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28 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: North Pile Chemical Stability

Please accept the attached technical memo titled "Snap Lake Diamond Project – North Pile Chemical Stability" for submission to the Public Registry. This memo was compiled in response to issues raised by Natural Resources Canada during the MVEIRB Technical Sessions.

Additionally, information contained within this memo should address the outstanding concerns identified by Indian and Northern Affairs Canada 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

ORIGINAL SIGNED BY

Robin Johnstone
Senior Environmental Manager

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TECHNICAL MEMORANDUM

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TO: Robin Johnstone
De Beers Canada Mining Inc.
DATE: February 28, 2003
FROM: Dawn Kelly and Rick Schryer
JOB NO: 03-1322-017/5470
Prepared By: Ken DeVos
RE: **SNAP LAKE DIAMOND PROJECT**
NORTH PILE CHEMICAL STABILITY

The purpose of this memorandum is to present a discussion of factors affecting the chemical stability of the North Pile, and to place the discussion in the context of the overall site water quality at the Snap Lake Diamond Project.

The following issues were raised by interveners in the Technical Sessions (November 26-December 6, 2002) and in communications leading up to the hearings.

1) North Pile Development Strategy (contingency in response to general North Pile geochemical stability issues);
2) issues related to cryoconcentration within the North Pile;
3) implications of thawing or partial thawing of the North Pile on geochemical stability;
4) acid rock drainage (ARD) issues related to placement of metavolcanic rock below the North Pile; and
5) ARD issues related to a temporary stockpile of metavolcanic rock.

A discussion of each of these issues as it relates to the current development strategy for the North Pile is provided below.

1.0 NORTH PILE DEVELOPMENT STRATEGY (CONTINGENCY IN RESPONSE TO GENERAL GEOCHEMICAL STABILITY ISSUES)

As a result of geochemical concerns expressed by Indian and Northern Affairs Canada (INAC) related to the environmental behaviour of kimberlite at the EKATI site and BHP's explanation for this behaviour (BHP 2002), INAC has suggested that contingency planning be conducted at the North Pile. In response to this and other issues raised by the interveners, the following mitigation, contingency and monitoring strategies will be employed for the North Pile:

Starter Cell – the starter cell provides a secure environment that allows for monitoring and refinement of the geochemical stability assessment of the material placed in the starter cell. The following assessments of North Pile behaviour can be accomplished using the starter cell:

- establishment of baseline geochemical data on kimberlite behaviour under ambient conditions;
- initial monitoring of the timing, rate and extent of permafrost aggradation;
- initial evaluation of the nature of cryoconcentration; and
- refinement of thermal modelling and cryoconcentration estimates based on the data collected.

Monitoring of the starter cell allows for initial refinement and/or modification of the development plan, contingency strategies and appropriate handling procedures, if required, prior to full-scale placement of processed kimberlite. Results of the ongoing starter cell monitoring will provide advance indications of conditions expected in the pile as a whole. In addition, monitoring of the starter cell will continue during full-scale deposition.

Mitigation to Contain Seepage – Seepage containment will be achieved using a combination of two elements related to the seepage interception ditch.

Firstly, the seepage ditch will be designed and constructed to minimize, if not eliminate altogether, seepage from the North Pile area to Snap Lake by establishing a reversal of the hydraulic gradient between the North Pile and Snap Lake. This reversal will change the seepage flow direction and will result in water from the North Arm of Snap Lake seeping into the collector ditch. For example, if the East Cell ditch is constructed with a depth 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 assumes that 1) the ditch is 50 m from the lake, 2) the material hydraulic conductivity is 1×10^{-5} m/s, which is the hydraulic conductivity measured in the fractured rock layer above the competent granite bedrock, and 3) the ditch length is 700 m.

Secondly, frozen seepage barriers will be established through the construction of embankments between the ditch and the lake. In time, the embankments will raise the level of permafrost above the level of the ditch bottom, thereby creating a seepage barrier. The barrier will force seepage from the North Pile upwards, into the ditch.

The seepage collection system will be used throughout the full operating life of the mine (22 years) and continue to function up to or after mine closure, 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.

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

These measures are expected to essentially eliminate seepage from the North Pile to the North Arm of Snap Lake, both during operations and at closure.

Water Quality Monitoring and Treatment As Necessary – As identified in the environmental assessment report (EAR), water from the North Pile seepage collection ditch will be directed to the water treatment plant during operations. At closure, monitoring of water quality from the North Pile and from the North Pile seepage collection ditch will continue. Water will continue to be treated after closure until the untreated water meets the required water quality discharge criteria.

2.0 CRYOCONCENTRATION IN THE NORTH PILE

As was suggested in the Technical Sessions, the thermal modelling for the North Pile has been refined, and laboratory frost heave testing has been completed on the processed kimberlite (PK) (Golder 2003b,c). The results of the refined thermal modelling and laboratory testing suggest that the pile freezes within two winters of deposition, and that the temperature of much of the processed kimberlite over the life of the mine is in the range -0.1 to -0.3 degrees Celsius, decreasing slowly at post closure. At these temperatures, about 10 to 50% of the water in the pile will be in an un-frozen state (Golder 2003b). Laboratory testing on the Snap Lake processed kimberlite suggests that the material will develop ice lenses, rather than extrude water, resulting in retention of the water and chemical mass within the pile.

The results from the modelling and laboratory testing confirm that the original chemical mass loading assumptions for cryoconcentration, as used in the Site Water Quality (GoldSim) model were appropriate (i.e., the water is retained in the pile and not released), given that the current GoldSim model allows mass release from 14% of the water in the pile, and that (based on the laboratory testing) some of this water will not likely be released, but retained in the pile. Section 6.2 does, however, present a chemical release scenario whereby it is assumed that the water is extruded (released) from the pile.

The use of a starter cell in the development of the North Pile will allow for refinement of the predicted mass release rates under ambient conditions, based on the data collected (even if complete freezing is not realized), in a setting that is well characterized and closely monitored. In addition, given the current seepage collection strategy, mass released from the North Pile will not report to the North Arm of Snap Lake until closure and only after it meets acceptable water quality criteria, regardless of the nature and extent of cryoconcentation.

3.0 IMPLICATIONS OF (PARTIAL) THAWING OF THE NORTH PILE ON CHEMICAL STABILITY

Currently the release of mass from the North Pile is assumed to be governed by the unfrozen material in the upper active layer. The active layer thickness in GoldSim is currently estimated at 2 m with 0.5 m of granite and 1.5 m of PK. Current model results show that the active layer develops in the PK to about 1.5 m (Golder 2003b). Based on the modelling results, the active layer thickness used in the GoldSim model is appropriate. Should the pile thaw, this active layer thickness would increase. Under the current assumptions incorporated into the GoldSim model, an increase in active layer thickness results in an increase in mass release (and hence concentrations in seepage) from the pile. A sensitivity analysis evaluating the effects of increases in active layer thickness was completed in Appendix IX.1 of the EAR.

Should the active layer thickness increase, or should the pile thaw, processes that would tend to limit mass release in the pile are either accounted for in the model (solubility constraints) or could be incorporated into the model calculations (seepage rates and weathering rates). These processes are discussed briefly below:

- **Seepage rates** - currently, mass release in the GoldSim model is allowed to instantaneously report to the receiver (i.e. all mass released in a given year reports in the same year). In reality, this mass release will be governed and attenuated by seepage release rates in the pile. This will cause the mass reaching Snap Lake (or the interceptor ditch) on an annual basis to be smaller than predicted by the model.
- **Solubility controls** – many of the parameters currently included in the model runs are governed by solubility and other geochemical constraints as determined in the PHREEQC modelling completed for the North Pile seepage (EAR Appendix IX.1). These controls will continue to limit the seepage concentrations of many parameters, even if enhanced mass release were to take place due to (partial) thawing.
- **Weathering Rates** – weathering rates used for modeling of mass release from kimberlite are based on kinetic test cells that are designed to intentionally accelerate weathering processes. This accelerated weathering rate is currently applied to all of the thawed material in the active layer. In reality, high rates of weathering will apply primarily to the material at surface, in contact with the atmosphere. It can be qualitatively argued that weathering rates below the first few tens of cm will be substantially lower than those currently used in the model due to reduced interaction with the atmosphere.

Given the above discussion, we feel that the assumptions as incorporated into the North Pile assessment of mass release are appropriate and conservative (that is, they over predict mass release rates and potential changes).

The use of a starter cell in the development of the North Pile will allow for refinement of the predicted mass release rates under ambient conditions, in a setting that is well characterized and closely monitored. Further, given the current seepage collection strategy, mass released from the North Pile will not report to the North Arm of Snap Lake until closure and only if it meets acceptable water quality criteria, regardless of the thawing/mass release conditions. As discussed below, the mass load implications on Snap Lake with respect to the North Pile (using a thawing scenario as proposed by INAC) are expected to have little impact on the assessed site discharge water quality.

4.0 ARD ISSUES RELATED TO PLACEMENT OF METAVOLCANIC ROCK BELOW THE NORTH PILE

The current assumption is that the metavolcanic rock placed within the footprint of the North Pile will have few implications, if any, with respect to mass release from the North Pile. This assumption is based on the following observations:

1) Water quality monitoring of runoff from surface areas where metavolcanic rock from the advanced exploration program is currently located shows that this rock has not generated any acidic runoff over the past three years. It is expected that any metavolcanic rock placed within the footprint of the North Pile will be covered by processed kimberlite within three years or less. After this time, sulphide oxidation, if any, would be significantly impeded.
2) Once covered, the metavolcanic rock is expected to freeze, which will effectively eliminate transport of oxidation products.
3) Should the metavolcanic rock not freeze, several factors will limit either acidity production, or acidity release:
    - Oxygen diffusion through the kimberlite will limit the amount of sulphide oxidation and subsequent production of acidity.
    - One tonne of kimberlite has the potential to neutralize the acidity produced by about six tonnes of metavolcanic rock. This is based on a balance between the potential acidity production of metavolcanics and the neutralizing potential of the kimberlite (Section 4.2.3 of EAR; Appendix III.2), using the lower 5th percentile neutralizing potential (NP) value for kimberlite, and the upper 95th percentile value for sulphide content of the metavolcanic material.
    - A simple acidity/alkalinity balance using the kinetic test data available in EAR Appendix III.2 was completed. It was assumed that a unit section of the metavolcanic material has a dimension of 1 m (l) x 5 m (h) x 20 m (w), and that a unit section of kimberlite overlying the groundwater flow path along which this water must seep has dimensions of 1 m (l) x 9 m (h) x 400 m (w). Using the results of the worst-case metavolcanic results (Column 3 from EAR Appendix III.2), the acid loading rate is about 18 kg $CaCO_3$/week. The alkalinity loading rate from the overlying kimberlite cover is estimated at 93.6 kg $CaCO_3$/week, or 4.2 times greater than the acid loading rate.

Based on the above observations, acidic drainage is not expected to be generated to any significant degree by the metavolcanics. Even if some acid were to be released, it is considered very unlikely that it would report from the pile to Snap Lake under the current North Pile design. As mentioned previously, the use of a starter cell in the development of the North Pile will allow for refinement of the predicted mass release rates under ambient conditions. In addition, given the current seepage collection strategy, mass released from the North Pile will not report to the North Arm of Snap Lake until closure and only after it meets acceptable water quality criteria.

5.0 ARD ISSUES RELATED TO METAVOLCANIC ROCK STOCKPILE

A stockpile consisting of metavolcanic rock should not be considered potentially acid generating without further definition of the metavolcanics' geochemical characteristics. As demonstrated by the kinetic testing and the site observations, it has become obvious that:

a) not all metavolcanic rock has the potential to generate ARD; and

b) even if this potential exists, it may not be realized under ambient site conditions for a considerable period of time.

As has been discussed in Appendix IX.1 of the EA and in previous reports (Winspear 2000; De Beers 2001), some metavolcanic rock is currently located on the surface as a result of the advanced exploration program (AEP). This rock is being monitored closely for signs of incipient acidity production and release. This rock has been exposed to the atmosphere for greater than three years, and to date, water quality analyses have shown that the runoff from this material is non-acidic (De Beers, 2001; and, EA Appendix III.2). Annual assessment of the seepage and runoff collection areas has shown no signs of acidification.

Any metavolcanic rock produced during operations that is stockpiled on surface (prior to being placed back underground or in the North Pile) will be located in an area where the runoff from the stockpile can be monitored, collected and diverted to treatment if necessary. In the unlikely event that the runoff from the stockpile did prove acidic, then the material will not be encapsulated in the North Pile, but rather be used as underground backfill, where any acidity will be neutralized through mixing with mine water and consolidation water from the PK. The potential for acidity release will be further eliminated when the metavolcanic rock is blended with the alkaline PK prior to deposition in the mine as backfill. After closure, the mine will be re-flooded, and sulphide oxidation will come to a halt.

6.0 RESPONSE TO CHEMICAL MASS LOADING ESTIMATES AS DETERMINED BY INAC

6.1 Addition of Chemical Mass Load due to Partially Thawed Pile

In Appendix A of the INAC comments, rough estimates of mass release under thermal conditions that are different than those used in the model (i.e., the INAC comments assumed that ¾ of the pile would be available to react) yield a maximum release rate (converted to kg/d) of approximately 495 kg/d.

As quoted from the report:

> "These products are due to weathering of the materials, and are beyond those sent to the pile in the process water. These soluble products would not immediately be flushed from the pile. The rate of release would be limited by the amount of water infiltrating the pile available to transport these materials, and thermodynamic equilibrium constraints, which was beyond the scope of this rough estimate. Thus the release rate identified [in INAC Appendix A] is

> unrealistically high. However, eventual freezing of the pile would likely result in a significant portion of these soluble products being expelled through cryoconcentration over an extended period of time."

If it is assumed that this rough estimate is correct, the result will be a larger mass that will be captured and will report to the treatment plant. Adding a mass load of 495 kg/d to the treatment plant during operations results in an incremental increase in operational load of less than 4% (Attachment 1). This could potentially increase the total dissolved solids (TDS) concentrations in the discharge from an expected value of 520 mg/L to a value of 541 mg/L. The TDS concentration from the discharge that was assessed in the EA was 594 mg/L. Even with the conservative mass load scenario proposed by INAC (which they pointed out is biased high), the expected values at the discharge are still ***lower*** than the assessed values.

Further, should release of water from the pile occur via seepage pathways, the rate of release will be governed by the hydraulic conductivity of the pile and underlying materials resulting in a much lower annual loading rate than predicted. Currently (as calculated), the chemical mass release from the pile is not limited by the pile hydraulic conductivity. Hydraulic conductivities in other frozen, fine-grained materials range from 10^{-7} to 10^{-11} m/s (Williams and Smith 1989). It is understood that these hydraulic conductivities may not be directly applicable to the processed kimberlite. However, as more data are generated during operations, a refined, site-specific hydraulic conductivity value and seepage estimate can be developed.

6.2 Addition of Chemical Mass Load due to Expulsion of Cryoconcentration Water

Also included in Appendix A of the INAC comments are rough estimates of mass release that would be expected if expulsion (release) of the cryoconcentration water occurs, assuming all of the porewater mass is released from the frozen water.

The values presented by INAC are admittedly conservative, and additional work could be completed to refine the mass released by looking at the annual freezing rates as predicted by the updated thermal modeling. However, for the purposes of this discussion, if it is assumed that the rough INAC estimate is correct, the result will be a larger chemical mass load that will be captured and will report to the treatment plant.

Adding a mass load of 301 kg/d to the treatment plant during operations results in an incremental increase in operational load of about 2% (Attachment 1). This could potentially increase the TDS concentrations in the discharge from an expected value of 520 mg/L to a value of 533 mg/L. The TDS concentration from the discharge that was assessed in the EAR was 594 mg/L. Even with the conservative mass load scenario proposed by INAC, the expected values at the discharge are still ***lower*** than the EAR assessed values.

6.3 Cumulative Conservative INAC Loading Estimates

When applied cumulatively, the additional mass load from both INAC estimates represents an additional 795 kg/d to the treatment plant during operations. This could potentially increase the TDS concentrations in the discharge from an expected value of 520 mg/L to a value of 554 mg/L. The TDS concentration from the discharge that was assessed in the EAR was 594 mg/L. The resulting expected values at the discharge are still lower than the assessed values.

7.0 CLOSING STATEMENT

For the reasons stated above, it is our opinion that the mass loading rates as applied in the Site Water Quality model used for the EA are both appropriate and conservative (that is they likely over predict potential impacts). Further, as indicated in Section 6, even when assuming the mass load increase from the North Pile derived from INAC's scenario, the resulting changes in the assessed site discharge water quality are minimal. Adding INAC's proposed mass load rates to the expected values from the treated discharge results in water quality predictions that are lower than the assessed values in the EAR.

The use of a starter cell in the development of the North Pile will allow for refinement of the predicted mass release rates and cryoconcentration under ambient conditions. Moreover, given proposed mitigation to collect seepage (i.e., reversal of the hydraulic gradient between Snap Lake and the North Pile and construction of frozen seepage barriers), release of mass from the North Pile will not report to the North Arm of Snap Lake until closure and only after it meets acceptable water quality criteria.

While it is true that additional refinements are always possible, we consider the best time to further refine water quality estimates for the North Pile is during operations. Once representative, field-scale data are available, current predictions can be updated, and the need for modified water management assessed.

References

BHP. 2002. 2001 Waste Rock Storage Area Seepage and Waste Rock Survey Report. Prepared in accordance with the requirements of Part F, Section 3(b) of Water License N7L2-1616. BHP Diamonds Inc. March 2002.

De Beers. 2002. Snap Lake Diamond Project Environmental Assessment. February 2002. Document submitted to Mackenzie Valley Environmental Impact Review Board. February, 2002.

De Beers. 2001. Class B Water License Monitoring Report. Document submitted to NWT Water Board. March, 2001.

Golder (Golder Associates Ltd.). 2003a. Technical Memorandum on North Lake Pile Seepage Collection. From Golder Associates Limited to De Beers Canada Mining Inc. February, 2003.

Golder. 2003b. Technical Memorandum on Snap Lake North Pile Thermal Modelling. From Golder Associates Limited to De Beers Canada Mining Inc. February, 2003.

Golder. 2003c Technical Memorandum on Snap Lake North Pile PK Frost-Heave Testwork. From Golder Associates Limited to De Beers Canada Mining Inc. February, 2003.

Williams, P.J. and M.W. Smith. The Frozen Earth: Fundamentals of Geocryology. Carleton University, Ottawa. Cambridge University Press. Cambridge. 1989.

Winspear. 2000. Acid/Alkaline Rock Drainage Generation Potential Monitoring Plan for the Snap Lake Site – Class B Water License – N17-1735. Letter submitted to Mackenzie Valley Water Review Board. March, 2000.

ATTACHMENT 1

The conservative proposed released rates by INAC are 1.8 x 1,011 mg/yr [TDS] and 1.1 x 1,011 mg/year [TDS] that would result from thawing of 3/4 of the pile, or expulsion of cryoconcentration water, respectively.

Partly Thawed Pile

For the estimated TDS release rate of the partially thawed pile:

$$1.8 \times 10^{11} \text{ [mg/yr]} / 1 \times 10^{6} \text{ [mg/kg]} /365 \text{ [days]} = 494 \text{ [kg/d] loading}$$

Under the current seepage cut-off scenario, this load will report to the treatment plant. The current expected treatment loading rate is about 12,280 kg/d. The loading rate assessed in the EA is 14,100 kg/d.

Using the assessed value, the additional 494 kg/d loading represents about 3.5% of the total assessed load from site. Using the average treated discharge flow of 23,730 m^3/d, this equates to a concentration increase of:

$$494 \text{ [kg/d]} / 23{,}730 \text{ [m}^3\text{/d]} * 1 \times 10^{6} \text{ [mg/kg]} / 1{,}000 \text{ [L/m}^3\text{]} = 21 \text{ mg/L increase in TDS}$$

concentrations at the treated discharge point.

Expulsion (release) of Cryoconcentration-Water

For the estimated TDS release rate due to cryoconcentration:

$$1.1 \times 10^{11} \text{ [mg/yr]} / 1 \times 10^{6} \text{ [mg/kg]} / 365 \text{ [days]} = 301 \text{ [kg/d] loading}$$

Under the current seepage cut-off scenario, this load will report to the treatment plant. The current expected treatment loading rate is about 12,280 kg/d. The loading rate assessed in the EA is 14,100 kg/d.

Using the assessed value, the additional 301 kg/d loading from expulsion of cryoconcentration-water represents about 2.1% of the total assessed load from site. Using the average treated discharge flow of 23,730 m^3/d, this equates to a concentration increase of:

$$301 \text{ [kg/d]} / 23{,}730 \text{ [m}^3\text{/d]} * 1 \times 10^{6} \text{ [mg/kg]} / 1{,}000 \text{ [L/m}^3\text{]} = 13 \text{ mg/L increase in TDS}$$

concentrations at the treated discharge point.

Combined Increase

Combining the two INAC loading estimates yields an increase of 5.6% (795 kg/d) of the total assessed load from site. Using the average treated discharge flow of 23,730 m^3/d, this equates to a concentration increase of:

$$795 \text{ [kg/d]} / 23{,}730 \text{ [m}^3\text{/d]} * 1 \times 10^{6} \text{ [mg/kg]} / 1{,}000 \text{ [L/m}^3\text{]} = 34 \text{ mg/L increase in TDS}$$

concentrations at the treated discharge point.