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REVIEW BOARD

27 February 2003

Mackenzie Valley Environmental Impact Review Board (MVEIRB)
Box 938, 5102 – 50th Avenue
Yellowknife, NT X1A 2N7

Attention: Glenda Fratton, Environmental Assessment Coordinator

Dear: Glenda

SUBJECT: Snap Lake North Pile Seepage Collection

Please accept the attached technical memo titled "Snap Lake North Pile Seepage Collection" for submission to the Public Registry. This memo was compiled in response to issues raised by Indian and Northern Affairs Canada (INAC) and Environment Canada during the MVEIRB Technical Sessions.

Additionally, information contained within this memo should address the outstanding concerns identified by INAC in their Request for Ruling to the Board dated 22 January 2003.

Should you have any questions, please feel free to contact the undersigned.

Sincerely,
SNAP LAKE DIAMOND PROJECT

Robin Johnstone
Senior Environmental Manager

DE BEERS CANADA MINING INC.

#300 – 5102 50th AVENUE
YELLOWKNIFE NT X1A 3S8 CANADA
TEL (867) 766-7300 FAX (867) 766-7347

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TECHNICAL MEMORANDUM

Golder Associates Ltd.
#500 - 4260 Still Creek Drive
Burnaby, B.C., Canada V5C 6C6

Telephone: 604-298-6623
Fax Access: 604-298-5253

TO:	Robin Johnstone De Beers Canada Mining	**DATE:**	February 27, 2003
FROM:	Dawn Kelly and Rick Schryer	**JOB NO:**	03-1322-017.5480
PREPARED BY:	Terry Eldridge, P.Eng		
RE:	**SNAP LAKE NORTH PILE SEEPAGE COLLECTION**		

1.0 INTRODUCTION

This memorandum reviews the seepage collection system between the northern toe of the North Pile and Snap Lake. Concerns have been raised by interveners that the seepage collection ditches would not be effective if ice wedges were to occur below the level of the ditches and these were to melt and create groundwater flow conduits between the North Pile and Snap Lake. In response, the design of the seepage collection ditches has been advanced and a construction sequence has been developed that will both identify if ice wedges occur along the proposed ditches and melt the ice before the ditches are put into operation. Measures have also been included in the seepage collection system design that will reduce or eliminate seepage from the North Pile reaching Snap Lake thereby mitigating environmental impacts.

The North Pile consists of Processed Kimberlite (PK) materials which are a mixture of silt, sand and fine gravel sized materials. The purpose of the seepage collection system is to collect surface water runoff and internal seepage from the North Pile, and to pass the water to the water treatment plant before it is discharged to Snap Lake.

The seepage collection system will be used throughout the full operating life of the mine (22 years). It will continue to function post-closure of mining, until either the North Pile and adjacent ground returns to permafrost conditions, or the surface runoff and any seepage waters are of acceptable quality to be discharged directly into Snap Lake.

The seepage collection system will be constructed in three stages: the Starter Cell ditch, the East Cell ditch and the West Cell ditch. These stages are developed sequentially to match the construction and progressive rehabilitation of the North Pile.

Performance of the Starter Cell ditch will be monitored. Where found necessary, modifications will be made to the design and operation of the subsequent East Cell and West Cell ditches to improve their performance.

Thermistors will be installed in each of the stages of the North Pile to measure the development of permafrost conditions within the North Pile. This information will be used to re-assess the ultimate post-closure performance of the North Pile and the need for any long-term post-closure care and maintenance.

The development plan for the North Pile uses a staged approach so that both the construction techniques and operating methods can be implemented and tested in the Starter Cell, which is located in an area well away from the shore of Snap Lake.

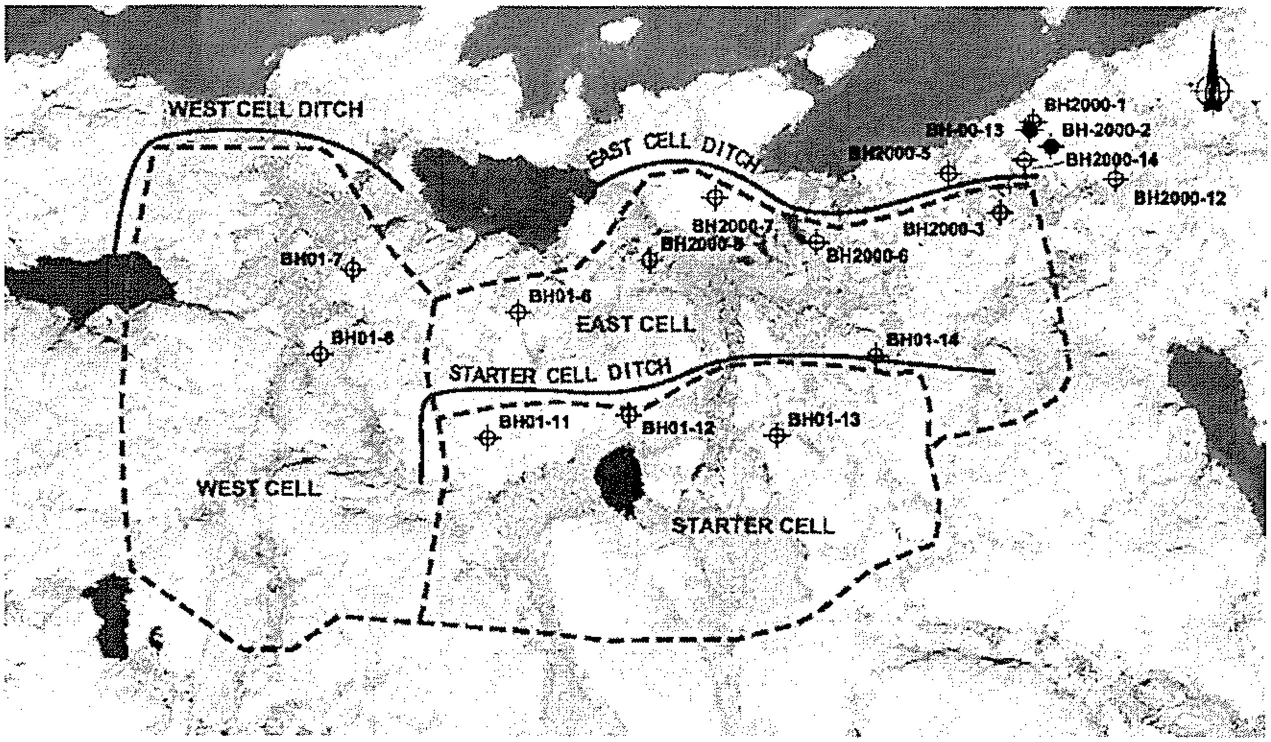
This memorandum describes the subsurface conditions, design, construction sequence and operating issues for the seepage collection system.

2.0 SEEPAGE COLLECTION SYSTEM

The layout of the North Pile seepage collection system is shown on Figure 1. The seepage collection system will be constructed between the North Pile and the North Arm of Snap Lake. Three collection ditches will be used, one for each of the three stages of the North Pile. The ditches will collect surface runoff and intercept any near surface seepage from the base of the North Pile. The water will be directed to sumps and then pumped from the sumps to the water treatment plant. The Starter Cell ditch will be 900 m long, the East Cell ditch will be 700 m long and the West Cell ditch will be 650 m long.

These seepage collection ditches will have a base width of 1 m and bottom out on granite bedrock. The side slopes will be formed in the till and fractured rock overlying the competent granite bedrock. The slopes will be cut to suit local soil conditions and lined where required.

Figure 1
North Pile Runoff and Seepage Collection Ditches



2.1 Starter Cell – Subsurface Conditions

A total of four boreholes have been drilled in the area of the north toe of the Starter Cell. The subsurface conditions at the borehole locations are summarized in Table 1. Locations of the boreholes are shown on Figure 1.

Table 1
Summary of Subsurface Conditions in Boreholes Located near Starter Cell Ditch

Borehole	Collar Elevation (m)	Thickness of Organics or Peat (m)	Thickness of Till / Broken Rock (m)	Depth to Top of Bedrock (m)	Top of Bedrock Elevation (m)
BH01-11	462.51	0.10	1.75	1.85	460.66
BH01-12	460.55	0.05	2.32	2.37	458.18
BH01-13	463.82	0.00	0.31	0.31	463.51
BH01-14	456.71	0.20	1.00	1.20	455.51

The boreholes encountered 0.3 to 2.4 m of overburden over granite bedrock. The soils comprise a thin layer of organics over typically cobbles and boulders with silt, sand and gravel infill. This soil could be till or the weathered bedrock surface. The ditch will cross a 20 to 30 m wide area that is expected to have 1 to 2 m of peat at surface. This area was not drilled.

2.2 East and West Cell – Subsurface Conditions

A total of 12 boreholes have been drilled in the area of the north toe of the North Pile. Locations of the boreholes are shown on Figure 1. The subsurface conditions at the borehole locations are summarized in Table 2.

Table 2
Summary of Subsurface Conditions in Boreholes Located near East and West Cell Ditches

Borehole	Collar Elevation (m)	Thickness of Organics or Peat (m)	Thickness of Till / Broken Rock (m)	Depth to Top of Bedrock (m)	Top of Bedrock Elevation (m)
BH01-7	453.58	-	0.5	0.5	453.08
BH01-6	453.73	-	2.13	2.13	451.6
BH2000-8 bog	447.68	3.10	2.80	5.90	441.78
BH2000-7	448.79	0.02	0.48	0.50	448.29
BH2000-6 Bog	447.43	1.60	1.35	2.95	444.48
BH2000-5 bog	445.21	1.70	4.40	6.10	439.11
BH2000-3 Bog	446.28	0.80	1.13	1.93	444.35
BH2000-13	-	0.15	0.85	1.0	441.29
BH2000-14	-	-	-	0	Surface
BH2000-1	447.38	0.03	1.64	1.67	445.71
BH2000-2	448.24	-	1.83	1.83	446.41
BH2000-12	-	1.07	1.25	2.32	-

Boreholes are listed from west to east.

Three typical soil profiles have been identified:

- Bog areas with about 1 to 3 m of peat overlying about 3 to 4.4 m of till and broken rock overlying granite bedrock.
- Mantle of organic soil about 0.5 to 1.0 m thick overlying 1.0 to 1.5 m of till and broken rock overlying granite bedrock.
- Veneer of soil or broken rock less than 0.5 m thick over granite bedrock or bedrock outcrop.

Massive, segregated ice occurs in the organic soils, but was not typically encountered in the mineral soils or the granite bedrock. The granite bedrock is massive and only slightly weathered beneath the broken surface.

Thermistor strings were installed in two holes near the northeast corner of the North Pile in 2000. These are located between 50 m and 90 m from Snap Lake and are in an area with a thin layer of organics overlying between 1 and 2 m of mineral soil overlying granite bedrock. The temperature measurements in these two holes show that the active layer develops to a depth of about 8 m. This is below the depth of the bedrock surface, so permanent ice would not be expected in the soils in these areas. The temperature at 20 m below the ground surface was -1.0 °C in the hole nearer Snap Lake and was -1.5 °C in the hole 90 m from Snap Lake. The thermal regime measured in these holes is considered to be representative of the conditions along the north toe of the North Pile, except in the low-lying bog areas. Active layer development in the bog areas is expected to be much shallower due to the insulating effect of the peat.

The elevation of the ground surface along the north toe of the North Pile varies from about 445 m to 449 m. The nominal elevation of the water surface of Snap Lake is 444.1 m. Some seasonal variation of the lake surface occurs.

3.0 DITCH DESIGN

The seepage collection ditches have been designed to extend through the soil layer and into the underlying granite bedrock. A nominal depth of 2 m has been used for the preliminary layout and cost estimates. The depth of the ditch will typically vary from about 1 m to 3 m. The sumps which will require a deeper excavation than the ditch will be located in the low areas which have the deeper soils.

3.1 Design Considerations

Construction of ditches in permafrost environments is typically avoided because the disturbance of the ground cover and the concentration of water flow increases the depth of thaw and potential erosion. In areas with ice-rich soils, this can lead to melting of ground ice, settlement along the ditch and sloughing of the ditch sides.

However, the North Pile area at Snap Lake has massive, granite bedrock at shallow depth and segregated ground ice has only been encountered in the bog areas. The organic soils and ice will be removed from these areas and the ditches bottomed on bedrock. Settlement of the ditch bottom caused by melting ground ice during the operating period will not be a problem. The sides of the ditches in overburden materials will be designed to be stable for the soils exposed in the excavations by the selection of the appropriate slope and slope protection.

Although segregated ice is not expected within the massive granite bedrock, a two-year construction sequence for the ditches along Snap Lake has been planned to promote melting of ice in the soil and rock along the ditch alignment before the ditch is put in service. During the first year of ditch construction, the organic soils will be stripped and the ditch rough graded. The ground will thaw during the summer period. The thaw will be deeper than the thaw that occured previously because of the removal of overburden materials. A ground penetrating radar (GPR) survey will be carried out to aid in identification of areas with ground ice. In the following year, the ditch will be excavated to final grade. Areas with settlement indicative of melting of ground ice and those identified by the GPR survey will be investigated with test pits in advance of construction and adjustments made to the design ditch depth and lining. Bedrock will be exposed along the full length of the ditch. Permeable areas in the bedrock will be identified and grouted and the surface treated or a liner placed in the ditch. Grouting would be carried out when the active layer has developed to its deepest extent in October.

Two methods will be used to reduce seepage flows from the East Cell ditches to Snap Lake. The information acquired from monitoring the performance of the Starter Cell and East Cell ditches will be used to refine the seepage control methods to be used with the West Cell ditch.

The first method of seepage control consists of constructing the bottom of the ditch below the level of Snap Lake (444.1 m) causing a small hydraulic gradient from the lake to the ditch. If the East Cell ditch is constructed with a bottom 10 cm below the level of the lake, the total near-surface groundwater flow *from the lake to the ditch* has been estimated to be between 600 and 1,200 litres per day (representing 0.005% of the daily capacity of the water treatment plant). This estimate is based on the following assumptions: the ditch is 50 m from the lake; the material hydraulic conductivity is $1x10^{-5}$ m/s, which is the hydraulic conductivity measured in the fractured rock layer above the competent granite bedrock; and the ditch length is 700 m.

The second method of reducing seepage flow to Snap Lake consists of constructing embankments between the ditch and the lake, which in time will raise the level of permafrost above the level of the ditch bottom, thereby creating a seepage barrier. Raising or aggrading the permafrost level by placing a granular fill is a common method used in road construction in permafrost environments. For road construction, granular materials are preferred because of their high shear strength, ease of placement and low frost susceptibility. A layer of insulation can be placed within the fill to reduce the thickness of the granular materials required. For the situation at Snap Lake, where the primary purpose of the fill would be to raise the permafrost level, and traffic along the fill will be limited to infrequent trips by maintenance vehicles, the strength of the fill materials would be of less concern than for a road. Mineral soils excavated as part of the site grading and foundation preparation could be used. Frost susceptible soils would be incorporated in sections of the fill where water movement to the frost susceptible soils would be limited. Snow will be cleared from the fill to increase ground cooling.

Alternatively, an Air Convection Embankment (ACE) could be constructed using relatively uniformly sized cobbles and boulders. An example of the performance of an Air Convection Embankment is provided by Goering (1998). This was a test embankment constructed at Fairbanks, Alaska. The embankment had a crest width of 6 m, was 2.5 m high and had side slopes at 2H:1V. The fill material was 5 to 8 cm sized rockfill. Over a two year period, the ambient air temperature averaged – 1.4 °C and -1.9 °C. The mean annual temperature in the upper portion of the embankment was +2 °C and the mean annual temperature on the subgrade surface ranged from – 1.2 °C to -3.6 °C. The use of an ACE could reduce the thickness of fill required, but would require greater material production effort than a fill constructed of the soils removed as part of the site preparation and unclassified quarried rockfill.

In the area of the northern toe of the North Pile, the active layer develops to a depth of about 8 m, most likely due to the thin soil layer, massive nature of the bedrock and proximity to Snap Lake. Therefore, the permafrost surface would need to be raised by 5 to 6 m for it to be above the level of the ditch bottom. Confirming that the permafrost level was raised sufficiently could take two to three years.

4.0 CONSTRUCTION SEQUENCE

The Starter Cell containment and seepage collection systems will be built during the construction period of the mine. The northern toe of the Starter Cell berm will be located 300 to 500 m from the shore of Snap Lake. The seepage collection system will consist of a ditch along the toe of the containment berm to collect both runoff and seepage emerging from the toe of the berm. The topography is such that the ditch can be graded to allow water to flow by gravity along the full length of the Starter Cell.

The ditch will be constructed by removing the organic layer and any peat deposits from the ditch alignment and downstream shoulder. This material will be placed in a stockpile for later use. The mineral soil will then be excavated to expose the bedrock surface. Soil that is suitable for berm construction will be placed along the downstream side of the ditch. Soil that is fine grained and wet or otherwise unsuitable for construction will be placed in the bottom of the Starter Cell. To prevent ponding along the bottom of the ditch, local high spots will be removed using a hydraulic hammer or controlled blasting and low spots will be filled. Thermistor strings will be installed through the downstream fill and along the base of the fill in four locations to provide data on the thermal performance of the ditch and downstream fill.

At the same time that the Starter Cell ditch is constructed, the organic soils along the East Cell ditch alignment will be stripped and stockpiled. The ditch will be rough graded, with excavation of most of the mineral soil. If suitable, the excavated soil will be placed on the lake side of the ditch and incorporated in the embankment constructed to raise the permafrost level. Otherwise, the material will be placed in the bottom of the East Cell.

Construction of the East Cell ditch will be completed the following year, while PK deposition occurs in the Starter Cell. Thermistor strings will be installed through the downstream embankment and along the base of the fill in four locations to provide data on the thermal performance of the East Cell ditch and downstream fill. This construction sequence allows the performance of the ditch to be monitored for one year before PK is deposited in the East Cell.

The ditch along the West Cell will be required in year 10 of operation. The ditch alignment will be stripped and rough graded in year 8, to promote melting of ground ice. The ditch will be completed in year 9 to allow one year of performance data to be acquired before PK is deposited in the West Cell.

Modifications to the seepage collection system will be implemented in response to the performance data collected during the operation. Modifications would most likely involve increasing the thickness or width of the embankment constructed between the ditch and the lake. These modifications will be implemented in the normal course of Adaptive Management as part of De Beers' Environmental Management System. The principles of DeBeers' Adaptive Management Program are incorporated in the design of the seepage collection at the North Pile.

5.0 CONCLUSIONS

Surface runoff and any seepage from the North Pile will be intercepted by a system of ditches, located near the toe of the pile, and pumped to the water treatment plant. The construction sequence has been developed to address the issues of ditch construction and operation in a permafrost environment. Specifically, construction over a two year period will promote melting of ground ice before the ditch is constructed to the final grade. Extending the ditch to the granite bedrock will allow permeable areas in the bedrock to be identified and sealed. The ditches along the East Cell and West Cell will be operated for one year before PK is deposited into these cells, providing an additional period to evaluate the performance of the ditches and modify them as needed before PK is deposited in these cells.

Seepage to Snap Lake is controlled by maintaining a small hydraulic gradient between the ditch and the lake. Constructing the ditch bottom below the level of the lake will cause shallow groundwater flow from the lake to the ditch. In addition, embankments constructed between the ditch and the lake will, with time, raise the level of the permafrost and develop an impermeable below-ground barrier between the North Pile and the lake. The performance of the system will be monitored throughout the mine life, and modifications made as needed. These measures will effectively control seepage from the North Pile reaching Snap Lake and should address the concerns raised by interveners on this issue.

6.0 REFERENCES

Goering, D.J. 1998. Experimental investigation of air convection embankments for permafrost-resistant roadway designs. Seventh International Permafrost Conference, Yellowknife, Pages 319-326.