capacity. This could constitute an upset condition for the central dike that could jeopardize mine operations. The Board recommends that models of this potentially more critical configuration be developed wherein holes of variable extent are assumed along the Willowstick conductors and the variation between discharge and pond level is computed. These should contribute to alternate Trigger Action Response Plan (TARP) considerations.

The Board wishes to be advised of the guidance that AEM will receive to safely operate the facility in the short term. It is to be noted that additional investigations, instrument installations and analyses are planned for the coming months.

## 3.0 STORMWATER DIKE

In August 2016, deformation of the downstream shell of Stormwater Dike was noted by the appearance of cracks in the dike crest between Stns. 10+500 and 10+750. The Board had the opportunity to observe this cracking when on site for the September 2016 meeting (Meeting #19).

Subsequently, the construction records have been examined and boreholes have been drilled to determine the nature of the foundation and to install piezometers and thermistors. The possible mechanism for the movement was discussed at the meeting #19 and the primary cause was deemed to be related to the rising pond level in the South cell which inundated the toe of the Stormwater Dike and introduced a heat flux sufficient to thaw frozen materials.

The study has revealed that the foundation for the 2010 embankment fill that constitutes the downstream toe, was prepared in winter conditions. The previous talik area beneath 2nd Portage Lake froze after lake draining and the cold conditions were locked in by the embankment fill. Freezing could have prevented the sediments from consolidating under the load of the embankment. The lakebed topography is such that any seepage and precipitation would drain away from the toe. Advective air currents in the rockfill could enhance the freezing process. Only when pond water in the South cell rose to the point of entering the toe of Stormwater Dike in 2016 could thaw be initiated. Therefore, the hypothesis is that the rockfill which had been placed on a frozen foundation finally penetrated the lakebed sediments as they thawed or that consolidation settlement renewed and a generalized movement of the embankment took place in the affected area.

The Board is satisfied that this represents a plausible mechanism for the occurrence of the observed cracking. Furthermore, the Board considers the construction of the stabilizing toe berm to be the appropriate response and anticipates that future behaviour as predicted by the slope stability analyses carried out by Golder, will be satisfactory. Nevertheless, the Board wishes to receive the final report before drawing further conclusions. It is suggested that the conditions for the stability analyses be reviewed to evaluate whether excess pore pressures or undrained strength should be included.

## 4.0 RESPONSES

Responses to the Board's observations and recommendations were transmitted by AEM on October 30th, 2017.

As far as the Central Dike is concerned, the responses covered the comments relating to:

- Inclusion of permafrost boundaries in future 3-D seepage analyses;
- Consideration for possible high conductivity pathways in the bedrock and overburden, and;
- Planning for monitoring and Trigger Action Response Plans to ensure safe operation.

It was pointed out that the final Golder report on the Stormwater dike includes the sensitivity analyses for the dike stability evaluation that covers the question of excess pore pressures in the effective stress analyses and makes mention of the undrained strength analyses.

The Board is satisfied with these responses insofar as they indicate actions taken or planned for in future work. As mentioned above, the topics have already received further attention in the course of the meeting #22 held on site in September, 2017.

## 5.0 ACKNOWLEDGMENTS

The Board once again wishes to thank the personnel of AEM and GAL for the excellent documentation and presentations which contributed to the efficiency and effectiveness of the proceedings.

Signed:

Norbert R. Morgenstern, P.Eng. Don W. Hayley, P.Eng D. Anthony Rattue, P.Eng.

ATTACHMENT A

AGENDA FOR BOARD MEETING NO. 20

March 23rd, 2017

Webex conference call, start at 9:00 am Central Time

9h00 **Connections on Webex**

9h05 **Meeting introduction** [AEM]

9h15 **Central Dike Seepage – Seepage Analysis Update – (P2)** [GAL]

10h30 **Stormwater Dike – Stability Analysis Update – (P3)** [GAL]

11h15 **Comments from the Board**

12h00 **End of the meeting**

August 7th, 2017

Mr. Bertin Paradis
General Manager
Agnico–Eagle Mines, Meadowbank Division
Baker Lake Office

Email: bertin.paradis@agnico-eagle.com

Dear Mr. Paradis,

Report No 21
Meadowbank Mine Dike Review Board
Meeting July 19, 2017

## 1.0 INTRODUCTION

The meeting of the Dike Review Board was held in the offices of SNC-Lavalin in Montréal on July 19th. Though the Board is comprised of three members, only Mr. D. W. Hayley and Mr. D. A. Rattue participated in the meeting. Dr. N. R. Morgenstern was unable to attend the meeting but has reviewed the material and has contributed to the report preparation.

The objectives were to review the status of the investigations and design studies for the Amaruq Project and, more specifically, the Whale Tail Dike.

The agenda for the meeting is included in Appendix A and the list of attendees at the meeting is given in Appendix B.

Paper copies of the various PowerPoint presentations were provided by Agnico-Eagle Mines (AEM) and SNC-Lavalin Inc. (SLI) during the meeting. Digital versions were also supplied at the end of the meeting to facilitate archiving.

The Board's comments and recommendations are underlined in the text.

## 2.0 MANAGEMENT AND OPERATIONS UPDATE

AEM provided an update on the overall project status for information. As the project is on a fast track, three groups are working in parallel. Rock mechanics for the mine pit will be covered by Knight Piesold, Hydrogeology by Golder Associates Limited (GAL), and SNC-Lavalin will deal with the Water Infrastructures. Investigations have indicated greater reserves in the area with increased footprints for the Whale Tail and IVR pits and for the waste rock storage facilities. The project is on schedule and construction of the Whale Tail Dike (WTD) is planned for the second quarter of 2018 to the second quarter of 2019. Operation planning indicates pit closure in 2024.

## 3.0 FIELD INVESTIGATIONS

The field campaigns have now extended over three winter seasons (2015, 2016 and 2017).

Construction materials have been identified at three eskers in relatively close proximity to the works. Esker #8 which parallels the shoreline on the west abutment of the WTD, has been estimated to contain approximately 50,000 $m^3$ of granular material. That estimate requires verification as no samples have been obtained at depth to date.

Fourteen boreholes were put down in the footprint of the WTD during the 2017 campaign. As far as the bedrock profile is concerned, the additional boreholes have permitted a more precise image but the anomaly encountered in 2016 by borehole AMQ16-WTD-013 that showed localized overburden thickness of 55 m remains to be explained.

Bedrock structure such as open joints and fracture zones were identified with a downhole camera (televiewer). The Board has received the detailed investigation report and makes the following comments. The optical and acoustic televiewer images indicate the presence of significant structural discontinuities in the bedrock. The Schmidt plots show that foliation predominates with structures striking parallel to the dike axis and dipping upstream. These features account for most of the openings. However, joint sets also strike perpendicular to the dike axis.

Hydraulic conductivity testing revealed values varying between $1.7x10^{-6}$ cm/s and $1.6x10^{-2}$ cm/s which denotes the potential for significant seepage.

The rock type is Greywacke with major Diorite intrusions.

## 4.0 THERMAL ANALYSES

Construction and operation of the WTD will alter the thermal regime in the vicinity of the dike and consideration of this effect is needed to ensure satisfactory performance. Permafrost conditions are noted on the abutments and in shallow water within the footprint, with a talik in deeper water near the western shore. Dewatering on the downstream side of the WTD will likely lead to permafrost aggradation in the exposed lakebed. However, on the upstream side where the water depth will increase by about 3.5 m, permafrost degradation will occur. Thermal analyses have been carried out by SLI to assist with understanding the consequences.

A longitudinal section across the lake was selected. Natural thermal conditions have been derived from two thermistor strings in the dike footprint complemented by the transposition of

readings from two other strings located in the vicinity of the Whale Tail Pit (WTP). The WTP installations are inclined and provide data for on-land permafrost conditions and beneath the lake.

Among the input parameters, the Board noted the selection of 2°C as a constant value representing the lake temperature. The Board recommends that this value be verified, as 4°C is commonly used as the average water temperature boundary condition for northern lakes. At least a sensitivity analysis on the effect of higher lake temperatures should be carried out. The current simulations may not be conservative.

The analyses were 2-dimensional and for the longitudinal section simulation of conditions immediately upstream of the WTD, thaw of the permafrost below the east abutment to a depth of 9 m is predicted over a 20-year time span. This phenomenon would obviously be accelerated with a 4°C water temperature.

The analyses clearly show the need to consider the thaw effect or to provide measures to reduce thaw as a component of the design concept. For detailed design, it has been indicated that transverse sections will be studied and the Board agrees that these will be required with particular emphasis on the abutments.

Though the life of mine for the WT pit is currently set at 5 years, and the thermal analysis simulation period is 20 years, consideration may be warranted to do a sensitivity analysis for a longer period, say 50 years to ensure functionality throughout closure and land reclamation .

## 5.0 HYDROGEOLOGICAL SEEPAGE ANALYSIS

Two models have been developed, both based on a section transverse to the WTD axis. The first, a small scale global model examines the influence of the geology on groundwater flow from beneath the dike towards the attenuation pond and into the WTP. The second, on a larger scale, examines the local conditions beneath the dike.

The hydraulic conductivity measurements from the 2016 and 2017 field investigations have been compiled and used to generate parameters for the hydrogeological simulations.

The area downstream is assumed to be dewatered, with the exception of the attenuation pond, while the upstream lake level is increased from the natural elevation of 152.5 m to 156 m.

For the global model, the simulation was used to ascertain the influence of different grout curtain depths on the seepage flux. The fractured bedrock zone has been modelled as a homogeneous isotropic layer of 30 m depth. As the grout curtain maximum depth was 15 m, the efficiency did not vary to a significant degree, as may be expected. It is suggested that the actual rock conditions may be anisotropic and, other than joint filling influence, would be expected to have a progressively diminishing conductivity with depth. The Board suggests that future studies investigate these aspects. However, the current studies provide an order of magnitude of anticipated seepage that would be captured by the attenuation pond or discharged into the pit. Discussions with AEM will be warranted to determine the design criteria for detailed design of the WTD.

The local model was also used to examine the influence of grout curtain depth. The conductivity along various lengths of the dike axis was adjusted, for the computation of total

flow, to take into account the observed values in the boreholes. However, a constant value for conductivity (presumably an average value) over the 30 m depth of the upper fractured rock horizon was again used. The grout curtain depth did have an influence on flux and on hydraulic gradients beneath the downstream shell but perhaps not to the extent that may be obtained if the rock conductivity actually decreases progressively with depth. It is recommended that this aspect be evaluated.

Given the overall seepage flux entering the attenuation pond based on the simulations, it has been concluded by SLI that inflow to the attenuation pond will likely be dominated by precipitation and snowmelt run-off rather than seepage beneath the WTD.

## 6.0 WHALE TAIL DIKE PRE-FEASIBILITY DESIGN

The WTD basic comparative design by SLI has drawn on the experience gained by AEM on the water retaining structures for the Portage and Bay-Goose pits. The preliminary section is composed of double groins across the lakebed to provide a working platform leaving a central space for excavation of the sediments, boulders, and other overburden presumed to be till, permitting the central core of fine filter and a downstream coarse filter to be placed on rock. The remaining embankment to crest elevation is placed in the dry. The low permeability element for control of underseepage in the base design would have included a soil-bentonite seepage control element (SB or CSB). This basic design was developed from Meadowbank experience and can be use as a basis for comparison of other options.

On the abutments, the central trench is excavated through the overburden materials down to bedrock including blasting if required. A fine filter central zone and a coarse filter are placed in layers. The low permeable cut-off would probably be of cement-soil-bentonite (CSB).

Both sections included curtain grouting of the bedrock below the CSB cutoff curtain.

The design team has proceeded, following early recommendations of the Board, to examine alternative cut-off techniques. The range of additional possibilities examined include:

- Plastic concrete;
- Steel sheet piles;
- Secant piles;
- Freeze wall;
- Rockfill embankment with geomembrane.

The base case was taken as CSB throughout rather than SB. The final outcome of the alternatives assessment is to move forward with Secant piles or CSB for comparative studies.

The Board was presented with the following site information that can impact the selection of alternative measures to control underseepage.

### 6.1 Thermal regime

The thermistors installed in the dike foundation indicate that permafrost in foundation soils extends from the east abutment to about one third of the width of the lake due to the shallow water depth. The permafrost may have influenced the rock conductivity measurements though only values obtained from known unfrozen areas were used in the simulations.

The current dam cross-section applicable to unfrozen foundation conditions includes excavation between the groins to rock and placement of the fine filter central zone with coarse filters on both upstream and downstream sides. The drawings indicate a grout curtain below the secant pile cut-off. This may be questionable if the embedment of the secant pile wall is sufficient to limit seepage magnitude to a manageable risk.

### 6.2 Construction materials

It was pointed out during the meeting that the coarse filter will be selected with a maximum particle size of 80 mm rather than the150 mm shown on the grain size envelopes (slide 48).

Rockfill will be obtained from a quarry operation within the footprint of the future WTP. Fine and coarse filters will be based on granular materials though the availability in esker #8 (east abutment) may be insufficient and recourse to #7 or #9 will required to satisfy needs.

### 6.3 Grout curtain

It is envisaged that the secant pile option may involve keying the cut-off into rock with a view to avoiding the need to carry out curtain grouting. The seepage analyses indicate satisfactory hydraulic gradients beneath the shells for the case without grouting.

The grouting could be limited to the more highly conductive zone between Stns. 0+225 and 0+500. Grouting in frozen ground is recognized as being problematic.

### 6.4 Abutments

The presence of the esker on the west abutment will necessitate excavation of this material prior to placement of engineered embankment fill for the central zones. On the eastern abutment, the foundation preparation will only involve excavation of the active layer if a secant pile cut-off solution is adopted.

### 6.5 Mix design

Several specialist contractors have been contacted for input to the cut-off design. The mix may be a cement-bentonite with 400 kg/m3 of GU cement and 45 kg/m3 of bentonite.

### 6.6 Conclusions

The design team have concluded that the Secant Pile wall option, though more expensive and requiring the importation of more cement, offers greater flexibility to adapt to site conditions. Furthermore, contact grouting may possibly be avoided.

## 7.0 RISK ASSESSMENT

A risk assessment has been carried out by AEM with the participation of SLI and GAL. Based on this and on the PFS design completed to date, AEM favours the CB wall cut-off but recognizes that the cut-off must be completed before the onset of cold weather.

The construction schedule may be the driver and consequently the two designs will be advanced in parallel to permit the choice to be made in a timely manner but based on more

extensive studies than currently available. The construction technique needs to be established by January 2018. The Board advises that the availability of the large secant pile drill machines needs to added to the equation.

## 8.0 BOARD COMMENTS ON THE WTD DESIGN

### 8.1 General cross-section

The slopes indicated for the interface between internal zones while flatter (1.3H:1V) than the earlier drawings (0.75H:1V) may still be steeper than the angle of repose of these materials, particularly if rounded natural particles are used. Incorporation of a crushed material fraction may help to ensure steeper angles of repose and facilitate placement of the coarse filter on the sides of the excavated central trench.

In order to facilitate production of satisfactory quarried products for dike construction, the drill pattern and powder factors may be adjusted from those normally adopted for mining operations.

If the grout curtain is to be omitted, consideration may be given to adding a filter blanket over the downstream shell foundation.

The Board concurs with the decision to restrict the maximum particle size in the filters to 80 mm.

### 8.2 CSB wall

The Board agrees that CSB should replace the SB in the base case for comparison with the SP option.

The CSB option has the advantage for AEM of their previous experience.

Keying into rock with conventional excavators is not feasible therefore a grout curtain is required for the upper fractured bedrock contact. Approximately one third of the centreline (East side) is located on permafrost till and /or rock that is not effective for grout injection. This factor alone renders the CSB cutoff option highly questionable from a performance perspective.

The abutments of the previous water retention dikes were not subject to increased water level above the natural lake level and to the thermal consequences thereof.

The deep excavation to rock at the abutments together with backfilling with a pervious material will encourage direct contact with lake water and accelerated thaw of the permafrost. However, during construction, grouting of the rock will have been precluded by the presence of permafrost. Consequently, the construction technique is ill adapted to providing a seepage barrier in the rock.

### 8.3 Secant piles (SP)

The method should permit keying into the bedrock (depth to be determined) whether in frozen or unfrozen conditions.

If it can be demonstrated that the upper meter or two would be the main avenue for seepage and the fractured rock zone can be penetrated then a grout curtain may not be a requirement.

As no deep excavation is indicated at the abutments, the heat source from a large open excavation to the bedrock and the subsequent penetration by lake water into the pervious backfill will be avoided and this will minimize impact on permafrost within the abutments.

However, the above advantages suppose the ability to penetrate the till overburden to reach and subsequently penetrate bedrock for an effective cutoff. The potential incidence of boulders that could restrict drilling depth along the alignment needs to be evaluated. Core photos and drill logs may have this information and should be further interrogated.

The need for curtain grouting associated with an SP cutoff wall is less likely but cannot be reasonably determined until after the SP wall is in operation. It can therefore be deferred until data collected from instrumentation strongly suggests there is value in its implementation.

The above mentioned deep overburden (or highly weathered rock) encountered in borehole AMQ16-WTD-013 could be effectively treated by the SP option.

### 8.4 Additional comments on thermal aspects

Further work is required to address the permafrost issues at the abutments. Preservation of the permafrost may be an option. As the construction season will extend into the second quarter of 2019, one winter season is available for passive thermosyphon operation if required. In addition, with a view to limiting thaw settlement at the upstream toe of the embankment, an insulating blanket of rockfill or granular material extending above future lake level may be added on the abutments on the upstream side.

### 8.5 Constructability risk

The project team should carry out a constructability risk based analysis of the two options as part of the subsequent engineering studies. The Board suspects that this may result in a re-ranking in favour of the Secant Pile wall option regardless of the current cost based ranking.

### 8.6 Conclusion

The priority should be to achieve a working cut-off wall that satisfies the requirement of erosion resistance. The secant piles may be extended deeper into rock than the nominal 1-2 m and close off upper fractured rock. Sound rock should be minimum target. Grouting may still be required but if erosion resistance has been assured this may be part of incremental seepage reduction aligned with established tolerable pumping rates.

Frozen ground has to be considered in any option. This may influence:

- the constructability e.g grout curtain:
- seepage through thaw zones;
- decision whether to preserve permafrost or re-instate permafrost through the use of thermosyphons. Note that, as mentioned above, one full winter of passive operation will likely suffice.

## 9.0 OTHER ASPECTS

It was noted that the PAG/NPAG ratio for the WTP is about 50/50 whereas the IVR pit rock is mainly PAG. AEM mentioned that progressive capping of the Waste Rock Storage Facilities will be designed to alleviate this potential shortage of NPAG rock at closure.

## 10.0 NEXT MEETING

The Board has been advised that the next meeting will be a site visit to be held from September 4-7, 2017

## 11.0 ACKNOWLEDGMENTS

The Board once again wishes to thank the personnel of AEM and SLI for the excellent documentation and presentations which contributed to the efficiency and effectiveness of the proceedings.

Signed:

Norbert R. Morgenstern, P.Eng. Don W. Hayley, P.Eng D. Anthony Rattue, P.Eng.

ATTACHMENT A

AGENDA FOR BOARD MEETING NO. 21

July 19th, 2017

## MDRB #21 AGENDA

8h00 **Meeting introduction** [AEM]

8h05 **Amaruq Water Management Strategy** – **(P1)** [AEM]

9h00 **Field Investigations – (P2)** [SNC]

10h00 Break

10h15 **Whale Tail Dike Thermal Analysis (P3)** [SNC]

11h00 **Whale Tail Dike Hydrogeological Seepage Analysis – (P4)** [SNC]

12h15 Lunch

13h00 **Whale Tail Dike PFS designs: Slurry wall & Secant Pile– (P5)** [SNC]

15h15 **Risk assessment and selection of construction technic – (P6)** [AEM]

15h45 Break

16h00 **Deliberation by Board Members**

16h30 **Preliminary Report by the Board Members**

17h00 **End of the meeting**

ATTACHMENT B

ATTENDANCE AT JULY 2017 MEETING
Held in SNC-Lavalin offices, Montreal

| Attendance | | |
|---|---|---|
| | | |
| Julie Bélanger | AEM | Engineering Superintendent |
| Fréderic Bolduc | AEM | |
| Michel Groleau | AEM | |
| Thomas Lépine | AEM | |
| Pierre McMullen | AEM | |
| François Petrucci | AEM | (By phone link) |
| | | |
| Angie Arbaiza | SNC-Lavalin | |
| Géraldine Cossette | SNC-Lavalin | |
| Yohan Jalbert | SNC-Lavalin | |
| Les MacPhie | SNC-Lavalin | |
| Dominique Tremblay | SNC-Lavalin | |
| | | |
| Don Hayley | | Dike Review Board |
| Anthony Rattue | | Dike Review Board |
| | | |
| | | |

October 10th, 2017

Mr. Luc Chouinard
General Manager
Agnico–Eagle Mines, Meadowbank Division
Baker Lake Office

Email: luc.chouinard@agnico-eagle.com

Dear Mr. Chouinard,

Report No 22
Meadowbank Mine Dike Review Board
Meeting September 4-7, 2017

## 1.0 INTRODUCTION

The meeting of the Dike Review Board was held on site as planned from September 4th to 7th. The Board is comprised of three members, Mr. D. W. Hayley, Dr. N. R. Morgenstern and Mr. D. A. Rattue. Dr. Morgenstern was unable to attend this meeting but has subsequently examined the documentation provided and has contributed to the present report.

The objectives were to review the status of the design, construction and operation of water and tailings retention structures at Meadowbank, and adaptation of the facilities to accommodate the production of the Amaruq project. A visit to the latter site was also included in the activities.

The activities covered those outlined in the agenda which is included as Appendix A. The Board made two field visits during the meeting, namely: a first, by helicopter to the Amaruq site but also an overview of the Meadowbank site facilities, and a second, by vehicle and on foot to observe conditions at Stormwater Dike, Central Dike, the Saddle Dams, and the Bay-Goose Dike above the push-back of Portage Pit.

The list of attendees at the meeting is given in Appendix B.

Paper copies of the various PowerPoint presentations were provided by Agnico-Eagle Mines (AEM), Golder Associates Limited (GAL) and SNC-Lavalin Inc. (SLI) during the meeting. Digital versions were also supplied at the end of the meeting to facilitate archiving.

A selection of photographs taken during the visits is to be found in Appendix C.

In the report which follows, the Board has included a section to give greater visibility to the major issues and following on with other matters. The recommendations are underlined in the text.

## 2.0 MANAGEMENT AND OPERATIONS UPDATE

AEM provided an update on the mine status for information.

The currently projected life of mine (LOM) for the Meadowbank and Vault pits is still into the third quarter of 2018 including the push-back of the Portage Pit. Construction of infrastructure to support the Amaruq pits is well advanced with the access road and temporary camp.

## 3.0 KEY ISSUES

As a result of the meeting No 22, the Board wishes to highlight the following issues. These are described in more detail in subsequent sections.

### 3.1 Central Dike

The Board still has concerns over the performance of Central Dike, though conditions are apparently stable at this time.

A void interpreted from the investigations and the instrument installation program merits further field work.

The Trigger Action Response Plan for the dike needs revision but should be implemented as soon as possible.

### 3.2 Amaruq

Though no additional information was provided at this time, the site visit enabled the Board to better appreciate site conditions for the Whale Tail Dike and Diversion Channel. Potential construction difficulties should not be underestimated, and robust and adaptable construction techniques will be essential to permit the fast-track program to succeed.

## 4.0 RESPONSE TO REPORTS NOS 19 and 20

A summary of the responses to the Board Reports was presented during the meeting. The Board is content that all items have been or are being addressed and hence no significant items are outstanding.

## 5.0 DEWATERING DIKE PERFORMANCE

Over the twelve-month period since the previous meeting, no unanticipated behaviour has been observed in any of the dewatering dikes i.e. East Dike and Bay-Goose as well as South Camp Dike and Vault Dike. The performance has been similar to last year. Piezometer and temperature readings vary according to seasonal cycles. Some piezometers may indicate a rise during freshet. However, the plots for others show a slow steady rise during the late winter period and a decline in the spring. This phenomenon may be due to seasonal freezing of the ground in the area downstream of the dike toe which inhibits seepage flow release, followed by pressure dissipation as the ground thaws.

Additional instruments have been installed in the vicinity of the North Channel of the Bay-Goose Dike in order to improve monitoring capabilities during the push back of sector E5 of Portage

Pit. Blast vibration monitoring has shown that the limit of peak particle velocity in the vicinity of the dike (50 mm/s) has been respected with maximum measured values in the 33 to 38 range.

## 6.0 STORMWATER DIKE

### 6.1 Introduction

The site team noted the first signs of cracking on the crest of the Stormwater Dike in August 2016. These subsequently spread and widened and indicated a deep-seated movement. It was concluded by AEM and GAL that the deformation originated in the sediments in the dike foundation. Stability analyses led to the decision to construct a rockfill berm at the toe. The movements are deemed to be the result of thaw settlement in the sediments and till foundation that was exposed to freezing conditions from the time of construction of the dike until pond raising initiated a thaw process.

### 6.2 2017

As the South Cell pond level rises (131 m in September 2016, 137 m in September 2017) inundating a greater length of the Stormwater Dike footprint (Photo #1), additional thaw settlement could be expected. This effect has materialized and additional movements and cracking have been observed since July 2017. Settlement at the downstream side of the crest has attained 70 cm (Photo #2), though it is noted that the deformation on the upstream side is considerably less and the integrity of the Coletanche liner is not jeopardized. Furthermore, the tailings deposited in the North Cell adjacent to the liner are now frozen. The area influenced by cracking now extends from Stn. 10+425 to Stn. 11+050. Additional prisms mounted on large boulders (Photo #3) and wire extensometers have been added to complement those installed in 2016.

### 6.3 Board Observations

The Board judges that:

- the deformation is adequately monitored but monitoring needs to be continued;
- the mechanism is reasonably well understood;
- continuation of movements is to be expected;
- now that most of the toe length is submerged, additional water level rise is likely to be less influential than the effect of time and the available heat flux from the pond water;
- the formation of a tailings beach along the downstream side of the Stormwater Dike would be useful in limiting the heat flux and eventually permitting freeze-back in the area.

In the previous report the Board recommended filling the cracks on the crest with bentonite to prevent ingress of rainwater, it would be advisable to continue this operation for the recent cracks. The finer cracks could be filled with bentonite but the wider ones could be treated with a bentonite-sand mixture to reduce shrinkage. This action would reduce the risk of pressures in the back scarp that could accelerate deformation.

Survey prisms have been installed on large boulders as may be appreciated from photo #3. The results indicate a tendency for the blocks to undergo local movement due to freezing of the crest and subsequent thaw. This limits their ability to represent true crest movements at these times. Evolution during the summer season may be adequately monitored but the evaluation of apparent movements in the spring and fall requires judgement.

As noted previously, the instruments P13265 and T147-1 were destroyed by the berm construction in 2016. The Board's recommendation to replace these instruments has been acted upon.

The thermistor chain SWD-02 installed at the downstream toe confirms that the till foundation is still frozen at mid-depth and that a talik exists in the bedrock. The piezometric level in rock at depth is some 7 m below the pond elevation, indicating a strong downward gradient and a potential source of the groundwater that appears in the seepage collection pond downstream of Central Dike.

The instruments installed in borehole SWD-03 confirm the presence of frozen till in the foundation with an underlying talik and also the downward piezometric gradient.

## 7.0 CONSTRUCTION PROGRESS

Construction activities at the Meadowbank Tailings Storage Facility in 2017 consisted of Stage 3 raises to the Central Dike, and Saddle Dams 3, 4 and 5 to bring the crest level to 145 m. At SD-3, SD-4 and SD-5, the limits of the foundation excavation covered the requirements for an eventual raise to el. 150 m.

The works were carried out by the same Contractors as in previous years however; more use was made of mine haulage equipment which was available this year.
The Board considers that:

- the work was well managed;
- appropriate field adaptation was made to the SD-3 axis to avoid the adjacent quarry;
- an appropriate approach was used in dealing with ground ice and allowing it to remain under the downstream shell.

As SD-3 will likely not be covered by a tailings beach, a protective layer of till and rockfill has been placed over the LLDPE liner. The Board recommends that the placement of additional rockfill be considered in order to encourage freeze-back of the foundation at the upstream toe and thus limit the potential for under-seepage.

## 8.0 CENTRAL DIKE INVESTIGATIONS

Significant seepage emanates from the toe of Central Dike with flow rates that increased in proportion to the head difference between the South Cell pond elevation and the downstream toe until such time as the deposition of tailings resulted in a blanketing effect. However, the seepage rates have not declined to the extent predicted by the numerical models.

In report No. 19, the Board expressed its concern over the situation despite the fact that the pumping equipment mobilized was able to evacuate the inflow to the seepage collection pond. The location of seepage pathways and the potential for erosion of foundation materials or joint fillings are the major unknowns.

AEM and GAL have been responsive to these concerns. Geotechnical investigations and the installation of additional instruments have been carried since the meeting in September 2016.

The Board is favourably impressed by the exercise that has been carried out to evaluate the measured hydraulic conductivities along with the rock cores and optical/acoustic televiewer images for joint and crack delimitation. An excellent presentation of this analysis was given to the Board. The work permits an appreciation of the role that the fractured rock plays in the transmissivity of the different rock formations.

The geotechnical drilling revealed an apparent void in borehole 700-P1 at the interface of the embankment fill and the foundation. This merits further investigation to confirm the presence of a void and its extent. The borehole location is along a line parallel to the second portage fault and passing through the area where overburden was left in the base of the cut-off trench. The potential for erosion cannot be discounted for the moment, despite the fact that no adverse reaction has been observed in the piezometer measurements. The high conductivities, including the void detected in the foundation, highlight the vulnerability of the situation.

Note that visual observation of the toe of the Central Dike cannot be made due to the presence of the pond as shown in Photo #6. Maintaining the pond at el. 115 m provides useful back pressure to control seepage and the Board concurs with this approach.

The Board suggests that geophysical specialists be consulted to ascertain whether Ground Penetrating Radar (GPR) and/or resistivity surveys could be expected to give useful results in the conditions (rockfill) at the location of hole 700-P1. Subsequent drilling would focus on any anomalies revealed by such surveys.

## 9.0 CENTRAL DIKE PERFORMANCE

The Board had been previously advised (Teleconference Meeting No. 20) of the appearance of chemical/bacteriological deposits in the seepage collection pond at the Central Dike toe (Photos #4 and #6). The comprehensive monitoring, both visual and by instrumentation, is on-going. The situation seems to be basically stable given the boundary conditions of south cell pond rise and continued tailings deposition.

There are still some anomalous instrument readings, particularly the unexplained high suction values. The Board requests that piezometer readings taken at the time of installation be re-examined to attempt to gain an understanding of the low-pressure values. Apparently, the piezometer filters are of the sintered metal variety (not ceramic). Unless the piezometers were installed in an inverted position, it is possible that de-saturation occurred during installation and/or during the curing of the cement grout which surrounds the instruments. Piezometric values that clearly do not represent field conditions could be removed from the instrument plots, though readings should continue to be taken in case the saturation is re-established.

The plausible instrument readings, including the recent installations, indicate a basically stable situation.

Chemical analysis of seepage water continues. The turbidity values in the downstream pond have varied up to a maximum value of 38NTU. Total suspended solids (TSS) are usually in the 0-10 mg/L range with an average of about 5 mg/L which is inferior to the south cell pond water value of about 15 mg/L. Metal concentrations are also lower than in the South Cell.

A depression in the sub-aqueous tailings surface was observed in July, from aerial reconnaissance, adjacent to SD-4. As the bedrock in this area is suspected to provide one of

the avenues for the seepage flows, the tailings deposition points were managed in such a way as to encourage blanketing by tailings. Despite rising pond levels, a gradual decrease in seepage flows is noted.

The temperature measurements still indicate a talik beneath the West Road in the vicinity of instruments 875-P3 and 975-P3. The potential for seepage flow to the Portage Pit (Photo #5) exists but flow captured by the in-pit pumping is apparently inferior to the quantity pumped from the seepage collection pond at the dike toe.

AEM has set out an action plan that is commensurate with the orange alert level which is maintained for the moment. This plan is outlined on pages 115 to 120 of the presentation P6-Central Dike Update submitted to the Board. The Board concurs with the action plan but questions the need to carry out additional 2D and 3D numerical analysis. Plotting of piezometric values along the presumed potential seepage pathways, including the oblique second Portage Fault alignment, may be more revealing than seepage modelling.

## 10.0 TRIGGER ACTION RESPONSE PLAN

In addition to the above-mentioned action plan, AEM and GAL have prepared a Trigger Action Response Plan (TARP) to ensure timely response to adverse changes in the Central Dike performance.

The Board views the plan as being a good start and one that addresses the major concerns. However, it is a work in progress. The alert notification needs some revision for certain scenarios. Given the ongoing orange alert status, the application of the TARP should be immediate and priority effort should be given to the required revisions.

## 11.0 TAILINGS STORAGE FACILITY OPERATION

### 11.1 South Cell

The Board was provided with an update of the tailings deposition plan for the South Cell. Until such time as approval for In-Pit-Deposition is obtained, the South Cell continues to accommodate the full mine production and constitutes the basin from which reclaim water is drawn.

The planning and operations continue to be State-of-the-Art. Deposition parameters, slope angles, densities etc., are updated on a year-to-year basis in the use of the software planning tool calibration and previsions.

A strategy of minimizing the south cell pond elevation while ensuring adequate water reclaim is part of the exercise. Consequently, seepage water is no longer pumped back into the South Cell but directed to the Bay-Goose Pit (Photo #8).

The Board recommends continuation of a deposition plan to encourage beaching along the SD-4 to SD-3 shoreline (Photo #7).

In view of the need to optimize tailings deposition that not only provides beaches along the geomembrane lined structures but also blankets suspected seepage entry points, a review of

the design criteria would be timely to ensure that all participants in the operation are working as efficiently as possible towards a common goal.

### 11.2 North Cell

The north cell is now dormant but monitoring continues. Temperature conditions beneath the Saddle dams indicate general cooling in near surface locations such that the now frozen ground contributes to limit seepage flow. Freezing of the tailings is also noted in all areas with the exception of locations in or near the pond boundaries as would be expected.

## 12.0 PIT SLOPE STABILITY AND PUSH BACK OF PORTAGE PIT

An appropriate high-quality review of the pit slope design is being carried out.

The monitoring by AEM continues to be of good standard including the use of radar for early indication of any movement. Rock falls continue to occur particularly in the ultramafic formations in Portage Pit A. Mining will cease in this area at the end of 2017.

As far as Portage Pit E is concerned, where push-back is on-going (Photo #9), instability of the Ultramafics is also noted but overall pit slope performance is judged to be good. In-place inclinometers and Time Domaine Reflectometer cables have been added to the instrumentation. Reliability of the inclinometers is considered marginal possibly due to inadequate grout installation of the casing. A Trigger Action Response Plan has been developed for the operation of this pit.

Good pit wall stability is reported for the Vault and Phaser Pits.
Ice walls are observed at some locations with accumulation depending on water source and orientation, particularly on the north facing wall of Goose Pit, where less control of surface water is exerted compared to the mining period.

## 13.0 AMARUQ

### 13.1 Introduction

The Board was given an update on the Amaruq project planning but, no presentations were made on the design work for the actual mine site as this was covered in meeting No 21 held in July 2017.

### 13.2 In-pit tailings deposition

Ore from the Amaruq pits will be processed at Meadowbank and consequently the capacity for tailings disposal is also required at this location. Given the concern with the under-seepage at Central Dike, the preferred option for the Amaruq operation will be in-pit disposal in the mined-out Portage and Goose Pits. Approval is still required but studies are ongoing to demonstrate the feasibility. Two presentations were made to the Board relating to Consolidation of the Tailings (pit volume required) and to predictions of ground water impact.

### 13.3 Tailings Consolidation and Water Balance

The study methodology for tailings deposition and consolidation is satisfactory for this stage of the evaluation of tailings and water mass balance. Additional work will be required to verify the minimum depth of water cover at closure to prevent re-suspension of particles due to wave effect and ice-formation. The Board has no further comments or recommendations to make at this time.

### 13.4 Hydro geological contaminant transport model

This study also constitutes a good approach that is adequate for the current level of study. The Board concurs with the recommendations for future work (parameter and geometry refinement for the model) and note that the provision of sampling wells for calibration has been included. This is obviously a long-term exercise with progressive up-date of parameters being required. This will continue into the period of monitoring post mine closure. Similar comments can be made related to the thermal modelling of conditions post-closure.

## 14.0 SITE VISITS

### 14.1 Amaruq by helicopter

After a general flight over the Amaruq site, stops were made on both banks of the Whale Tail Dike and at the proposed location for the Diversion Channel.

A general comment from the Board after having viewed the site is that despite the limited size of the dike and channel, construction difficulties may be under-estimated. This reinforces the previous recommendations that the dike and channel configuration, cross-sections, and construction methods all be selected for robustness and the ability to accommodate field adjustments. This is particularly important given the fast track planning and the possible inability to carry out more intensive site investigations prior to making commitments for construction equipment and imported materials.

### 14.2 Meadowbank site

A visit by vehicle was undertaken to appreciate the current status of the 2017 construction work, the condition of the Stormwater Dike and the downstream seepage collection pond at Central Dike. A brief stop was also made at a point overlooking the Portage Pit push-back area.

For the Stormwater Dike, the Board was able to better appreciate the extent of the cracking and deformations. As mentioned in the above text, filling of the new cracks is warranted. The instrumentation (monuments and simple extensometers) may be rudimentary but will suffice as long as diligent visual observation is also part of the monitoring program.

At the downstream toe of Central Dike, the current turbidity level was noted and it is readily apparent that little detailed observation of local flows is possible. Rockfill baffles across the pool may assist observation during the summer period but would be of little use during the winter and would exacerbate ice accumulation. Consequently, reliance has to be placed on frequent monitoring of pumping flow rates and the results of water sampling. A rapid determination of turbidity and/or TSS is obviously part of the procedure.

## 15.0 PRESENTATION BY MICHEL JULIEN

A discussion was held on the Terms of Reference (TOR) of the MDRB and Independent Reviews in general for AEM. It was agreed that a review of the TOR is justified. Succession planning was also discussed.

The position of Engineer of Record (EOR), a hot topic in the industry, was also reviewed. The approach by AEM would be that the EOR would be part of the internal management team but with the requisite authority to provide independent advice.

## 16.0 NEXT MEETINGS

The Board anticipates that there may be a need to hold conference calls in the coming months on the Amaruq project and on the evolution of the TSF South Cell performance.

No date has been suggested for the next site meeting but early September is viewed as an appropriate time. The Board awaits instruction from AEM in this regard.

## 17.0 ACKNOWLEDGMENTS

The Board once again wishes to thank the personnel of AEM for the organization of logistics and for their participation in the meetings, and for the excellent documentation and presentations made by AEM, GAL and SNC-Lavalin which contributed to the efficiency and effectiveness of the proceedings.

Signed:

Norbert R. Morgenstern, P.Eng. Don W. Hayley, P.Eng D. Anthony Rattue, P.Eng.

ATTACHMENT A

AGENDA FOR BOARD MEETING NO. 22

September 4th to 7th, 2017

# AGENDA

## DAY 1 - SEPTEMBER 4TH 2017

15:30 **P1- Welcome, Review of the Agenda** – [AEM]

16:00 Review of Answers to MDRB Report #19 & 20 [AEM]

16:30 Break

17:00 Site Safety Induction

17:30 **P2 - Overview of Dewatering Dike Performance** – [AEM]

18:30 Dinner

# AGENDA

## DAY 2 - SEPTEMBER 5TH 2017

| | |
|---|---|
| 07:30 | **P3 - Stormwater Dike Update** – [AEM |
| 08:15 | **P5 - Central Dike – Field Investigation & TARP** – [GAL] *(part 1)* |
| 09:45 | Break |
| 10:00 | **P6 - Central Dike – Instrumentation, Performance, Action Plan –** [AEM] *(part 1)* |
| 12:00 | Lunch |
| 12:30 | **Mine Site Tour** |
| 16:00 | **P6 - Central Dike – Instrumentation, Performance, Action Plan –** [AEM] *(part 2)* |
| 08:15 | **P5 - Central Dike – Field Investigation & TARP** – [GAL] *(part 2)* |
| 19:00 | Dinner |

# AGENDA

## DAY 3 - SEPTEMBER 6TH 2017

| | |
|---|---|
| 07:30 | **P7 - Tailings Storage Facilities - Operation** – [AEM] |
| 08:30 | **P8 - Tailings Storage Facilities – Instrumentation Review** - [AEM] |
| 09:00 | Break |
| 09:15 | **P4 - Summary of 2017 Construction Progress (SD3, SD4, SD5)** |
| 09:30 | **P9 - Reviews of Pits Wall Stability and Geomechanics** – [AEM] |
| 10:00 | **Mine Site Tour** |
| 12:00 | Lunch |
| 13:00 | **P10 - Amaruq – Project Update–** [AEM] |
| 13:30 | **P12 - In-Pit Deposition – Consolidation, Water Balance & Quality –** [SNC] |
| 14:30 | **P13 - In-Pit Deposition – Hydrogeological Contaminant Transport Model –** [SNC] |
| 15:30 | Break |
| 15:45 | **Bonus 1 – Debriefing of the site tour** |
| 18:00 | **Bonus 2** – **Independent Review, Engineering record & Liability** |
| 18:30 | End of the meeting |

# AGENDA

## DAY 4 - SEPTEMBER 7TH 2017

| | |
|---|---|
| 07:30 | **Deliberation by the Board Members** |
| 09:30 | **Preliminary Report by the Board Members** |
| 11:00 | Meeting Closure |
| 11:05 | Lunch |
| 12:00 | Approximate Time of Departure |

ATTACHMENT B

ATTENDANCE AT SEPTEMBER 2017 MEETING
Held at the Meadowbank Mine site, Nunavut

| Attendance | | |
|---|---|---|
| | | |
| Michel Julien | AEM | VP, Environment |
| Patrice Gagnon | AEM | Geotechnical Engineer |
| Michel Groleau | AEM | Geotechnical Coordinator |
| Alexandre Lavallée | AEM | Geotechnical EIT |
| Thomas Lepine | AEM | Technical Specialist, Env. Management |
| Pier-Eric McDonald | AEM | Water Engineer |
| Pierre McMullen | | Engineering Superintendent |
| | | |
| Yves Boulianne | GAL | Geotechnical Engineer |
| | | |
| Dominic Tremblay | SNC-Lavalin | Project Manager |
| Guillaume Comeau | SNC-Lavalin | Project Manager, Hydrogeology |
| Anh-Long Nguyen | SNC-Lavalin | Water Treatment Engineer |
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| Don Hayley | | Dike Review Board |
| Anthony Rattue | | Dike Review Board |
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ATTACHMENT C

PHOTOGRAPHS

Photo #1 Stormwater dike

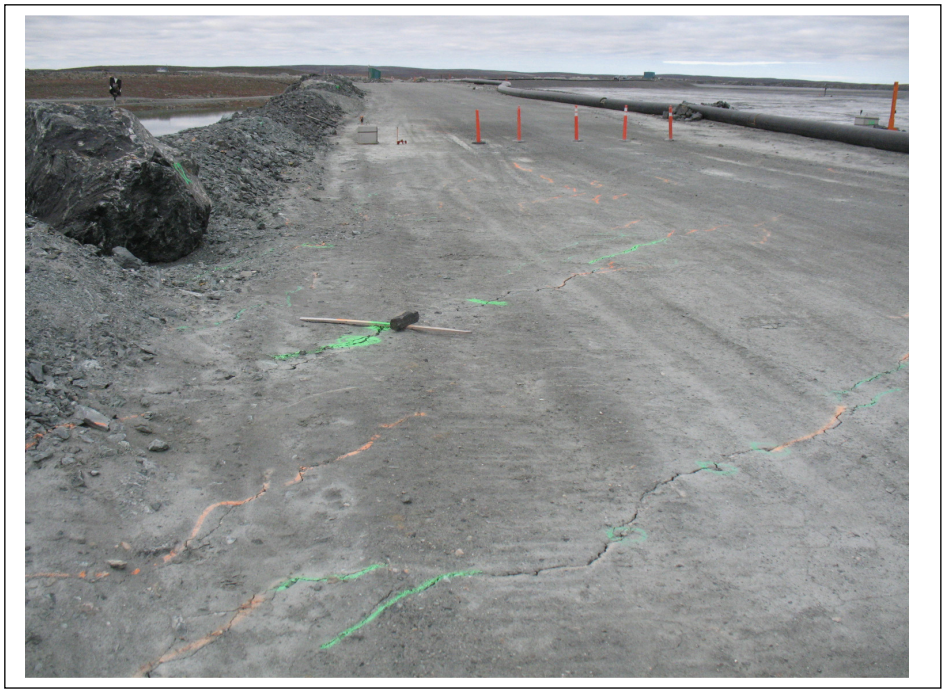

Photo #2 Location of new depression. 70cm max settlement on D/S (left)

Photo #3 Typical survey prism mounted on large boulder

Photo #4 Central Dike. Portage Pit to the left of photo.

Photo #5 Wall of Portage Pit downstream of Central Dike

Photo #6 Seepage collection pond at toe of Central Dike


Photo #7 South Cell of TFS


Photo #8 Goose Pit

Photo #9 Push-back in Portage Pit E5