TECHNICAL MEMORANDUM

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		JOB NO:	06-1122-386 (7000)
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EMAIL:	dchorley@golder.com, cclayton@golder.com		
RE:	**MITIGATIVE MEASURES FOR POTENTIAL SEEPAGE FROM TAILINGS FACILITY**		

1.0 INTRODUCTION

Meadowbank Mining Corporation (MMC), formerly Cumberland Resources Ltd. (Cumberland), is proposing to develop the Meadowbank Gold Project located approximately 70 km north of Baker Lake in Nunavut. The Project is subject to the environmental review and related licensing and permitting processes established by Part 5 of the Nunavut Land Claims Agreement (INAC and TFN, 1993).

On March 31, 2003, Cumberland submitted its Project Description Report for the Meadowbank Gold Project to the Nunavut Impact Review Board (NIRB). Following receipt of the MMC's application and NIRB's screening review, the Minister of the Department of Indian Affairs referred the Project to an environmental impact review under Part 5 or 6 of Article 12 of the Nunavut Land Claims Agreement.

Following submission of a Final Environmental Impact Statement (FEIS), and completion of the screening and environmental impact review process, NIRB recommended that the Project proposal proceed subject to certain terms and conditions. On November 17, 2006, the Minister of Indian and Northern Affairs Canada, on behalf of the federal government and pursuant to Article 12.5.7 of the NLCA, approved the Nunavut Impact Review Board's recommendation and the Meadowbank Gold Mine

Project Certificate (Nunavut Land Claims Agreement Article 12.5.12) was issued (NIRB 2006).

A list of commitments that were made by Cumberland to NIRB at the close of the environmental impact review process was included as part of the NIRB submission to the Minister for approval of the Meadowbank Gold Project. The Nunavut Water Board (NWB) has compiled certain of these commitments into the terms and conditions to be met as part of the water license application for the Project. The following Technical Memorandum is provided to address, in part, Condition #20, which encompasses Commitments 4 and 5 of the final hearing.

1.1 Condition #20: Mitigation Measures to Address Potential Seepage from Tailings along Fault.

Condition #20 states the following:

"Prior to construction, Cumberland shall identify mitigation measures that can be taken if groundwater monitoring around the tailings facility demonstrates that contamination from tailings has occurred through the fault. Upon drawdown of the North arm of Second Portage Lake, Cumberland shall conduct further tests to assess the permeability of any faults and provide the results to regulators. If doubt remains Cumberland shall seal the fault and conduct further permeability testing and monitoring."

The following presents a list of potential mitigation options that could be used should groundwater monitoring around the tailings facility demonstrate contamination from the tailings has occurred through the fault. A detailed Fault Testing and Monitoring Plan outlining the planned testing and monitoring that will be completed within the fault area upon drawdown of the north arm of Second Portage Lake is presented in the *Meadowbank Gold Project Fault Testing and Monitoring Plan* (MMC, 2007a).

Certain aspects relating to NWB Condition #20 have been discussed previously in *Technical Memorandum on "Meadowbank Gold Project Internal Conformity to PHC Decision* (Golder, 2005) as follows:

- Page 3, Section 2.1 – Monitoring of Tailings Freezeback.

- Page 4, Section 2.2 – Key Issue 6.4. This section discusses monitoring of permafrost development within the Tailings Storage Facility (TSF), and mitigation if freezing does not occur as predicted.

- Page 9, Section 5.0 – Item No. 31. This section provides a response to NIRB PHC request for a discussion of the extent to which the Central Dike grout curtain mitigates the effects of seepage through the fault under the Central Dike during operation and post closure.

Portions of the above document are reiterated where necessary below.

1.2 Additional Field Investigations Following March 2006 NIRB Hearings to Investigate Second Portage Fault

Following the public hearings carried out in Baker Lake and surrounding communities, comments and questions relating to the foundation conditions of the Central Dike, and specifically the hydraulic conductivity of the fault through Second Portage Lake, beneath the Central Dike and TSF, comprised a commonly occurring theme to be evaluated further, beyond the mandate of the NIRB hearings. Although sufficient geotechnical drilling for feasibility design and for the NIRB hearings had been completed up to that time, some questions remained regarding the nature of the fault, its hydraulic conductivity, and potential flow paths from the TSF. In response to the public interest in these issues, Cumberland carried out additional geotechnical drilling and sampling, and testing to gather additional information to evaluate these concerns further during the water license application phase of the project. Specifically, three geotechnical boreholes were drilled along the proposed dike alignment to gather additional information relating to the fault zone, and general foundation conditions. These boreholes were in addition to the nine boreholes previously drilled in the general area of the proposed Central Dike. The results of the field investigations were presented in a factual report to Cumberland referenced as:

- Golder Associates Ltd., 05 July, 2006: Report on Winter 2006 Second Portage Central Dike Geotechnical Drilling, Hydrogeological, and Televiewer Investigation, Meadowbank Gold Project, Nunavut.

The following data collection and testing was carried out:

- Geotechnical core logging for rock mass characterization;
- Hydraulic conductivity testing;
- Fluid temperature probe;
- Caliper log;
- Optical and acoustic televiewer to provide a visual and acoustic record of the in-situ rock conditions;

- Vibrating wire piezometer installation (three points installed at vertical intervals) to provide information on potential flow gradients within the fault zone prior to draw down, and during drawdown of the lake; and
- Thermistor installation (three nodes at the same vertical intervals as the vibrating wire piezometer) to provide information on the thermal regime in the bottom of the lake.

The boreholes were drilled from the ice between 08 May 2006 and 30 May 2006, and piezometer and thermistor readings were recorded immediately after installation. The wire leads were then dropped through the ice for retrieval once the ice thawed from the lake. Once the wire leads were retrieved from the bottom of the lake, they were extended to shore, and now form permanent installation to collect additional data within the materials that will form the foundation of the dike, prior to and during de-watering of the lake.

The data that were collected from the piezometers and thermistors in May 2006, and again in the summer of 2006, were used to update the thermal model for the Central Dike and TSF, and to update the seepage model and assessment of seepage cutoff measures that may be required during construction of the Central Dike (Golder, 2007).

Based on field investigations to date at Meadowbank, the faults and associated fractured rock zones of enhanced permeability at the site are typically up to 5 m wide, and have a hydraulic conductivity (K) of up to approximately 1×10^{-5} m/s. Typically, the K value reduces substantially at depth due to increased stress; however, the depth and degree of reduction is not clearly understood at this time.

2.0 PREVENTIVE MEASURES INCORPORATED INTO DESIGN AND OPERATIONS

Preventive measures that are incorporated into the design of the Central Dike and the TSF to reduce the risk of potential seepage from the TSF towards the pit include the following:

- Installation of a grout curtain beneath the Central Dike;

- Westward advancement of the Reclaim Pond within the TSF to decrease the potential seepage pathway;

- Maintenance of a tailings beach at the dike to reduce seepage flux through the dike and through the foundation materials;

- Collection of seepage at the Portage Pit west face during operations, and re-direction back to TSF; and,

- Natural freezing of the Central Dike and TSF resulting in permafrost encapsulation (this is a natural process resulting from climatic conditions at site).

Additional information on the design of the Central Dike and TSF can be found in the following Type-A Water License Application support document:

- Golder Associates Ltd., 16 March, 2007: Final Report on Detailed Design of Central Dike, Meadowbank Gold Project.

3.0 MONITORING

During the operation of the mine, MMC plans to install a series of monitoring wells and thermistors beneath and downstream of the TSF, within the Central Dike, and between the downstream (pit side) toe of the Dike and the crest of the Portage Pit (MMC, 2007a). It is planned that some of these monitoring wells will be installed into faults beneath the TSF and downstream of the facility. The location of these faults would be identified during the exploration and testing conducted in the area of the TSF. Water samples will be periodically collected from the monitoring wells, and analysed to evaluate the quality of the groundwater. Thermal data will also be monitored to evaluate freeze back of the TSF, and of the Central Dike and foundation (MMC, 2007a).

During the excavation of the Portage Pit, the quality of seepage into the pit, particularly those seeps emanating from the west wall of the pit which is closest to the Central Dike, will also be monitored (MMC, 2007a).

4.0 MITIGATIVE MEASURES

Should water from either the monitoring wells or pit wall seeps demonstrate that seepage of unacceptable quality from the TSF has occurred through the fault, or may occur through the fault, and that the volume of this seepage requires modifications to the water management plan, then mitigation measures to limit the flow through the fault will be required. Briefly, potential mitigation options could include the following actions:

- Installation of an additional grout curtain between the down stream toe of the dike and the crest of the pit; and/or

- Freezing of the fault zone and talik.

A further description of each of these potential options is provided below. It should be noted that the current thermal modeling of the Central Dike and TSF indicate that the dike and facility will freeze with time, and will remain frozen (Golder, 2007). If, during monitoring, it is found that the freeze-back of the dike and tailings deposit are occurring at a rate less than predicted, then enhancement by artificial freezing methods may also be considered.

4.1 Grouting of the Fault Zone

4.1.1 General

Groundwater flow in fractured rock is essentially entirely within interconnected flow channels of the fractures (where 'fracture' means discontinuities of any type from small joints to regional fault-related shear planes). Grouting replaces the void space in the interconnected flow channels with a fluid that gels or sets to an impervious mass.

Modern grouting of fractured rock is dominated by polymer modified cement grouts, the polymers being the same as used in modern concrete mixes, mixed in high speed "colloidal" equipment. The cement ranges from normal concrete cement through to especially fine grinds of these (ultrafine grouts). Depending on the cement chosen, modern grouts can penetrate and form a reliable cut-off in a wide range of fracture sizes – from large open zones in very transmissive faults through to very fine hair-line cracks.

Although grouts are now formulated to effectively deal with virtually any fractured rock mass, a central feature of grouting remains: the location and connectivity of the actual flowpaths in the ground can only be discovered during the grout injections. This affects grouting operations in several ways. First, the grouting protocol must allow for the ground response to grout injection to be measured and for the grouting to be adjusted based on that measured response. As such, electronic transducers linked to data loggers and display systems are an integral part of modern grouting. Second, the ground response must be assessed in near-real time; engineering control of grouting is central to achieving the desired result. Third, grouting must be progressive, starting from widely spaced holes and becoming progressively closer as the work proceeds. Fourth, the effectiveness of the grouting must be measured – this requires water pressure tests in the early stages of the grouting to verify the grouting protocol based on actual ground conditions, with grouting then proceeding site-wide using that verified protocol.

4.1.2 Site Specific

It is anticipated that the grout curtain located beneath the Central Dike will mitigate the effects of seepage through the fault under the dike. In the event that monitoring during operations indicates that there remains significant seepage along the fault, then the most effective mitigation would be the installation of a grout curtain between the Central Dike and the Portage Pit, just downstream of the dike. This being said, it is noted that natural freezing of the overburden, bedrock, and Central Dike will be occurring while these are exposed to the climate conditions at the site. Therefore, it is expected that the overburden and bedrock conditions will be frozen to some degree which will act as a barrier to seepage from the facility.

In the event it is determined that a grout curtain would be required between the Central Dike and the Portage Pit, just downstream of the dike to act as a barrier to the release of tailings pore water constituents from the TSF, the curtain should initially be constructed using two holes at 2 to 3 m spacing to seal the fault zone. If the fault is found to be wider than 5 m, then additional boreholes can be installed as required. The grout would be injected in 3 to 5 m long vertical stages using a packer to isolate the injection zone.

At a depth of approximately 40 m, the hydraulic conductivity (K) of this zone was measured at up to approximately 1×10^{-5} m/s (Golder, 2006). The depth at which this K reduces to be essentially the same as the un-faulted rock is presently unknown. Grouting should be carried out to depths such that the curtain terminates into rock having a lower permeability due to the increased stress at depth. The length of the injection zone can be increased when the grouting is at depths of more than 50 m. At least one round of split-spacing would be needed. Depending on the depth, the required thickness of the grout curtain, fracture orientation, dominance of a particular fracture set, and in-situ rock stress, the grouting may be in one to five rows. The boreholes for the grouting can be any convenient diameter, generally between 50 mm to 75 mm. The thickness (along the fault strike) and the hydraulic conductivity (K) of the grout curtain required to effectively seal the faults should be determined using numerical hydrogeologic models.

Provided that due care and diligence is exercised in the design and execution of grouting, modern grouting methods and techniques typically can achieve in-place hydraulic conductivities that are equivalent or less than the un-faulted rock at Meadowbank (1×10^{-7} m/s or less) using inexpensive cements. If numerical modelling indicates that lower K values of the grouted rock mass are required then alternative strategies, such as the use of ultrafine cements, would need to be investigated to achieve low permeability.

Typically, the results of water pressure tests in the grouted mass provide a reliable indicator to the overall curtain performance when water is impounded behind the grout curtain; such tests are used as proof-of-adequacy when assessing whether sufficient grout has been injected. Nevertheless, it is also common to install a piezometer array as an additional proof of curtain performance and to provide an ongoing monitoring of the curtain integrity over time. Such arrays need piezometers upstream and downstream of the curtain. It is recommended that both methods – water pressure tests and piezometer arrays - be used to monitor the effectiveness of the grout at sealing the fault, if it is determined that grouting between the Central Dike and the Portage Pit is required.

4.2 Freezing of the Fault Zone and Talik

4.2.1 General

As described above, groundwater flow within the fractured rock occurs within flow channels. The concept of freezing of the fault zone is similar to that of grouting in that the end result is to seal the void space and fluid pathways with frozen interstitial water. In the case of mitigating potential seepage along the Second Portage Fault, and beneath the Central Dike, freezing of the fault zone downstream (pit side) of the dike would only be a viable measure during the actual operational phase of the pit, and providing appropriate physical conditions exist, such as a sufficiently low flux within the fault zone, to allow freezing to be effective. Thermal modeling to date indicates that over time the Central Dike and tailings deposit itself will freeze, becoming encapsulated in permafrost (Golder, 2007). A number of mitigation measures are available to control ground temperature and to enhance freezing. These include the use of passive or active thermosyphon systems.

Passive systems rely on natural (or wind induced) ventilation, while active systems rely on forced ventilation or circulation of refrigerants through a heat exchanger. Passive systems utilizing natural circulation are less costly, and are easily implemented, consisting essentially of an air convection pile, or pipe, that is open to the atmosphere. Heat is exchanged by convective circulation resulting from the cold air from the surface environment sinking within the open pipe, and warm air inside the pipe rising. These systems can also be closed systems having some internal fluid that is used as the heat transfer medium. Active (forced ventilation) systems utilize pumps and refrigerants to achieve the same cooling effect but at an accelerated rate. Both systems are used reliably in northern climates to preserve or promote freezing.

4.2.2 Site Specific

The plan for monitoring the permafrost development in the TSF includes the installation of thermistors within the impoundment area, within the Central Dike, and downstream of the Central Dike toe (MMC 2007a, 2007b; Golder 2007). Field hydraulic conductivity testing of bedrock has shown the measured permeability to be very low, on the order of 10^{-8} m/s to 10^{-9} m/s in the sound bedrock (Golder, 2006). Modeling has also shown that the rate of advance of the freezing front penetration through the TSF and into the bedrock will be greater than the rate of advective transport of constituents out of the TSF (MMC, 2007b; Golder, 2007). Consequently, the tailings and any constituent release are predicted to be encapsulated by permafrost, based on the current available data. If it is determined by monitoring during operations that the tailings are freezing at lower rates than predicted, then mitigation measures could be implemented.

Although freezing of the tailings is predicted and expected, as a secondary preventive measure, provision has also been included for the covering of the tailings with a minimum 2 m thickness of non-acid generating ultramafic waste rock (MMC, 2007b; Golder, 2007). In addition to providing a layer to limit the depth of potential thaw penetration into reactive tailings pile, the layer would also serve a number of purposes that are independent of the strategy to develop permafrost within the pile. Specifically, the cover layer would:

- reduce the potential for wind blown tailings;
- be composed of acid buffering waste rock; and,
- contribute to shedding of water from the surface of the tailings, and consequently would limit infiltration of water into the tailings pile.

The beneficial effects of the cover layer would provide an alternative, and preventive, strategy for the management of the TSF in the event that permafrost develops more slowly than predicted, or not at all.

In the long term, the most effective strategy for managing the site will be to minimize the infiltration of water into the system, and more importantly to minimize the flux through the system. The current plan to cover the TSF would contribute to this strategy by shedding water from the surface of the facility.

Yours very truly,

GOLDER ASSOCIATES LTD.

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