Crown-Indigenous Relations and Northern Affairs Canada | Relations Couronne-Autochtones et Affaires du Nord Canada

Government of Northwest Territories | Gouvernement des Territoires du Nord-Ouest

GIANT MINE REMEDIATION PROJECT

Planned Minewater Level Raise Reclamation Research Plan

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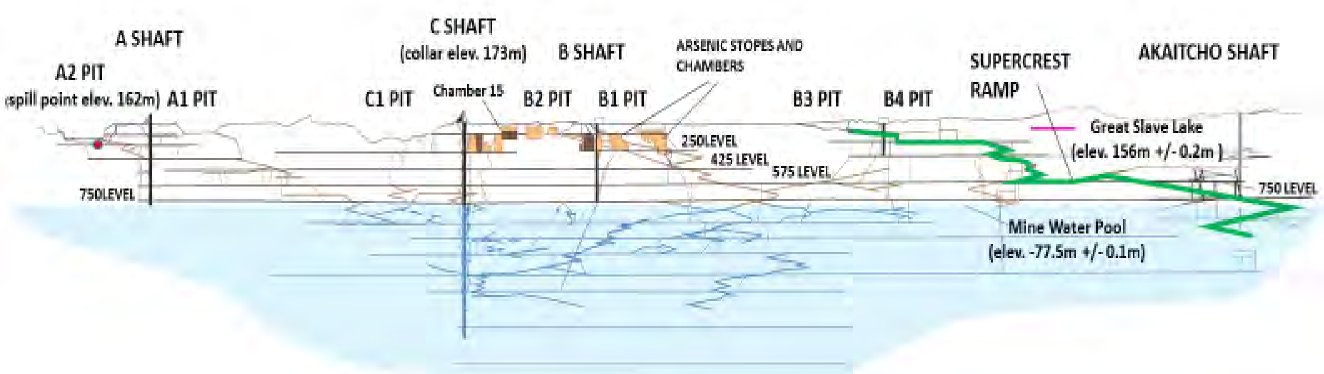
1.0 INTRODUCTION

The water level in the Giant underground mine is presently maintained at approximately 22 metres (m) below the 750 L (Figure 1) which is between -77.4 m and -76.7 m elevation (asml) (Figure 1). As outlined in the Developers Assessment Report ([DAR]; INAC and GNWT 2010) and the Reasons for Decision (MVEIRB 2013), the minewater level could be raised in a controlled manner to support the Giant Mine Remediation Project (GMRP). Specifically, this would support site-wide and specific closure objectives associated with the underground and open pits (see Section 5.1 and 5.3) including:

- SW3: Remaining operational engineered structures/controls meet appropriate design levels required for long-term care;
- UG2: the minewater level will be managed to maintain mine physical stability and chemical stability; and
- P2: public, worker, and wildlife risks associated with pits are reduced.

Figure 1: Schematic Longitudinal Section of Giant Mine (Looking West) Showing Current Location of Minewater Elevation and Submerged Workings Below



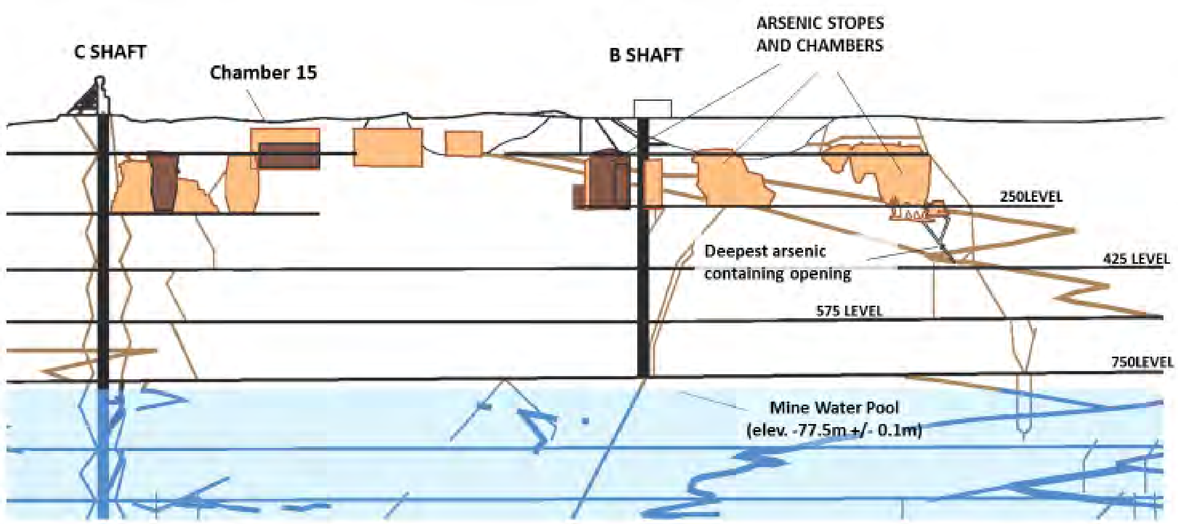
It is common practice in mine closure projects to allow underground minewater levels to rise so long as the receiving environment is protected. There are several advantages to including the option of raising the minewater above the 750 L during the active remediation and adaptive management phases of the GMRP including:

- Submerged mine workings and stope backfill are typically more stable than dry ones and are much more stable than areas where minewater levels fluctuate between wet and dry, so allowing select areas of the mine to become submerged can stabilize these portions of the mine workings.
- Reducing the potential for geotechnical instabilities by lowering the potential energy. It is noted that initial rising of water levels may induce local instabilities that may or may not need to be mitigated, however it reduces the potential for future instabilities over time.
- Limiting oxidation of exposed wall rock and waste rock and tailings backfill in the underground.
- Raising the minewater level will reduce the vertical gradient that pulls deep connate groundwater into the mine pool which will have higher total dissolved solids (salt).
- Reducing power consumption by raising the water intake pumps to maintain the minewater level.

- Reductions in groundwater inflow by reducing the vertical hydraulic gradient between the mine pool and key surface groundwater drivers, such as Great Slave Lake, and thereby reducing the total volume to be treated by the water treatment plant.
- Raising the minewater level may dilute zones of concentrated arsenic contamination and mixing in the mine pool may create a consistent water quality profile to make water treatment plan operation more efficient.
- Raising the minewater level to frozen zones will result in cracks being infilled with ice which will stop rapid movement of water and minewater through the rock mass.

The DAR (Section 6.8.3 in INAC and GNWT 2010) suggested that prior to completion of the initial ground freezing the minewater level should not be raised above the 425 L (~33m elevation at C Shaft). This interim measure was included to reduce the risk of arsenic seepage and to keep the arsenic trioxide dust in the chambers and stopes dry (see Figure 2 for relative locations underground). The 425 L is approximately 12 m below the deepest arsenic containing void and approximately 50 m below the 250 L. The bottom of most of the arsenic containing openings are generally coincident with the 250 L but one localized raise filled with arsenic is as deep as approximately 10 to 15 m above the 425 L (Figure 2). The DAR also stated that once freezing was complete, the minewater could be raised to a proposed maximum level of just below the bottom of the A2 pit (see red dot on Figure 1) which is at an elevation of approximately 120m.

Figure 2: Schematic Long Section Showing Arsenic Stopes and Chambers and Mine Levels Above Current Water Level (Looking West)



The preliminary studies presented in the DAR supported a possible minewater level raise; the timing of such a raise has not been planned. For now, the mine needs to remain open to complete stabilization of the underground and to allow removal of physical infrastructure and relevant hazardous wastes, to protect the arsenic chambers as they freeze, to keep the contaminated minewater and not allow later transfer of contaminants to nearby groundwater or lakes, and to remain as storage for minewater for water treatment. Additional studies are required to provide details on how the minewater level and minewater quality will respond. These details will allow determination of 'if, when, and how' the overall minewater level can be raised above the 750 L to maintain freeze containment criteria and to limit impacts to chemical and physical stability.

A Reclamation Research Plan (RRP) has been developed to determine if, when, and how the overall minewater level can be permanently raised above the 750 L (above the current range of -77.4 m and -76.7 m elevation, which will fluctuate seasonally related to the new WTP) during the Water Licence period. As such, no final closure option for minewater level in the underground has been evaluated or developed. The closure criterion for closure objective UG2 (managing minewater level to maintain mine physical stability and chemical stability) is currently listed as: "UG2-1 Maintain minewater level below -77 m * above mean sea level (amsl) ± seasonal fluctuation (i.e., approximately the 750 L)". This criterion is noted to be in development (see Section 5.1 of the Closure and Reclamation Plan); this RRP will help refine this criterion. The Water Management and Monitoring Plan provides the relevant details on monitoring and maintenance of the minewater level.

The Mackenzie Valley Land and Water Board (MVLWB) Guidance on Closure and Reclamation Plans (MVLWB/AANDC 2013) outlines that 'Proponents develop reclamation research plans to resolve uncertainties and answer questions pertaining to environmental risks for closure options or selected closure activities. While RRPs are often used to resolve closure criteria, the Land and Water Board Guidance outlines that it can be used to aid in determining closure options: Reclamation research will facilitate the transition from operations to closure and reclamation, as it will aid in determining which closure option is suitable for the selected closure activity (MVLWB/AANDC 2013). It is in this context that Giant Mine proposes to use the Planned Minewater Level Raise RRP – to help inform closure options for if, when and how the water level in the underground can be raised and appropriately executed, which will in turn refine the closure criterion.

2.0 KEY UNCERTAINTIES

There a number of key uncertainties associated with when and how the minewater level can be raised:

- Could the minewater level raise cause a “slug” or mass of contaminants into the mine pool as exposed wall surfaces and mine voids that are filled with contaminated material are wetted? Could temporary increases in mine pool constituent concentrations affect the management of the proposed new water treatment plant including where water is drawn from the mine? Specific uncertainties include:
    - Distribution and concentration of fugitive arsenic that has leaked into underground mine workings from the arsenic stopes and chambers.
    - Distribution and concentration of fugitive arsenic that has collected into the underground due to leakage of contaminated Northwest pond water into the underground.
    - Distribution and concentration of contamination present in the mine fills including sand filled stopes and past backfill added as part of the remediation plan.
- Could contaminated fill present in some of the open pits (A1, B1, and possibly B2) cause a “slug” of mass when the minewater reaches the elevation of the base of the pits or higher? Specific uncertainties include:
    - Distribution and concentration of contamination present in the pit fill after years of infiltration.
- Could the minewater level raise de-stabilize portions of the underground or the open pits and damage critical infrastructure such as pit covers (should they be needed) and limit access for the public to surface areas? Specific uncertainties include:
    - Location and condition of wooden structures in the underground such as wooden bulkheads and sill mats which could fail during water level variations.
    - Depth to volume storage curve of the underground workings including the porosity of void filling material.
    - Variation in the permeability of the void filling material including sand fill in the stopes.
- Could the minewater level raise impact the cooling front of the passive freeze system?
- Could the mine cease to be a sink following the minewater elevation raise, such that untreated water in the underground workings could flow towards the receiving environment?

3.0 OBJECTIVES AND TASKS

The objective of the RRP is to determine if, when, and how the overall minewater level can be permanently raised above the 750 L. This involves reducing the numerous uncertainties listed above, through a multi-staged set of tasks:

- refining water quality predictions of changes that could occur from a minewater raise (Task 1, 2 and 3)
- verification of changes that occur from short-term planned minewater raise trial (Task 4 and 5)
- verify freeze criteria can be maintained (Task 6)
- assessment of whether a minewater raise is feasible and should occur (Task 7)
- development of an implementation plan for the possible long-term minewater raise (Task 8)

Note that the planned minewater raise in this RRP is a temporary, short-term raise where pumping ceases allowing the minewater level to rise, then pumping is initiated again to bring the minewater level back down. This is referred to as the ‘planned minewater raise’ trial. This is distinguished from a long-term permanent minewater raise. It is envisioned that the long-term raise would be done in stages, demonstrating physical and chemical stability after each incremental raise. This RRP would end at the preparation of a plan to implement the long-term raise. The actual implementation of the long-term minewater raise, if deemed appropriate, is outside of this RRP and would require separate MVLWB approvals.

4.0 RESEARCH AND RECLAMATION PLAN TASKS

The following section outlines the staged studies to address the uncertainties related to a possible long-term minewater level raise by use of staged studies and a planned minewater level raise trial. These studies include tasks that are in progress or will be conducted in future years.

Eight main tasks are proposed:

Task 1: Improve understanding of current minewater quality and quantity

Task 1 will improve the understanding of groundwater and surface water conditions to help validate assumptions used in the existing underground and surface water balances and associated water quality models while the water is held just below the 750L (range -77.4m and -76.7m elevation) (CIRNAC and GNWT 2019). This work will improve the reliability of the developed models to predict potential changes in groundwater quantity and quality arising from a minewater level change by refining the estimates of assumptions in the existing models. Key assumptions to be updated or refined include estimates of groundwater flow and infiltration to the underground, groundwater and surface water quality, and the depth-volume storage curve.

Items included in this Task include:

a. *Expansion of the surface water monitoring program and re-initiation of the groundwater monitoring program.* Groundwater and minewater monitoring was reinitiated in full at Giant Mine in 2017 and includes the collection of mine pool samples for quality analysis and hydraulic head measurements in the shallow and deep monitoring well network. Related to overall water quality in support of modelling, surface water monitoring was expanded in 2017 to include seasonal samples in Yellowknife Bay, full parameter suites for runoff and operational sampling locations and a third year of surface runoff sampling in freshet. Groundwater and surface water monitoring programs will continue at the mine site to monitor groundwater and surface water quality and to verify model predictions made in support of closure plans. This will include monitoring of underground sumps and mine pool locations. The monitoring programs and data are considered ‘living’ documents that are reviewed each year following data collection and completion of RRP tasks presented in this document. This will verify that the programs are collecting relevant data necessary to support the closure plans for the Site based on the evolving understanding of the Site conditions.

b. *Development of a 3D numerical groundwater model to simulate and predict groundwater flow conditions near the existing underground development at Giant Mine*. The model is calibrated to measured hydraulic heads and pumping rates at Giant Mine and utilized, in its initial development, spatial estimates of infiltration predicted using a watershed hydrologic model. The calibrated groundwater predicts groundwater inflow to the underground development for the present minewater elevation and a possible future minewater raise, and the relative proportion of water to the Mine that is derived from difference sources (i.e., infiltration versus groundwater inflow). The model will be used to predict overall groundwater flow conditions surrounding the mine for various water level elevations to assess at what minewater level elevation the underground development will cease to act as a hydraulic sink for contamination associated with the underground development. Sensitivity analysis will be conducted to determine what factors (e.g. bedrock hydraulic conductivity, infiltration rates) most significantly affect the groundwater model predictions and to evaluate if any additional work is needed to reduce the uncertainty in those values to improve confidence in the closure plans. Predictions of infiltration and groundwater inflow from the calibrated model have been compared to assumptions in the previously developed underground water quality models and corresponding site models have been updated accordingly. Seasonal fluctuations in water level will be monitored and modelled.

c. *Refinement in the range of allowable minewater level changes that will not affect stability of the underground.* This work includes the assessment of mechanisms that drive the potential for underground instability due to changes in minewater level, such that allowable rate of change in water level can be refined which may impact allowable amount of surface water that can be diverted to the underground or whether temporary surface water storage is required during the active remediation phase.

d. *Refinement of depth / volume storage curve.* This includes examination of the distribution of filled and unfilled openings and the porosity of both filled and partially filled openings including stopes. The Water Management and Monitoring Plan lists the current curve; the calculation of the curve is outlined in the technical appendices to the Effluent Quality Criteria Report (CIRNAC and GNWT 2018).

Task 2: Improve understanding of inputs to predict future minewater quality

This task is designed to improve the understanding of future minewater quality in advance of minewater elevation fluctuations and any minewater raises. This work consists of the following tasks:

a. Development of a study plan to sample minewater quality in various locations underground to refine and build on the existing sampling program.

b. Development of a comprehensive estimate of the spatial location of fugitive arsenic in the accessible underground development openings near the arsenic stopes and chambers including underground piping and ditching. This will be used to develop a map of, and a quantified estimate of the amount of fugitive arsenic present in the mine workings below the arsenic stopes and chambers.

c. Completion of controlled wall wash or other geochemical tests in an isolated area with a large amount of fugitive arsenic to provide overall estimates of water quality during a minewater level raise. This test will provide a calibration of the estimate of the total amount of fugitive arsenic determined during the following step.

d. Focused leachate testing of select materials that could leach to the underground at closure. These materials may include material to be placed at the mine during closure (pit backfill material) and material that may be modified during closure (such as the covering of the tailings).

Task 3: Evaluation of potential changes to minewater quality

Evaluate potential changes to minewater quality during a minewater level raise for both the planned minewater level raise and information toward a possible long-term raise. This work consists of the following tasks:

a. Based on the completion of Task 1 and 2 the model inputs in the current underground GoldSim water balance and water quality models as well as GoldSim surface water models will be reviewed. If modifications are required based on the results of this comparison.

b. The GoldSim and 3D groundwater model, as well as other evidence collected in Task 2, would be used to evaluate potential changes to water quality and groundwater flow conditions to help design a short-term planned minewater raise trial (See Task 5) including the magnitude of the raise.

c. The groundwater and surface water monitoring programs would be reviewed to assess if the existing sampling points in the plans are enough for monitoring the effects of the short-term planned minewater raise trial. If needed, a modified monitoring program would be designed in 2019 for implementation in 2019/2020. The modified sampling program, if needed, would further establish the existing water quality and provide a point of comparison for evaluating the potential effects of the planned minewater raise.

Task 4: Physical hazard review and overview minewater balance

Task 4 focusses on the development of an understanding of physical hazards that could occur during the short-term planned minewater level raise and either design the test in a way to mitigate them, bring planned backfilling work for the overall remediation forward, or develop hazard avoidance or mitigation plans to deal with unexpected destabilizing events.

During mining operation, the underground stopes at Giant were backfilled with a variety of materials including waste rock, surficial fluvial material (river gravel), and classified tailings (sand). Wooden structures such as sand fill fences and sill mats were also used during mining which have degraded over time. Changes in water level will alter pore pressures in these fills and loadings on these wooden structures that could cause instability including liquefaction of sand and mobilization of it to move to lower elevations in the mine. Movement of sand fill deep in the mine could cause a cascading propagation of voids towards surface that could impact the stability of non-arsenic stopes near surface and under open pits which are slated to be filled. Mine instability associated with water most often occurs during the time when the minewater level is pumped back down as high pore pressure that has developed in fine grained backfill remains as water pressure drops quickly in the well-connected development openings resulting in liquefaction.

Future detailed design work for both the underground and open pits will need to consider the potential for physical hazards to be created during possible future minewater level raises. For example, if the potential for existing backfill that is present in a stope that is scheduled to be “topped-up” as a closure action for stability reasons (See Section 5.1), the design needs to address this potential. Most of the planned backfill that will be used to stabilize underground voids will make use of cemented paste tailings to remove voids space. In some cases, self-supporting lean concrete backfill will be used where stability is critical and responding in a timely manner may not be practical or defensible.

The backfilling work planned for near surface non-arsenic stopes and for voids under the pits may be underway or not yet started at the best time for the planned minewater level raise and the following additional following tasks are required.

a. Develop a list of areas that could potentially become de-stabilized during the planned minewater level raise trial and outline impacts on worker safety, public safety, impacts to the remedial plan, and any impacts to critical infrastructure.

b. Design the test procedures to including maximum rate of minewater level raise and pump down rates and duration of trial.

c. Design the target elevation of the planned minewater level raise trial.

d. Develop re-entry plans for areas that were submerged during the planned minewater level raise trial including areas of possible destabilization.

e. Schedule the backfilling work for as many high priority areas or those with a high consequence of destabilisation as soon as possible on the list for early backfilling if possible.

f. Carry out hazard assessments to understand how destabilisation could impact remaining areas and develop mitigation plans including worker safety.

g. Develop contingency plans to backfill areas important to the remediation construction plan or where critical infrastructure is located that show signs of unexpected instability during the planned minewater level raise trial.

Task 5: Design and execute short-term planned minewater level raise

This task is to design and execute the planned minewater level raise trial to verify predictions of groundwater quantity and quality for a long-term minewater level raise. The detailed design and execution are planned for early in Active Remediation while the existing effluent treatment plant and surface water storage (Northwest Pond) are operational.

This work consists of the following key steps:

a. Design of the test and completion of a fatal flaws analysis to assess potential problems that could arise during the test and how they would be mitigated. This design will include the identification of data to be collected in the underground development or Mine property during the planned minewater level raise trial (i.e., water level monitoring, stability monitoring or water quality sampling locations).

b. Execution of the planned minewater level raise and collection of appropriate groundwater and water quality measurements to verify the effects of the water level raise.

c. Review of the collected data to assess if the data matches model predictions. If the data shows significant differences, the site models (Goldsim and the 3D groundwater model) should be recalibrated to the new data and updated closure predictions would be provided.

Task 6. Studies to confirm minewater raise management to maintain freeze criteria.

Desktop studies using outcomes of the Freeze Optimization Study and the first few freeze chambers will be reviewed to determine if the freeze criteria can be met under wetted conditions. Further studies may be required but would form subsequent RRPs, if needed.

Task 7: Review and assess cost-benefit analysis and feasibility of minewater raise during closure

Using the information gained during the model refinement and planned minewater elevation raise trial and related tasks, model scenarios will be used to determine the feasibility of, and potential cost-benefits to raising the minewater level in the long-term. This feasibility assessment will include an assessment of risks associated with raising the minewater level. Refined estimates of costs and benefits of planned minewater level raises during the water license term would be made, using the results of the test to inform decisions. This task would include an identification of risks associated with a permanent minewater raise for closure and feasibility of this closure strategy.

Task 8. Develop implementation plan of staged minewater level raises

If the results of Task 6 indicate a minewater level raise is a feasible, and a decision is made to implement a long-term minewater level raise, the schedule and detailed implementation plan for minewater level raise will be drafted and for approval to the MVLWB and its reviewers, when and as appropriate. Regardless of outcomes of the predictive models, any minewater level raise would be carried out in a controlled manner using a phased, step-wise approach with monitoring of groundwater levels, minewater chemistry, ground temperature, and other key criteria to manage such increases.

Data and modelling information current to mid-2018 are provided in the Effluent Quality Criteria report appendices (CIRNAC and GNWT 2018). New information will be provided in annual reports to the MVLWB. A summary of each task will be reported in the Annual Closure and Reclamation Plan update to the MVLWB. As noted above, the actual implementation of the long-term minewater raise, if deemed appropriate, is outside of this RRP; separate approvals from the MVLWB are anticipated.

5.0 SCHEDULE

A draft schedule for execution of the RRP is outlined in Table 1.

Table 1: Planned Minewater Level Raise Reclamation Research – Schedule of Tasks

#	Task	Approximate Schedule	Status (as of Jan 2019)
1	Improve understanding of current minewater quality and quantity	2017-2020	In Progress
2	Improve understanding of inputs to predict future minewater quality	2017-2019	In Progress
3	Update predictions future minewater quality	2020-2021	In Progress
4	Physical hazard review and overview minewater balance	2017 - 2020	In Progress
5	Design and execute short-term planned minewater level raise trial	2021-2022*	Pending
6	Studies to confirm minewater raise management to maintain freeze criteria	TBD	Pending
7	Review and assess cost-benefit analysis	2023-2023*	Pending
8	Develop implementation plan of long-term minewater level raise	2020-2024*	Pending

*Dates are approximate only. Results of tasks 1 to 4 will determine feasibility and design and timelines for planned minewater level raise trial.

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