TECHNICAL MEMORANDUM

DATE October 15, 2019 **Reference No.** 19120487/7000

TO Karyn Lewis
Lupin Mines Inc.

CC Dionne Filiatrault

FROM Ken Bocking **EMAIL kbocking@golder.com**

CONCEPTUAL DESIGN FOR THE WASTE ROCK “DOME” AT LUPIN MINE

1.0 INTRODUCTION

Lupin Mines has applied for a renewal and amendment of their existing Type “A” water licence No. 2AM-LUP1520. A Final Closure and Reclamation Plan (FCRP) was filed as part of the application. In connection with the application, a Technical Meeting / Pre-Hearing Conference (TM/PHC) was held in Kugluktuk on June 6 and 7, 2019. The decision from the TM/PHC is provided in Nunavut Water Board (NWB), 2019. Appended to the decision was a list of commitments for additional information to be provided to the NWB.

Commitment 5 requires LMI to submit a Technical Memo providing:

> *Preliminary design level explanation of waste rock storage “Dome” design (including typical cross section, seepage, topography, geochemistry and stormwater drainage estimates, etc.)”.*

This Technical Memo addresses Commitment 5.

2.0 BACKGROUND

2.1 Mine History

The Lupin Mine (the Site) is a past producing mine located in western Nunavut, approximately 400 km northeast of Yellowknife. The mine is owned by Lupin Mines Incorporated (LMI). Development of the Site to extract gold began in 1980 and operations occurred from 1983 until 2005. From 2005 to present, the Site has been in “care and maintenance” with mine operations suspended and progressive rehabilitation works conducted.

Underground mining at Lupin Mine produced approximately 1 million cubic metres (m3) of waste rock (URS, 2005). The waste rock was used to construct various elements of mine infrastructure, including roads, the airstrip and a large pad underlying the mill site and camp facilities. Figure 1 shows the approximate current distribution of the waste rock in the area of the mine/mill/camp/airstrip complex. The current area of exposed waste rock (i.e., the sum of orange and purple areas on Figure 1) is estimated to be about 54.5 ha.

2.2 Surface Drainage and Seepage

The mine/mill/camp/airstrip complex is located on a local topographic high. As illustrated in Figure 1, runoff and seepage from the complex currently reports to multiple sub-watersheds as follows:

- Upper Sewage Lake;
- Lower Sewage Lake;
- Boot Lake;
- East Lake; and,
- Contwoyto Lake.

The existing waste rock areas present a relatively flat porous surface, which encourages infiltration of precipitation rather than runoff. Because the site is underlain by permafrost, the infiltration cannot flow downwards, rather it flows laterally and emerges as seeps near the perimeter of the waste rock areas. In the past, toe seepage has been noted and sampled in at least 13 discrete points around the perimeter.

It should be noted that some of the precipitation currently reports to the existing open crown pillars, which have an estimated watershed area of about 4.91 ha. The Crown Pillar Watershed drains internally into the underground mine workings. Measurements by LMI staff in 2019 indicate that the depth to water within the mine workings is greater than 100 m. The mine workings have been permitted to flood since closure (2006); however, the current water level remains greater than 50 m below the water level of Contwoyto Lake. It is therefore apparent that the underground mine workings do not have a strong hydraulic connection with either the talik below Contwoyto Lake or the sub-permafrost groundwater flow system.

2.3 Geochemistry

The geochemistry of waste rock currently at surface at the Site was evaluated in a previous investigation by Golder (2017), based on a dataset of 127 samples collected in 2004 (URS 2005), 2006 (Morrow 2006) and 2017. This investigation involved collection of thirty waste rock and overburden grab samples to confirm the acid rock drainage and metal leaching potential if in situ materials at the Site. Waste rock samples were submitted for geochemical testing, including acid base accounting (ABA), net acid generating testing (NAG), whole rock and trace metal analysis, and short-term leach testing. Additionally, nine seepage surface water samples were collected to evaluate the composition of water after interaction with waste rock. Analytical results of seepage samples, NAG leachate, and short-term leach test leachate were compared to Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines (CEQG) Water Quality Guidelines for the Protection of Aquatic Life (Freshwater). Comparison to CEQG criteria was completed for the purpose of identifying parameters of potential environmental concern.

Geochemical test results for samples collected as part of the field investigation completed by Golder (2017) were added to the existing waste rock geochemistry database, which was described in Morrow (2006). Acid generation potential was evaluated according to the criteria in MEND (2009), using the ratio of neutralization potential (NP) to acid potential (AP). The combined geochemical dataset consists of 127 samples, of which 41 were classified as non-PAG (NP/AP > 2), 59 were classified as PAG (NP/AP < 1) and 27 had an uncertain acid generation potential (NP/AP between 1 and 2). Using this dataset, up to 68% of the waste rock at the Site could be potentially acid generating (PAG and uncertain samples).

Metal leaching potential was evaluated using the results of short-term leach tests (shake flask extraction [SFE], and comprehensive analysis of NAG leachates), and seepage water quality results. Analytical results of SFE leachates indicated that most samples produced leachate concentrations of aluminum, arsenic, cadmium, copper, iron, nickel, and zinc greater than CEQG criteria. Analytical results of NAG leachate indicated that most samples produced leachate concentrations of aluminum, arsenic, cadmium, chromium, copper, iron, nickel, phosphorus, and selenium greater than CEQG criteria. Seepage sample results indicated that most samples contained pH values outside the range of applicable CEQG criteria, and concentrations of aluminum, arsenic, cadmium, copper, nickel, and zinc greater than CEQG criteria. (Golder, 2019c).

3.0 DESIGN CONCEPT

The FCRP for the Site proposes to consolidate much of the waste rock in the mill and camp area into a central “dome” area (shown in purple on Figure 1). In addition to the central dome, smaller areas of waste rock will remain in the existing landfill (about 0.2 ha), the new landfill (about 1.5 ha) and around the existing adit (about 0.1 ha). After consolidation, the final area of the central dome is estimated to be about 23.2 ha.

The dome (and the three small ancillary areas) will then be capped with an infiltration reduction cover comprising a 1.0 m thick layer of esker sand and gravel (Golder, 2018). The objectives of the cover are:

1) to reduce the surface area of the waste rock, and
2) to reduce the amount of infiltration into waste rock in order to control the volume of acid rock drainage (ARD) impacted seepage out of the toe of the dome.

The reduction in surface infiltration will rely in part on the cover being frozen during winter and early spring to promote surface runoff rather than infiltration during the freshet period.

After closure, the waste rock dome is expected to be roughly circular and to cover an area of about 23.2 ha. It will contain or overlie about 820,000 m^3 of waste rock. To prevent surface ponding, to reduce infiltration through the cover and to encourage surface runoff over the cover, the dome will have a surface slope of about 1.6%. Figure 2 provides a schematic cross-section of the planned waste rock dome.

4.0 EXPECTED SEEPAGE AND RUNOFF

Golder (2019b) discusses the assumptions and results of coupled thermal – seepage modeling that was carried out to predict the post-closure seepage out of the toe of the proposed waste rock “dome”. The model was run for two climatic cases:

1) For 2019, (using 2005 climate data from the Lupin A climate station with temperatures increased by 0.7 degrees C to account for 14 years of climate warming), and
2) For 2100, (using 2005 data increased by 4.95 degrees C, which is the median between 2.1ºC [from the RCP2.6 model] and 7.8ºC [from the RCP8.5 model]).

The model considered the annual thawing of the esker cover. It predicted that runoff volumes would be large during the spring freshet period as the esker and top of waste rock are still frozen, leading to almost no infiltration of water from the base of the esker into the underlying waste rock during the freshet. Later in the summer, after the cover material is thawed, surface infiltration and waste rock percolation will occur, but part of the rain water will still be removed by evaporation. The results are summarized in Table 1.

Table 1: Summary of Computed Flux Volumes for 2019 and 2100.

Model Year	Rainfall	Snowmelt	Runoff	Actual Evaporation	Infiltration into Waste Rock	Percolation (% Rain + Snow)
Year 2019 Yearly Unit Flow Volumes (m^3/m^2)	31488	31478	0314:8	0313::	03137:	15.8%
Year 2100 Yearly Unit Flow Volumes (m^3/m^2)	0.177	0.126	-0.130	-0.096	-0.076	25.0%

The model predicts that, for 2019 climatic conditions, and after the dome is formed and covered with 1.0 m of esker material, about 58% of the annual precipitation will runoff over the surface of the dome, while 15.8% will infiltrate into the underlying waste rock from whence it will eventually report as a toe seep. The model also predicts that, for 2100 climatic conditions, 43% of the annual precipitation will runoff, while 25% will infiltrate into the underlying waste rock and report as toe seeps.

No attempt was made to model the current conditions of relatively flat uncovered waste rock; however, it is estimated that, under current conditions, infiltration and toe seepage amounts to at least 70% of annual precipitation. On a unit area basis, the construction of the covered dome is expected to reduce the infiltration to about 23% of its present value for 2019 climatic conditions and to about 36% for 2100 climatic conditions.

5.0 CONCLUSIONS

At present, waste rock is stored in relatively shallow stockpiles across the Site, and seepage characteristic of ARD is discharging from the toes of these stockpiles. Relative to current conditions, the proposed waste rock dome design is expected to reduce the current environmental impact of the waste rock by the following mechanisms:

- a smaller waste rock footprint than the existing stockpile area (i.e., a total waste rock area of about 46% of the existing area)
- capping the waste rock dome with a granular esker material so that runoff does not come in contact with the waste rock
- using grading and seasonal freezing to limit infiltration; thereby reducing the fraction of the direct precipitation that comes in direct contact with the waste rock

6.0 CLOSURE

We trust that this technical memorandum meets your present requirements. If you have any questions, please do not hesitate to contact the undersigned.

GOLDER ASSOCIATES LTD.

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Attachments: Figure 1 – Mine and Mill Site Area – Watersheds
Figure 2 – Covered Waste Rock Dome Concept

https://golderassociates.sharepoint.com/sites/107254/project files/6 deliverables/prelim dome design memo final/19120487-rev0-lupin_conceptual design of waste rock cover.docx

REFERENCES

Golder Associates Ltd. (2017). Updated Phase I and II Environmental Site Assessment, Lupin Mine, Nunavut. Report No. 1663416-6000, October 2017.

Golder Associates Ltd. (2018). Lupin Mine Site, Final Closure and Reclamation Plan. Report No. 1789942_003_Rpt_Rev0, July 2018.

Golder Associates Ltd. (2019a). Human Health and Ecological Risk Assessment, Lupin Mine, Nunavut. Report No. 19120487_7000, October 2019.

Golder Associates Ltd. (2019b). Coupled Thermal-Seepage Modelling for Performance Evaluation of the Esker Cover for the Waste Rock “Dome” at Lupin Mine. Report No. 19120487_7000, October 2019.

Golder Associates Ltd. (2019c). Closure Geochemical Source Term and Seepage Water Quality Model for performance evaluation of the esker cover for the waste rock “dome” at lupin Mine. Report No. 19120487_7000, October 2019.

MEND (Mine Environment Neutral Drainage). 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials. MEND Report 1.20.1. December 2009.

Morrow (Morrow Environmental Consultants Inc.). 2006. Phase 1 and 2 Environmental Site Assessment, Lupin Mine Site, Nunavut Territory. January 11, 2006.

ATTACHMENTS

Figure 1 – Mine and Mill Site Area

Figure 2 – Covered Waste Rock Dome Concepts

LEGEND

- CONTOUR (10 m INTERVAL)
- FLOW DIRECTION
- WATERSHED BOUNDARY
- WATERCOURSE
- ROAD
- INFRASTUCTURE FOOTPRINT
- LANDFILL
- REHABILITATED DISTURBED AREA
- TAILINGS TO BE REMOVED TO TCA
- WASTE ROCK COVERED
- WASTE ROCK REMOVED
- WATERBODY

0 250 500
1:15,000 METRES

NOTE(S)
1. AFTER BLASTING, THE CROWN PILLAR WATERSHED WILL DRAIN INTERNALLY INTO THE UNDERGROUND MINE WORKING.
2. SPILLWAYS WILL BE EXCAVATED THROUGH THE SEWAGE LAKE DAMS AT CLOSURE LEAVING THEM FREE DRAINING.

REFERENCE(S)
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DATUM: NAD83 PROJECTION: UTM ZONE 12

CLIENT
MANDALAY RESOURCES CORPORATION

PROJECT
LUPIN MINE CLOSURE

TITLE
MINE AND MILL SITE AREA – WATERSHEDS

LUPIN MINES INCORPORATED

YYYY-MM-DD	2019-10-15
DESIGNED	IM
PREPARED	AA
REVIEWED	IM
APPROVED	KAB

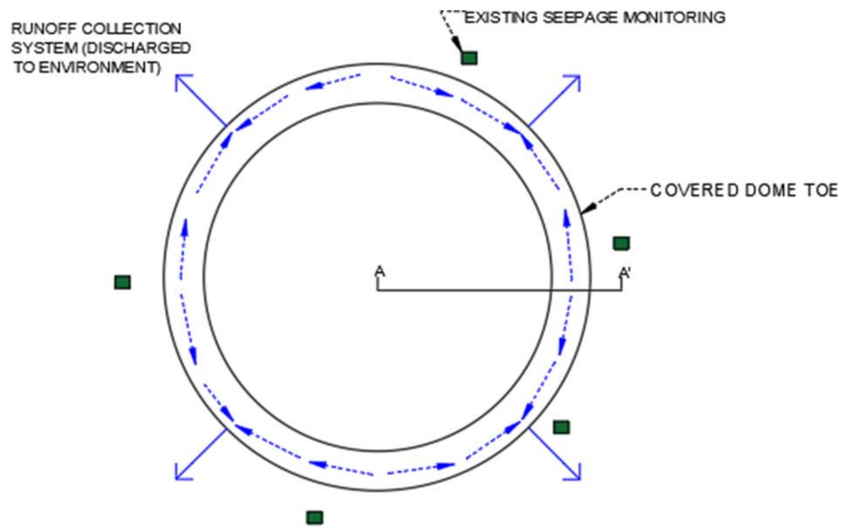
PROJECT NO.	CONTROL	REV.	FIGURE
19120487	6000	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

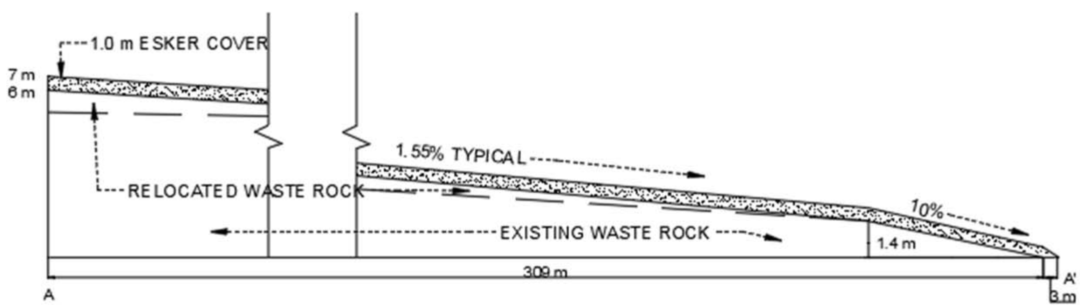
25mm

PATH: I:\2019\19120487\Mapping\Products\Hydrology\19120487_6000_Fig01_MineSite_Watersheds_Rev0.mxd PRINTED ON: 2019-10-15 AT 6:52:02 AM

Covered Waste Rock Dome Concept



PLAN VIEW - SCHEMATIC



TYPICAL CROSS SECTION A - A'

GOLDER