HOPE BAY PROJECT
GROUNDWATER MANAGEMENT PLAN

HOPE BAY, NUNAVUT

JUNE 2016

PLAIN LANGUAGE SUMMARY

This Groundwater Management Plan describes how we will manage and work to minimize water that flows into the mine to protect workers, the environment, and ensure the mine can keep operating.

REVISION HISTORY

Revision #	Date	Section	Summary of Changes	Author	Approver
0	June 2016	Entire Document	Initial Document	SRK	TMAC

GLOSSARY AND ACRONYMS

TERM	DEFINITION
WMP	Water Management Plan
AEMP	Aquatic Effects Monitoring Program
GWMP	Groundwater Management Plan
MIMP	Mine Inflow Management Program
MMER	Metal Mining Effluent Regulations
TIA	Tailings Impoundment Area
L/s	Litres per second
m3/day	Cubic meter of water per day (equivalent to 1,000 litres per day)
NIRB	Nunavut Impact Review Board
NWB	Nunavut Water Board
SOP	Standard Operating Procedure
SPT	Specific Performance Thresholds
TIA	Tailings Impoundment Area
QA/QC	Quality Assurance / Quality Control
TDS	Total Dissolved Solids

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1. INTRODUCTION

The Doris underground mine (Doris Mine) is being developed in permafrost and talik (unfrozen ground). No groundwater interaction will be encountered in permafrost zones, but mining the Doris Connector and Central zones, that take place in the talik below Doris Lake, will result in groundwater inflow. Detailed hydrogeological modeling was carried out to estimate the predicted groundwater inflow (quantity and quality) over the life of the project (Construction, Operations, Closure and Post-Closure). This mine inflow rate is made up from Doris Lake inflow, which makes up approximately 70% of the overall inflow rate, with the remaining 30% being contributed from the surrounding rock mass. Mine inflow water quality is dominated by high salinity, specifically chloride, which is naturally present in the surrounding rock mass, also known as connate water (i.e. ancient sea water).

Mine inflow collected in underground sumps, will be pumped to surface, from where it will be discharged to a marine outfall diffuser in Roberts Bay, either directly, or via the Tailings Impoundment Area (TIA). The estimated mine inflow (quantity and quality) is not expected to cause safety concerns or environmental impacts. To ensure this, TMAC will actively manage and mitigate inflows to protect workers, the environment, and ensure the mine can keep operating.

1.1. OBJECTIVES

Mine inflow, of which 70% originates from Doris Lake, are collected in underground sumps, pumped to the surface and discharged to Roberts Bay, either directly, or via the TIA. This mine water is therefore integrally linked with overall site water management. To provide for environmental protection and integration with the Water Management Plan (WMP), the objectives of the GWMP are to:

- Minimize influence of mining in the talik on Doris Lake water levels; and
- Characterize discharge water volumes and chemistry, and resulting loading.

This is accomplished by:

- Describing issues related to groundwater flow into the Doris Mine; and
- Outlining management response, mitigation and adaptive management measures taken to protect workers and the environment, and to minimise operational impacts.

The current state of knowledge for the site hydrogeological and associated water management plans are summarized herein, so as to inform the basis for the adaptive management trigger points or specific performance thresholds (SPTs), followed by specific responses and a discussion of adaptive management.

The remainder of this document presents this adaptive response plan for managing underground inflows as part of the overall site water management plan.

1.2. RELEVANT LEGISLATION AND RELATED DOCUMENTS

Worker health and safety and operational components of the GWMP are part of TMAC's mine plan and come under the jurisdiction of the Nunavut Mines Inspector. Environmental elements of the GWMP come under the jurisdiction of the Nunavut Water Board (NWB), the Nunavut Impact Review Board (NIRB) and other regulatory agencies.

Implementation of the GWMP is part of overall site water management and should be considered alongside the following relevant legislation:

- Workers Safety and Compensation Commission (WSCC) Chief Mines Inspector as per Mine Health and Safety Act, and its associated Regulations (Government of Nunavut, 1995) .

The documents listed in Table 1 are expected to be referenced and utilized in conjunction with the GWMP.

Table 1: List of Document Related to the Hope Bay Groundwater Management Plan

Document Title	Year	Relevance
Hydrogeological Modeling of the Proposed Doris North Project	May 2015	Documents the hydrogeological data and results of modelling designed to estimate inflows into the underground mine during operations (SRK, 2015a).
Doris North Project – Water and Load Balance	June 2015	Provides an update of the existing site wide water and load balance model. The model was designed to evaluate water management needs and predict water quality at the Project and downstream receptors. Other key objectives of the model are to optimize reclaim demand for mill operations, assess the effect of underground mining on Doris Lake water levels and discharge, and evaluate alternative discharge scenarios for groundwater and TIA effluent (SRK, 2015b).
Response to NRCan IR-3 & AANDC IR#13: Estimation of the Time Required for the Underground Mine to Fill	December 2015	Provides an estimate of the time for reflooding the Doris underground mine once dewatering stops (TMAC, 2015a).
Water Management Plan	2015	Describes the water management procedures including discharge from the TIA and associated water quality criteria (TMAC, 2015b).
Doris Aquatic Effects Monitoring Plan (AEMP)	2016	Designed to ensure that drawdown in Doris Lake due to inflows to the underground mine do not impact fisheries habitat (TMAC, 2016).

1.3. PLAN MANAGEMENT AND EXECUTION

Revisions to the GWMP can be triggered by activities such as changes in the mine plan, operational performance, personnel or organizational structure, mine ownership, regulatory or social considerations, and life cycle or design philosophy. The GWMP is reviewed annually and is revised or updated as necessary in accordance with changing circumstances.

Overall responsibility for the GWMP implementation and updates lies with the Vice President of Operations. The functional site-based lead for assigning and applying appropriate resources to execute the GWMP rest with the Mine Manager. The Mine Operations Superintendent is responsible for day-to-day execution of activities associated with the GWMP.

2. GROUNDWATER MANAGEMENT ISSUES

2.1. MINE INFLOW RATES

A comprehensive hydrogeological model was developed for the Doris Mine (SRK, 2015a) to estimate the rate of inflow as mine development progresses. The modelling takes into account the site hydrogeological testing, mine design (3D geometry and void volumes), and sequencing (when tunnels and stopes are developed and then backfilled). Figure 1 shows the predicted total inflow to the mine, which peaks at approximately 70% coming directly from Doris Lake and 30% from the rock mass (combination of drained storage and sub-permafrost flow).

Maximum inflow rates to the mine are estimated to be slightly less than 3,000 m^3/day or 1,095,000 m^3/year. Of this flow, based on the 70:30 ratio, approximately 2,100 m^3/day infiltrates from Doris Lake and 700 m^3/day from the rock mass.

Environmental impacts were conservatively assessed assuming a constant mine discharge rate over the life of the mine of 3,000 m^3/day. This assessment threshold of a constant discharge rate takes into account the fact that site water management volumes during the autumn/winter low flow season when surface water flows are minimal, would be dominated by mine inflow.

2.1.1. MANAGEMENT RESPONSE

To guide response planning, a maximum mine inflow rate of 3,000 m^3/day is conservatively set as the maximum acceptable inflow into the mine, beyond which adaptive management needs to occur to mitigate increasing flow volumes. This rate will be reassessed as part of the annual Plan review process to see if it should be set at a higher or lower value as understanding of the system increases.

Prior to development in a particular section within the mine, risk zones are mapped and control/exclusion measures are put in place as outlined in Section 3. Based on the observed mine inflow rate, the Mine Inflow Management Program (MIMP) is implemented, as per Table 2.

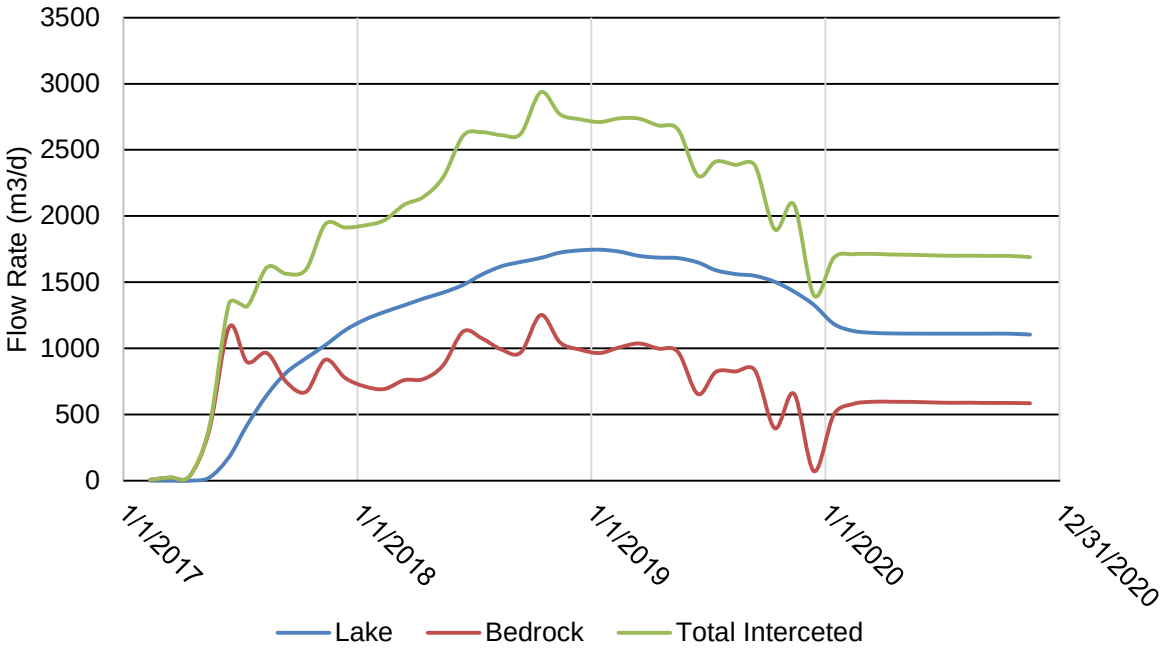

Figure 1: Estimated Volume of the Mine over Time for the Doris Central and Connector Zones

2.2. MINE INFLOW CHEMISTRY

The chemistry of discharged mine water considered in the site water and load balance was based on a mixture of Doris Lake water chemistry and sub-permafrost (connate water) chemistry, at the 70:30 ratio. This concentration has been used in the water and load balance at the conservative constant maximum underground pumping rate of 3,000 m^3/day for loading calculations. The Doris Lake water chemistry, which is equivalent to background concentrations for all constituents, dilutes the sub-permafrost chemistry, which is naturally elevated in chloride, boron, cadmium, manganese, mercury, cobalt, copper and nickel. The water and load balance also accounts for mine water chemistry impacted as a result of mining operations though blasting (elevated nitrate), permafrost drilling with brine, and introduction of oxidation products from backfilled waste rock and detoxified tailings.

Increases to the mine inflow rate could occur if mine development intersects uncontrolled/ungrouted faults, joint sets, open drill holes, etc. As geological structures in the Doris Mine area have been observed to be sub-vertical, the increased flow will likely originate from the lake. Also, the lake bed sediments which dominate the inflow rate from the lake could prove to be more permeable than anticipated. The effect of these conditions on the mine water chemistry would be to change the mixing ratio from 70:30, to a ratio more in favour of the lake inflow. Therefore, while inflow volumes/rates would increase, the concentrations of the constituents from the groundwater should decrease as fresh water increases in the mixing ratio.

Conversely, if the lake bed sediments prove to be less permeable, mine inflow rates would reduce and the mixing ratio could favor towards the rock mass inflow, with a subsequent increase in concentrations of the constituents from the groundwater.

2.2.1. MANAGEMENT RESPONSE

Operations induced water quality changes will be managed to the extent practical. Underground mine water will be internally recycled for drilling purposes which reduces the amount of additional calcium chloride introduced to the mine. A Standard Operating Procedure (SOP) for Low Salt Underground Brine Use that outlines the specific procedures adopted in this regard has been developed.

To manage nitrates from blast residues, blasting practices will continuously be reviewed to evaluate opportunities to reduce blast residues in the mine water.

Mine inflow quality will be monitored in accordance with Section 5 of this Plan. If mine water discharge water quality exceed MMER criteria, discharge to Roberts Bay occurs via the TIA and/or with treatment.

2.3. MINE DISCHARGE

Discharge from the mine is both pumped directly to Roberts Bay and discharged via a diffuser, or directly to the TIA for temporary storage, prior to discharge to Roberts Bay. Discharge, whether directly to Roberts Bay, or via the TIA, will be at a constant rate of 3,000 m^3/day. This discharge could occur any time of the year, and would be intermittent as the mine sumps fill naturally given the actual mine inflow rate (Figure 1).

Water discharged from the TIA to Roberts Bay, will be carried out as described in the Water Management Plan, but will be at a constant pumping rate of 4,000 m^3/day during the open water season (June to September).

Water and load balance modeling (SRK, 2015b) confirms that there is no impact on the receiving environment (ERM, 2016a; b) for direct discharge to Roberts Bay, under the conservative case of continuous mine water discharge at a rate of 3,000 m^3/day for the life of the mine. This modeling also confirms that the TIA has sufficient holding capacity for storing the maximum annual mine discharge volume.

2.3.1. MANAGEMENT RESPONSE

Given that the 3,000 m^3/day mine pumping rate is not limited by either water management scenario, maximum underground pumping rate of 3,000 m^3/day is considered sufficient.

2.4. DORIS LAKE WATER LEVELS

The current Water Licence (2AM-DOH1323) allows for the withdrawal of 480,000 m^3/year from Doris Lake for operations. Based on the stage capacity curve (Figure 2) for Doris Lake, which shows the volume of the lake versus depth profile, this will result in a lake level drop of approximately 0.10 to 0.15 m. The estimated peak underground inflow from the lake to the mine (2,100 m^3/day or 767,000 m^3/year) would result in an additional 0.20 m decrease in lake level, for a total of 0.30 to 0.35 m decrease in lake level. These water level changes were found to be within the natural range of fluctuation for Doris Lake.

Should a catastrophic event occur, that would result in rapid flooding of the mine with Doris Lake water, it would not result in a catastrophic drop in Doris Lake water level. Figure 3 illustrates the void space in the mine. Assuming no mine backfill, the total void space in the mine at an elevation below the Doris

Lake surface elevation of 21.5 m, to which the mine would flood is approximately 1,000,000 m^3. Mine backfill is however required as a structural component of the mine plan, and therefore, the peak void space at any time available, assuming the planned backfill is being carried out is just under 500,000 m^3. Therefore, if a catastrophic flooding event were to occur when the mine void space it at its peak, the maximum drop in Doris Lake water level would be approximately 0.10 to 0.15 m. Since the mine portal is at elevation 40 m, there is also no risk of the flooded mine overflowing to surface.

2.4.1. MANAGEMENT RESPONSE

The Doris Lake water level needs to be monitored to ensure there are no residual effects to the Doris Lake system. The management response to a changes in Doris Lake water levels is to implement lake level monitoring as outlined in the Aquatic Effects Monitoring Program (AEMP).

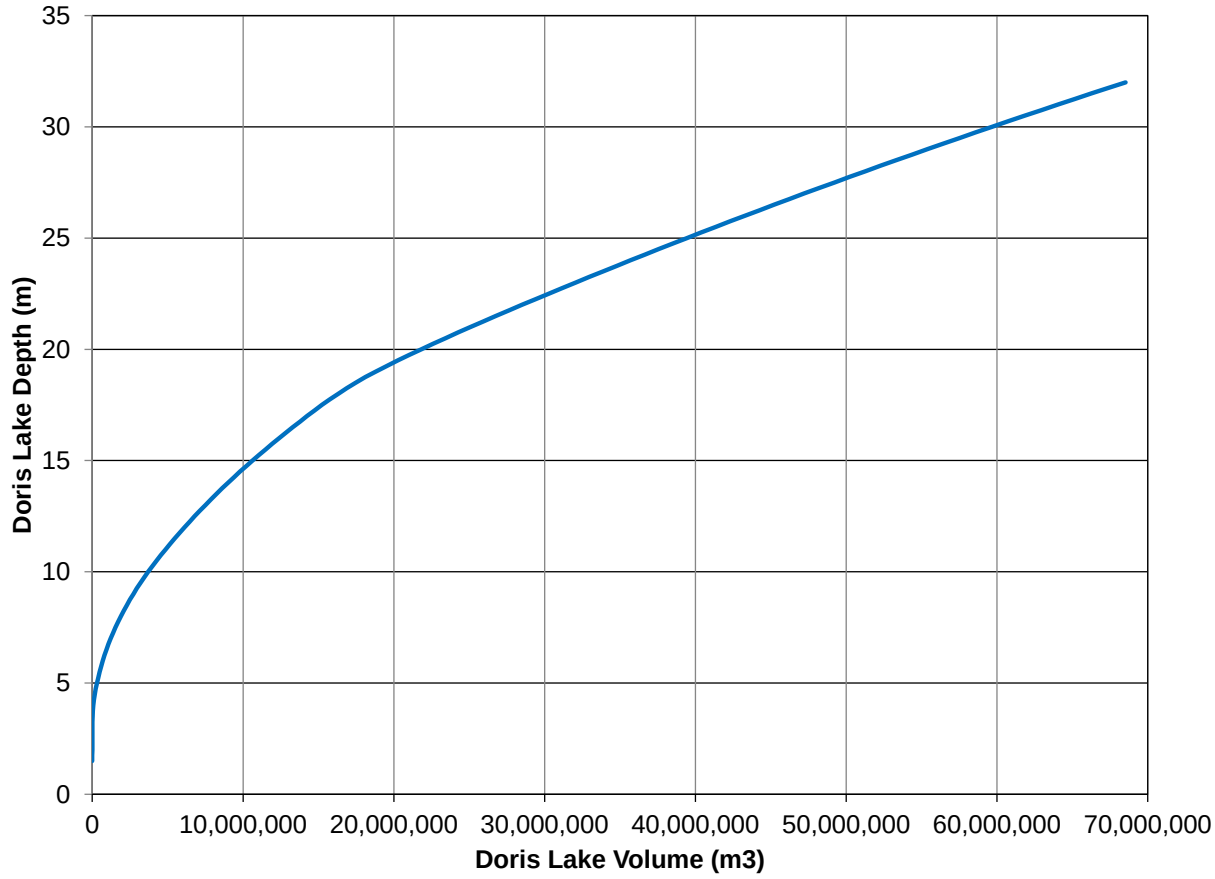

Figure 2: Doris Lake Stage Capacity Curve

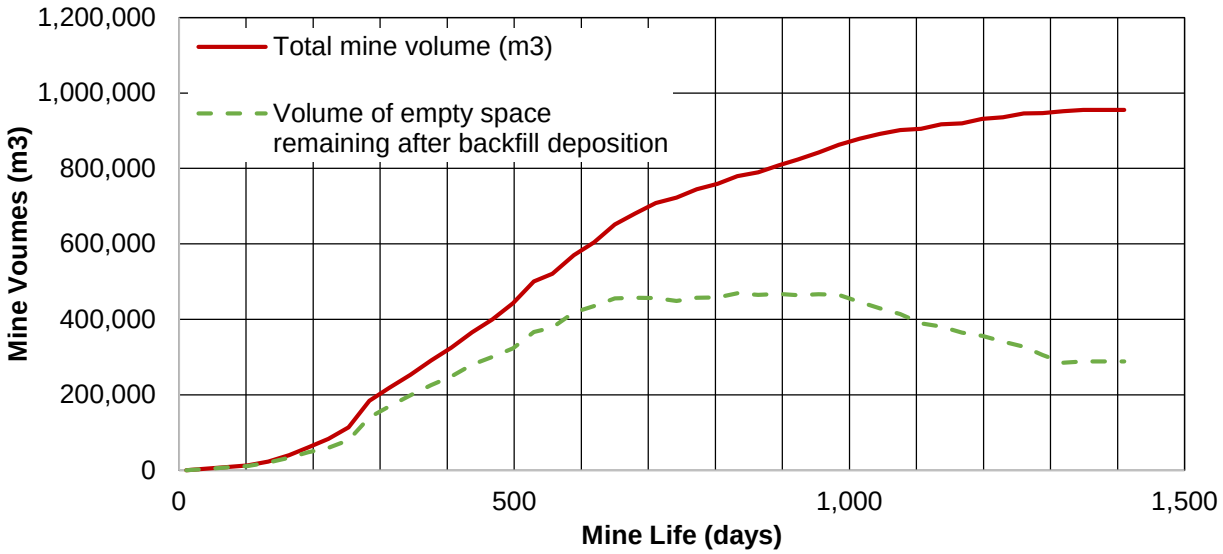

Figure 3: Estimated Volume of the Mine over Time for the Doris Central and Connector Zones

3. INFLOW CONTROL ZONES

Inflow control measures are put in place to adaptively limit the inflow to the underground mine to:

- Protect worker health and safety;
- Prevent negative impacts due to mine inflow; and
- Provide improved working conditions for operations.

3.1. RISK ZONE MAPPING

Risk zone mapping is part of the official mine plan and is used to guide daily development plans, with control measures worked into the mine schedule and consideration of related costs. Risk zone mapping takes into account the mine layout/geometry, access issues, geology, and known locations of old drill holes. Zones are ranked as Low, Moderate, or High. Zones are reassessed based on performance observations and evaluation as part of this Plan. Therefore, zone boundaries can change based on what happens as mining progresses and knowledge of the site increases.

Risk zone mapping is carried out prior to mining into a new development heading or major travel way. Based on the expected distribution of suspected inflow features, the mine is divided into inflow risk zones, with the risk rating correlated to the expected density and open size (aperture) of fractures, etc. mapped out for planned development.

As inflow is dominated by fractures, faults, or historic drill holes (referred to as “features” in following discussion) rather than through the unbroken rock mass, control measures are aimed at plugging these features. Although it is very difficult to accurately predict where all of these features will occur, the geological knowledge of the site will allow TMAC to produce a 3D model of the mine that shows the probability of intercepting a significant flow feature.

3.2. INFLOW EXCLUSION OR CONTROL MEASURES

Inflow control measures are tailored to the risk rating of inflow risk zones and are focussed on inflow exclusion or control measures that can be used to limit the amount of inflow. Each zone has specific assessment and control procedures to be followed during development, as provided in the Mine Inflow Management Program (Table 2).

Inflow control measures are implemented according to a standard operating procedure (SOP) for development (new mining excavation) in each zone. The key components of the SOP are the requirements for:

- Probe drilling – to conform to *Mine Health and Safety Act* and Regulations, additional drilling contingent on zone; and
- Pre-grouting – mandatory or discretionary based on zone "rules".

4. MINE INFLOW RATE MONITORING

The inflow management program described below complements the site Water Management Plan with a decision-based structure for ensuring that negative impacts from underground inflows are avoided. Indicators, performance thresholds, and site-specific responses are listed in Table 2.

4.1. SPECIFIC INDICATORS

Specific Indicators are target values used to assess performance of the system and potential trigger response plan actions. The specific indicators for the Doris GWMP are defined as:

Total Mine Inflow

- Daily flow measured at the main portal flow metering point.

Point Source Inflow

- Estimate of flow from specific geological feature (structure/joint set) or drill hole; and
- Estimate of flow from a limited, specific mine area (i.e. heading or stope).

4.2. SPECIFIC PERFORMANCE THRESHOLDS

SPTs are inflow rate-based decision points, triggering an escalating level of response to total mine discharge volumes and more localised inflows. The inflows are measured such that the behaviour of the inflow system can be assessed and re-evaluated as part of the review process as mining progresses to ensure SPTs are appropriate.

The SPTs are presented in Table 2 and represent escalating inflow rates for the total mine and point source inflows.

4.3. SPECIFIC RESPONSES

Given that the mine inflow is expected to come from defined geological features or open drill holes, rather than dispersed inflow through the general rockmass, "Point Source" inflow monitoring will be an

important part of the continuing underground inflow characterisation as it relates to the understanding of the hydrogeological system and interaction with the mine development. Consequently, the SPTs and responses have been set to assess the effectiveness of control measures and outline a review process for on-going management.

Table 2: Mine Inflow Management Program (MIMP)

Specific Indicators	Specific Performance Thresholds	Specific Responses
Mine inflows measured as: **Total Mine Inflow** • Daily flow measured at the main portal flow metering point **Point Source Inflow** • Estimate of flow from specific geological feature (structure/joint set) or area • Estimate of flow from a limited, specific mine area (i.e. heading or stope)	**SPT-1** • Total mine pumping rate exceeds 1,000 m^3/day • Point source inflow exceeds 250 m^3/day (~1.25 Lps) for > 3 days	**Notification** • TMAC Management **Review** • Identify inflow point sources/areas and correlate to mine plan and MIMP • Review of pre-grouting work carried out (QA/QC of work to date) • Review inflow management records for development in affected areas • Review inflow records versus geological model and mine layout to assess correlation • Review lake level monitoring data • Review records of mine pumping rates and discharge chemistry **Evaluation** • Review of UG inflow monitoring data to be undertaken by qualified professional and appropriate recommendations to be developed • Review must consider the risk narrative (i.e. impact on Doris Lake water level and site discharge water quality objectives) • Determine if lake level fluctuations exceed natural variability **Action** • Point source flow feature/area to be assessed by TMAC geological staff and compared to current geological model with objective to improve ability to predict significant inflow areas and correlation to pre-grouting planning • Review of inflow control plan to see if techniques, coverage, materials, etc. should be modified or enhanced • Supplemental grouting of source to reduce inflow
	SPT-2 • Total mine pumping rate exceeds 2,000 m^3/day • Point source inflow exceeds 500 m^3/day (~3 Lps) for > 3 days	**Notification** • As in SPT-1 • Mines Inspector **Review** • As in SPT-1 • Review of geological model versus underground mapping and any new drilling data available • Review probe drilling procedures and control measures in MIMP **Evaluation** • Review of underground inflow monitoring data to be undertaken by qualified professional, and appropriate recommendations to be developed • Review must consider the effectiveness of predictive and control measures to date **Action** • As in SPT-1 • Update MIMP to integrate recommendations from review of prediction and control measures
	SPT-3 • Total mine pumping rate exceeds 2,500 m^3/day • Point source inflow exceeds 800 m^3/day (~6 Lps) for > 3 days	**Notification** • As in SPT-2 **Review** • As in SPT-2 **Evaluation** • Detailed review of all inflow events/sources to be undertaken by qualified professional, in addition to a 3rd party grouting specialist to provide peer review on control program • Review of underground water management plan to deal with unexpected inflows that may exceed total mine discharge rate of 3,000 m^3/day **Action** • As in SPT-2 • Provide update to MIMP based on outcome of Peer Review o assess potential impacts on Site Water Management Plan o assess potential change in risk narrative • Determine if mitigation measures required to maintain Doris Lake levels

5. MONITORING AND EVALUATION

5.1. UNDERGROUND INFLOW MONITORING

Monitoring underground flows will aid in providing a feedback loop for evaluation of the effectiveness of the control measures and the accuracy of the predictive zone mapping. The accuracy and detail of the monitoring is a key component in the Plan review and evaluation process, so is included in the daily reporting structure of the underground management team (i.e. part of the Shift Boss daily report).

Underground flow monitoring includes pre- and post-grout flow measurement and flow feature description.

5.1.1. Pre-Grout Flow Measurement

Pre-grout flow measurement is needed to both aid in characterizing the feature and to support verifying the effectiveness of the grouting program. Inflow from specific features or stopes will be measured by monitoring pumping rates at the nearest collection sump. Pumps will be sized to move 200 to 250 m^3/day; therefore, if inflow rates exceed this it will be noted as a rise in sump level and another pump will be mobilised to increase pumping capacity. These observations will be documented in the daily mine reports.

5.1.2. Post-Grout Flow Measurement

Post-grout flow measurement is the primary means of verifying the effectiveness of the grouting program. Measurement techniques will be the same as for pre-grouting.

The operator may find that other features have now started to flow if the primary features have been blocked. If the required maximum inflow rate for the area is still exceeded, additional grouting may be necessary to seal any residual features.

The results and observations of the post-grouting measurement are considered as part of the Review phase of the Specific Response in the Mine Inflow Management Program and considered in the review of inflow control SOPs.

5.1.3. Flow Feature Description

Detailed geological and geotechnical mapping is carried out using predetermined codes for specific rock types and conditions. To make the mapping of inflow features accessible for the review and evaluation process, a descriptive code system is incorporated into the site mapping codes. These coded features are added to the site geological/geotechnical mapping database for review and visualisation using standard reporting and modelling tools for the project.

5.2. MINE INFLOW QUALITY MONITORING

During periods of continuous mine water discharge, either directly to Roberts Bay, or to the TIA, mine water will be sampled weekly at the mine sump and tested for chloride, Total Dissolved Solids (TDS), and nitrate. This testing will be the responsibility of the Mine Operations Superintendent. Results will be reported to the Environmental Site Coordinator.

Underground sampling will be carried out at primary collection sumps on a monthly basis and from backfilled stopes twice annually. Samples will be analysed for:

- Total ammonia-N;
- nitrate-N;
- nitrite-N;
- pH;
- EC;
- ICPMS Metals;
- Alkalinity;
- Acidity;
- Sulphate; and
- Total and WAD CN.

6. Adaptive Management

The review process outlined in the Specific Responses allows for performance (ingress control) to be assessed relative to the expanding knowledge of the site hydrogeological system, feedback on inflow control measures provided and inflow control measures adapted as a result. The following adaptive changes to inflow control measures could include:

- Review of discretionary vs. mandatory pre-grouting planning;
- Confirmation that pre-grouting plans are adequate for anticipating and preventing inflow;
- Modifications to pre-grouting plans or procedures to provide better inflow control; or
- Changes to grouting techniques and materials.

7. Documentation and Reporting

Documenting inflows, adhering to SOPs and consistent recording of grouting operations will allow for an accurate assessment of the effectiveness of the ingress prediction and controls. Records pertaining to inflows and grouting are maintained and reviewed as part of the Plan review and evaluation process.

7.1. Inflow Inspections and Documentation

The underground operational crews are responsible for regular inspections of safely accessible non-working areas and providing daily reports of active work areas. Non-working areas are inspected on a monthly basis, or as necessary, if combined flows from those areas observed to increase at main collection sumps.

Where new inflow or a change in inflow higher than 250 m^3/day is encountered, a description of the feature and related inflow characteristics are documented as part of the shift boss's daily mining report. This report includes:

- Description of features encountered;
- Inflow rates; and
- Estimated pressures.

7.2. GROUTING LOGS

Grouting operations are documented to record the specific work done to stop/reduce inflows and to provide data for the Plan evaluation process. To capture the required data, the following details are logged during grouting events:

- Grout zone, location in mine plan, date, time, shift, crew members, and pre-grouting flow from numbered holes;
- SOP used for probing;
- SOP used for grouting;
- Materials used (type and volume); and
- Injection data such as packer position, pressures at start and end of each hole, flow rate development, and especially, any cross hole grout flow observed to come out of other holes or fractures as this gives a good indication of fracture connectivity.

8. CONTINGENCIES

In the event that excess inflow to the mine occurs and TMAC is unable to reduce total inflow to below the SPT-3 level, emergency storage of water in the mine will be undertaken.

The planned volume of the mine comes into play with respect to underground water management in that unexpected inflows, assuming they do not pose a safety risk, can often be temporarily managed and stored underground in sumps or, in some situations, lower parts of the mine. The cumulative final volume of the mine in the Doris Lake talik (where greatest inflows are expected to occur; Figure 3) of just less than 1,000,000 m^3 and 425,000 m^3 (both open volume and including backfill at 30% porosity) is approximately the same as the estimated total annual pumping rate. Therefore, the mine has capacity to store excess inflow if required.

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