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PO Box 1500
YELLOWKNIFE, NT X1A 2R3

February 14, 2003

Glenda Fratton
Mackenzie Valley Environmental Impact
Review Board
PO Box 938
YELLOWKNIFE, NT X1A 2N7

Dear Ms. Fratton:

Re: Technical Review of the Environmental Assessment (EA) Report and subsequent information submitted by De Beers Canada Mining Inc. (DCMI) for the Proposed Snap Lake Diamond Project

The attached technical report represents the Indian and Northern Affairs Canada (INAC) review of the information received between February 1, 2001 to January 31, 2003, including the responses to Information Requests by all parties and technical sessions. If INAC should have further comments on additional material received after January 31, 2003, the Mackenzie Valley Environmental Impact Review Board (Board) will be informed once the review of the additional information has been completed.

INAC manages the waters of the NWT and Nunavut and advises the Department's Minister on water-related matters. The Department participates in environmental assessments, and ensures that the appropriate Waters Acts and Regulations are applied, such as the *Northwest Territories Waters Act*. The Department also is responsible for the management of the land in the Northwest Territories under the control, management and administration of the INAC Minister by virtue of the *Territorial Lands Act*, Territorial Land Regulations and the *Federal Real Property and Federal Immovables Act* and subsequent Regulations as they apply to Territorial Lands. INAC acts as an expert advisor to the Board, is a Regulatory Authority and represents the Federal Minister in the decision-making process for this assessment.

To date, INAC has not received written responses to its Request for Ruling dated January 22, 2003 and reasons for why three of its Information Requests (IR) were not included in the IR stage.

INAC has provided technical advice in the following areas (see attachments):

- Predictions of minewater quality;

- Management of paste kimberlite and waste rock in the North Pile;
- Impacts of wastewater discharges to Snap Lake;
- Abandonment and Restoration; and
- Cumulative impact assessment on aquatic resources.

Please refer to the executive summaries (Attachment I and II) for a comprehensive list of technical issues to be presented at the pre-hearing conference on February 28, 2003.

From a water resources perspective, INAC has a substantial number of concerns that have not been resolved through the information request, technical session, or other processes associated with the EA. Together, the uncertainties associated with these unresolved issues has lead INAC to conclude that the effects of mining activities on water quality in Snap Lake and associated impacts on aquatic organisms are substantially underestimated. Until the outstanding issues have been resolved, INAC is unable to reach a conclusion as to the water related impacts of the proposed project.

INAC's review of this project will continue. The recent submissions by DCMI, and those that it has indicated will be forthcoming are not considered in this assessment to date. We do note, however, that the recent technical memoranda provided by DCMI are intended to respond to some of the concerns previously expressed by reviewers. These may or may not address the concerns we identified, however, due to the timing of DCMI's submission INAC is not able to consider the information contained therein. As stated earlier, this technical report is based solely upon the information received prior to January 31, 2003.

From a lands perspective, the impact of the proposed development is to be generally negligible to minor with the suggested mitigation measures identified in the Lands section of the report (see Attachment II). The uncertainty and issues surrounding the abandonment and reclamation activities as outlined by DCMI can be addressed at this stage of the environmental assessment process through DCMI commitment to remove all materials from the land upon closure. As well, DCMI commits to reclaim the land to a stable state, facilitating its return to a condition that is functionally similar to its original state. Without these commitments, alternatives to the above recommendation would require further review before INAC could respond.

Where other land management issues or requirements may exist, we will request they be resolved through the regulatory phase of this project review, prior to the issuance of land tenure documentation.

If you have any questions regarding this technical review, please do not hesitate to contact Tamara Hamilton, Environment & Conservation at 669-2616.

Yours sincerely,

David Livingstone
Director, Renewable Resources and Environment

Attachments

cc: Tamara Hamilton, Environment & Conservation
Ed Hornby, District Manager, Operations
Malcolm Robb, Manager, Mineral Resources
Sevn Bohnet, Water Resources
Buddy Williams, Land Administration

ATTACHMENT I **February 14, 2003**

An Evaluation of the Environmental Assessment of the Proposed Snap Lake Diamond Project Submitted by Water Resources Division, Indian and Northern Affairs Canada

Executive Summary

As part of its mandate, the Water Resources Division has conducted a thorough review of the Environmental Assessment (EA) of the proposed Snap Lake Diamond Project that was submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) by DeBeers Canada Mining Incorporated (DCMI). Our review of the EA report focussed on the water-related aspects of the proposed project, considering the requirements for the environmental assessment that were established under the Terms of Reference that was issued for this project by the MVEIRB. In conducting our review, we participated in several rounds of information requests, technical sessions, and conference calls to discuss and attempt to resolve many of the issues identified herein.

The issues that are identified and discussed in this report have been previously submitted to the Board and DCMI throughout the various stages of the EA process. In spite of these attempts to obtain further information from DCMI, numerous issues and concerns remain unresolved at the time of this submission. For ease of reference, we have combined similar issues that are associated with specific project components and/or effects, including:

- Predictions of minewater quality;
- Management of paste kimberlite and waste rock in the north pile; and,
- Impacts of wastewater discharges to Snap Lake.

Due to the number and importance of the unresolved issues, there are many uncertainties with respect to the potential effects of this project on the receiving environment of Snap Lake and the Lockhart River Basin. Until the outstanding issues have been resolved, INAC considers the EA to be incomplete, and does not provide an adequate basis for assessing the impacts of the proposed project.

Minewater Quality and Wastewater Storage Capacity

There are a number of hydrogeological issues that have significant implications for prediction of the effects of mining activities on aquatic resources in the Lockhart River Basin. The most significant outstanding hydrogeological issue is the potential for connate groundwater in the vicinity of the mine workings to contain higher than expected concentrations of dissolved constituents (e.g., total dissolved solids-TDS; chloride, other major ions, and/or phosphorus). This issue is critical because higher than expected levels of dissolved constituents in connate groundwater are likely to result in higher than expected levels of these constituents in mine water and higher than expected loadings of these constituents to Snap Lake. The proposed water treatment plant is unlikely to remove most of these dissolved constituents. Accordingly, it is likely that the EA report has underestimated the adverse effects of mining activities on ecological receptors in Snap Lake.

In addition to the above concems relative to minewater quality and management, INAC still has serious concerns regarding the capacity of the water management pond. More specifically, our review of the technical information that has been provided by DCMI indicates that the water management plant does not have sufficient storage capacity to handle excessive inflows, should upsets of the water treatment plant occur for extended periods of time (i.e., in excess of 10 to 20 days). If such upsets occur, there is significant potential for release of untreated mine water to Snap Lake.

Management of Paste Kimberlite and Waste Rock in the North Pile

At this time there is no precedent for surface disposal of paste tailings composed of kimberlite material in an arctic setting. The proponent has acknowledged the uncertainty associated with the disposal method by proposing to develop a starter cell that will be monitored to check operational conditions.

As a consequence of these and other uncertainties, there are a number of concerns with respect to the containment and management of water within the North Pile. There is potential for greater than predicted rates of release of wastewater from the North Pile during and following construction. Such releases of wastewater may arise due to:

- excess water in the paste discharge,
- seepage and runoff escaping beyond the perimeter ditches,
- freezing being much slower than anticipated,
- cryo-concentration of paste pore water,
- elevated levels of leaching from the paste, and/or,
- oxidation of the PAG meta-volcanic rocks.

Excess Water in the Paste - There are several factors which may cause the kimberlite paste to be wetter than assumed. Paste abrasiveness, high pump pressure due to distance to the North Pile, and the need for low viscosity to produce flat beaches all suggest a need for a wet paste. A wet paste will result in more free water (as opposed to pore water) and also a reduction in the freezing rate of the material.

Seepage, Runoff and Ditches - The originally proposed ditches are unlikely to meet the performance objectives suggested by the proponent. In addition, the lack of definition of ice wedges under or near the perimeter of the North Pile may confound interpretation of seepage routing and losses. Given the original design, and in the absence of ice wedge delineation, some seepage and runoff from the North Pile is likely to by-pass under the ditches and some of the captured seepage is also likely to escape. A modified ditch design was suggested as a contingency by the proponent during a break-out session from the Technical Sessions. The results of the monitoring conducted to evaluate starter cell performance would be used to determine the need for implementing such a contingency plan. An assessment of the environmental impacts on the north arm of Snap Lake associated with more realistic objectives for the original ditch design, as well as the modified ditch design have not been adequately conducted. INAC expects that appropriate monitoring and criteria for implementation of a modified ditch design will be developed as a condition of the EA review.

Slower Freezing Rate - The proponent has acknowledged that the thermal modeling completed to date is inadequate to predict the rate of freezing of the North Pile. It is possible that a significant portion of the pile, in the order of 50% or more, will not freeze during the life of the mine. Should this occur, there will be a greater mass of unfrozen kimberlite that may leach chemicals of potential concern (COPCs) to the environment. Importantly, bleed water from the discharged paste may infiltrate into the pile and not pool on the surface for collection and routing to the water treatment plant.

Cryo-Concentration of Paste Pore Water - As indicated above, the thermal modeling presented to date is not adequate. The key weakness of the thermal modeling is the lack of confidence in the rate at which the pile will freeze and the resulting expulsion of pore water. A rapid onset of freezing (i.e. nearly instantaneous under winter) may yield a nearly completely frozen pile with little pore water expulsion. If the applied layer freeze over a time scale of two years or more (i.e. within mine life) as projected by De Beers, then process water may be expelled with consequential impacts on Snap Lake. If the pile freezes very slowly (i.e. in the order of decades to centuries), then the COPCs may be released over greater periods of time, with decreased impacts. However the actual manner in which the pile freezes will influence the rate of expulsion and may result in increased pore pressure followed by instability of the surface and/or perimeter of the pile. Due to cryo-concentration process, essentially all of the soluble COPCs that were present in the unfrozen pore water will be expelled.

Leaching of COPCs - For the Snap Lake project, the primary mechanism for control of leaching of COPCs from kimberlite paste is through the establishment of permafrost. As noted above, the thermal modeling that was presented in the EA report is inadequate. Consequently, there may be a greater mass of un-frozen material within the North Pile. In turn, unexpected leaching of COPCs from this material could occur.

Meta-Volcanic Waste - The meta-volcanic rocks are expected to be potentially acid generating. In the event that the North Pile freezes much more slowly than expected, oxidation and acid generation could occur in these rocks. These processes will not be inhibited by exclusion of oxygen because the pile is expected to be essentially unsaturated if it is unfrozen. We lack confidence that this material will be frozen, as the thermal modeling is inadequate. The proponent has not shown that, in the absence of freezing conditions, acid rock drainage will not occur.

The uncertainties related to these six issues are important because slower than expected freezing of the North Pile has the potential to increase COPCs produced in and release from the facility. Loadings of various COPCs to Snap Lake could be greater than predicted in the EA report, if this additional contaminant load is not effectively collected and treated. The impacts of any release of water to the environment could be concentrated in the north arm of Snap Lake. The proponent has argued that they have conservatively allowed for a high rate of flushing of COPCs from the underground and from the North Pile. However, their estimated loading of COPCs is distributed over the entire volume of Snap Lake and not concentrated in the north arm of the lake. Should there be a greater release from the North Pile due to one or more of the above factors, then the impacts to the north arm and Snap Lake as a whole, will be greater than estimated.

Impacts of Wastewater Discharges to Snap Lake

A number of Issues relative to the methods used to predict the effects of mining activities on ecological receptors have not been adequately addressed and these issues have not been resolved in the EA report, in the responses to information requests, or in the MVEIRB Technical Sessions. First, the site-specific water quality benchmarks that were developed to support the assessment were not developed using the procedures that have been developed by the Canadian Council for Ministers of the Environment (CCME). Application of such procedures would likely have resulted in the development of lower benchmarks. As a result, the predicted effects on fish and other aquatic organisms are likely underestimated. In addition, the impact assessment criteria used in the EA report do not consider that zooplankton are keystone species in Snap Lake and that adverse effects on these organisms could lead to cascading effects on other species in the aquatic food web that consume zooplankton (e.g., lake trout). As a result, it is likely that the effects of mining activities on fish and other aquatic organisms will be substantially greater than predicted. DCMI has not provided the information that was requested to evaluate the extent to which such effects have been underestimated.

Relative to the discharges of wastewater from the mine site and associated water quality in Snap Lake, INAC has raised a number of concerns that have not been resolved in the EA report, in the responses to information requests, or in the MVEIRB Technical Sessions. More specifically, the results of the INAC evaluation of the information provided by DCMI suggest that the levels of several water quality variables (e.g., total dissolved solids and chloride) could be higher than predicted in wastewater discharged from the mine site. In addition, the lack of mixing under ice-covered conditions and the negative buoyancy of the effluent could result in higher than anticipated levels of such COPC's in water at the bottom of Snap Lake during the winter, and in water recharging the underground workings. Furthermore, the potential effects of increased levels of total dissolved solids and associated major ions on the structure of the aquatic community have not been adequately assessed in the EA report, associated documentation, nor in any of the supplemental information provided to date. This is important because the abundance of, for example, certain zooplankton could be reduced to such an extent that adverse effects on other components of the food web (e.g., fish) could occur. Consequently, it is likely that the effects on sensitive environmental receptors that were predicted in the EA report are substantially underestimated.

The validity of the nutrient modelling that was conducted to support the EA remains a serious concern for INAC. More specifically, it is likely that the concentrations, loadings, and availability of key aquatic plant nutrients (i.e., dissolved phosphorus and orthophosphate) in wastewater from the mine have been underestimated. Consequently, it is likely that the severity of eutrophication (i.e., increased levels of aquatic plant growth) that will occur in Snap Lake in response to phosphorus releases from the mine has likely been underestimated. Eutrophication in Snap Lake represents an important issue because enhanced algal production and subsequent settling of algae on the lake bottom can lead to depressed concentrations of dissolved oxygen (DO) under ice. The results presented in the EA report indicated that DO levels under ice could decrease by 1 to 3 mg/L and approach levels of concern for lake trout. Because the phosphorus modelling that was presented in the EA report may underestimate effects in Snap Lake, it is possible that the levels of DO in Snap Lake during the winter could be depressed to levels that are associated with chronic effects in fish and/or other aquatic organisms. Hence, it is likely that the EA report has underestimated effects on fish and other aquatic organisms.

Based on the results of INAC's technical evaluation, it is apparent that the assessment of cumulative effects presented in the EA report does not provide a basis for fully evaluating the effects of the proposed Snap Lake diamond project nor the interactive effects between the project and other anthropogenic activities that could influence aquatic resources in the Lockhart River Basin. More specifically, it is INAC's considered opinion that the EA has underestimated the effects of the various mining activities and associated discharges of COPCs on aquatic organisms (i.e., the effects of releases of phosphorus, TDS, and possibly metals have likely been underestimated). In addition, the interactive effects of multiple COPCs have not been adequately addressed (i.e., the issue not been resolved) in the EA report (although the implementation of whole effluent toxicity tests mitigates this concern to a certain extent). Furthermore, the interactive effects of the Snap Lake project with other land and water use activities in the Lockhart River Basin (e.g., exploration activities, sport and subsistence fishing, etc.) have not been fully evaluated. Finally, the interactive effects of the project with other human activities (e.g., long-range transport of atmospheric pollutants, global climate change, etc.) have likewise not been assessed. While the terms of reference of the EA do not explicitly require DCMI to conduct a broader assessment of cumulative effects, it is reasonable to expect the EA to assess the interactive effects of project activities and interactions between project activities and activities that occur elsewhere in the Lockhart River Basin. These shortcomings render the EA inadequate in terms of assessing cumulative effects.

Conclusions

In summary, the Water Resources Division has a substantial number of concerns that have not been resolved through the information request, technical session, or other processes associated with the EA. Together, the uncertainties associated with these unresolved issues lead us to conclude that the effects of mining activities on water quality in Snap Lake and associated impacts on aquatic organisms are substantially underestimated. Until the outstanding issues have been resolved, INAC considers the EA to be incomplete and, as such, does not provide an adequate basis for assessing the impacts of the proposed project.

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Definitions of Acronyms for Reference

AEP	Advanced Exploration Program
CCME	Canadian Council of Ministers of the Environment
COPC	Chemicals of Potential Concern
CTT	Chronic Toxicity Threshold
DCMI	DeBeers Canada Mining Inc.
DO	Dissolved Oxygen
EA	Environmental Assessment
INAC	Indian and Northern Affairs Canada
MVEIRB	Mackenzie Valley Environmental Impact Review Board
TDS	Total Dissolved Solids
ToR	Terms of Reference
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency

ATTACHMENT I **February 14, 2003**

1.0 Introduction

As part of its mandate, the Water Resources Division has conducted a thorough review of the Environmental Assessment (EA) of the proposed Snap Lake Diamond Project that was submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) by DeBeers Mining Canada Incorporated (DCMI). To ensure a thorough technical review of the project, the Water Resources Division retained a team of expert consultants and internal staff. The technical review reports submitted to the division by the expert consultants have been included in the appendices and form part of this report.

Our review of the EA report focussed on the water-related aspects of the proposed project, considering the requirements for the environmental assessment that were established under the Terms of Reference that was issued for this project by the MVEIRB. In conducting our review, we participated in several rounds of information requests, technical sessions, and conference calls to discuss and attempt to resolve many of the issues identified herein.

This review of the EA report focussed on several key topic areas, including:

- Geochemical Issues
- Hydrogeologic Issues
- Geotechnical Issues
- Permafrost and Thermal Issues
- Hydrological Issues
- Impact Assessment Issues
- Environmental Quality Issues
- Cumulative Effects Assessment

Specific comments on each of these issues are provided the following sections of this report and in the technical appendices to this report. These comments are offered to the MVEIRB on behalf of the responsible minister (i.e., the Minister of INAC).

2.0 Specific Comments

As indicated above, INAC has identified a number of issues related to the proposed Snap Lake diamond project that were not been adequately addressed in the EA report, in the responses to information requests, or in the MVEIRB Technical Sessions. Each of these issues are identified in the following sections of this report. In addition, the developers conclusion regarding the issue, INAC's conclusion regarding the issue, the rationale for INAC's conclusion, and INAC's recommendation relating to the issue are detailed in the following specific comments.

2.1 Geochemical Issues

INAC has two major and three minor unresolved geochemical issues concerning the predicted quality of water released from stored waste materials and discharged to Snap Lake as part of the proposed Snap Lake Diamond Project. These issues have not been adequately addressed in the EA Report, in the responses to information requests, or in the MVEIRB Technical Sessions, and thus, are unresolved at this time.

The five geochemical issues are:

- Geochemical Reactivity of North Pile
- Pore Water Expulsion from the North Pile

- Potentially Incomplete Understanding of Kimberlite Geochemistry;
- Management of a Surface Stockpile of PAG material; and
- Quality Control for Construction Material.

The detailed discussion of the five individual issues is provided in Appendix A of this report. To facilitate the discussion, the two first geochemical issues are described as one major issue below, as they are inter-related.

2.1.1 Geochemistry of the North Pile

MVEIRB Terms of Reference: MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development impacts on surface and ground waters, in particular the water chemistry impacts of surface runoff , and the effects of kimberlite and other materials stored in the North Pile, considering acid rock drainage, metal leaching and geochemistry (ToR Reference: line #336 to 341, 379 to 380 and 392). MVEIRB Terms of Reference also require De Beers to provide an analysis of the proposed development impacts on surface and ground waters, in particular the impact of water contained in the process kimberlite deposited in the North Pile and the potential for pore water expulsion during freeze back of the pile (ToR line # 307 to 308, 336 to 341, 379 and 380).

Developer's Conclusion: De Beers estimated the release of contaminants from the North Pile would arise from two sources:

- release of process water as the paste settled (consolidated) into place in the North Pile, and

- chemical loads produced from the weathering of unfrozen material at the surface of the pile during operations and after closure.

De Beers estimated that the release of contaminants associated with process water would be limited to 14% of the process water discharged to the North Pile, and would be released due to consolidation of the disposed kimberlite paste. De Beers assumed that, since most materials were anticipated to freeze to below 0 °C within two years of placement, the majority of remaining process water would be trapped within the North Pile as small ice lenses or small brine lenses. Therefore De Beers did not account for additional draining of process water from unfrozen material, or the potential release of COPCs associated with process water expelled as the pile froze in their impact assessments (page IX.1-54). De Beers assumed that virtually all discharges from the North Pile would report to the treatment plant (page IX.1-55) via the collection ditches and ponds.

De Beers also assumed that chemical loads generated from weathering of the paste would be limited to portions of a 2 metre thick active layer, since thermal modelling suggested that the paste below this depth would be below 0 °C within two years of placement. Any material below 0 °C was assumed to be unreactive. Thus, at any time, only the top 2 m of material in the North Pile were assumed to provide a possible source of soluble contaminants from chemical weathering, and reactivity within this 2 layer was controlled by assigned temperatures that varied with depth and season.

INAC's Conclusion:

The quality of water generated from the North Pile will depend on the thermal conditions that develop within the pile. De Beers has acknowledged that the thermal modelling conducted to date is inadequate to predict the rate of freezing of the North Pile. It is possible that a significant portion of the pile, in the order of 50% or more, will not freeze during the life of the mine. Should this occur, there will be a greater mass of unfrozen kimberlite which may leach chemicals of potential concern (COPCs) to the environment. Bleed water from the discharged paste may infiltrate in the pile and not pool on the surface for collection and routing to the water treatment plant. COPCs held in the unfrozen kimberlite, arising from both processing and leaching, will be expelled as the pile freezes, given that ice tends not to incorporate contaminants. Thus impacts to Snap Lake will be higher than indicated in the EA. Impacts may also be more concentrated in the North Arm of Snap Lake than projected, since the collections ditches were considered unlikely to meet the performance objectives suggested by the proponent, such that seepage and runoff from the North Pile would by-pass under the ditches (see Section 2.3).

INAC's Rationale/Evidence:

Initial review by MEMI of the predicted water quality for discharges from the North Pile identified that De Beers assumed all waste materials at a temperature below 0 °C would not contribute to a weathering load. This assumption was considered reasonable given the predominantly low sulphide content of materials at the site, if not particularly conservative. Temperature is known to have a significant influence on reactivity of materials, but materials may still contribute to chemical loads, albeit at a reduced rate, at temperatures below 0°C.

INAC considers that a significant portion of the pile, in the order of 50% or more, may not freeze during the life of the mine (see Section 2.4). An increase in the anticipated mass of unfrozen or barely frozen materials would provide a larger source of weathering products that would be released to Snap Lake, or sent to the treatment plant..

As a rough scoping of the potential increase in chemical loads that might be attributed to modified thermal conditions, estimated potential increase in mass TDS load that might be released should the ¾ of the material below De Beers assumed 2 m active layer remain unfrozen at temperatures of about 0 to 2 °C for the mine life of 22 years was conducted. Calculations and assumptions are provided in Appendix A. The estimate does not take into account potential reductions in the mass load due to thermodynamic equilibrium reactions and flushing in Snap Lake, which could be significant. Should the estimated TDS load be released to the North Arm of Snap Lake between the two constrictions, concentrations in this portion of the Lake could increase up to an additional 40 mg/l annually after closure when no seepage is to be recovered. Annual impacts during operations would be less due to the smaller mass of waste stored in the North Pile, and the potential for partial seepage collection. Note that these estimates are not considered definitive estimates, but a rough scoping to support the need for further analysis by De Beers.

An increase in the anticipated mass of unfrozen or barely frozen materials would provide a greater mass from which process water could drain, and would more easily allow process water or precipitation to flow down into the pile, with a greater potential to by-pass the collection system.

INAC understanding of the mechanics of cryoconcentration (also called 'pore water expulsion') is provided in Section 2.4. The consequence of cryoconcentration is that all contaminants held in the pore water of the unfrozen North Pile, whether associated with process water or weathering reactions, would tend to be expelled as freezing occurs. The rate of freezing would determine the rate at which the COPC's would be expelled. More rapid freezing (as projected by De Beers) could result in the COPCs associated with process water being expelled early in the mine life. A slower rate of freezing would allow a larger mass of unfrozen material to weather, producing a larger load of COPCs that would be expelled over a longer period of time as the pile froze. De Beers did not consider theses contaminants in their assessment of impacts to Snap Lake, thus impacts to the lake are considered to have been underestimated..

As a rough scoping of the potential increase in chemical loads that might be attributed to underestimating pore water expulsion of contaminants, estimated potential increases in mass TDS that could be expelled each year during operations should the pile freeze back as rapidly as projected by De Beers was conducted. Details of assumptions and calculation are provided in Appendix A.

The scoping calculation suggests that additional impacts to the North Arm of Snap Lake between the two constrictions could be as much as 8 mg/l annually should the pile freeze as quickly as predicted by De Beers, assuming 50% of the seepage was captured by the collection system. This concentration could accrue annually in that localized portion of Snap Lake due to the lack of mixing and flushing. Note that these estimates are not considered definitive estimates, but a rough scoping to support the need for further analysis by De Beers.

A related issue associated with warmer than projected thermal conditions is the selection of appropriate mitigation measures. For example, locating potentially acid generating metavolcanics at the base of the North Pile may have a greater than anticipated influence on water quality should the North Pile not freeze as rapidly as currently projected by De Beers. Alternatively there may be benefits in placing reactive metavolcanics in quarried areas so that they are flooded early in the mine life.

Recommendations:

De Beers should reassess the potential release of soluble chemical products from materials in the North Pile on the basis of revised temperature conditions from upgraded thermal modeling. A conservative bracketing of potential loads should consider potential for release from materials that are just below 0 °C.

De Beers should reconsider potential impacts associated with cryoconcentration and pore water expulsion in light of revised thermal modeling and updated temperature conditions.

De Beers should reassess selected mitigation strategies in light of modified thermal conditions and rates of freezing.

2.1.2 Geochemistry of Kimberlite

MVEIRB Terms of Reference: MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development's impacts on surface and ground waters, in particular the water chemistry impacts of surface runoff, and the effects of kimberlite and other materials stored in the North Pile, considering acid rock drainage, metal leaching and geochemistry (ToR line # 336 to 341, 379, 380, and 392). MVEIRB ToR also require De Beers to consider accidents and malfunctions (ToR line # 160 – 164).

At issue is an incomplete understanding of the cause of acid seeps associated with kimberlite at BHP's Ekati™ site, and a need to address this uncertainty with a conceptual contingency response plan.

Developer's Conclusion:

Characterization of the kimberlite at the Snap Lake site through the geochemical baseline program has concluded that runoff or discharge from any disposal alternative for processed kimberlite will be neutral or slightly alkaline, and contain low metal concentrations (page III.1.i of the Snap Lake EA).

INAC's Conclusion:

Uncertainties regarding kimberlite reactivity suggest that conceptual contingency planning may be appropriate.

INAC's Rationale/Evidence:

INAC concurs that the testwork and prediction methods conducted by De Beers relative to kimberlite have been generally appropriate for the Snap Lake site. However, similar testwork failed to predict the acidic water quality of seeps associated with kimberlite at the Ekati™ site. Hypotheses for the unanticipated behaviour at Ekati™ have been addressed by De Beers in their planning for the North Pile, in that peat is to be stripped from the North Pile site prior to placement of the kimberlite paste. Peat and the natural acidity of the tundra have been sited as a potential cause for the high neutralization potential of the kimberlite to be overwhelmed (SRK Consulting, 2001). However, it is still unclear if the hypothesized mechanism is responsible for the unanticipated behaviour at the Ekati™.

Recommendations: INAC considers it prudent that DeBeers be required to provide a description of conceptual mitigation measure that could be employed should the Snap Lake kimberlite act in a similarly unanticipated manner.

2.1.3 PAG Stockpile

MVEIRB Terms of Reference: MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development impacts on surface and ground waters, in particular the water chemistry impacts of surface runoff , and the effects of kimberlite and other materials stored in the North Pile, considering acid rock drainage, metal leaching and geochemistry (ToR Reference: line #336 to 341, 379 to 380 and 392).

A PAG stockpile was identified by DeBeers during the technical sessions which had not previously been part of the project descriptions.

Developer's Conclusion: No description or assessment of this stockpile provided.

INAC's Conclusion: The stockpile has the potential to act as an unconsidered source of contaminants.

INAC's Rationale/Evidence: De Beers has indicated that logistics and timing of waste rock removal from the mine may result in the stockpiling of PAG material on the surface. Mitigation measures for other PAG material (placement in the North Pile, rapid covering by kimberlite and rapid freezing to reduce weathering rates) may not be applicable for this stockpiled material.

Recommendations: DeBeers should be required to clarify the location and proposed management of this previously unidentified surface stockpile of PAG material, including logistics for pile build-up and removal, proposed containment measures, proposed mitigation measures during operations and closure.

2.1.4 Quality Control for Construction Material

MVEIRB Terms of Reference: MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development's impacts on surface and ground waters, in particular the water chemistry impacts of surface runoff, and the effects of kimberlite and other materials stored in the North Pile, considering acid rock drainage, metal leaching and geochemistry (ToR line # 336 to 341, 379, 380, and 392).

At issue is the basis used by De Beers in developing a criteria for identifying potentially problematic material, and, in particular, suitable rock for construction purposes. Selection of an inappropriate criteria may result in higher than predicted impacts.

Developer's Conclusion: De Beers concluded that material with a sulphide-sulphur content of less than 0.3% should be considered as benign rock suitable for construction purposes on the basis of guidelines developed by the British Columbia Ministry of Energy and Mines (Price 1997).

INAC's Conclusion: INAC's review concluded that there was inappropriate application of the guideline, and insufficient site specific justification for the selection of 0.3% sulphide-sulphur as a criteria for identifying benign rock.

INAC Rationale / Evidence: In the reference quoted by De Beers, a cutoff of 0.3% sulphide-sulphur for construction material is considered appropriate when there is no reason to expect a low neutralization potential (NP), and the rock matrix does not consist of base poor minerals (i.e. poorly neutralizing minerals such as quartz). The granite and metavolcanics at the Snap Lake site are anticipated to contain low NP, and consist of base poor minerals. Thus a more detailed justification for criteria that identify material suitable for construction should be required, based on site and rock specific kinetic test results.

Review of the EA submission, and the appendices for EA Appendices III.2 (Geochemistry Report) received under a Round 1 Information Request (IR) indicated that comprehensive data had been collected for site materials in a well documented program that is considered by INAC to meet standards applicable in the ARD field. However, the data has not been used to develop a site specific criteria to separate problematic or potentially acid generating (PAG) rock from relatively benign rock.

Of note are results from Column 5, consisting of granites located near the metavolcanic unit with a total sulphur content of 0.17%. De Beers long term prediction was that this sample would be non-acid generating (Table III.2-8). However, the results suggest the column just barely contained sufficient neutralization potential to buffer sulphide oxidation, in that the sulphur in the column was estimated to be depleted in 34.1 years, while neutralization potential would be depleted in 35.1 years.

Recommendations: De Beers be required to provide a more detailed justification for criteria that identify material suitable for construction should be required, based on site and rock specific kinetic test results.

This requirement could be delayed to the Regulatory stage, since the geochemistry baseline report identifies numerous samples of granite with very low sulphide content that are likely suitable for construction. At worst, construction material might require quarrying from identified clean granite sources.

2.2 Hydrogeologic Issues

INAC has three unresolved hydrogeological issues concerning the quality of water pumped from the underground mine workings and discharged to Snap Lake as part of the proposed Snap Lake Diamond Project. These issues have not been adequately addressed in the EA Report, in the responses to information requests, or in the MVEIRB Technical Sessions, and thus, are unresolved at this time.

The three hydrogeological issues are:

- Quality of Connate Groundwater Inflow;

- Quality of Mine Water Discharges to Snap Lake; and
- Water Quality in Snap Lake.

These issues are inter-related, in that the quality of connate groundwater inflow influences the quality of mine water discharge, which in turn influences the quality of water within Snap Lake. Reliable characterization of the quality of connate groundwater inflow to the proposed mine is an important issue because large quantities of connate groundwater are predicted to be pumped from the underground mine workings to mine water discharge and to Snap Lake. The vast majority of the dissolved chemical load to Snap Lake from the mining operation is derived from connate groundwater inflows as the proposed water treatment technology (filtration/sedimentation) will not remove most major ions.

The detailed discussion of these three individual issues is provided in Appendix B of this report. To facilitate the discussion, these three inter-related hydrogeological issues are described as one major issue below.

MVEIRB Terms of Reference: MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development impacts on surface and ground waters, in particular the water chemistry impacts of groundwater inflow to underground mine workings on mine water discharge and ultimately on Snap Lake and the Lockhart River watershed (ToR Reference: line #221, 337 to 341, 344 to 355 and 381).

These issues are addressed in the EA Report in Sections 9.2.1, 9.4.2 and 9.6.3; Table Q-1, Appendix Q, Appendix III.2; Appendix IX.1 (Sections 5.2, 5.3 and 5.4); and Appendix IX.7.

Developer's Conclusion: De Beers concluded that the concentrations of connate groundwater that provide the vast majority of dissolved contaminant load to mine water discharge and ultimately to Snap Lake during mining operations are represented by the average concentration of groundwater measured from granite water samples collected during the Advanced Exploration Program (AEP). In particular, De Beers assumes the average connate groundwater has 902 mg/L total dissolved solids (TDS), 330 mg/L chloride, and 0.06 mg/L dissolved phosphorous and that these concentrations will be representative of connate water quality inflows throughout the mining period.

De Beers concluded that the mine water discharge to Snap Lake during operations, will have peak average annual and median TDS of 1229 mg/L and 602 mg/L, respectively, peak annual average and median chloride of 417.5 and 245.5 mg/L, respectively, and peak annual average and median dissolved phosphorous of 0.012 mg/L and 0.008 mg/L, respectively. These discharge concentrations, which are calculated using GoldSim, represent the major mass loading to Snap Lake from mining operations.

De Beers concluded that the maximum ice-covered concentration after initial mixing in Snap Lake during mine operations will be 137 mg/L for chloride and 350 mg/L for TDS. De Beers concludes that the maximum ice-free concentration within 1% of Snap Lake will be 177 mg/L for chloride and 444 mg/L for TDS. The higher ice-free concentrations are due to the fact that Snap Lake model used to determine the values does not consider the turbulent mixing of the diffuser. De Beers also concludes that maximum average TDS concentration in Snap Lake will be about 330 mg/L. These results are generated based on modelling of water quality in Snap Lake in the near-field using the US EPA Cormix model for the diffuser and in the far-field using the RMA 2-D plan models of Snap Lake. GoldSim provides the mine water quality and quantity discharge data for input to these models.

INAC's Conclusion: INAC does not agree with De Beers conclusion that the concentrations of TDS, chloride, other major ions and dissolved phosphorous in connate groundwater inflow, mine water discharge and Snap Lake throughout the duration of mining operations will be as defined in the EA Report. INAC believes that the concentrations in connate groundwater, mine water discharge and Snap Lake will all be substantially higher than indicated in the EA Report. Therefore, impacts to Snap Lake will also be higher than indicated in the EA.

INAC's Rationale/Evidence: Review of the AEP groundwater quality in summary Table Q-1from Appendix III.2, shows that there is a pronounced profile of increasing salinity with depth in the granite bedrock to depths of 168 m. Such increases with depth are well known and common within the Canadian Shield and result in the ubiquitous presence of brackish to saline groundwater at depths of several hundred meters and brine with TDS of greater than 100,000 mg/L at depths of about 1000 to 1500 m.

The current hydrogeologic understanding of the occurrence of high salinity and TDS groundwaters in the Canadian Shield, ascribes the depth distribution of TDS to an upward diffusion of ions from a deep Ca-Na/Cl source brine over geologic time frames. Active groundwater circulation that is driven by surface topography and decreases significantly with depth in the upper 500 m of the Canadian Shield, modifies the diffusional salinity profile by flushing salinity to groundwater discharge areas. Consequently, it is expected that groundwater in the area of the Snap Lake Diamond Project, will show increases in TDS, chloride and other major ions with increasing depth, as occurs throughout the Canadian Shield.

Since the deepest groundwater samples are only from a depth that is less than half the expected mine depth of 450 to 500 m, and salinity increases with depth, it is reasonable to assume that the granite groundwater concentrations at 200 to 500 m depth will be much higher than the values used in the GoldSim calculations. Chloride, TDS and dissolved phosphorous concentrations in the bottom half of the mine could well approximate much more than the 500 to 600 mg/L, 1300 to 1600 mg/L and 0.032 to 0.138 mg/L, respectively, measured at 125 to 165 m depth. Considering the need for a crown pillar thickness of about 100 m and that the data from 125 to 165 m depth are likely representative of upper one third of mining operations, average connate groundwater concentrations over the entire mine depth would be much greater than the values measured at 125 to 165 m depth.

Data from the recent North Lakes investigations also provides corroborating evidence as to probable connate groundwater chemistry. The groundwater samples from wells MW02-05 (depth 110 to 130 m) and MW02-03 (depth 190 to 215 m) show average chloride values of about 380 mg/L and 610 mg/L, respectively, average TDS values of about 1100 mg/L and 1600 mg/L, respectively, and average dissolved phosphorous of about 0.11 and 0.38, respectively. These chloride, TDS and dissolved phosphorous concentrations are consistent with the inference above, that the concentrations of these parameters in connate groundwater will be much greater than the 330 mg/L, 902 mg/L and 0.06 mg/L assumed in the GoldSim modeling.

Considering up-welling of deeper more saline water due to the depressurization created by the deeper mine workings, the average connate groundwater inflow concentrations over the life of the mining operation could easily increase to more than 800 mg/L for chloride, 2200 mg/L for TDS and 0.4 mg/L (i.e., by applying De Beers conclusion from the FEFLOW up-welling modeling, that average concentrations would increase by 50 to 60%)

Data from the Diavik project and elsewhere in the Canadian Shield also indicate that higher connate groundwater concentrations should be used in GoldSim modeling. Based on the De Beers Figure 2.4.14-1 (log TDS vs depth plot based on Diavik, Lupin and Canadian Shield data), concentrations of TDS of 1000 to 4700 mg/L and of chloride of about 400 to 1800 mg/L (assuming chloride is 40 % of TDS) would be expected at about 450 m depth, using the two TDS versus depth relationships provided in the Figure. A representative connate water concentration for the entire mining operations should be based on a mine depth-average of values adjusted for up-welling effects.

Considering the above, connate water TDS, chloride, other major ions and dissolved phosphorous concentrations could be about 2 to 3 times higher than predicted in the EA Report.

The De Beers analysis of mine water discharge chemistry assumes that the connate groundwater inflows are mixed with recharge water infiltrating from Snap Lake within the mine. The concentrations of infiltrating Snap Lake water are calculated within the Effective Lake Volume, the volume of Snap Lake where mine water discharges are completely mixed with Snap Lake water and the resultant water recharges the underground mine workings. The Effective Lake Volume is 8.7 Mm^3, which is about 10% of the total volume of Snap Lake. This is a large mixing volume, that under conditions of complete mixing, significantly reduces mine water discharge concentrations in Snap Lake.

The existing GoldSim model makes assumptions about complete mixing within the Effective Lake Volume of Snap Lake. Given the fact that mine water with higher TDS and higher density will be discharged to Snap Lake, there is potential for density separation and settling of mine water to the depressions within Snap Lake. Figure 9.4-10 and the text on pages 9-218 and 9-219 of the EA Report acknowledge that such density settling and reduced mixing will occur. Although such settling and limited mixing may be reduced by wind action on the Lake during the summer open water period, the degree to which this will occur is unknown because there is a lack of information on effects of currents on Lake mixing. During winter, which represents 2/3 of the year, the degree of mixing is expected to be significantly reduced due to the presence of ice cover on the Lake.

If significant density separation and incomplete mixing occurs, either seasonally or over a longer time period, there is potential that Lake bottom water within the Effective Lake Volume that recharges the mine will have higher concentrations than those calculated in GoldSim assuming complete mixing. This would result in increased concentrations of Snap Lake recharge water and therefore increased concentrations of mine water discharge. Increased concentrations of mine water discharge would then result in increased potential for further density separation and settling. This cycling of higher concentration recharge water would cause the evolution of the quality of mine water discharge toward that of the connate groundwater, rather than the mixture of relatively clean Snap Lake water and connate groundwater assumed in the EA Report.

This type of density-driven flow separation is also not considered by 2-D plan RMA models of Snap Lake used to calculate water quality in Snap Lake. The RMA models assume that the vertical profile in Snap Lake is fully mixed and hence that depth concentration profiles do not exist within Snap Lake. Therefore, the RMA models underestimate the concentration of water quality parameters, particularly TDS, chloride and other major ions, in the deeper parts of the Lake, that could be ecologically sensitive.

The RMA models estimate mixing due to flow velocities in the Lake under ice cover by not including wind stress on the water surface. However, these computations are uncertain as there is no baseline water current data for Snap Lake with which to calibrate or assess the RMA model results, particularly for the ice cover period that represents 2/3 of the year.

It is difficult to assess the degree to which concentrations of TDS, chloride and other major ions have been underestimated in Snap Lake. Given the underestimation of connate water concentrations by factors of 2 to 3, the expectation that density separation effects could increase maximum mine water discharge concentrations by 25 to 50 %, the limitations of the GoldSim models, and the limitations of the RMA models, it is estimated that concentrations of TDS, chloride, other major ions and dissolved phosphorous in Snap Lake may be underestimated in the EA Report by factors of 2 to 4.

Recommendations: It is recommended that GoldSim be run in its current form assuming more representative concentrations of TDS, chloride, other major ions and dissolved phosphate for connate groundwater to assess impact to Snap Lake. It is suggested that 600 and 900 mg/L chloride, 1800 and 2700 mg/L for TDS and 0.2 and 0.4 mg/L for dissolved phosphorous be used, recognizing that the lower values might be considered best estimates and upper values as probable maximum estimates.

It is recommended that a full 3-D model that considers density-dependent flow be used to quantify the effects of incomplete mixing within the Effective Lake Volume on the quality of Snap Lake water that will recharge the underground mine workings. The model should incorporate the known bathymetry of Snap Lake, baseline current Lake data and consider effects under both ice-covered and open water conditions. The model should also use the range of higher connate groundwater concentrations recommended above and the initial conservative assumption that the mine water discharge concentrations are equal to connate groundwater concentrations.

The same type of model should be used to estimate water quality within Snap Lake under both ice-covered and open water conditions. The model should also use revised estimates of higher mine water discharge concentrations and consider the loss of mass due to recharge of water from the bottom of Snap Lake to the underground mine workings.

2.3 Geotechnical Issues

There are a number of geotechnical issues that have not been adequately addressed (i.e., the issue not been resolved) in the EA report, in the responses to information requests, or in the MVEIRB Technical Sessions. These can be considered in three categories: paste technology, water management, and slope stability.

Specifically, paste technology has not be demonstrated for kimberlite paste, it has limited precedent for surface disposal, and it has not been used for surface disposal in permafrost environment. The inability to assess the North Pile in light of experience elsewhere creates an element of uncertainty for all the predictions of it's performance.

There are several related factors in the water management aspect of the North Pile performance. There may be more water discharged to the pile. It is unlikely to freeze as fast as expected by the proponent. The seepage collection ditches are very unlikely to perform as well as anticipated by the proponent. These factors all suggest a potential for increased seepage from the North Pile, much of which will flow to the north arm of Snap Lake. The quantity and water quality of this flow over the mine life has not been reasonably predicted. Impacts to Snap Lake will likely be higher than predicted in the EA.

Depending on the deposition sequence and the rate of freezing of the paste, it is possible that there will be unfrozen lenses in the North Pile. Expansion of the pore water as these freeze may result in elevated pore pressure within the pile. The slope stability analyses presented by the proponent have not considered this possibility. Slope instability and disruption of the cover on the North Pile may occur after closure.

2.4 Permafrost and Thermal Issues

The intervention is guided by section 2.6.2 of the ToR, especially item I, lines 299-310.

The principal issue is the prediction of temperatures in the North Pile as presented in the EA Submission and in response to IR 3.4.17. A second issue is the behavior of processed kimberlite paste when subjected to freezing, and a third is the delineation of ice wedges in the footprint of the North Pile.

Several issues regarding permafrost and the ground thermal regime were raised in the IRs and at the Technical Sessions held in December 2002. There was no resolution at the Technical Sessions of the thermal status of the North Pile. At the time of writing, over two months later, no new information regarding thermal conditions in the North Pile has been provided to INAC, and therefore this remains unresolved. The unknown state of the Pile, whether it will be frozen, thawed, or partially frozen, influences the magnitude of potential seepage from the Pile to the Northwest Arm of Snap Lake. Since the condition of the Pile is unresolved, the impact on Snap Lake has not been determined.

There are three principal aspects of the thermal modeling of the North Pile that are unsatisfactory and at variance with field conditions at Snap Lake or the literature cited by the proponent. These concern:

- the geothermal flux entering the Pile from below,
- the characterization of surface temperatures by n-factors, and
- the specification of thermal properties by the proponent.

In addition, modeling of undisturbed ground temperatures has failed to reproduce field measurements.

2.4.1 General Considerations Regarding the North Pile

ToR line 300-301. *Impact on permafrost physical conditions and thermal regime.*

The North Pile proposal for containment of mine tailings represents the first attempt at this method of mine waste disposal in a permafrost environment. Therefore, MVEIRB must recognize that the technology is untried and untested for an environment with potentially severe operating conditions during several months of the year. INAC considers that in this context it is the responsibility of DCMI to provide firm evidence that the North Pile is likely to perform as proposed.

DCMI has indicated that the paste deposited in the Pile will freeze within two years, and therefore the potential geochemical effects of the Pile, especially on the quality and quantity of seepage to the Northwest arm of Snap Lake are considered to be minimal (Appendix IX, pp. 1-52 – 1-55).

INAC considers that this conclusion is premature, because we maintain serious reservations about:

- the results of geothermal modeling presented by DCMI in support of their position
- the unknown extent of ice wedges in the country rock
- the unknown behavior of the pore contents of processed kimberlite paste when subject to freezing
- the projected efficiency of perimeter ditches to collect seepage.

2.4.2 North Pile Geothermal Modeling

ToR lines 300-301 and lines 307-309 refer to *the impact on the permafrost thermal regime* and *the impact of the pore water contained in the processed kimberlite deposited in the north pile and the potential for pore-water expulsion during freeze back of the pile.*

DCMI has presented the results of modeling with TEMP/W (EA Report p. 10-46) to assess the thermal conditions in the North Pile from deposition of paste until closure of the Mine. DCMI considers that for a paste deposition rate of 3 m/yr, the entire pile will freeze within two years of deposition (EA Report p. 10-48).

IR 3.4.17 requested the initial foundation temperatures for the geothermal model. The response to IR 3.4.17, in Figure 3.4.17-1 showed discrepancies of several degrees Celcius between the modeled predictions of ground temperatures beneath the North Pile and field measurements. **In each case the model under-predicted the field values.**

The response to IR 3.4.17 also supplied, in Fig. 3.4.17-3, a geothermal analysis of the North Pile. Large portions of the cross-section report temperatures above -0.5°C. Since these are the data used by DCMI to infer that the North Pile will be frozen, and since the calibration data are in error by several degrees, INAC does not consider the model output to predict reliably the thermal state of the Pile.

2.4.3 Geothermal Flux

The geothermal flux prescribed for the model by DCMI was 0.004 Wm^{-2} (EA submission, p. 10-46). Standard values for the geothermal flux in the Canadian Shield are one order of magnitude higher (Judge 1973). IR3.4.17(b) requested DCMI to clarify the assignment of 0.004 Wm^{-2}. The response indicated that this value was chosen as it "provided the best fit for the existing thermal regime". At the Technical Hearing INAC pointed out that the value was too low, and showed that DCMI's field data from the North Lakes program indicated a geothermal flux of between 0.03 and 0.05 Wm^{-2} from data collected in holes TH02-01 and TH02-02. INAC requested resolution of the effect of this error on the performance of the geothermal model.

At the Technical Hearing DCMI did not contest the conclusion reached by INAC. Since the Technical Hearing, no further information has been supplied to INAC by DCMI on this matter.

2.4.4 N-Factors

TEMP/W uses n-factors to obtain the surface temperature of the pile. The n-factors are the ratio of the number of degree-days measured at the ground surface to the number of degree-days measured in the air for the freezing and thawing seasons. The n-factors used in the thermal modeling are presented on p. 10-47 of the EA report. Since the n-factors assigned are the same for all months of each season, INAC considers that these have been assigned without consideration for changing snow conditions through the winter season, and are a source of error in the model. INAC presented this issue to DCMI at the Technical Hearing, but, to date, we have received no further comment from the proponent. Therefore, INAC considers this issue unresolved.

2.4.5 Thermal Properties

The specification of thermal properties of the North Pile constituents is critical to determination of the thermal regime of the Pile. INAC has noted several errors in the thermal properties described in the documentation submitted by DCMI. These errors were communicated to DCMI at a break-out session from the Technical Hearings. At the time of writing, no correction to these specifications has been submitted by DCMI. Until these corrections have been made, the modeling is incomplete.

2.4.6 Cryoconcentration

ToR lines 307-309 concerns the *Impact of water content contained in the processed kimberlite deposited in the North Pile and the potential for pore-water expulsion during freeze back of the pile*

The behavior of the North Pile during freezing is the subject of considerable concern expressed at the Technical Hearings by INAC. The paste is to be saturated with process water when it is deposited in the pile and the destination of the water is at issue. DCMI has assumed that the majority of the pore water will freeze in the pile, and the majority of the brines will be retained in the pile along with it. INAC cannot assess this assumption, because no freezing tests or characterization of the freezing behavior of the paste have been performed or described. Therefore, characterization of the Pile's predicted behavior is incomplete.

INAC's position is that notwithstanding the demonstrated deficiencies in the thermal modeling, characterization of the freezing behavior of the paste is required to predict the composition of seepage from the Pile, and characterization of the oxidation conditions within the Pile is required to assess the seepage from the pile under unfrozen conditions.

2.4.7 North Pile Ground Ice Conditions

ToR lines 302-305 concern the occurrence of ice wedges beneath containment structures and in the footprint of the North Pile.

Ice wedges represent potential flow paths for uncontrolled discharge beneath the North Pile and its ditches. In the bedrock that dominates the area, ice wedges generally occur in fractures, rather than in the polygonal configuration characteristic for unconsolidated materials. The ToR, especially line 305, require DCMI to account for the location of ice wedges beneath the various structures.

In the response to IR 3.4.22(a) DCMI states that "Massive ice was not encountered in the fractured bedrock in the 25 holes that have been drilled within the footprint of the proposed North Pile". From this evidence, DCMI indicated at the Technical Hearings that ice wedge occurrence beneath the North Pile was not of concern.

Ice wedges are unlikely to be intercepted by borehole drilling as they are dominantly vertical features. Delineation of ice wedges is by probing surface cracks and fractures, or by survey with Ground Penetrating Radar. In the absence of either type of evidence, INAC considers that there has been insufficient effort made to determine the location of ice wedges in the footprint of the North Pile or its perimeter ditches, and therefore their presence cannot be discounted.

The presence and location of ice wedges forms a critical component of the information regarding the North Pile and its ditching system that INAC currently considers incomplete.

Therefore it is recommended that DeBeers undertake the following:

a. Unfrozen water content characteristic curves for the North Pile paste mixes, determined by laboratory test.

b. Frost heave tests on the North Pile paste mixes to determine whether the paste is frost susceptible, or whether pore water is expelled during freezing.

c. Results from revision of the thermal modeling, to incorporate: (i) a field value of the geothermal gradient; (ii) a temporally sensitive assignment of n-factors; (iii) thermal properties which are recalculated to include results from (a).

d. With the new thermal modeling, an assessment should be made of the rates of cryoconcentration in the pore water of the North Pile, and the influence these may have on the quality of water seeping from the Pile.

e. Investigation of the footprint of the North Pile with Ground Penetrating Radar must be undertaken to determine the location of ice wedges in the country rock.

2.5 Hydrological Issues

Although the hydrological issues associated with the development of the Snap Lake Diamond Project have largely been resolved, there remains several key questions that, to some degree, have not been adequately addressed in the EA report, in the responses to Information Requests, or in the MVEIRB Technical Sessions. These questions have to do with three key elements of the Project.

2.5.1 Water Management Components: Water Treatment Plant WTP) and Water Management Pond (WMP).

INAC remains concerned that the existing WMP does not have sufficient capacity to deal with an upset condition at the WTP. DCMI have not adequately addressed the question of

what might be a reasonable estimate of potential down-time periods of the WTP in the event of failure of some part of the plant's operation.

It is DCMI's position that any repairs could be completed in a matter of hours, so there will always be sufficient storage to mange the temporary by-pass flow.

DCMI subsequently indicated at the MVEIRB Technical Sessions that the down-time could extend to one or more days and that the WMP could have perhaps 20 percent of its capacity utilized prior to the WTP upset. INAC are of the opinion that this issue needs further consideration, particularly with respect to a more detailed assessment of potential down-times, together with scenarios that might evolve where storage capacity becomes compromised; for example, an extreme flood runoff period during May or June, in combination with breakdown of the WTP.

Should this concern not be adequately addressed, it is recommended that the two WMP dams be raised by at least one metre at the beginning of construction to mitigate this concern.

2.5.2 WMP Effluent Mixing in Snap Lake.

Discharge water will be somewhat heavier than lake water, so the mixing will involve a three-dimensional process once outside the initial 60 m radius mixing zone adopted for the CORMIX model. INAC are concerned that the analysis of mixing potential beyond this 60 m radius surrounding the diffuser has not adequately account of the vertical mixing component.

DCMI adopted the RMA model to assess horizontal mixing of the effluent plume beyond the initial mixing zone.

The RMA model is two-dimensional, so it assumes complete vertical mixing. INAC are concerned that the model does not have the capability of assessing mixing of plume water in the vertical direction where the effluent water and lake water have different densities. Nor has the model adequately represented the influence of winds and currents because no lake current data have been collected, the role of the wind/current regime in the mixing process has necessarily been based on conjecture.

Recommendations:

INAC recommends that DCMI undertake a more comprehensive analysis of effluent mixing in Snap Lake. This analysis should utilize a three-dimensional computerized model that can account for a variation of water density in the vertical direction. As well, there must be a program involving current and concurrent wind measurements in Snap Lake at locations and frequency appropriate to model input requirements.

2.5.3 North Pile Seepage.

The water balance model for the North Pile indicates that in the order of one percent of pile seepage plus surface runoff water from the pile would enter the north arm of Snap Lake by seeping beneath the proposed perimeter ditches paralleling the north side of the pile. INAC are concerned that: the volume of water may be greater than assumed; and, that no serious consideration has been given to the fate of seep water within this area of the lake.

It appears that DCMI are of the opinion that the volume of seepage water that might enter the north arm of the lake is minor and unlikely to have a measurable impact on the quality of lake water.

INAC are of the opinion that this issue requires a more comprehensive assessment that must address: the possibility of a larger volume of North Pile water seeping into the lake; and, the mixing of this seep water in the north arm of Snap Lake. The area of lake potentially affected is somewhat physically isolated by a higher lake bed at its exit to the main part of snap Lake, as well as at a point half-way along the arm. This factor may work to enhance any impacts on water quality – the proposed water intake is along the north shore of the north arm and immediately east of the North Pile.

2.6 Impact Assessment Issues

INAC has two main unresolved issues relative to the procedures that were used by DCMI to assess the impacts associated with the construction and operation of the Snap Lake diamond project, including:

- Procedures that were used to develop site-specific water quality benchmarks; and,
- Impact assessment criteria that were selected to evaluate the spatial and temporal extent of environmental impacts.

Both of these issues are discussed in this section of the report and further in Appendix F.

2.6.1 Development of Site-Specific Water Quality Benchmarks

MVEIRB Terms of Reference: In Section 5.5 of the ***Terms of Reference and Work Plan for the Environmental Assessment of the DeBeers Canada Mining Inc. Snap Lake Diamond Project (MVEIRB 2001)***, the MVEIRB instructed the proponent to explicitly document the assumptions, models, information sources, information limitations, and associated levels of uncertainty for all of the steps of the EA report (Line 191 to 192). In addition, DCMI was instructed to fully describe the methods used in the analysis and in the prediction of impacts to ensure that reviewers could easily understand how the direct and indirect impacts were analysed (Section 5.5.5, Lines 239 - 241). Furthermore, DCMI was explicitly instructed to refrain from providing significance conclusions in the EA report (Section 5.5, Lines 185 - 186; Section 5.5.5, Lines 241 - 242).

Developer's Conclusion: In accordance with the terms of reference (ToR), DCMI developed site-specific benchmarks for assessing the potential effects of mining activities on water quality conditions in the vicinity of Snap Lake. The procedures used were consistent with the methods that have been established by the U.S. Environmental Protection Agency (USEPA) for developing the site-specific benchmarks and the developer has concluded that these procedures are appropriate for application at the Snap Lake site.

INAC's Conclusion: Contrary to the position presented by DCMI, INAC concludes that the procedures that were used by DCMI to develop site-specific benchmarks are not appropriate for use at the Snap Lake site or elsewhere in the north.

INAC's Rationale/Evidence: This conclusion is based on the fact that the methods that were used to derive the benchmarks were not consistent with the procedures that have been established by the CCME (2002). As the Snap Lake project is located in Canada, it seems more reasonable to apply the procedures that have been developed explicitly for deriving site-specific water quality benchmarks in Canada.

INAC has reviewed the underlying toxicological data presented in the EA report and was used by the developer to derive the site-specific benchmarks for assessing the potential effects of mining activities on water quality conditions in the vicinity of Snap Lake. The results of this review suggest that application of the procedures that were established by the CCME (2002) would likely have resulted in the derivation of lower benchmarks for certain COPC's, e.g., an HC_{20} concentration for copper of 21.3 ug/L was derived using the USEPA procedures, while a chronic toxicity threshold of 1.45 ug/L could be calculated using the CCME procedures, with both values derived for a water hardness of 180 mg/L) than those that were used in the EA. Therefore, it is reasonable to conclude that the nature, severity, and areal extent of impacts on fish and/or other aquatic organisms could have been different than those presented in the EA report and that such impacts were likely underestimated.

Recommendations: The site-specific benchmarks represent an essential component of the overall EA process. Therefore, it is recommended that DCMI derive benchmarks using the procedures that have been developed by the CCME (2002) and apply them to evaluate the effects associated with discharges of treated wastewater into Snap Lake. It is also recommended that a single benchmark be established for each COPC that represents the chronic toxicity threshold (CTT) for the most sensitive receptor group in the lake (i.e., typically zooplankton; i.e., rather than the four benchmarks for each COPC that were derived by the developer).

It is further recommended that DCMI provide maps of Snap Lake which show concentration isopleths radiating from the diffuser for key COPCs, including total suspended solids (TSS), turbidity, total ammonia, nitrate, phosphorus (i.e., total phosphorus, dissolved phosphorus, and ortho-phosphate - TP, DP, and OP), chloride, total dissolved solids (TDS), copper, cadmium, and chromium (III and IV). These modelling results should reflect the need to incorporate more conservative assumptions, as specified by participants at the recent Technical Sessions. Ideally, these isopleths would be provided for various depths in the lake, based on the results of three dimensional water quality modelling.

2.6.2 Selection of Impact Assessment Criteria

MVEIRB Terms of Reference: In Section 5.5 of the ***Terms of Reference and Work Plan for the Environmental Assessment of the DeBeers Canada Mining Inc. Snap Lake Diamond Project (MVEIRB 2001)***, the MVEIRB instructed the proponent to explicitly document the assumptions, models, information sources, information limitations, and associated levels of uncertainty for all of the steps of the EA report (Line 191 to 192). In addition, DCMI was instructed to fully describe the methods used in the analysis and in the prediction of impacts to ensure that reviewers could easily understand how the direct and indirect impacts were analysed (Section 5.5.5, Lines 239 - 241). Furthermore, DCMI was explicitly instructed to refrain from providing significance conclusions in the EA report (Section 5.5, Lines 185 - 186; Section 5.5.5, Lines 241 - 242).

Developer's Conclusion: In accordance with the ToR, DCMI developed criteria for assessing the potential impacts of mining activities (i.e., as negligible, minor, moderate, or major) based on areal extent of exceedances of various effects thresholds (e.g., HC_{20} values). The developer has concluded that the methods used provide a reasonable basis for predicting the effects of mine construction and operation on Snap Lake.

INAC's Conclusion: INAC concludes that the assessment criteria that were selected by DCMI are not appropriate.

INAC's Rationale/Evidence: Contrary to the position presented by DCMI, INAC concludes that the assessment criteria that were selected by DCMI are inappropriate for the following reasons. First, the selected assessment criteria are intended to provide a basis for classifying the predicted impacts into four categories (i.e., as negligible, minor, moderate, or major), based on their significance. This approach is not consistent with the ToR that was provided to DCMI (i.e., the developer was instructed to not provide conclusions regarding the significance of the impacts). Second and more importantly, the selected assessment criteria tend to minimize the potential for rating predicted effects as high because COPC concentrations in more than 20% of the lake must exceed the levels that would adversely affect 20% of the aquatic species in Snap Lake before the effects would be considered to be high. Negligible, low, or moderate impacts were predicted if the severity or areal extent of the effects was lower.

The approach that was selected by DCMI is flawed because it ignores that fact that zooplankton tend to be the most sensitive group of aquatic organisms to many of the COPCs at this site and that impacts on these sensitive species could destabilize the aquatic community (i.e., result in changes in the structure of the aquatic community such that some species may become less abundant or disappear, while other species become more abundant or their abundance stays the same as under baseline conditions). This possibility is greater in the north because the structure of aquatic communities tends to be simpler than is the case in aquatic ecosystems located further south (i.e., because the level of functional redundancy is likely lower in the north, the loss of a few species could create voids in the ecosystem that might not be easily filled by other species). Those fish species that rely on zooplankton for food at key times of their life history would necessarily be adversely affected by such changes in the zooplankton community. Because the impact assessment criteria that were used in the EA report do not consider that zooplankton are keystone species in Snap Lake and that adverse effects on these organisms could lead to cascading effects on other species in the aquatic food web that consume zooplankton (e.g., lake trout), it is likely that the effects of mining activities on fish and other aquatic organisms could be substantially greater than were predicted in the EA report.

Recommendations: Because zooplankton tend to represent the most sensitive species to the COPCs that will be discharged into Snap Lake, it is recommended that alternate impact assessment criteria be established that consider the potential for effects on these organisms. More specifically, chronic toxicity thresholds (CTTs) should be developed for each COPC using the procedures that have been established by the CCME (2002). It is further recommended that more conservative criteria be applied in the EA, such as:

- Exceedance of the CTT in <1% of Snap Lake - Negligible Impact;
- Exceedance of the CTT in 1 to 10% of Snap Lake - Low Impact;
- Exceedance of the CTT in 10 to 20% of Snap Lake - Moderate Impact; and,
- Exceedance of the CTT in >20% of Snap Lake - High Impact.

Application of such assessment criteria would substantially reduce the potential for under-estimating the impacts on ecological receptors associated with the construction and operation of the proposed Snap Lake diamond project.

2.7 Environmental Quality Issues

The unresolved issues related to environmental quality fall into five main categories, including adequacy of baseline environmental quality data, the accuracy of the predicted concentrations of COPCs in Snap Lake during mine operations, the adequacy of the assessment of the impacts of total dissolved solids (and associated major ions) on aquatic organisms, the adequacy of the nutrient modelling that has been conducted to evaluate the potential for lake eutrophication, and the adequacy of evaluation of the secondary impacts of lake eutrophication on aquatic organisms. Each of these issues is discussed in the following sections of this report.

2.7.1 Adequacy of Baseline Environmental Information

MVEIRB Terms of Reference: In Section 5.5 of the ***Terms of Reference and Work Plan for the Environmental Assessment of the DeBeers Canada Mining Inc. Snap Lake Diamond Project (MVEIRB 2001)***, the MVEIRB instructed the proponent to provide information on the environment (Line 182). More specifically, DCMI was instructed to provide sufficient information on the existing environment to facilitate prediction of the potential impacts of the proposed development, including but not limited to surface water quality, aquatic organisms and habitats, and lake sediments (Section 5.5.2, Line 212 - 228). Baseline data in existing reports and documents were to be appropriately referenced.

Developer's Conclusions: In accordance with the ToR, DCMI has generated a substantial quantity of baseline data in the vicinity of the proposed Snap Lake mine site, including information on water quality, sediment quality, and biological conditions. The developer has concluded that these data provided in the EA report and associated documentation are sufficient.

INAC's Conclusions: While INAC generally agrees that the baseline water quality and sediment quality data are generally sufficient to support the EA, INAC is concerned that the baseline data that have been collected to date are insufficient for evaluating the accuracy of those predictions during mining activities (i.e., to support the assessment of effects using the results of the aquatic effects monitoring program).

INAC's Rationale/Evidence: Baseline environmental information is required to support two main environmental assessment initiatives associated with the Snap Lake diamond project, including prediction of the impacts of mining activities (i.e., as has been done in the EA report) and evaluation of those predictions during mining activities (i.e., assessing the actual impacts of the project). Accordingly, sufficient data are needed to characterize both the spatial and temporal variability of the various metrics (e.g., the concentration of copper in surface water) that are used to characterize baseline environmental conditions in the vicinity of the mine site. While the available water quality and sediment quality data presented in the EA report and associated documentation are generally sufficient to support the EA, the data will not be sufficient for evaluating the impact hypotheses that are presented in the EA. That is, the water quality and sediment quality data may not be sufficient to support statistical analyses to determine changes in the physical, chemical, and/or biological characteristics of Snap Lake or to evaluate the severity of any changes that have occurred. Importantly, biological data that have been collected to date may not be sufficient to support the EA and are unlikely to support subsequent evaluations of the impact hypotheses.

Recommendations: It is recommended that statistical power analyses be conducted to determine the quantity of data that is required for each variable to detect changes of various specific magnitudes (e.g., 10%, 20%, 50%) with specific levels of confidence (e.g., p=0.5, p=0.75, p=0.9). The results of such statistical analyses will provide the information needed to identify the additional pre-development water quality, sediment quality, and biological data that are needed to adequately characterize temporal and spatial variability in baseline conditions in Snap Lake and associated water bodies. The goal of this effort should be to ensure that sufficient data have been collected prior to construction to support the design of an aquatic effects monitoring program (AEMP) that is sufficiently robust to evaluate the impact hypotheses that are presented in the EA report (i.e., to assess the nature, magnitude, and extent of environmental effects associated with the development).

2.7.2 Predicted Concentrations of COPCs in Snap Lake

MVEIRB Terms of Reference: In Section 5.5 of the ***Terms of Reference and Work Plan for the Environmental Assessment of the DeBeers Canada Mining Inc. Snap Lake Diamond Project (MVEIRB 2001)***, the MVEIRB instructed the proponent to provide information on how the environment could be affected by the proposed development (Line 182 - 183). This information was required to provide a basis for estimating the impacts of the proposed development on water quality (Section 5.6.4, Line 303).

Developer's Conclusion: In accordance with the ToR, DCMI has developed predictions of the concentrations of COPCs in Snap Lake during mine operations. The developer has concluded that the predicted concentrations of COPCs in Snap Lake are conservative and provide a basis for estimating the environmental impacts of the proposed development.

INAC's Conclusion: INAC concludes that the levels of several COPCs (e.g., total dissolved solids and chloride) are likely to be higher than those that were predicted in the EA report.

INAC's Rationale/Evidence: Based on the information presented in the EA report and in documentation that was provided subsequently (i.e., the north lakes study), INAC concludes that the levels of several water quality variables (e.g., total dissolved solids and chloride) could be substantially higher than was predicted for wastewater discharged from the mine site (Also see Raven 2003). In addition, the lack of mixing under ice-covered conditions and the negative buoyancy of the effluent could result in higher than anticipated levels of such COPCs in water at the bottom of Snap Lake during the winter (Also see

Appendix E). Therefore, the concentrations of these substances in Snap Lake are likely to be higher than was predicted in the EA report in portions of the lake (i.e., particularly in deeper areas) and, consequently, are likely to result in adverse effects on ecological receptors that are greater in severity and areal extent than was predicted in the EA report.

Recommendations: To resolve this issue, DCMI should re-evaluate the predicted concentrations of key COPCs in Snap Lake (i.e., based on the information provided by Raven 2003 and Yaremko 2003), including total dissolved solids, chloride, calcium, sodium, total phosphorus, dissolved phosphorus, and orthophosphate.

2.7.3 Adequacy of the Assessment of the Impacts of Total Dissolved Solids

MVEIRB Terms of Reference: In Section 5.5 of the ***Terms of Reference and Work Plan for the Environmental Assessment of the DeBeers Canada Mining Inc. Snap Lake Diamond Project (MVEIRB 2001)***, the MVEIRB instructed the proponent to provide information on how the environment could be affected by the proposed development (Line 182 - 183). More specifically, DCMI was instructed to describe the impacts resulting from the proposed development, after mitigation (Section 5.5.5, Line 239). The residual impacts were to be described at least in terms of magnitude, geographic extent, timing, duration, frequency, irreversibility of impacts, ecological resilience, and probability of occurrence and confidence level (Section 5.5.2, Line 247 - 256). As the release of total dissolved solids (TDS) and associated major ions represents an important consequence of the development of the Snap Lake diamond project, the proponent should have provided a detailed and conservative analysis of the potential impacts associated with releases of TDS from the mine site.

Developer's Conclusion: In accordance with the ToR, DCMI has developed qualitative predictions of the potential impacts of TDS and associated major ions on aquatic organisms in Snap Lake. The developer has concluded that these predictions are adequate.

INAC's Conclusion: INAC concludes that the assessment of the impacts associated with the releases of TDS and other major ions into Snap Lake is inadequate.

INAC's Rationale/Evidence: The assessment of the impacts associated with the releases of TDS and other major ions into Snap Lake, as presented in the EA report and clarified at the MVEIRB Technical Sessions, is considered to be inadequate for several reasons. First, it is likely that the predicted concentrations of these COPCs are not based on accurate estimates of the loadings of these substances to Snap Lake (also see Appendix B). Accordingly, the predicted COPC concentrations used in the assessment are too low, likely by a factor of two or three. Such elevated levels of major ions (especially chloride) could be approaching chronic toxicity thresholds for sensitive aquatic organisms.

Second, the potential effects of increased levels of total dissolved solids and associated major ions on the structure of the aquatic community have not been adequately assessed in the EA report, associated documentation, nor in any of the supplemental information provided to date. This is important because the abundance of, for example, certain zooplankton (i.e., those that are well-adapted to low levels of TDS) could be reduced to such an extent that adverse effects on other components of the food web (e.g., fish) could occur. Other organisms (i.e., those that thrive at higher levels of TDS), currently at low levels due to the existing low levels of major ions, could become overly abundant and out-compete the currently dominant species for food resources. Consequently, it is likely that the effects on sensitive environmental receptors that were predicted in the EA report are substantially underestimated. In addition, it is likely that ecosystem-level impacts would occur within the lake due to releases of TDS and associated major ions.

Recommendations: It is recommended that the potential for toxic effects of major ions on aquatic organisms in Snap Lake be re-evaluated using more conservative assumptions regarding the concentrations of these substances during mine operations. It is further recommended that the potential effects of releases of TDS and associated major ions on the structure of the aquatic ecosystem be further evaluated. This later evaluation should rely on the data that have been published in the scientific literature and on recent data collected at the Ekati diamond mine.

2.7.4 Adequacy of the Nutrient Modelling

MVEIRB Terms of Reference: In Section 5.5 of the ***Terms of Reference and Work Plan for the Environmental Assessment of the DeBeers Canada Mining Inc. Snap Lake Diamond Project (MVEIRB 2001)***, the MVEIRB instructed the proponent to provide information on how the environment could be affected by the proposed development (Line 182 - 183). More specifically, DCMI was instructed to describe the impacts resulting from the proposed development, after mitigation (Section 5.5.5, Line 239). The residual impacts were to be described at least in terms of magnitude, geographic extent, timing, duration, frequency, irreversibility of impacts, ecological resilience, and probability of occurrence and confidence level (Section 5.5.2, Line 247 - 256). As the release of aquatic plant nutrients (e.g., total phosphorus, total dissolved phosphorus, and orthophosphate) represents an important consequence of the development of the Snap Lake diamond project, the proponent should have provided a conservative analysis of the potential impacts associated with releases of nutrients from the mine site.

Developer's Conclusion: In accordance with the ToR, DCMI has developed and applied a nutrient model for Snap Lake to assess the effects of nutrient releases on the trophic status of the lake. The developer has concluded that the results of the nutrient modelling provides a conservative basis for predicting the impacts of the Snap Lake diamond project.

INAC's Conclusion: INAC concludes that the results of the nutrient modelling that was conducted by DCMI are likely to substantially underestimate the impacts of the proposed Snap Lake diamond project.

INAC's Rationale/Evidence: The validity of the nutrient modelling that was conducted to support the EA remains a serious concern for INAC. More specifically, the results of the analyses that have been conducted by INAC's experts in this area indicate that the concentrations and loadings of key aquatic plant nutrients (i.e., total phosphorus, dissolved phosphorus, and orthophosphate) in wastewater from the mine have likely been substantially underestimated (see Appendix B). Consequently, it is likely that the concentrations of these nutrients will be substantially higher in Snap Lake than has been predicted in the EA report. Because phosphorus has been identified as the principal limiting factor for aquatic plant growth, it is likely that the results of the nutrient modelling that was conducted by DCMI underestimates the severity of eutrophication (i.e., increased levels of aquatic plant growth) that will occur in Snap Lake in response to phosphorus releases from the mine.

Recommendations: It is recommended that the nutrient model for Snap Lake be re-run using more conservative assumptions regarding the loadings of key aquatic plant nutrients (i.e., total phosphorus, dissolved phosphorus, and orthophosphate) to Snap Lake and the associated in-lake concentrations. The results of the additional modelling efforts should be used to predict the effects of the proposed development on the productivity of aquatic plants and associated trophic status of the lake.

2.7.5 Adequacy of the Assessment of the Secondary Effects of Lake Eutrophication

MVEIRB Terms of Reference: In Section 5.5 of the ***Terms of Reference and Work Plan for the Environmental Assessment of the DeBeers Canada Mining Inc. Snap Lake Diamond Project (MVEIRB 2001)***, the MVEIRB instructed the proponent to provide information on how the environment could be affected by the proposed development (Line 182 - 183). More specifically, DCMI was instructed to describe the impacts resulting from the proposed development, after mitigation (Section 5.5.5, Line 239). The residual impacts were to be described at least in terms of magnitude, geographic extent, timing, duration, frequency, irreversibility of impacts, ecological resilience, and probability of occurrence and confidence level (Section 5.5.2, Line 247 - 256). As increased production of aquatic plants represents an important consequence of the development of the Snap Lake diamond project, the proponent should have provided a conservative analysis of the potential impacts associated with lake eutrophication.

Developer's Conclusion: In accordance with the ToR, DCMI has developed and applied a nutrient model for Snap Lake to assess the effects of nutrient releases on the trophic status of Snap Lake. The developer has utilized these results to predict the effects of nutrient releases on the trophic status of Snap Lake and concluded that the secondary effects of lake eutrophication (i.e., on dissolved oxygen levels under ice) are likely to be minor.

INAC's Conclusion: INAC concludes that the results of the nutrient modelling that was conducted by DCMI are likely to substantially underestimate the impacts of the proposed development on the trophic status of Snap Lake. Therefore, it is likely that the secondary effects of lake eutrophication have also been substantially under-estimated.

INAC's Rationale/Evidence: Eutrophication in Snap Lake represents an important issue because enhanced algal production and subsequent settling of algae on the lake bottom can lead to depressed concentrations of dissolved oxygen (DO) under ice. The results presented in the EA report indicated that DO levels under ice could decrease by 1 to 3 mg/L and, as a result, approach levels of concern for lake trout. The phosphorus modelling presented in the EA report is likely to underestimate the effects in Snap Lake, therefore the levels of DO in Snap Lake during the winter could be depressed to levels that are associated with chronic effects in fish and/or other aquatic organisms. Additionally, low levels of DO tend to result in increased toxicity of other COPCs, which would result in decreased chronic toxicity thresholds for other COPCs. Therefore, it is likely that the EA report has underestimated the secondary effects of lake eutrophication on fish and other aquatic organisms.

Recommendations: It is recommended that the secondary effects of lake eutrophication be re-evaluated once the nutrient model has been re-run using more appropriate predictions of phosphorus loadings and concentrations within Snap Lake. This evaluation should include an assessment of the effects of lake eutrophication on the levels of DO under ice and on the aquatic organisms that are likely to be exposed to depressed DO levels.

2.8 Cumulative Effects Assessment Issues

MVEIRB Terms of Reference: In the ***Terms of Reference and Work Plan for the Environmental Assessment of the DeBeers Canada Mining Inc. Snap Lake Diamond Project (MVEIRB 2001),*** the MVEIRB instructed the proponent to provide an evaluation of the cumulative effects that are likely to result from the development in combination with other developments and other developments within the regulatory process as of June 1, 2001 (Section 5.9, Line 416 - 418).

Developer's Conclusion: In accordance with the ToR, DCMI has conducted a cumulative effects assessment and presented it in the EA report. The developers have concluded that the cumulative effects assessment fully meets the needs identified in the ToR.

INAC's Conclusion: Based on the results of its technical evaluation, INAC concludes that the assessment of cumulative effects presented in the EA report does not provide an adequate basis for evaluating the effects of the proposed Snap Lake diamond project nor the interactive effects between the project and other anthropogenic activities that could influence aquatic resources in the Lockhart River Basin.

INAC's Rationale/Evidence: Based on the results of INAC's technical evaluation, it is apparent that the information presented in the EA report does not provide a complete basis for assessing the cumulative effects of the proposed development in combination with other developments and other developments within the regulatory process as of June 1, 2001. The cumulative effects assessment is considered to be incomplete for several reasons. First, it is apparent from the foregoing discussions on impact assessment issues and on environmental quality issues that the EA report has underestimated the effects of the various mining activities and associated discharges of COPCs on aquatic organisms. That is, the effects of releases of phosphorus, TDS, and possibly metals have likely been underestimated in the EA report.

Second, the interactive effects of multiple COPCs have not been adequately addressed in the EA report. That is, no attempt has been made to evaluate the cumulative effects of, for example, releases of metals, TDS, and nutrients from the mine site. Although the implementation of whole effluent toxicity tests mitigates this concern to a certain extent, such tests do not provide information on the effects of elevated levels of TDS on the structure of aquatic communities nor on the primary and secondary effects of releases of nutrients into Snap Lake. Therefore, such tests do not provide information on the interactive effects of metal, TDS, and nutrients.

Third, the interactive effects of the Snap Lake project with other land and water use activities in the Lockhart River Basin have not been fully evaluated. For example, activities such as ongoing mineral exploration, sport fishing, and subsistence fishing have not been considered in the cumulative effects assessment. Finally, the interactive effects of the project with other human activities (e.g., long-range transport of atmospheric pollutants, global climate change, etc.) have not been assessed.

Recommendations: While the terms of reference of the EA do not explicitly require DCMI to conduct a broader assessment of cumulative effects (i.e., beyond a regional assessment), it is reasonable to expect the EA to assess the interactive effects of project activities. It is also reasonable to expect that the cumulative effects assessment would evaluate interactions between project activities and human activities (i.e., land and water uses) that occur elsewhere in the Lockhart River Basin. These shortcomings render the EA inadequate in terms of assessing cumulative effects. For this reason, it is recommended that the cumulative effects assessment be expanded to evaluate interactive effects of project activities and interactions between project activities and other activities that occur elsewhere in the Lockhart River Basin.

3.0 Summary of Recommendations

i. It is recommended that De Beers should reassess the potential release of soluble chemical products from materials in the North Pile on the basis of revised temperature conditions from upgraded thermal modeling. A conservative bracketing of potential loads should consider potential for release from materials that are just below 0 °C.

ii. It is recommended that De Beers reconsider potential impacts associated with cryoconcentration and pore water expulsion in light of revised thermal modeling and updated temperature conditions.

iii. It is recommended that DeBeers be required to provide a description of conceptual mitigation measure that could be employed should the Snap Lake kimberlite act in a similarly unanticipated manner.

iv. It is recommended that GoldSim be run in its current form assuming more representative concentrations of TDS, chloride, other major ions and dissolved phosphate for connate groundwater to assess impact to Snap Lake. It is suggested that 600 and 900 mg/L chloride, 1800 and 2700 mg/L for TDS and 0.2 and 0.4 mg/L for dissolved phosphorous be used, recognizing that the lower values might be considered best estimates and upper values as probable maximum estimates.

v. It is recommended that a full 3-D model that considers density-dependent flow be used to quantify the effects of incomplete mixing within the Effective Lake Volume on the quality of Snap Lake water that will recharge the underground mine workings. The model should incorporate the known bathymetry of Snap Lake, baseline current Lake data and consider effects under both ice-covered and open water conditions. The model should also use the range of higher connate groundwater concentrations recommended above and the initial conservative assumption that the mine water discharge concentrations are equal to connate groundwater concentrations.

vi. It is recommended that the same type of model should be used to estimate water quality within Snap Lake under both ice-covered and open water conditions. The model should also use revised estimates of higher mine water discharge concentrations and consider the loss of mass due to recharge of water from the bottom of Snap Lake to the underground mine workings.

vii. It is recommended that unfrozen water content characteristic curves for the North Pile paste mixes, determined by laboratory test.

viii. It is recommended that DCMI conduct frost heave tests on the North Pile paste mixes to determine whether the paste is frost susceptible, or whether pore water is expelled during freezing.

ix. It is recommended that results from revision of the thermal modeling, incorporate: (a) a field value of the geothermal gradient; (b) a temporally sensitive assignment of n-factors; (c) thermal properties which are recalculated to include results from (vii).

x. It is recommended that with the new thermal modeling, an assessment should be made of the rates of cryoconcentration in the pore water of the North Pile, and the influence these may have on the quality of water seeping from the Pile.

xi. It is recommended that investigation of the footprint of the North Pile with Ground Penetrating Radar must be undertaken to determine the location of ice wedges in the country rock.

xii. It is recommended that DCMI undertake a more comprehensive analysis of effluent mixing in Snap Lake. This analysis should utilize a three-dimensional computerized model that can account for a variation of water density in the vertical direction. As well, there must be a program involving current and concurrent wind measurements in Snap Lake at locations and frequency appropriate to model input requirements.

xiii. It is recommended that DCMI derive benchmarks using the procedures that have been developed by the CCME (2002) and apply them to evaluate the effects associated with discharges of treated wastewater into Snap Lake.

xiv. It is recommended that a single benchmark be established for each COPC that represents the chronic toxicity threshold (CTT) for the most sensitive receptor group in the lake.

xv. It is recommended that DCMI provide maps of Snap Lake which show concentration isopleths radiating from the diffuser for key COPCs.

xvi. It is recommended that alternate impact assessment criteria be established.

xvii. It is recommended that statistical power analyses be conducted to determine the quantity of data that is required for each variable to detect changes of various specific magnitudes (e.g., 10%, 20%, 50%) with specific levels of confidence (e.g., p=0.5, p=0.75, p=0.9).

xviii. DCMI should re-evaluate the predicted concentrations of key COPCs in Snap Lake.

xix. It is recommended that the potential for toxic effects of major ions on aquatic organisms in Snap Lake be re-evaluated using more conservative assumptions regarding the concentrations of these substances during mine operations.

xx. It is recommended that the potential effects of releases of TDS and associated major ions on the structure of the aquatic ecosystem be further evaluated.

xxi. It is recommended that the nutrient model for Snap Lake be re-run using more conservative assumptions regarding the loadings of key aquatic plant nutrients (i.e., total phosphorus, dissolved phosphorus, and orthophosphate) to Snap Lake and the associated in-lake concentrations.

xxii. It is recommended that the secondary effects of lake eutrophication be re-evaluated once the nutrient model has been re-run using more appropriate predictions of phosphorus loadings to, and concentrations in, Snap Lake.

xxiii. It is recommended that the cumulative effects assessment be expanded to evaluate interactive effects of project activities and interactions between project activities and other activities that occur elsewhere in the Lockhart River Basin.

4.0 Conclusions

The Water Resources Division has a substantial number of concerns that have not been resolved through the information request, technical session, or other processes associated with the EA. Together, the uncertainties associated with these unresolved issues lead us to conclude that the effects of mining activities on water quality in Snap Lake and associated impacts on aquatic organisms are substantially underestimated. Until the outstanding issues have been resolved, INAC considers the EA to be incomplete and, as such, does not provide an adequate basis for assessing the impacts of the proposed project.

Our review of this project will continue. The recent submissions by DCMI, and those which it has indicated will be forthcoming are not considered in our assessment to date. We do note however that the recent technical memorandum provided by DCMI are intended to respond to some of the concerns previously expressed by reviewers. These may or may not address the concerns we identified, however due to the timing of their submission we are not able to consider the information contained therein. Therefore this report is based solely upon the information received prior to January 31, 2003.

APPENDIX A

Geochemical Issues

Mehling Environmental Management Inc.

REVIEW OF ENVIRONMENTAL ASSESSMENT
DE BEERS SNAP LAKE DIAMOND PROJECT –

ACID ROCK DRAINAGE/METAL LEACHING ISSUES

Submitted to:

Water Resources Division
Indian and Northern Affairs Canada
Yellowknife, Northwest Territories
X1A 2N7

February 7, 2003

Prepared by:

Mehling Environmental Management Inc.

3826 Balaclava Street
Vancouver, B.C. V6L 2S8
Telephone: (604) 731-4150
Fax: (604) 733-4255

MEM Project No. 019-004-01

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1.0 INTRODUCTION

This report summarizes Mehling Environmental Management Inc.'s (MEMI) technical review of the geochemical issues (specially acid rock drainage (ARD) and metal leaching issues) identified in the Environmental Assessment and associated documentation submitted for the Snap Lake Diamond Project by De Beers Canada Mining Inc. (De Beers). The review was conducted at the request of Water Resources Division of the Department of Indian Affairs and Northern Development (DIAND).

This report is based on review of the following sources of information:

- Environmental Assessment Report, De Beers Canada Mining Inc., Snap Lake Diamond Project. Report submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) on February 25, 2002.
- De Beers responses to MVIRB Information Requests (IRs), in particular Appendices for EA Appendix III.2 and IX.1; and third round IR's 3.10.1, 3.10.2 and 3.10.3;
- Documentation and discussions at the Water Quality/Water Quantity Technical Discussion Sessions sponsored by De Beers and held on June 4 and 5, 2001, November 15 and 16, 2001, and January 10, 2002;
- Documentation of EA Technical Sessions on Geotechnical and 'A&R" issues, organized by MVEIRB and held on December 3 and 4, 2002;
- A conference call held with representatives of Water Resources Division of DIAND, De Beers and Golder Associates on January 30, 2003; and,
- Discussions with other members of Water Resources Division technical review team.

The review focussed on the adequacy of geochemical characterization of site materials, predicted water quality for discharges from the underground workings, and predicted water quality for discharges from the North Pile deposit of waste rock and processed kimberlite as summarized below:

1.1 Geochemical Characterization of Site Materials

Review of the EA submission, and the appendices for EA Appendices III.2 (Geochemistry Report) received under a Round 1 Information Request (IR) indicated that comprehensive data had been collected for site materials in a well documented program that is considered by MEMI to meet standards applicable in the ARD field. However, differences in interpretation of the data gives rise to an unresolved issue discussed in Section 6.

1.2 Discharges from the Underground Workings

The methods used to estimate quality of discharges from the underground workings appeared reasonable, with the exception of the quality of connate groundwater inflow and incomplete mine water discharge mixing issues identified and discussed by Intera Engineering Ltd. (2003). Initially, MEMI queried the assumption that water entering the mine would not pick up soluble products from contact with natural rock fractures and/or excavated wall rock in the mine. However, a convincing argument was made that Snap Lake water will move rapidly through the natural rock into the mine workings, and that the limited contact time would limit increases in dissolved components. In addition, water quality data collected during the advanced exploration program was used by De Beers to develop estimates for underground mine water quality, so that values have been incorporated that should include products released from natural rock fractures and/or excavated wall rock in the mine.

1.3 Discharges from the North Pile

The review of the predicted discharges from the North Pile has raised the greatest numbers of issues by MEMI and others. Although the estimated quantities of effluents from this source are much smaller than those from the underground workings (E. Yaremko, 2003), issues include:

- the projected efficiency of the proposed collection ditches and ponds to recover seepage and runoff, identified and discussed by Brodie Consulting Ltd. (2003); and,
- the projected temperature conditions identified and discussed by Dr. C. Burn (2003), which drive the geochemical nature of the stockpiled materials in terms of both reactivity and pore water expulsion.

The geochemical issues which remained unresolved, as of the date of this report are described in Sections 2 thorugh 6 below:

2.0 GEOCHEMICAL REACTIVITY OF NORTH PILE

2.1 Issue

MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development's impacts on surface and ground waters. In particular, the MVEIRB required the water chemistry impacts of surface runoff, and the effects of kimberlite and other materials stored in the North Pile, considering acid rock drainage, metal leaching and geochemistry (ToR line # 336 to 341, 379, 380, and 392).

An initial assessment of the pile and the leaching estimates indicated that the work had been done reasonably well and due diligence has been undertaken. MEMI was satisfied that the results, while not conservative, were adequate for environmental assessment.

However, given the questions have been raised by Dr. C. Burn as to adequacy of the thermal model, the geochemical reactivity of materials stored in the North Pile are considered to have been underestimated in terms of the contributing mass of material and the potential rates of reactivity. An increase in the contributing mass and rates would increase the dissolved chemical load emanating from the North Pile, and may influence the choice of appropriate mitigation measures.

2.2 De Beers Conclusion

Thermal modelling by De Beers concluded that waste materials below a 2 metre thick active layer would freeze to below 0 °C within two years of placement. Any material below 0 °C was assumed to be essentially unreactive, and was assumed not to contribute soluble contaminants through weathering reactions. Thus, at any time, only the top 2 m of material in the North Pile were assumed to provide a possible source of soluble contaminants from chemical weathering, and reactivity within this 2 layer was controlled by assigned temperatures that varied with depth and season.

2.3 MEMI Conclusion

Freezing rates may be slower than projected by De Beers (Dr. C. Burn, 2003) and given the warm freezing temperatures predicted within the pile by De Beers (-0.1 to –0.2 °C), the ground may not freeze at all. Overly optimistic estimates of freezing rates may prematurely remove large portions of the North Pile material as a potential source of soluble chemicals to seepage and runoff which will otherwise remain unfrozen and contribute to potential impacts. Furthermore, any material just below 0 °C, while technically frozen, may still contribute to the potential loads.

2.4 MEMI Rationale / Evidence

Initial review by MEMI of the predicted water quality for discharges from the North Pile identified that De Beers assumed all waste materials at a temperature below 0 °C would not contribute to a weathering load. This assumption was considered reasonable given the predominantly low sulphide content of materials at the site, if not particularly conservative.

Freezing is known to slow the chemical and biological processes that are responsible for oxidation (Kyhn et al., 2001), and thus, limits the generation of ARD. However, it is recognized that oxidation of sulphide materials can occur even if the materials are frozen. A laboratory study of oxygen uptake from high sulphide tailings collected at Nanisivik Mine showed that at a temperature of 0°C, the overall rate of sulphide oxidation may be as high as 20% of full capacity (Kyhn et al., 2001). It has also been reported that for chemical oxidation, which predominates around neutral pH, the oxidation rate near freezing is about 15% of the rate around 25°C (Dawson et al., 1996). For biologically mediated oxidation, which dominates at acidic pH, the rate below 8°C is less than 20% of the oxidation rate at 30°C (Dawson et al., 1996). Observations at the Nanisivik site (containing tailings with up to 80% sulphide sulphur) suggested that sulphide oxidation may be occurring at temperatures as low as -4°C (Kyhn et al., 2001). Laboratory testing conducted on the Nanisivik tailings samples indicated that significantly reduced but measurable oxidation was occurring at -2°C (i.e. when compared to oxidation rates at 30°C). However, the testing indicated that no measurable oxidation of the tailings occurred at a temperature of -10°C (Meldrum et al., 2001).

Thus, although temperature is known to have a significant influence on reactivity of materials, materials may still contribute to chemical loads, albeit at a reduced rate, as temperatures below 0°C.

As a rough scoping of the potential increase in chemical loads that might be attributed to modified thermal conditions, MEMI estimated potential increase in mass TDS load that might be released should the ¾ of the material below De Beers assumed 2 m active layer remain unfrozen at temperatures of about 0 to 2 °C for the mine life of 22 years. Calculations and assumptions are provided in attachment 1. The estimate does not take into account potential reductions in the mass load due to thermodynamic equilibrium reactions and flushing in Snap Lake, which could be significant. Should the estimated mass load be released to the North Arm of Snap Lake between the two constrictions, concentrations in this portion of the Lake would increase by approximately 40 mg/l annually after closure when no seepage would be recovered. Annual impacts during operations would be less due to the smaller mass of waste stored in the North Pile, and the potential for partial seepage collection. Note that these estimates are not considered definitive estimates, but a rough scoping to support the need for further analysis by De Beers.

A related issue to this is that changing thermal conditions may also influence the selection of appropriate mitigation measures. For example, locating potentially acid generating metavolcanics at the base of the North Pile may have a greater than anticipated influence on water quality should the North Pile not freeze as rapidly as currently projected by De Beers. Alternatively there may be benefits in placing reactive metavolcanics in quarried areas so that they are flooded early in the mine life,

2.5 Recommendations

De Beers should reassess the potential release of soluble chemical products from materials in the North Pile on the basis of revised temperature conditions from upgraded thermal modeling. A conservative bracketing of potential loads should consider potential for release from materials that are just below 0 °C.

3.0 PORE WATER EXPULSION FROM NORTH PILE

3.1 Issue

MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development's impacts on surface and ground waters, in particular the water chemistry impacts of surface runoff, and the effects of kimberlite and other materials stored in the North Pile, and the impact of water contained in the process kimberlite deposited in the North Pile and the potential for pore water expulsion during freeze back of the pile (ToR line # 307 to 308, 336 to 341, 379, and 380).

At issue is the reliability of De Beers estimate for impacts associated with pore water expulsion from freeze back of the North Pile. Release of contaminants could be substantially greater than predicted, resulting in potentially increased impacts to Snap Lake. This issue is discussed in more technical detail by Dr. C. Burn (2003).

3.2 De Beers Conclusion

De Beers estimated that contaminants associated with 14% of the process water discharged to the North Pile will be released due to consolidation of the disposed kimberlite paste. However, De Beers expects that, although most materials are anticipated to freeze to below 0 °C in two years, the majority of remaining process water be trapped within the North Pile as small ice lenses or small brine lenses, and does not account for loads from pore water expulsion in their impact assessments (Page IX.1-54). Moreover, De Beers assumes that virtually all discharges from the North Pile will report to the treatment plant (page IX.1-55).

3.3 MEMI Conclusion

MEMI concluded that impacts from pore water expulsion were underestimated, in that a substantial amount of the contaminants associated with process water would be concentrated and expelled by freeze back, beyond that expelled through consolidation.

3.4 MEMI Rationale / Evidence

A discussion of pore water expulsion (or cryoconcentration) is provided by Dr. C Burn's submission.

As a rough scoping of the potential increase in chemical loads that might be attributed to with underestimating pore water expulsion of contaminants, MEMI estimated potential increase in mass TDS that could be expelled each year during operations should the pile freeze back as rapidly as projected by De Beers. Details of assumptions and calculation are provided in Attachment 2.

The scoping calculation suggests that impacts to the North Arm of Snap Lake between the two constrictions could be as much as 8 mg/l should the pile freeze as quickly as predicted by De Beers. This concentration could accrue annually in that localized portion of Snap Lake due to the lack of mixing and flushing. Note that these estimates are not considered definitive estimates, but a rough scoping to support the need for further analysis by De Beers.

Should freezing of the pile occur less rapidly than predicted, impacts from cryoconcentration of process water would be reduced. However, the greater mass of unfrozen material would provide a larger weathering source that

3.5 Recommendations

De Beers reconsider potential impacts associated with cryoconcentration and pore water expulsion in light of revised thermal modeling and updated temperature conditions.

4.0 GEOCHEMISTRY OF KIMBERLITE

4.1 Issue

MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development's impacts on surface and ground waters, in particular the water chemistry impacts of surface runoff, and the effects of kimberlite and other materials stored in the North Pile, considering acid rock drainage, metal leaching and geochemistry (ToR line # 336 to 341, 379, 380, and 392). MVEIRB ToR also require De Beers to consider accidents and malfunctions (ToR line # 160 – 164).

At issue is an incomplete understanding of the cause of acid seeps associated with kimberlite at BHP's Ekati™ site, and a need to address this uncertainty with a conceptual contingency response plan.

4.2 De Beers Conclusion

Characterization of the kimberlite at the Snap Lake site through the geochemical baseline program has concluded that runoff or discharge from any disposal alternative for processed kimberlite will be neutral or slightly alkaline, and contain low metal concentrations (page III.1.i of the Snap Lake EA).

4.3 MEMI Conclusion

Uncertainties regarding kimberlite reactivity suggest that conceptual contingency planning may be appropriate.

4.4 MEMI Rationale / Evidence

MEMI concurs that the testwork and prediction methods conducted by De Beers relative to kimberlite have been considered appropriate for the Snap Lake site. However, similar testwork failed to predict the acidic water quality of seeps associated with kimberlite at the Ekati™ site. Hypotheses for the unanticipated behaviour at Ekati™ have been addressed by De Beers in their planning for the North Pile, in that peat is to be stripped from the North Pile site. Peat and the natural acidity of the tundra have been sited as a potential cause for the high neutralization potential of the kimberlite to be overwhelmed (SRK Consulting, 2001). However, it is still unclear if the hypothesized mechanism is responsible for the unanticipated behaviour at the Ekati™.

4.5 Recommendations

MEMI considers it prudent that DeBeers be required to provide a description of conceptual mitigation measure that could be employed should the Snap Lake kimberlite act in a similarly unanticipated manner.

5.0 PAG STOCKPILE

5.1 Issue

A PAG stockpile was identified by DeBeers during the technical sessions which had not previously been part of the project descriptions.

5.2 De Beers Conclusion

N/A

5.3 MEMI Conclusion

The stockpile has the potential to act as an unconsidered source of contaminants.

5.4 MEMI Rationale / Evidence

Logistics and timing of waste rock removal from the mine may result in the stockpiling of PAG material on the surface. Mitigation measures for other PAG material (placement in the North Pile, rapid covering by kimberlite and rapid freezing to reduce weathering rates) may not be applicable for this stockpiled material.

5.5 Recommendations

DeBeers should be required to clarify the location and proposed management of this stockpile, including logistics for pile build-up and removal, proposed containment measures, proposed mitigation measures during operations and closure.

6.0 QUALITY CONTROL FOR CONSTRUCTION MATERIAL

6.1 Issue

MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development's impacts on surface and ground waters, in particular the water chemistry impacts of surface runoff, and the effects of kimberlite and other materials stored in the North Pile, considering acid rock drainage, metal leaching and geochemistry (ToR line # 336 to 341, 379, 380, and 392).

At issue is the basis used by De Beers in developing a criteria for identifying potentially problematic material, and, in particular, suitable rock for construction purposes. Selection of an inappropriate criteria may result in higher than predicted impacts.

6.2 De Beers Conclusion

De Beers concluded that material with a sulphide-sulphur content of less than 0.3% should be considered as benign rock suitable for construction purposes on the basis of guidelines developed by the British Columbia Ministry of Energy and Mines (Price 1997).

6.3 MEMI Conclusion

MEMI review concluded that there was inappropriate application of the guideline, and insufficient site specific justification for the selection of 0.3% sulphide-sulphur as a criteria for identifying benign rock.

6.4 MEMI Rationale / Evidence

De Beers proposed criteria of 0.3% sulphide-sulphur appears to be based on what MEMI believes to be an incomplete interpretation of guidelines developed in BC (Price, 1997). These guidelines are not intended to be site specific.

In that reference, a cutoff of 0.3% sulphide-sulphur for construction material is considered appropriate when there is no reason to expect a low neutralization potential (NP), and the rock matrix does not consist of base poor minerals (i.e. poorly neutralizing minerals such as quartz). The granite and metavolcanics at the Snap Lake site are anticipated to contain low NP, and consist of base poor minerals. Thus a more detailed justification for criteria that identify material suitable for construction should be required, based on site and rock specific kinetic test results.

Review of the EA submission, and the appendices for EA Appendices III.2 (Geochemistry Report) received under a Round 1 Information Request (IR) indicated that comprehensive data had been collected for site materials in a well documented program that is considered by MEMI to meet standards applicable in the ARD field. However, the data has not been used to develop a site specific criteria to separate problematic or potentially acid generating (PAG) rock from relatively benign rock.

Of note are results from Column 5, consisting of granites located near the metavolcanic unit with a total sulphur content of 0.17%. De Beers long term prediction was that this sample would be non-acid generating (Table III.2-8). However, the results suggest the column just barely contained sufficient neutralization potential to buffer sulphide oxidation, in that the sulphur in the column was estimated to be depleted in 34.1 years, while neutralization potential would be depleted in 35.1 years.

6.5 Recommendations

A more detailed justification for criteria that identify material suitable for construction should be required, based on site and rock specific kinetic test results.

This requirement could be delayed to the Regulatory stage, since the geochemistry baseline report identifies numerous samples of granite with very low sulphide content that are likely suitable for construction. At worst, construction material might require quarrying from identified clean granite sources.

Mehling Environmental Management Inc.
per:

Peri Mehling, M.Sc., P.Eng.
President and Senior Consultant

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SRK Consulting. 2001. Panda Waste Rock Storage Area Beartooth-Bearclaw Drainage 2000 Seepage and Waste Rock Survey Report Ekati™ Diamond Mine. Report No. 1CB009.01 Prepared for BHP Diamonds Inc. February 2001.

Attachment 1

Rough scoping estimate of potential addition soluble products available in the North Pile should the pile not freeze as predicted by De Beers:

Assume that 3/4 of the mass below the 2 m active layer remains unfrozen at end of mine life at 22 years (Dr. C Burn, 2003), and assume that the predicted leachate from the 2 m active layer remains similar to De Beers prediction despite potential amendments to the thermal model. The North Pile is considered likely to drain, such that saturation with not be sufficient to prevent entry of oxygen at depth.

Paste deposited in North Pile over mine life (Section 3.5.2 of Project Description)
= 12 million tonnes (including dilution)

Mass of paste included in the 2 m active layer (which includes 0.5 cap material)
= 1.5 m x 920,000 m^2 area at 1.35 t/m^3 bulk density
= 1.86×10^6 tonnes

Unfrozen mass below active layer
= 3/4 x 12 million tonnes paste - 1.86×10^6 tonnes
= 7.1×10^6 tonnes unfrozen paste = 7.1×10^9 kg unfrozen paste

Assume temperature to be 0 to 2 degrees C, so that kinetic test rates are approximately 1/4 of the rates shown in Table IX.1-23. 80% of the unfrozen mass is kimberlite, the other 20% being dilution rock made up of 5.5% metavolcanics and 14.5% granite as per De Beers assumptions on page IX.1-61.

Release of TDS in mg/kg/year based on kinetic tests corrected for temperature
= approx. 5 mg/kg/week

Incorporating De Beers assumption of a drop of an order of magnitude
= approx. 0.5 mg/kg/week

Loading each year from unfrozen mass at end of mine life (ignoring potential thermodynamic equilibrium constraints and assuming no capture by collection ditches)
= 0.5 mg/kg/week x 52 week/year x 7.1×10^9 kg unfrozen paste
= 1.8×10^{11} mg/year

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 below 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.

The *maximum* increase in concentration each year after closure that could occur if the soluble products produced in each year were discharged directly to the portion of the North Arm of Snap Lake between the two constricted sections (Estimated volume of 4.5 million cubic metres or 4.5×10^9 liters - E Yaremko, 2003, *without thermodynamic equilibirum constraints*, would be
= 1.8×10^{11} mg / 4.5×10^9 litres
= 40 mg/liter/year

TDS levels in this portion of the North Arm would continue to increase after closure, and could accrue given the lack of significant mixing and flushing in Snap Lake. The increase could be comparable to De Beer's predicted concentrations in this portion of the North Arm of 150 to 300 mg/L (Figure 9.4-14).

ATTACHMENT 2

Rough scoping estimate for potential effects of cryoconcentration in the North Pile, should the paste freeze in two years as predicted by De Beers:

Paste deposited in North Pile over mine life (Section 3.5.2 of Project Description)
= 12 million tonnes (including dilution) at 1.35 t/m^3 bulk density
= 8.9×10^6 m^3 paste
Paste deposited in pile annually over 22 year minelife (average)
= 8.9×10^6 m^3 paste/22 years
=4.0×10^5 m^3/year
Unconsolidated porosity of paste = 48% (Table IX.1-16)
Total water deposited in pile with paste each year
= $0.48 \times 4.0 \times 10^5$ m^3
= 1.9×10^5 m^3
Loss of 14% of water due to consolidation (porosity from 48% to 42%) (Table IX.1-55) which reports via collection ditches to ponds and treatment plant.
Total water retained in pile each year
= 1.7×10^5 m^3 = 1.7×10^8 litres
The paste is assumed to freeze in two years, so that, after a delay as the water freezes, the contaminants are assumed to be expelled from the North Pile each year, with the other 50% reporting to the collection ponds and treatment plant.
TDS (excluding Si) in the initial paste porewater
= approx. 650 mg/l (Table IX.1-22)
Total TDS in the pore spaces each year after consolidation
= 650 mg/L x 1.7×10^8 litres
= 1.1×10^{11} mg
If expelled to the portion of the North Arm of Snap Lake between the two constricted sections (Estimated volume of 4.5 million cubic metres or 4.5×10^9 liters - E Yaremko, 2003), the increase in concentration each year
= 50% x 1.1×10^{11} mg / 4.5×10^9 litres
= 12 mg/liter/year
Over 22 years, this might result in an increase to TDS levels in this portion of the North Arm by 270 mg/L, an increase comparable to the predicted concentrations without cryoconcentration in this portion of the North Arm of 150 to 300 mg/L (Figure 9.4-14).

APPENDIX B

Hydrogeological Issues

Interra Engineering Ltd.

8089

REVIEW OF ENVIRONMENTAL ASSESSMENT DE BEERS SNAP LAKE DIAMOND PROJECT - HYDROGEOLOGICAL ISSUES

Submitted to:

Water Resources Division
Indian and Northern Affairs Canada
Yellowknife, Northwest Territories
X1A 2N7

Submitted by:

INTERA Engineering Ltd.
265 Carling Ave., Suite 208
Ottawa, ON K1S 2E1

Prepared by:

Kenneth Raven, M.Sc., P.Eng.

Project No. 01-214-2
February 6, 2003

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1. INTRODUCTION

This report summarizes Intera Engineering Ltd. (INTERA) technical review of hydrogoelogical issues identified during review of the Environmental Assessment (EA) documentation of the proposed Snap Lake Diamond Project, that was submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) by De Beers Canada Mining Incorporated (De Beers) in February, 2002. This review has been completed on behalf of the Indian and Northern Affairs Canada (INAC), Yellowknife, Northwest Territories.

This document is based on review of the following sources of information:

- Environmental Assessment Report, De Beers Canada Mining Inc., Snap Lake Diamond Project, Report submitted to MVEIRB on February 25, 2002;
- Snap Lake Diamond Project, 2002 Environmental Information, North Lakes Program, Report prepared by Golder Associates Ltd. and submitted to De Beers Canada Mining Inc., October, 2002;
- De Beers responses to MVEIRB Information Requests (IRs), in particular Second Round IR# 2.3.7 to 2.3.11, 2.4.13 to 2.4.17, 2.6.2 and 2.6.3, and Third Round A IR# 3.4.12 to 3.4.14;
- Facilitator's documentation of Water Quality/Water Quantity Workshop Technical Discussion Sessions sponsored by De Beers and held June 4 and 5, 2001 and January 10, 2002;
- Documentation of EA Technical Sessions organized by MVEIRB and held November 26 and 27, 2002 in Yellowknife; and
- A visit to the Snap Lake site and on-site presentation given by De Beers on September 19, 2002.

Several hydrogeological issues raised in initial reviews of the EA Report were addressed in IR responses, in Water Quality/Water Quantity Workshop Technical Sessions, and in the EA Technical Sessions. The following hydrogeological issues remain unresolved, as of the date of preparation of this report, and are discussed in this report:

- Quality of Connate Groundwater Inflow;
- Quality of Mine Water Discharges to Snap Lake; and
- Water Quality in Snap Lake.

INTERA presents these comments in its capacity as an expert advisor representing the interests of INAC as an intervener in the EA review process.

2. QUALITY OF CONNATE GROUNDWATER INFLOW

2.1 Issue

MVEIRB Terms of Reference (ToR) require De Beers to provide an analysis of the proposed development impacts on surface and ground waters, in particular the water chemistry impacts of groundwater from underground mine workings on Snap Lake (ToR Reference: line #221, 337 to 341, 344 to 355 and 381). Reliable characterization of the quality of connate groundwater inflow to the proposed mine is an important issue because large quantities of connate groundwater are predicted to be pumped from the underground mine workings to Snap Lake, and the vast majority of the dissolved chemical load to Snap Lake from the mining operation is derived from connate groundwater inflows.

The issue is whether the quality of connate groundwater inflows described in the EA Report are reliable given the available information, in particular, in light of the probability that higher connate water concentrations will be encountered.

This issue is addressed in the EA Report in Sections 9.2.1.3, 9.4.2.2, and 9.6.3; Table Q-1, Appendix Q, Appendix III.2; and Appendix IX.1 (Sections 5.3.1, 5.4.1, 5.4.3).

2.2 De Beers Conclusion

De Beers concluded that the concentrations of connate groundwater that provide the vast majority of dissolved contaminant load to mine water discharge and ultimately to Snap Lake during mining operations are represented by the average concentration of groundwater measured from granite water samples collected during the Advanced Exploration Program (AEP). In particular, De Beers assumes the average connate groundwater has 902 mg/L total dissolved solids (TDS), 330 mg/L chloride, and 0.06 mg/L dissolved phosphorous and that these concentrations will be representative of connate water quality inflows throughout the mining period.

Connate groundwater of this quality is mixed with Snap Lake inflows, and to a much lesser degree other water and chemical sources in the mine, on a time-varying basis using GoldSim, to determine the average quality of mine water discharge to the water treatment plant, to Snap Lake and ultimately within Snap Lake. Since the proposed water treatment technology (filtration/sedimentation) will not remove most major ions, the discharge to Snap Lake will be similar to the mine water discharge, particularly for TDS, chloride, and most major ions (e.g., calcium, sodium, potassium).

2.3 INTERA Conclusion

INTERA does not agree with De Beers conclusion that the average concentration as measured for granite water samples during the AEP will be representative of average connate groundwater quality inflow to the mine throughout the duration of mining operations. INTERA believes that the concentrations of connate groundwater inflow to the mine and hence the quality of mine water discharge to Snap Lake will be substantially higher than indicated in the EA Report (particularly for TDS, chloride, other major ions and dissolved phosphorous), and therefore impacts to Snap Lake will also be higher than indicated in the EA.

2.4 INTERA Rationale / Evidence

Review of the AEP groundwater quality in summary Table Q-1from Appendix III.2, shows that there is a pronounced profile of increasing salinity with depth in the granite bedrock to depths of 168 m. Such increases with depth are well known and common within the Canadian Shield and result in the ubiquitous presence of brackish to saline groundwater at depths of several hundred meters and brine with TDS of greater than 100,000 mg/L at depths of about 1000 to 1500 m.

The current hydrogeologic understanding of the occurrence of high salinity and TDS groundwaters in the Canadian Shield, ascribes the depth distribution of TDS to an upward diffusion of ions from a deep Ca-Na/Cl source brine over geologic time frames. Active groundwater circulation that is driven by surface topography and decreases significantly with depth in the upper 500 m of the Canadian Shield, modifies the diffusional salinity profile by flushing salinity to groundwater discharge areas. Consequently, it is expected that groundwater in the area of the Snap Lake Diamond Project, will show increases in TDS, chloride and other major ions with increasing depth, as occurs throughout the Canadian Shield.

Chloride concentrations (a surrogate for TDS and other major ions) in the deepest granite samples (collected from 125 to 165 m depth range) average 500 to 600 mg/L, although a couple of samples had lower concentrations at 121 and 248 mg/L. In assessing representativeness of AEP granite groundwater samples for selection of connate water quality in the GoldSim calculations, it is appropriate to use the higher concentrations. Lower concentration samples are often not representative due to drill water and shallow groundwater/Lake water inflow contamination and dilution. The presence of elevated nitrate/nitrite and elevated pH in many of the AEP granite water samples indicates contamination of the water samples by mining activities and raises concerns over the degree to which the samples can be considered representative of granite groundwater.

Since the deepest groundwater samples are only from a depth that is less than half the expected mine depth of 450 to 500 m, and salinity increases with depth, it is not unreasonable to assume that the granite groundwater concentrations at 200 to 500 m depth will be much higher than the values used in the GoldSim calculations. Chloride, TDS and dissolved phosphorous concentrations in the bottom half of the mine could well approximate much more than the 500 to 600 mg/L, 1300 to 1600 mg/L and 0.032 to 0.138 mg/L, respectively, measured at 125 to 165 m depth. Considering the need for a crown pillar thickness of about 100 m and that the data from 125 to 165 m depth are likely representative of upper one third of mining operations, average connate groundwater concentrations over the entire mine depth would be much greater than the values measured at 125 to 165 m depth.

Data from the recent North Lakes investigations also provides corroborating evidence as to probable connate groundwater chemistry. The groundwater samples from wells MW02-05 (depth 110 to 130 m) and MW02-03 (depth 190 to 215 m) show average chloride values of about 380 mg/L and 610 mg/L, respectively, average TDS values of about 1100 mg/L and 1600 mg/L, respectively, and average dissolved phosphorous of about 0.11 and 0.38, respectively. These chloride, TDS and dissolved phosphorous concentrations are consistent with the inference above, that the concentrations of these parameters in connate groundwater will be much greater than the 330 mg/L, 902 mg/L and 0.06 mg/L assumed in the GoldSim modeling.

De Beers has argued that the increased TDS, chloride, other major ions and dissolved phosphorous detected in MW02-03 located near the North Lakes, are due to geochemical evolution along a longer groundwater flow path and are not representative of groundwater expected at this depth near Snap Lake. Such an explanation is inconsistent with the conceptual and numerical hydrogeologic model developed and used by De Beers in assessing the impact to the North Lakes. The flowpath length and travel time between Snap Lake and the North Lakes are too short to explain the increase in salinity be geochemical evolution.

Considering up-welling of deeper more saline water due to the depressurization created by the deeper mine workings, the average connate groundwater inflow concentrations over the life of the mining operation could easily increase to more than 800 mg/L for chloride, 2200 mg/L for TDS and 0.4 mg/L (i.e., by applying De Beers conclusion from the FEFLOW up-welling modeling, that average concentrations would increase by 50 to 60%)

Data from the Diavik project and elsewhere in the Canadian Shield also indicate that higher connate groundwater concentrations should be used in GoldSim modeling. Based on the De Beers Figure 2.4.14-1 (log TDS vs depth plot based on Diavik, Lupin and Canadian Shield data), concentrations of TDS of 1000 to 4700 mg/L and of chloride of about 400 to 1800 mg/L (assuming chloride is 40 % of TDS) would be expected at about 450 m depth, using the two TDS versus depth relationships provided in the Figure. A representative connate water concentration for the entire mining operations should be based on a mine depth-average of values adjusted for up-welling effects.

Considering the above, connate water TDS, chloride, other major ions and dissolved phosphorous concentrations could easily be about 2 to 3 times higher than predicted in the EA Report. The impact of such increases in TDS, chloride, other major ions and dissolved phosphorous concentrations in mine water discharge are, of course, determined with GoldSim. Based on chloride variability runs of GoldSim (Figure IX.1-14), increasing connate water concentrations by 2 to 3 times over assumed values would result in time-varying concentrations in mine water discharge that would be increased by somewhat less than 2 to to 3 times over assumed values, due to other mine sources. Similar results for TDS, other major ions and dissolved phosphorous are expected, recognizing that the connate groundwater is the predominant source of mass loading to mine water discharge.

The existing GoldSim runs in the EA Report only assume a connate groundwater concentration of 330 mg/L for chloride. BeBeers has argued that the "assessed chloride" concentration used in the EA Report that included an incremental chloride mass load of 88 mg/L as measured in the AEP, provides adequate conservatism because the incremental chloride loading is now not expected to occur. The effective chloride concentration in connate water that includes the AEP defined incremental loading is estimated at about 500 mg/L. In our opinion this still underestimates the likely average chloride concentration in connate groundwater inflow. For TDS, other major ions and dissolved phosphorous, the expected mine water loadings are the assessed mine water loadings, and hence no similar arguments over conservatism are raised for these parameters.

2.5 Recommendations

The existing GoldSim runs in the EA Report only assume a connate groundwater concentration of 330 mg/L for chloride, 902 mg/L for TDS and 0.06 mg/L for dissolved phosphorous. As GoldSim is a complicated model that considers numerous interactions and mixing of waters and loadings, it is difficult to reliably quantify the effects of increases in connate water chemistry to assessment of impact to Snap Lake, without rerunning GoldSim.

It is recommended that GoldSim be run assuming more representative concentrations of TDS, chloride, other major ions and dissolved phosphate for connate groundwater to assess impact to Snap Lake. It is suggested that 600 and 900 mg/L chloride, 1800 and 2700 mg/L for TDS and 0.2 and 0.4 mg/L for dissolved phosphorous be used, recognizing that the lower values might be considered best estimates and upper values as probable maximum estimates.

3. QUALITY OF MINE WATER DISCHARGES TO SNAP LAKE

3.1 Issue

MVEIRB Terms of Reference require De Beers to provide an analysis of the proposed development impacts on surface and ground waters, in particular the water chemistry impacts of mine water discharge on Snap Lake (ToR Reference: line #221, 337 to 341, 344 to 355 and 381). Reliable characterization of the quality of water discharges from the proposed mine is an important issue because large quantities of mine water will be pumped to Snap Lake. For many of the dissolved constituents present in the mine water at elevated concentrations (e.g., TDS, chloride and other major ions), the proposed water treatment plant will not reduce the concentrations of these constituents, effectively resulting in discharge of untreated mine water to Snap Lake.

The issue is whether the quality of mine water discharges to Snap Lake described in the EA Report are reliable given the available information, in particular, the probability of higher connate water concentrations and incomplete mixing within Snap Lake.

This issue is addressed in the EA Report in Sections 9.4.2.2, and 9.6.3; and Appendix IX.1 (Sections 5.2, 5.3, 5.4).

3.2 De Beers Conclusion

DeBeers concluded that the mine water discharge to Snap Lake during operations, will have peak average annual and median TDS of 1229 mg/L and 602 mg/L, respectively, peak annual average and median chloride of 417.5 and 245.5 mg/L, respectively, and peak annual average and median dissolved phosphorous of 0.012 mg/L and 0.008 mg/L, respectively. These discharge concentrations, which are calculated using GoldSim, represent the major mass loading to Snap Lake from mining operations.

3.3 INTERA Conclusion

INTERA does not agree with De Beers conclusion that the concentrations of mine water discharge to Snap Lake throughout the duration of mining operations will be as defined in the EA Report. INTERA believes that the concentrations of mine water discharge to Snap Lake and hence the quality of Snap Lake water will be substantially higher than indicated in the EA Report (particularly for TDS, chloride, other major ions and dissolved phosphorous). Therefore, impacts to Snap Lake will also be higher than indicated in the EA.

3.4 INTERA Rationale / Evidence

There are two principal reasons to expect that the concentrations of mine water discharges to Snap Lake will be greater than predicted in the EA Report:

- Increased concentrations of connate groundwater inflow; and
- Incomplete mixing within the Effective Lake Volume of Snap Lake.

The rationale and evidence for increased concentrations of connate groundwater inflow to the mine during mining operations are discussed in Section 2.4 of this report.

The De Beers analysis of mine water discharge chemistry assumes that the connate groundwater inflows are mixed with recharge water infiltrating from Snap Lake within the mine. The concentrations of infiltrating Snap Lake water are calculated within the Effective Lake Volume, the volume of Snap Lake where mine water discharges are completely mixed with Snap Lake water and the resultant water recharges the underground mine workings. The Effective Lake Volume is 8.7 Mm^3, which is about 10% of the total volume of Snap Lake. This is a large mixing volume, that under conditions of complete mixing, significantly reduces mine water discharge concentrations in Snap Lake.

The existing GoldSim model makes assumptions about complete mixing within the Effective Lake Volume of Snap Lake. Given the fact that mine water with higher TDS and higher density will be discharged to Snap Lake, there is potential for density separation and settling of mine water to the depressions within Snap Lake. Figure 9.4-10 and the text on pages 9-218 and 9-219 of the EA Report acknowledge that such density settling and reduced mixing will occur. Although such settling and limited mixing may be reduced by wind action on the Lake during the summer open water period, the degree to which this will occur is unknown because there is a lack of information on effects of currents on Lake mixing. During winter, which represents 2/3 of the year, the degree of mixing is expected to be significantly reduced due to the presence of ice cover on the Lake.

If significant density separation and incomplete mixing occurs, either seasonally or over a longer time period, there is potential that Lake bottom water within the Effective Lake Volume that recharges the mine will have higher concentrations than those calculated in GoldSim assuming complete mixing. This would result in increased concentrations of Snap Lake recharge water and therefore increased concentrations of mine water discharge. Increased concentrations of mine water discharge would then result in increased potential for further density separation and settling. This cycling of higher concentration recharge water would cause the evolution of the quality of mine water discharge toward that of the connate groundwater, rather than the mixture of relatively clean Snap Lake water and connate groundwater assumed in the EA Report.

It is difficult to assess the scope of this effect of density separation and incomplete mixing on the resultant concentrations of TDS, chloride and other major ions in mine water discharge. The probable maximum long-term effect would be that mine water discharge concentrations would approximate connate water concentrations. However, this probable maximum effect is unlikely to occur over the duration of mining operations. A very approximate estimate of this effect is that the maximum mine water discharge concentrations could be increased by about 25 to 50 % over those predicted based on assumptions of complete mixing. This estimate assumes that concentrations of bottom water in the Effective Lake Volume would be greater than those assumed in the EA Report. In the GoldSim model this would be equivalent to assuming that the Effective Lake Volume was smaller. Reducing the Effective Lake Volume increases the rate of increase of dissolved constituents in the Effective Lake Volume of Snap Lake.

3.5 Recommendations

The existing GoldSim model that is used to calculate the quality of mine water discharge to Snap Lake for

EA purposes, assumes complete mixing of mine water discharge within the large Effective Lake Volume in determining the quality of Snap Lake water that will recharge the underground mine workings. This simply mixing model does not consider the very real probability that there will be incomplete mixing within the Effective Lake Volume due to density effects that will increase the concentrations of Snap Lake water recharging the underground workings.

It is recommended that a full 3-D model that considers density-dependent flow be used to quantify the effects of incomplete mixing within the Effective Lake Volume on the quality of Snap Lake water that will recharge the underground mine workings. The model should incorporate the known bathymetry of Snap Lake and consider effects under both ice-covered and open water conditions. The model should also use the range of higher connate groundwater concentrations recommended in Section 2.5 of this report and the initial conservative assumption that the mine water discharge concentrations are equal to connate groundwater concentrations.

4. WATER QUALITY IN SNAP LAKE

4.1 Issue

MVEIRB Terms of Reference require De Beers to provide an analysis of the proposed development impacts on surface and ground waters, in particular the water chemistry impacts of underground mine water discharges on Snap Lake and the Lockhart River watershed (ToR Reference: line #221, 337 to 341, 344 to 355 and 381). Reliable characterization of the water quality within Snap Lake is important because Snap Lake is the receptor for all mine water discharges.

The issue is whether the predictions of water quality within Snap Lake described in the EA Report are reliable given the available information, in particular the probability of higher connate water concentrations and incomplete mixing within Snap Lake.

This issue is addressed in the EA Report in Sections 9.4.2.2, 9.4.2.3 and 9.6.3; Appendix IX.1 (Sections 5.2, 5.3 and 5.4); and Appendix IX.7.

4.2 De Beers Conclusion

De Beers concludes that the maximum ice-covered concentration after initial mixing in Snap Lake during mine operations will be 137 mg/L for chloride and 350 mg/L for TDS. De Beers concludes that the maximum ice-free concentration within 1% of Snap Lake will be 177 mg/L for chloride and 444 mg/L for TDS. The higher ice-free concentrations are due to the fact that Snap Lake model used to determine the values does not consider the turbulent mixing of the diffuser. De Beers also concludes that maximum average TDS concentration in Snap Lake will be about 330 mg/L. These results are generated based on modeling of water quality in Snap Lake in the near-field using the US EPA Cormix model for the diffuser and in the far-field using the RMA 2-D plan models of Snap Lake. GoldSim provides the mine water quality and quantity discharge data for input to these models.

4.3 INTERA Conclusion

INTERA does not agree with De Beers conclusion that the concentrations of TDS, chloride, other major ions and dissolve phosphorous in Snap Lake throughout the duration of mining operations will be as defined in the EA Report. INTERA believes that the concentrations in Snap Lake will be substantially higher than indicated in the EA Report (particularly for TDS, chloride, other major ions and dissolved phosphorous at depth in the Lake). Therefore impacts to Snap Lake will also be higher than indicated in the EA.

4.4 INTERA Rationale / Evidence

There are two principal reasons to expect that the concentrations in Snap Lake will be greater than predicted in the EA Report:

- Increased concentrations in mine water discharge; and
- Density-driven flow separation in Snap Lake.

The rationale and evidence for increased concentrations of mine water discharge during mining operations are discussed in Sections 2.4 and 3.4 of this report.

The rationale and evidence for the flow of higher density mine water discharge into the deeper parts of Snap Lake are described in Section 3.4 of this report. This type of flow separation is not considered by 2-D plan RMA models of Snap Lake. The RMA models assume that the vertical profile in Snap Lake is fully mixed and hence that depth concentration profiles do not exist within Snap Lake. Therefore, the RMA models underestimate the concentration of water quality parameters, particularly TDS, chloride and other major ions, in the deeper parts of the Lake.

The RMA models also estimate mixing due to flow velocities in the Lake under ice cover by not including wind stress on the water surface. However, these computations are uncertain as there is no baseline water current data for Snap Lake with which to calibrate or assess the RMA model results, particularly for the ice cover period that represents 2/3 of the year.

It is important to note that the current RMA models appear to use the water quality and quantity data generated in GoldSim as a source conditions for the mine water discharge to Snap Lake. It is not apparent that the RMA models consider the dissolved mass loss due to recharge of Snap Lake water to the underground workings. If the cycling of dissolved mass from Snap Lake to the underground working is significant, then the RMA models that use the GoldSim computations of mine water discharge may overestimate mass loading to Snap Lake.

It is difficult to assess the degree to which concentrations of TDS, chloride and other major ions have been underestimated in Snap Lake. Given the underestimation of connate water concentrations by factors of 2 to 3, the expectation that density separation effects could increase maximum mine water discharge concentrations by 25 to 50 %, the limitations of the GoldSim models, and the limitations of the RMA models, it is estimated that concentrations of TDS, chloride, other major ions and dissolved phosphorous in Snap Lake may be underestimated in the EA Report by factors of 2 to 4.

4.5 Recommendations

The existing RMA models that are used to calculate the quality of water in Snap Lake for EA purposes, assume complete vertical mixing of mine water discharge within the water column of Snap Lake, and lack baseline Lake current data under open water and ice cover conditions. The existing RMA models also use mine water discharge concentrations that are underestimated.

It is recommended that a full 3-D model that considers density-dependent flow and utilizes Snap Lake bathymetry and baseline current data, be used to estimate water quality in Snap Lake. The model should consider effects under both ice-covered and open water conditions. The model should also use revised estimates of higher mine water discharge concentrations as discussed in Section 3.5 of this report, and consider the loss of mass due to recharge of water from the bottom of Snap Lake to the underground mine workings.

APPENDIX C

Geotechnical Issues

Brodie Consulting Ltd.

February 12, 2003

Mr. Sevn Bohnet
Department of Indian Affairs and Northern Development
Water Resources Division
Box 1500 4914 - 50th Street
Yellowknife, NT, X1A 2R3

RE: SNAP LAKE MINE – ENVIRONMENTAL ASSESSMENT
GEOTECHNICAL ISSUES

Dear Sevn,

INTRODUCTION

This letter provides a summary of the review of the geotechnical issues for the Environmental Assessment of the Snap Lake diamond project. The focus of the geotechnical issues is the construction, operation and closure of the North Pile which is to contain the paste kimberlite tailings.

In this review, the geotechnical issues are presented in the context of the project setting, potential environmental impacts, and the risks/uncertainties which have been accepted for other recently permitted projects.

The proponent's original EA submission, information requests and responses, technical sessions, and review team meetings form the technical basis of the review.

There are three main aspects of the North Pile which warrant discussion in the context of the EA process. These are: precedent for paste technology for surface disposal of the kimberlite tailings, potential for greater than predicted rates of release of water from the North Pile during and following construction, and slope stability. Each issue is discussed separately.

SURFACE DISPOSAL OF KIMBERLITE PASTE

Brodie Consulting Ltd.
572 St. Andrews Place, West Vancouver, B.C. V7S 1V8
604-922-2034 fax: 604-922-9520 email:mjohnbrodie@shaw.ca

Surface disposal of kimberlite paste is an unproven technology. There are three aspects to this concern.

1. There is no existing mining operation producing kimberlite tailings paste on an ongoing operational basis.
2. There are only two mining operations worldwide which are disposing of paste tailings using surface disposal.
3. There are no existing mining operations employing surface disposal of thickened or paste tailings in an arctic environment.

Test work by the proponent shows that a paste mixture can be produced and pumped. However, prior experience world wide with kimberlite paste is limited to test work conducted by DeBeers at three sites in South Africa. It is worth noting that the properties of the Snap Lake kimberlite paste, although slightly different from paste mixes made from other types of tailings, are not so different to suggest that kimberlite paste production is not viable.

At this time, it is understood that the Cluff Lake uranium mine in Saskatchewan and the Bulyanhulu Mine in Tanzania are using paste technology for surface disposal. The proponent does not seem to have drawn upon that experience (no references cited).

There does not appear to have been any experience in the mining industry worldwide involving the surface disposal of tailings paste from any type of ore in an arctic setting. The effects of low temperature on the dewatering and flow characteristics have not been observed in the field. As with any advancing technology, it should be expected that modifications to existing practices will be required in order to make the new methods practical. Some modifications have been envisioned by the designers. Others may be necessary. Upset conditions may occur until the problems are resolved.

The water management plan for the North Pile is only a concept at this time. Such an operational plan has not been attempted in a northern setting.

In the context of the EA process, these uncertainties must be recognized as being a source of doubt regarding the predictions of project performance and potential impacts. The proponent has acknowledged this concern with the proposal for a "starter cell" wherein the design and performance issues with the paste disposal will addressed.

A number of contingencies have been identified to address some of the problems. These include: dual heat-traced paste lines, use of discharge "towers" to increase the discharge volume before moving discharge points, and a modified seepage ditch should there be elevated seepage levels (ref. Technical Session, geotechnical break-out session). It should be noted that the use of discharge towers is likely to significantly slow the freezing of the North Pile due to the greater thickness of deposited paste.

To summarize, the following opinions are presented for consideration by Water Resources:

- the use of surface disposal for kimberlite paste tailings is an unproven technology, especially in a northern setting,
- the proponent has attempted to prepare a conservative design for the tailings disposal,
- a starter cell has been proposed to resolve design and operation details before the tailings disposal is expanded over the full disposal area,
- there are some contingencies which could be invoked to aide in meeting the design objectives.

It is recommended that the general uncertainty regarding the use of paste technology for surface disposal on the Snap Lake project only be accepted as tolerable for the EA phase of the project, once the results of the following assessments are presented.

1. identify the range of paste deposition properties, moisture content, discharge methods and water management plans which may occur during summer and winter operation of the starter cell and entire North Pile,
2. describe conservative mitigation strategies be proposed to deal with any adverse conditions which may arise,
3. provide means for monitoring and reporting of the starter cell performance and threshold criteria for invoking mitigation measures.

WATER MANAGEMENT

There is potential for greater than predicted rates of release of water and possibly contaminated water from the North Pile during and following construction. This may arise due to:

- excess water in the paste discharge,
- seepage escaping beyond the perimeter ditches,
- freezing being much slower than anticipated,
- cryo-concentration of paste pore water,
- elevated levels of leaching from the paste, or,
- oxidation of the PAG meta-volcanic rocks.

The impacts of any release of water to the environment would occur in the north arm of Snap Lake. The proponent has argued that they have conservatively allowed for a high rate of flushing of contaminants from the underground and the North Pile (and metal release to Snap Lake via the water treatment plant). However, their estimated loading is distributed over the entire volume of Snap Lake and not concentrated in the north arm.

Should there be a greater release from the North Pile due to one of the above factors, then the impacts to the north arm will be greater than estimated. Each of these issues is briefly discussed as follows.

Excess Water in the Paste

There are several factors which may cause the paste to be wetter than assumed. Paste abrasiveness, high pump pressure due to distance to the North Pile and the need for low viscosity to produce flat beaches all suggest a need for a wet paste. A wet paste will result in more free water (as opposed to pore water) and also a reduction in the freezing rate.

Seepage and Ditches

The originally proposed ditches were very unlikely to meet the performance objectives suggested by the proponent. Seepage from the North Pile was likely to by-pass under the ditches and some of the capture seepage was likely to escape. A modified ditch design was suggested as a contingency by the proponent during a break-out session from the Technical Sessions.

Monitoring of the starter cell performance would be used to determine the need for the ditch contingency.

Slower Freezing Rate

The proponent has acknowledged that the thermal modeling completed to date is inadequate to predict the rate of freezing of the North Pile. It is possible that a significant portion of the pile, in the order of 50% or more, will not freeze during the life of the mine. Should this occur, there will be a greater mass of unfrozen kimberlite which may leach contaminants to the environment. Bleed water from the discharged paste may infiltrate into the pile and not pool on the surface for collection and routing to the water treatment plant.

Cryo-Concentration of Paste Pore Water

The thermal modeling which has been presented to date is not adequate and is addressed in more detail by other reviewers. The key weakness of the thermal modeling is the lack of confidence in the rate at which the pile will freeze and the resulting expulsion of pore water. Three scenarios are possible: freezing upon or immediately after deposition, delayed freezing and very slow freezing. A rapid onset of freezing, during winter operations, would yield a completely frozen material with little pore water expulsion. However, this would not apply to material which is deposited during the summer.

If the pile freezes during the life of the mine, then there may be significant increase in pore pressure followed by expulsion of pore water. Due to cryo-concentration process, that water will contain essentially all of the soluble contaminants which were present in the unfrozen pore water. Release of these contaminants to the environment has not been considered in the EA.

Finally, if the pile were to freeze very slowly, over a period of many decades or longer, then there may be a significant mass of unfrozen kimberlite material which will leach contaminants to the environment.

At this stage, the freezing of the North Pile has not been evaluated in sufficient detail to determine which of these scenarios is most likely. The proponent has acknowledged that the current thermal modeling is inadequate. Given this uncertainty with how the North Pile will freeze, it is not possible to determine if adverse impacts to Snap Lake will be prevented.

Leaching of Contaminants

The issue of leaching of contaminants is addressed from a geo-chemical perspective by other reviewers. However, on the Snap Lake project, the primary mechanism for control of leaching is through the establishment of permafrost. As noted above, the thermal modeling is inadequate. Consequently, there may be a greater mass of un-frozen material which may leach contaminants. In addition, these materials may release contaminants at a higher rate due to being warmer.

Meta-Volcanic Waste

The meta-volcanic rocks are expected to be potentially acid generating. In the event that the North Pile freezes much more slowly than expected, oxidation and acid generation could occur in these rocks. These processes will not be inhibited by exclusion of oxygen because the pile is expected to be essentially unsaturated if it is unfrozen. Currently, there is no confidence that this material will be frozen, as the thermal modeling is inadequate. The proponent has not shown that, in the absence of freezing conditions, acid rock drainage will not occur.

SLOPE STABLITY

There are two slope stability issues which have not been adequately addressed. These are discussed as follow.

As noted above, the North Pile may be partially unfrozen at the end of the mine life. If this occurs, then there is potential for elevated pore pressures in sections of the pile as they freeze due to the expansion of pore water upon freezing. If these sections are near to the perimeter of the pile then local slope failure could result. The proponent should assess this potential and if necessary, provide for measures to mitigate slope failure.

The freeze/thaw characteristics of the PK coarse and grits has not been assessed. It was recommended during the Technical Session – geotechnical breakout session that further testing be conducted. There is potential for evolution of the kimberlite paste into a frost-susceptible material due to freeze thaw degradation. Should the kimberlite paste be, or become, frost-susceptible then the granite cover on the pile at closure may fail due to solifluction.

CONCLUSIONS & RECOMMENDATIONS

The proponent has not demonstrated that adverse effects will not arise from the Snap Lake project. There are a number of uncertainties associated with the North Pile which have not been fully addressed or considered by the proponent. These uncertainties could result in greater impacts to the North Arm of Snap Lake during and/or following operations. Many of these uncertainties arise from the lack of industry precedent in the use of paste tailings technology for surface disposal in a northern setting.

The following additional studies should be completed in order for the proponent to demonstrate that the potential impacts to the environment are acceptable.

1. Assessment of the range of possible paste discharge conditions (and implications for freezing and water management), mitigation strategies, monitoring plans and threshold criteria for mitigation, for the starter cell and full size North Pile.
2. Thermal modeling issues should be further evaluated, and if necessary, contingency measures and design modifications should be prepared.
3. Slope stability after closure should be further assessed to demonstrate long-term stability.

I trust that this letter addresses your requirements for this project. Please call if you any questions.

Yours truly,
Brodie Consulting Ltd.

M. J. Brodie, P. Eng.

APPENDIX D

Permafrost and Thermal Issues

Dr. C. R. Burn

REVIEW OF ENVIRONMENTAL ASSESSMENT DEBEERS SNAP LAKE DIAMOND PROJECT –

PERMAFROST AND GEOTHERMAL ISSUES

Submitted to:

Water Resources Division
Indian and Northern Affairs Canada
P.O. Box 1500
Yellowknife, Northwest Territories
X1A 2R3

Submitted by:

Dr C.R. Burn
169 St Laurent Blvd.
Ottawa ON K1K 2Y6

February 10, 2003

TABLE OF CONTENTS

1. INTRODUCTION

This report summarizes a technical review of permafrost and geothermal issues identified in the Terms of Reference (ToR) of the Environmental Assessment (EA) submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) by DeBeers Canada Mining Incorporated (DCMI) regarding the Snap Lake Diamond Project (SLDP). The review has been completed on behalf of the Water Resources Division, Indian and Northern Affairs Canada (INAC), Yellowknife, N.W.T. The following commentary is presented in the capacity of an expert advisor to INAC, as an intervention in the EA review process.

The review has been based on:

- Water Licence Application and Supporting Information submitted to Mackenzie Valley Land and Water Board on March 5, 2001.
- Field visit and on-site presentation by DCMI at the SLDP on 19 September 2001.
- ToR of the EA, issued by MVEIRB on September 20, 2001.
- EA Report, DCMI, SLDP, submitted to MVEIRB on 25 February 2002.
- SLDP, 2002 Environmental Information, North Lakes Program, Report prepared by Golder Associates Ltd, submitted to DCMI n October 2002.
- Responses by DCMI to Information Requests (IRs) in the second and third rounds, especially IRs # 2.4.34 and 2.4.35, and 3.4.16 through 3.4.20.
- Presentations and responses to questions at EA Technical Sessions held in Yellowknife on December 3 and 4, 2003.
- Evening breakout session on December 3, 2003, held at DCMI, Yellowknife, attended by representatives for DCMI, INAC, and Mr Don Hayley, EBA Engineering.

Several issues regarding permafrost and the ground thermal regime were raised in the IRs and at the Technical Sessions held in December 2002. There was no resolution at the Technical Sessions of the thermal status of the North Pile. At the time of writing, over two months later, no new information regarding thermal conditions in the North Pile has been provided to INAC, and therefore this remains unresolved. The unknown state of the Pile, whether it will be frozen, thawed, or partially frozen, influences the magnitude of potential seepage from the Pile to the Northwest Arm of Snap Lake. Since the condition of the Pile is unresolved, the impact on Snap Lake has not been determined. Therefore the EA is, at present, incomplete.

There are three principal aspects of the thermal modelling of the North Pile that are unsatisfactory and at variance with field conditions at Snap Lake or the literature cited by the proponent. These concern:

- the geothermal flux entering the Pile from below,
- the characterization of surface temperatures by n-factors, and
- the specification of thermal properties by the proponent.

In addition, modelling of undisturbed ground temperatures has failed to reproduce field measurements. These aspects, discussed in detail below, require resolution before any corroboration of the EA submitted by DCMI can be achieved.

The intervention is guided by section 2.6.2 of the ToR, especially item I, lines 299-310.

2. UNDERGROUND CONDITIONS

ToR line 302-303. *Impact of modified permafrost temperatures and ground ice conditions underground in the mine.*

Maintenance of permafrost conditions and ground ice below ground is an aspect of mine operation. Given that the underground workings will be handling a large volume of water daily, it is unlikely that permafrost in the mine will be unaffected. While this may, ultimately, become a stability issue for mine management, it is unlikely to lead to a surface or lacustrine impact significantly greater than the impact expected by the mine as currently designed.

3. MINE BUILDINGS AND ROADWAYS

ToR line 302-303. *Impact of modified permafrost temperatures and ground ice conditions on roadway, waste rock piles etc.*

The proposal invokes standard geotechnical construction procedures for roads and the airstrip. The proposal similarly describes design of buildings appropriate for a permafrost environment. Construction of these facilities is well understood by northern engineers and no undescribed impact is likely to occur from these facilities.

4. NORTH PILE GROUND ICE CONDITIONS

ToR lines 302-305. Occurrence of ice wedges beneath containment structures and in the footprint of the North Pile.

4.1 Issue

Ice wedges represent potential flow paths for uncontrolled discharge beneath the North Pile and its ditches. In the bedrock that dominates the area, ice wedges generally occur in fractures, rather than in the polygonal configuration characteristic for unconsolidated materials. The ToR, especially line 305, require DCMI to account for the location of ice wedges beneath the various structures.

IR 3.4.22 was, in part, intended to clarify this issue.

4.2 DCMI Conclusion

In the response 3.4.22(a) DCMI states that "Massive ice was not encountered in the fractured bedrock in the 25 holes that have been drilled within the footprint of the proposed North Pile". From this evidence, DCMI indicated at the Technical Hearings that ice wedge occurrence beneath the North Pile was not of concern.

4.3 INAC Conclusion

Ice wedges are unlikely to be intercepted by borehole drilling as they are dominantly vertical features. Delineation of ice wedges is by probing surface cracks and fractures, or by survey with Ground Penetrating Radar. In the absence of either type of evidence, INAC considers that there has been insufficient effort made to determine the location of ice wedges in the footprint of the North Pile or its perimeter ditches, and therefore their presence cannot be discounted.

The presence and location of ice wedges forms a critical component of the information regarding the North Pile and its ditching system that INAC currently considers incomplete.

4.4 Recommendation

INAC recommends that surveys of the North Pile and perimeter ditch footprints be undertaken with Ground Penetrating Radar, and the results assessed and documented to MVEIRB as part of completion of the EA.

5. GENERAL CONSIDERATIONS REGARDING THE NORTH PILE

ToR line 300-301. *Impact on permafrost physical conditions and thermal regime.*

5.1 Issue

The North Pile proposal for containment of mine tailings represents the first attempt at this method of mine waste disposal in a permafrost environment. Therefore, MVEIRB must recognize that the technology is untried and untested for an environment with potentially severe operating conditions during several months of the year. INAC considers that in this context it is the responsibility of DCMI to provide firm evidence that the North Pile is likely to perform as proposed.

DCMI has indicated that the paste deposited in the Pile will freeze within two years, and therefore the potential geochemical effects of the Pile, especially on the quality and quantity of seepage to the Northwest arm of Snap Lake are considered to be minimal (Appendix IX, pp. 1-52 – 1-55).

INAC considers that this conclusion is premature, because we maintain serious reservations about:

- the results of geothermal modelling presented by DCMI in support of their position
- the unknown extent of ice wedges in the country rock
- the unknown behaviour of the pore contents of processed kimberlite paste when subject to freezing
- the projected efficiency of perimeter ditches to collect seepage.

The following sections address the geothermal and freezing characterization issues. Ditch design is addressed elsewhere.

6. NORTH PILE GEOTHERMAL MODELLING

6.1 Issue

ToR lines 300-301 and lines 307-309 refer to *the impact on the permafrost thermal regime* and *the impact of the pore water contained in the processed kimberlite deposited in the north pile and the potential for pore-water expulsion during freeze back of the pile.*

DCMI has presented the results of modelling with TEMP/W (EA Report p. 10-46) to assess the thermal conditions in the North Pile from deposition of paste until closure of the Mine. DCMI considers that for a paste deposition rate of 3 m/yr, the entire pile will freeze within two years of deposition (EA Report p. 10-48).

IR 3.4.17 requested the initial foundation temperatures for the geothermal model. The response to IR 3.4.17, in Figure 3.4.17-1 showed discrepancies of several degrees Celcius between the modelled predictions of ground temperatures beneath the North Pile and field measurements. **In each case the model underpredicted the field values.** This point was made by Gartner Lee Limited (from EBA Engineering opinion) in their Issues Rationale Document submitted to MVEIRB before the Pre-technical Session Conference held on 8 November 2003.

The response to IR 3.4.17 also supplied, in Fig. 3.4.17-3, a geothermal analysis of the North Pile. Large portions of the cross-section report temperatures above -0.5°C. Since these are the data used by DCMI to infer that the North Pile will be frozen, and since the calibration data are in error by several degrees, INAC does not consider the model output to predict reliably the thermal state of the Pile.

As a result, INAC does not consider that the EA of the North Pile's impact on the surrounding environment is complete.

There are three principal sources of error that may have contributed to these discrepancies. Before discussing these in detail, a brief summary of the modelling is provided.

6.2 Geothermal modelling technique

The TEMP/W model calculates the flow of heat in a designed structure and predicts the temperature throughout the structure after defined time intervals. In this model, heat flow is by conduction only. No radiative or convective transfers are considered. The latter may be of considerable importance in a structure such as the North Pile, but for the purposes of EA, conduction, if properly described, is likely a sufficient estimate. For the purposes of regulation and design, convective components must be considered.

Heat flows into the bottom of the pile from the Earth, at a rate specified as the geothermal flux. Heat flows into or out of the upper surface of the pile at a rate determined by the surface temperature of the pile and the surface temperature gradient. Within the pile temperatures are controlled by the heat flow and the thermal properties of the materials, especially the thermal conductivity and heat capacity. For freezing conditions, the rate of freezing is affected by the latent heat of freezing of pore solution, and the distribution of this latent heat over the range of freezing temperatures for such solutions.

TEMP/W is a model that allows surface temperature to change over time, but is relatively inflexible in the geometry of the cross-section being examined. **In the Technical Hearing, DCMI indicated that the model was developed for logistical purposes, to assist design of the paste spigot points and timetable. However, output from the model was also used to estimate the geochemistry of seepage from the North Pile (EA submission, Appendix IX pp. 1-52 – 1-55). INAC considers that this estimate is in error, because the geothermal model is in error.**

7. GEOTHERMAL FLUX

7.1 Issue

The geothermal flux prescribed for the model by DCMI was 0.004 Wm^{-2} (EA submission, p. 10-46). Standard values for the geothermal flux in the Canadian Shield are one order of magnitude higher (Judge 1973). IR3.4.17(b) requested DCMI to clarify the assignment of 0.004 Wm^{-2}. The response indicated that this value was chosen as it "provided the best fit for the existing thermal regime". At the Technical Hearing INAC pointed out that the value was too low, and showed that DCMI's field data from the North Lakes program indicated a geothermal flux of between 0.03 and 0.05 Wm^{-2} from data collected in holes TH02-01 and TH02-02. INAC requested resolution of the effect of this error on the performance of the geothermal model.

6.2 DCMI Conclusion

At the Technical Hearing DCMI did not contest the conclusion reached by INAC. Since the Technical Hearing, no further information has been supplied to INAC by DCMI on this matter.

6.3 INAC Conclusion

The error has been demonstrated and DCMI must be required to correct it and report the implications of this for the model results. The critical point is that this increase in modelled geothermal flux will increase the temperatures projected for the North Pile, indicating that the Pile may not freeze, as assumed by DCMI.

6.4 INAC Rationale

The Geothermal flux, Q, is given by:

$Q = dT/dz \ . \ k$

Where dT/dz is the geothermal gradient, or the temperature gradient in the ground, and k is the thermal conductivity of the rock. In response 3.4.17 (f) DCMI state that the thermal conductivity of granite is 3 W m^{-1} $°C^{-1}$. The temperature gradient in hole TH02-01, as measured and published from the North Lake hydrogeological investigation is 0.015 °C m^{-1}. **The regional geothermal flux is therefore 0.04 W m^{-2} or greater**. A similar conclusion may be reached with the geothermal gradients measured in boreholes TH02-02 and at BH 30 from the mine site.

6.5 Recommendations

INAC recommends that DCMI be required to incorporate a corrected geothermal flux in TEMP/W and evaluate the impact of this correction on the predicted temperatures in the North Pile.

8. N-FACTORS

8.1 Issue

TEMP/W uses n-factors to obtain the surface temperature of the pile. The n-factors are the ratio of the number of degree-days measured at the ground surface to the number of degree-days measured in the air for the freezing and thawing seasons. For a specific site, there are two n-factors, one for freezing conditions, n_f, and one for thawing conditions, n_t.

The n-factors used in the thermal modelling are presented on p. 10-47 of the EA report. Since the n-factors assigned are the same for all months of each season, INAC considers that these have been assigned without consideration for changing snow conditions through the winter season, and are a source of error in the model. INAC presented this issue to DCMI at the Technical Hearing, but, to date, we have received no further comment from the proponent. Therefore, INAC considers this issue unresolved.

8.2 DCMI Conclusion

INAC requested justification for the choice of n-factor in IRs 2.4.35(b) and 3.4.17(c). In both cases, DCMI indicated that the n-factor was selected according to the user manual of TEMP/W, which, in turn, was prepared with reference to Lunardini (1978). The specific n-factors were justified in terms of the "calibration process described above", i.e. adjusting the model to provide the best fit to field temperatures (response to IR 3.4.17(c)).

8.3 INAC Conclusion

Given that the calibration process used was unsatisfactory for determining the state of the North Pile, INAC does not consider the n-factors to have been implemented in a satisfactory manner. Furthermore, INAC disagrees with the assignment of a single n-factor for the whole season, when the surface temperatures vary on a monthly basis. INAC requires that the n-factors be selected so that they are more representative of field conditions.

8.4 INAC Rationale

The theory of n-factors was developed for the estimation of the depth of freezing and thawing, and the n-factors have been shown to be "valuable in calculating the total seasonal depth of phase change" (Lunardini 1978, p. 41). However, the theory was developed to apply to conditions aggregated over a freezing or thawing season, rather than individual weeks or months within that season. DCMI has neglected in its modelling that "the n-factor for a given site will vary with time, from month to month and from year to year" (Lunardini 1978, p. 41). Indeed, Lunardini (1978) indicates that "the n value can change by 30% from the first half of a month to the latter half".

The freezing-season n-factor has generally been rationalized in terms of the insulating effect of the snow cover. Thus when the snow cover is thin the n-factor is high (close to 1), as air and surface temperatures are nearly equal, but as the snow cover deepens, the n-factor declines. However, the flow of heat during the freezing season is driven upwards by the heat flux near the ground surface. Therefore, when the ground is freezing, ground surface temperatures remain warm because of the ready supply of latent heat (Outcalt et al. 1990). So, in early winter, the n-factor is characteristically low.

The assignment of a single n-factor throughout the freezing season neglects the variation in this ratio due to latent heat effects and the influence of a changing snow cover. **While such simplification may be suitable for the original purpose of model application, i.e. logistical aspects of spigot configuration, INAC does not consider it suitable for EA purposes of characterizing the frozen/thawed state of the pile.**

8.5 Recommendation

INAC recommends that DCMI be required to assign n-factors to TEMP/W in a manner that incorporates considerations of ground freezing and seasonal changes in snow cover, if TEMP/W is to be the primary tool for determination of the thermal state of the Pile.

9. THERMAL PROPERTIES

9.1 Issue

The specification of thermal properties of the North Pile constituents is critical to determination of the thermal regime of the Pile. INAC has noted several errors in the thermal properties described in the documentation submitted by DCMI. These errors have been communicated to DCMI. At the time of writing, no correction to these specifications has been submitted by DCMI. Until these corrections have been made, the modelling is incomplete.

9.2 DCMI Conclusion

The thermal properties used in the thermal analyses were presented in Table 10.2-7 of the EA submission, in Table 3.4.17-1 of the response to IR 3.4.17, and in Figure 3.4.17-4 of the same response. The properties were selected from Johnston et al. (1981) and Goodrich and Gold (1981).

9.3 INAC Conclusion

Several of the properties identified by DCMI differ from those published by Johnston et al. (1981), and the absence of scales on the axes of Fig. 3.4.17-4 renders the figure useless for the purposes of assessment. DCMI must assign thermal properties correctly and provide an explicit determination of the latent heat vs. temperature relation.

9.4 INAC Rationale

8.3.1. EA Submission Table 10.2-7 assigned two separate values for the Thermal Conductivity of materials in the North Pile. It is not clear which is the correct value, and it is not clear why there are no values for the volumetric heat capacity of these materials in the frozen state.

8.3.2. In EA Submission Table 10.2-7 the coarse PK saturated is assigned a degree of saturation of 1.0%.

8.3.3. In EA Submission Table 10.2-7 Full mix unsaturated, with porosity 42% and degree of saturatiuon 90% is assigned a volumetric water content of 0.4, not 0.38.

8.3.4. IR Response 3.4.17, Figure 3.4.17-4 is presented without scales on either the horizontal or vertical axis. It is therefore impossible to determine how "latent heat is included in the thermal model where phase changes occur", as stated in the Response.

8.3.5. The response to IR 3.4.17 (f) provides Table 3-4-17-1 indicating the volumetric heat capacity of ice. The value has been selected from Johnston et al. (1981, Table 3.9). The value selected, however, is the mass heat capacity, not the volumetric heat capacity.

8.3.6. The response to IR 3.4.17 (f) provides Table 3-4-17-1 indicating the volumetric heat capacity of mineral soil. The value has been selected from Johnston et al. (1981, Table 3.9). The value selected, 1.3 is not published. Johnston et al. (1981) present a value of 1.875.

8.3.7. The values for the thermal properties of granite presented in Table 3.4.17-1 are inconsistent with the thermal diffusivity of granite 15 x 10^{-7} m^2/s cited by Johnston et al. (1981, Table 3.10).

8.4 Recommendation

INAC requires that corrections are made to the assignment of thermal properties in TEMP/W, and the results of these revisions submitted to MVEIRB for analysis before the EA may be considered complete. INAC requires a freezing characteristic curve to be determined in the laboratory for the full-mix processed kimberlite paste, in order to obtain the distribution of latent heat with temperature in this material.

9 CRYOCONCENTRATION

10.1 Issue

ToR lines 307-309. *Impact of water content contained in the processed kimberlite deposited in the North Pile and the potential for pore-water expulsion during freeze back of the pile*

The behaviour of the North Pile during freezing is the subject of considerable concern expressed at the Technical Hearings by INAC. The paste is to be saturated with process water when it is deposited in the pile and the destination of the water is at issue. DCMI has assumed that the majority of the pore water will freeze in the pile, and the majority of the brines will be retained in the pile along with it. INAC cannot assess this assumption, because no freezing tests or characterization of the freezing behaviour of the paste have been performed or described. Therefore, characterization of the Pile's predicted behaviour is incomplete. In other parts of these reports a general scoping of the potential implications of error in the assumption has been made. At issue here is the lack of information pertaining to the issue stated explicitly in the ToR.

10.2 DCMI Conclusion

DCMI has maintained that most of the process water will freeze in the pile and that the bulk of the remainder will be collected by the perimeter ditches.

10.3 INAC Conclusion

INAC's position is that notwithstanding the demonstrated deficiencies in the thermal modelling, characterization of the freezing behaviour of the paste is required to predict the composition of seepage from the Pile, and characterization of the oxidation conditions within the Pile is required to assess the seepage from the pile under unfrozen conditions.

10.4 INAC Rationale

Freezing of soils characteristically leads to either absorption of pore fluids into the freezing medium, and frost heave, or expulsion of the excess volume of the fluids as they expand by approximately 9% upon freezing. Soils of silt and clay size typically exhibit heave upon freezing at rates commonly observed in the field, while sands and gravels generally expel pore water. This is because the 9% expansion cannot be accommodated in the existing pore space. Pore-water expulsion is the process that leads to the growth of pingos (Mackay 1998).

In addition to the expulsion of pore fluids, dissolved solutes are also excluded from developing ice crystals, and so the pore fluids are enriched in solute. This enrichment characteristically lowers the freezing point of the pore fluids, so that further freezing takes place at progressively lower temperatures (Mackay 1997). In many settings, the soil is not saturated, and the excess volume can be accommodated in empty pore space. If the ground is saturated before freezing, the pore-water expulsion leads to elevated pore pressures, unpredicted movement of pore fluids, and, perhaps, hydrofracturing, as described by Don Hayley in the Geotechnical break-out session (Mackay 1998).

As stated above, the ToR require DCMI to characterize the susceptibility of North Pile materials to pore-water expulsion during freezing, because of the potential for mobilization of concentrated process water and its unexpected discharge from the Pile.

IR 2.4.35(a) requested data on the frost susceptibility of the processed kimberlite fines to be deposited in the North Pile. The response described the grain-size composition of the coarse, grits and combined coarse and grits material. Therefore the frost susceptibility of the material remains undisclosed, and this IR remains unanswered. DCMI indicated in the response to IR 3.4.18(c) that the full mix processed kimberlite paste is frost susceptible, as 29% of the paste is in the fine fraction (Table 3.4.18-1). However, the freezing behaviour of the paste, whether water is expelled or drawn into the material, has not been determined.

IRs 3.4.18(e) and 3.4.18(f) requested data on the expected concentration of pore water in the north pile due to freezing and the expected freezing-point depression of the water. No data were provided by DCMI in answer to IR 3.4.18(e) and a semi-quantitative answer was provided for IR 3.4.18(f) without regard to field conditions.

When these issues were raised in the Technical Hearing and at the Tuesday evening breakout session, no evidence was produced indicating that DCMI had conducted laboratory tests to characterize the freezing behaviour of this material.

It is not possible to characterize the behaviour of the process water deposited in the North Pile without a demonstration of the behaviour of the paste material under freezing conditions.

10.5. Recommendation

INAC requires freezing tests on the full-mix processed kimberlite paste with equivalent to process pore water, to determine the behaviour of this water upon freezing of the paste. These tests will resolve whether the paste will exclude pore water, leading to cryoconcentration, or whether the water will be accommodated as ice lenses in the material.

11. ABANDONMENT AND RECLAMATION

10.1 Issue

ToR lines 568-570 indicate *the description of plans required for Abandonment and Restoration of the Mine Site.*

The current plans for Abandonment and Restoration include the assumption that the North Pile will be frozen at the end of mine life. Earlier portions of this report have demonstrated that this assumption is untenable until the thermal modelling has been improved. In the event that revised modelling projects extensive unfrozen zones within the Pile at the time of Abandonment, DCMI must make clear its plans for potential hydrofracturing of the pile and instability of the retaining slopes.

This issue is brought to the Board's attention, as it is a consequence of the weak thermal modelling conducted to date. Under the terms of reference, the components of Abandonment and Reclamation practices cannot be comprehensively described until the final state of the pile is understood adequately.

11. CONCLUSION

In this report we have demonstrated that EA of the North Pile is, at present, incomplete. We have demonstrated that there are material limitations to the geothermal modelling presented in DCMI's EA Submission, and that with these errors, it is impossible to determine the extent to which the the Pile will be frozen during mine life and thereafter. With this uncertainty, DCMI cannot assess the potential impact of North Pile seepage on the northwest arm of Snap Lake.

This report on Permafrost and Geothermal Issues has considered the freezing conditions in the North Pile. The report has not described the geochemical implications for Snap Lake, which are indicated in a general fashion elsewhere. The report has not considered the design of the ditches around the perimeter of the North Pile, which are designed to collect such seepage. These are also discussed elsewhere.

The summary recommendations are:

a. Unfrozen water content characteristic curves for the North Pile paste mixes, determined by laboratory test.
b. Frost heave tests on the North Pile paste mixes to determine whether the paste is frost susceptible, or whether pore water is expelled during freezing.
c. Results from revision of the thermal modelling, to incorporate: (i) a field value of the geothermal gradient; (ii) a temporally sensitive assignment of n-factors; (iii) thermal properties which are recalculated to include results from (a).
d. With the new thermal modelling, an assessment should be made of the rates of cryoconcentration in the pore water of the North Pile, and the influence these may have on the quality of water seeping from the Pile.
e. A survey of the footprint of the North Pile should be undertaken to delineate the location of ice wedges in the country rock. The survey should be conducted by Ground Probing Radar.

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ATTACHMENT I

February 14, 2003

APPENDIX E

Hydrological Issues

Northwest Hydraulic Consultants Ltd.

DE BEERS SNAP LAKE DIAMOND PROJECT REVIEW OF ENVIRONMENTAL ASSESSMENT SURFACE WATER QUANTITY ISSUES

Submitted to:

Water Resources Division
Department of Indian Affairs and Northern Development
Yellowknife. N.W.T.

Submitted by:

Northwest Hydraulic Consultants Ltd.
Edmonton, Alberta

Prepared by:

E.K. Yaremko, P.Eng.

February 2003

6169/4340

CONTENTS

FOREWORD

This report summarizes **nhc's** technical review of the proponent's proposed Water Management Plan encompassing surface water aspects associated with the environmental impact assessment documents submitted for the De Beers Diamond Project. This review has been carried out on behalf of the Department of Indian Affairs and Northern Development (DIAND), Yellowknife, N.W.T.

The document "De Beers Snap Lake Environmental Assessment Report" (submitted to the MVEIRB 25 February 2002) provided the majority of material for review. Additional information was obtained during two De Beers sponsored "Water Quality/Water Quantity Technical Discussion Sessions": 4-5 June 2001; and, 10 January 2002. The purpose of these sessions was largely to provide De Beers with an opportunity to increase our understanding of the technical approaches adopted for the Project environmental impact assessments pertaining to water quality and quantity issues. As well, there were the following information sources:

- a site visit was undertaken during the fall of 2001;
- MVEIRB Information Requests (IR's) together with corresponding responses by De Beers: rounds 1 and 2;
- MVEIRB Technical Sessions (Yellowknife): 26, 27 November 2002.

This review addressed the following subjects pertaining to surface water within the project's proposed development area:

1. baseline data
2. water balance modeling
3. water treatment plant (WTP) capacity
4. water management pond (WMP) capacity
5. WTP effluent mixing within Snap Lake
6. North Pile seepage

Detailed comments addressing any concerns about each of these subjects have been presented in the following sections.

nhc presents these comments in its capacity as an expert advisor representing the interests of DIAND as an intervener in the EA review process.

1 BASELINE DATA

1.1 Issue

To enable the proponent to make reasonable and acceptable assessments of project impacts with regard to: WTP and WMP capacities; drainage ditch, sump and settling pond capacities; and mixing capabilities within Snap Lake, is important that the natural quantities of surface water and their corresponding probable range of quantities be adequately defined. Where this has not been done, there may result unsatisfactory management of the water and undesirable impacts to the natural environment. This is fundamental to the objective stated in Section 2.6 of the "Terms of Reference and Work Plan for the Environmental Assessment of the De Beers Canada Mining Inc. Snap Lake Diamond Project".

It should be noted that there are four types of surface water to be considered:

- precipitation and runoff from surface areas within the mine development area;
- water derived from underground seepage into the mine workings – this water is to be pumped to the surface;
- water from the area encompassing the North Pile deposits – the source of this water will be a combination of precipitation runoff and seepage from the processed kimberlite stream;
- water pumped from Snap Lake that is used as a source for potable water and fire-suppression – given the anticipated large supply of mine water, the proponent expresses the view that Snap Lake water will never have to be directly used as part of processing Kimberlite ore, but in fact, should the WTP have to be shut down, it may be necessary to use Snap Lake water for a short period of time.

1.2 De Beers Position

- Baseline data, generation of surface water runoff estimates, flood frequencies and flow durations for local water sheds are addressed in: Section 9.3.1 ("Hydrology; Baseline"); Appendix IX.4 ("Climate and Hydrology Data") of the EA. De Beers have utilized the outcome of their analyses of these baseline data in the water balance modeling, the preliminary design of drainage ditches and ponds, and analysis of impacts.
- Baseline data and estimated inflow into the underground mine workings are addressed in: Section 9.2.1 ("Hydrogeology; Baseline Setting"); Appendix IX.3 ("Predicted Quantity of Water Discharged From Snap Lake Diamond Project") of the EA. These data have been utilized for the prediction of rates of groundwater inflow into the mine. De Beers are of the opinion that flow estimates are on the conservative (high) side.
- Estimates of surface runoff from the North Pile were based on the baseline data set identified in the above first point.
- Given that the volume of water to be taken from Snap Lake water for potable and fire suppression requirements is likely to be relatively small, the corresponding impact on lake levels is likely to be insignificant. Beyond this, the issue of what actual volumes of lake water might be required for these or other uses can be left to the water licensing stage.

1.3 nhc Position

- Together with a limited amount of site data, the proponent has assembled and utilized a satisfactory set of regional baseline precipitation, meteorological, wind, stream characterization and runoff data; we have no concerns regarding the question of adequacy of baseline data.
- It is for others to assess the adequacy of the baseline data utilized in modeling and predicting mine water inflow rates and volumes. We have, however, addressed the sensitivity of these estimates in Section 2, "Water Balance Modeling".
- As with the first point above, the baseline data set utilized to make estimates of surface runoff from the North Pile are considered to be adequate.
- Adequate baseline data have been collected to enable estimates of Snap Lake volume versus lake level. At this stage it appears that potential volumes of lake water to be withdrawn will have no significant impact on lake levels. A detailed assessment of this issue should be left to the water licensing stage.

1.4 nhc Rationale

The EA documents provide a comprehensive description of the baseline data utilized in establishing the surface water hydrology regimes associated with the Snap Lake Project. Short term local data collected by De Beers in the form of measured runoff, lake levels, lake outflow, precipitation, snow depths and climate data, combined with corresponding long term regional data have been effectively used to establish hydrological factors adopted in the preliminary design of drainage and storage structures and assessment of surface water related project impacts. We have compared the results of the proponent's analyses of the hydrological baseline conditions with what was derived for the Diavik site and there is reasonable consistency between the two.

1.5 Recommendations

We have no recommendations concerning this issue.

2 WATER BALANCE MODELING

2.1 Issue

It is necessary to take account of the disposition of all sources of surface water within the area affected by mine activities throughout the projected design life of the mine. This accounting must be undertaken in sufficient detail to enable assessments of water related issues such as: adequacy of preliminary design capacities of water treatment and storage facilities, as well as drainage ditches and outfall structures; loadings of selected water quality parameters within the system (dissolved and suspended solids; nutrients; metals); impact on Snap Lake water levels. This follows the objective outlined in Section 2.6.4 of the "Terms of Reference and Work Plan for the Environmental Assessment of the De Beers Canada Mining Inc. Snap Lake Diamond Project".

The proponent has developed spread sheet-based models that keep account of water inflows and outflows over a 22-year mine life period. The output from the modeling indicates that monthly time steps have been used. The inputs and outputs of two models have been reviewed: North Pile Water Balance; and, Site Water Balance.

The issue is whether these models comprehensively, physically and realistically balance, in a time-wise manner, the inflow, movement of surface water within the mine-affected area and outflow.

2.2 North Pile Water Balance

2.2.1 *De Beers Position*

The model inputs and assumptions are summarized as follows:

- The model was set up to operate in four sub-periods within a proposed 22 year mine life period: Year 1, Year 2, Years 3-9, Years 10-22 – input parameters are consistent within each sub-period.
- Average annual precipitation was assumed in every year, as were the runoff coefficients of 0.7 and 0.9 for undisturbed and disturbed terrain.
- Production of processed kimberlite (PK) slurry was increased from 0.870 x 10^6 m^3 in Year 1 to 1.080 x 10^6 m^3 in Years 2 through 22; it was assumed that 52.2 percent of the PK produced would be sent to the North Pile and that 14 percent of contained water would be released (temporarily frozen and available for runoff).
- Total pile area was increased from 220,000 m^2 in Years 1 and 2, 500,000 m^2 in Years 3-9 and 900,000 m^2 in Years 10-22.
- Annual seepage from the North Pile would average 8,140 m^3 in Years 1 and 2, 16,872 m^3 in Years 3-9 and 32,338 m^3 in Years 10-22.
- It was assumed that all runoff would be intercepted by collector ditches and directed into sumps and temporary sedimentation ponds during the summer months, before being sent to the WTP.

The model predicted outflow to the WTP of 79,862 m^3 in Year 1(maximum monthly of 49,633 m^3), 139,743 m^3 in Year 2 (maximum monthly of 100,980 m^3), 157,767 m^3 in Years 3 –9 (maximum monthly of 109,825 m^3) and 150,963 m^3 in Years 10-22 (maximum monthly of 108,915 m^3). It was assumed that 60 percent of this annual runoff volume would occur during the month of May.

2.2.2 nhc Position

The North Pile model, as it was set up, adequately encompasses all of the components that would contribute to runoff from the North Pile. However, normal practice is to establish sensitivity of a model such as this one to a range of input parameters to test the capacity of all portions of the water management system under extreme conditions. For example, rather than average runoff it would be prudent to assume a 100-year flood runoff year, which for the North Pile could see runoff volumes 2.0 to 3.0 times greater than for the average condition. For an average runoff year, the volume of water predicted to be sent to the WTP in Year 2 would represent only 5.0 percent of the total being treated; by Year 17 this percentage would decline to about 1.7 percent. Should a 100-year runoff year occur, the corresponding percentage of water to be treated at the WTP could increase to perhaps 15.0 percent if this flood were to occur during the first few years of mine operation, or 5.1 percent during the latter years.

We would therefore have expected that model input parameters which have the potential to vary from their initially adopted values would have been adjusted to reflect the possibility of different or extreme values to assess what downstream consequences might be in terms of water management system capacities. There is no evidence to indicate that this has been done. Although apparently ditches and sumps will be designed to have 100-year flood capacity, the model was not utilized to estimate what a North Pile 100-year flood volume might be.

2.2.3 nhc Rationale

Even though model sensitivity to ranges of input parameters was not established, realistically it should become apparent early-on from snow depth monitoring whether there is an impending major runoff issue to be dealt with during the month of May, when the majority (sixty percent) of annual runoff can be expected to occur. It is expected that there will be sufficient response time for De Beers to make provision for management of this water, by ensuring that WTP and WMP capacities are sufficient as the runoff season approaches. Even if 100-year runoff from the North Pile were to average 10,000 m^3/d during May plus 3000 m^3/d from plant site and catchment runoff, this flow could be diverted to the WMP where minimum storage capacity would likely be in the order of 100,000 m^3/d, as a minimum. This will provide considerable ability to manage the water, provided the WTP does not suffer a breakdown at the same time.

2.2.4 Recommendations

Recommend that the water license incorporate a requirement that snow depth monitoring and a flow forecasting plan be included as part of the final (operational) Water Management Plan.

2.3 Site Water Balance

2.3.1 Issues

Under the EA Terms of Reference concerning "impact on water quantity, including changes in timing, volume and deviation of peak and minimum flows resulting from developments", the proponent addressed two "key" questions:

1. "What impacts will the ...Project have in near surface water tables and flows, and water levels in receiving streams, lakes and wetlands?"
2. "What Impacts will the ...Project have on sediments yields and sediment concentrations in receiving streams, lakes and wetlands?"

2.3.1.1 De Beers position on water quantity (Question 1)

Fundamental to the approach of assessing impacts on water quantity was development of a water balance model that incorporated all of the components involving surface water. This is a spread sheet-based model using monthly time steps. Four representative periods were modeled, the results of which have been reviewed: Year 2 (first year of operation); Year 6 (early operation); Year 10 (mid-point operation); Years 17-22 (late operation).

With regard to the predicted impact on Snap Lake levels, the approach was to compare the averaged natural outflows from the lake with outflows predicted by the model.

The model assumptions, inputs and some of the outputs are summarized as follows:

- The components of the model related to water feed to the WTP, WMP and Snap Lake includes inflow from the North Pile, mine water (pumped groundwater), precipitation, along with runoff from the plant site and natural catchments.
- Runoff rates were based on average values
- On a daily basis, mine water inflow was assumed to vary from 7000 m^3/d in Year 2, 11,000 m^3/d in Year 6, 15,700 m^3/d in Year 10 and 22,580 m^3/d in Years 17-22.
- North Pile runoff and mine water outflow are to go directly to the WTP; plant site and catchment runoff are directed to the WMP and ultimately to the WTP.
- Treated water is directed to one or all of three routes: the mill for processing kimberlite; to Snap Lake; and, dust suppression.
- The percentage of mine water treated as a percentage of total water treated varied from: 91 percent (Year 2); 94 percent (Year 6); 95 percent (Year 10); and, 95.6 percent (Years 17-22).
- The percentage of treated water discharged to Snap Lake as a percentage of total water treated varies from: 96 percent (Year 2); 95 percent (Year 6); 95 percent (Year 10); and, 96 percent (Years 17-22).
- Treated sewage would be combined with outflow from the WTP; the volume of treated sewage compared to WTP outflow into Snap Lake would be no more than 0.3 percent and normally 0.1 percent; the rate of treated sewage discharge equaled the rate of diversion from Snap Lake.

On-balance, it is predicted Snap Lake outflows will increase over the course of mining operations, which will produce a corresponding rise in lake levels. The primary reason is ascribed to small differences in the recharge to groundwater versus rates of groundwater pumped out of the mine. Averaged over a year, lake level increases over mean natural levels are expected to be in the range of 3.3 to 5.3 cm. On a monthly basis, the predicted maximum impact of 14 cm would be in April when natural levels become lowest. No mitigation action has been offered as Snap Lake outflow and level increases are considered to be insignificant and short term.

It is acknowledged that Project site surface drainage will be impacted by construction activities, roadways, North Pile and buildings. The Water Management Plan (WMP) will include directing runoff from impacted areas to the WTP. The total drainage area impacted by mining operations is small relative to the area contributing to Snap Lake.

2.3.1.2 nhc position

We agree with the position that Snap Lake outflows and levels will not be significantly impacted and that the impact of mine development elements (roads, North Pile and buildings) on surface runoff rates and volumes will be mitigated by collecting flows in temporary storage ponds for treatment.

2.3.1.3 nhc rationale

The water balance model encompasses all of the necessary elements. Normally, we might recommend varying input parameters to establish sensitivity of the model to these variations, but given the overwhelming proportion of pumped mine water compared to other sources, it makes sense to only deal with mine water volumes. There has been much discussion concerning the accuracy of the mine water quantity predictions. As the impact on Snap Lake levels depends on the difference between the loss of lake water to groundwater versus amount of water pumped from the mine, it is likely that this difference will not vary much no matter what the amounts are.

2.3.1.4 Recommendations

Continuous monitoring (recording) of Snap Lake outflows is recommended.

2.3.2.1 De Beers position on sediment yields (Question 2)

It is De Beers position that:

- Enhanced sediment loading will be generated where natural surface areas have been disturbed by Project construction activities and mine-related structures. They propose to provide the necessary drainage system and incorporate storage facilities that would encourage sediment to deposit. Ultimately, this flow will be directed to the WMP and then pumped to the WTP, which should mitigate any concern about extra sediment being deposited in Snap Lake.

- Runoff from some project elements – airstrip, roads and emulsion plant – will not be collected and sent to the WTP, but the intention is to locate them on locally higher ground, so runoff amounts will be minimal. As well, sumps will be located at low points along roads to encourage sediment to drop out. Where this is not the case and sediment-laden flows are allowed to pass through road grades, these flows will be directed to low lying wetlands – the objective will be to reduce the risk of this flow from entering Snap Lake.

2.3.2.2 nhc position

The overall plan offered by the proponent to deal with runoff from disturbed areas is considered reasonable. However, we have a concern about the ability of ditches and sumps to be in a condition to function adequately at the beginning of the spring runoff period. These elements might be packed full with snow and unable to convey runoff.

2.3.2.3 nhc rationale

The amount of surface area that would be disturbed by the Project will cover a relatively small area, so it should be relatively easy to provide the drainage system outlined. The approach adopted to deal with runoff is the common procedure. However, winter road clearing could leave ditches filled with snow. As well, ditches surrounding the North Pile may be located in areas that are difficult to access if work is required to open them up prior to runoff. Or, it is possible that ditches around the North Pile could become infilled with seepage water.

2.3.2.4 Recommendations

It is recommended that the proponent be requested to reply to the concern about possible operational problems associated with snow/ice-filled ditches and sedimentation sumps.

3 WATER TREATMENT PLANT AND WATER MANAGEMENT POND

3.1 Issues

The WTP plant is to be installed in the year prior to mine start-up, with treatment capacity increasing in the following year. Treatment will consist of removing suspended solids, followed by discharge into Snap Lake. The WMP is a critical component in the water management plan and operational strategies involving the WTP, as it will be used for temporary storage in the event that an upset occurs at the WTP.

It appears that only cursory consideration has been given to evaluating the risk of an interruption to the WTP and the need to dump untreated water into Snap Lake in the event that available storage capacity is exceeded. This is the primary issue.

A further issue is the question of what would be the source of processing water in the event that the WTP has to be shut down.

3.2 De Beers Position

The proponent's position on this matter, beyond what is outlined in the EA, was provided in a response to an IR, as follows:

- An unscheduled shut-down of the WTP was defined as having a maximum duration of approximately six hours.
- An inventory of spare parts would be maintained onsite to minimize the WTP down time.
- A six-hour shut-down would result in about 6,300 m^3 of water being directed to the WMP, which represents approximately 0.25 m of pond level increase, assuming that the pond is initially at Elev. 450.5 m (current maximum operating level of pond).
- The pond would behave as a settling pond for the WTP. Water would (then) be decanted from the pond at the same rate as the inflow from the WTP, subject to achieving the discharge requirements for suspended solids.

The proponent acknowledges that a water balance for potential upset conditions in the WMP was not undertaken and that the water balance results assuming normal mine operating conditions indicates that that available storage would be adequate to accommodate upset conditions.

It is also pointed out that additional storage capacity would be available in water collection ponds adjacent to the North Pile. As well, there would be temporary storage available within the mine sumps (in the order of 30,000 m^3).

3.3 nhc Position

De Beers have not satisfactorily addressed risk scenarios in a formal way with regard to operation of the WMP in the event of failure of the WTP and the risk of then having to pump untreated water into Snap Lake. There does not appear to be agreement within De Beers as to what might be a reasonable down time for the WTP in the event of a mechanical or processing failure.

3.4 nhc Rationale

We are concerned that situations could develop in which storage capacity becomes compromised. At the present time, the available storage in the WMP is 115 x 10^3 m^3, assuming the pond is empty and water level is at Elev. 450.2 m, which is 1.0 m below the adopted operating level (1.0 m below HDPE liner). However, it was suggested by Be Beers at the November 2002 Technical Sessions that 20 percent of pond capacity would likely be unavailable, so available storage is more likely about 90 x 10^3 m^3. Raising the existing WMP dams 1.0 m would increase storage capacity to 200,000 m^3, assuming again that the pond remains at least 20 percent full at all times.

The critical question is what is a realistic down time for the WTP. The IR response suggested 6.0 hours, while one or more days was the response to this question during the Technical Sessions. Assuming a shutdown of two days during the high runoff period of May, combined with an extreme runoff condition where volumes are double the normal amount and mine water inflow is 24,000 m^3/d, the total inflow to the WMP could be in the order of 65,000 m^3. In this case pond capacity would be within one day of being exceeded with the existing pond size.

3.5 Recommendations

It is recommended that the proponent provide a meaningful argument as to what might be a reasonable down time to expect for the WTP, based on operation of similar remote WTP installations in the climatic conditions that exist at the Snap Lake site.

Otherwise, consideration must be given to raising the WMP dams 1.0 m from Year 1 in order to essentially remove any risk of pond storage capacity being exceeded during some future WTP upset condition.

4. WMP EFFLUENT MIXING IN SNAP LAKE

4.1 Issues

Because the discharge water from the WTP will be somewhat heavier than the lake water and once outside the initial mixing zone (established as being within a 60 m radius around the outfall diffuser), it will have a propensity to move downwards towards the lake bed to occupy deeper zones of the lake during the winter months. During the summer months, wind generated waves and lake currents would, to some degree, disturb and move the bottom water. Although the proponent has indicated that wind data were applied in their assessment of mixing, they acknowledge that no baseline current measurement data were available with which to calibrate their analysis. There is concern that there will be an accumulation of TDS water in certain areas where wind and current effects are minimal.

4.2 De Beers Position

Utilizing a combination of the CORMIX Model and RMA model, a lake area has been identified as representing the extent of the effluent plume for an open water condition. The modeling apparently included the north arm of the lake; as well, it accounts for lake circulation effects. The area represents about one percent of the total lake area. It is argued that TDS concentrations at the plume boundary are no higher than base levels. As well, the concentration levels of selected constituent parameters (metals, chemicals) at the plume boundary are compared with guideline levels as a measure of impact. It is the proponent's position that the approach used produces conservative estimates of impact on water quality.

4.3 nhc Position

The analysis of open water behaviour of the effluent plume, as proposed by the proponent, lacks adequate site data to back up the results of this analysis. As well, because the RMA model is two-dimensional, it does not properly represent the vertical mixing process – complete vertical mixing may not be occurring, given the possible differences in water densities.

4.4 nhc Rationale

The outline of Snap Lake has a form and size which in our opinion makes it difficult to adequately quantify current patterns and strengths without the aid of site lake current measurements with which to calibrate the mixing model and plume growth. As well, prediction of the mixing process will necessarily require a three dimensional model.

4.5 Recommendations

So that a more confident prediction can be made of the plume boundary, it is recommended that the proponent undertake a program of lake current measurements for both open water and ice cover conditions.

Given the concern about vertical mixing of the effluent plume beyond the initial (CORMIX) boundary, it is advisable that a 3-dimensional mixing model be used.

If these measurements and three dimensional modeling cannot be undertaken at this time, then this must ultimately be done in combination with a comprehensive monitoring program as part of the mine operation Water Management Plan.

5 NORTH PILE SEEPAGE

5.1 Issue

It is proposed to construct perimeter ditches around the toe of the North Pile to intercept surface runoff and seepage. This water would be conveyed by these ditches through a series of sumps and sedimentation ponds, and ultimately to the WTP. It is our concern that the ditches might not intercept all of the seepage and surface runoff – in particular, seepage beneath the ditches along the northerly side of the North Pile, with this water eventually entering the north arm of Snap Lake. It appears that the fate of this seepage water within the north area of the lake has not been assessed in an acceptable manner. Because it is proposed to locate the potable water intake near to the south shoreline of the north arm, it may be in an area where seepage water will migrate too.

5.2 De Beers Position

The water balance model developed for the North Pile assumed that seepage from the North Cell would amount to about 14,000 m^3 annually, which equates to eight percent of the total estimated water volume coming from the northerly side of the North Pile during Years10-22 of mine operation. Based on comments by De Beers in a 'break-out' session during the November 2002 MVEIRB Technical Sessions, it is expected that only ten percent, or less, of this volume might pass into the north arm of Snap Lake.

5.3 nhc Position

Because it is possible that a greater volume of water within the North Pile would be available to seep out, than what has been assumed by De Beers, and because the ability of the perimeter ditches to capture seepage may be optimistic, we are of the opinion that further assessment on this issue is required.

5.4 nhc Rationale

The shallow sill separating the north arm of Snap Lake from the remainder of the lake likely results in both water bodies having somewhat independent current regimes. Furthermore, a similar kind of sill that exists half-way along the length of the north arm may result in two different current regimes (cells) within the north arm. The portion of the two-cell north arm that might be the most greatly impacted by seepage from the North Pile has a volume of 4.5×10^6 m^3, compared to about 100×10^6 m^3 for the entire lake. Thus, the impact of seepage on water quality in the north arm could be magnified because of the limited area in which mixing will occur.

5.5 Recommendations

- Re-evaluate potential for seepage from the North Pile in light of arguments from DIAND experts that De Beers may be over-optimistic about the ability of P.K. water to freeze back within the North Pile. Further to this, re-evaluate potential for seepage water to pass beneath the westerly perimeter ditches and move into the north arm of Snap Lake, or for seepage water and snow to combine and infill these same ditches so that seepage is forced out of a ditch, into the north arm.

- Pursue mitigation options that would largely prevent seepage water from entering the north arm; during the Technical Sessions break-out meeting, the idea of constructing a boulder pile along the upstream side of the ditch was suggested as a possible way of raising the permafrost table to block the seepage path.
- If a plausible approach cannot be established to prevent seepage water from reaching the lakes's north arm, then there must be an analysis of how this seepage water might mix with the lake water, and what might be the corresponding impact on water quality. It should be established whether the potable water intake is in a position to receive poor quality water.

ATTACHMENT I **February 14, 2003**

APPENDIX F

Water Quality and Impact Assessment Issues

MacDonald Environmental Services Ltd

7089

An Evaluation of the Environmental Assessment and Associated Documentation Submitted by DeBeers Mining Canada Incorporated for the Proposed Snap Lake Diamond Project

Report Submitted to:

Indiana and Northern Affairs Canada
Bellanca Building, POB 1500
Yellowknife, Northwest Territories
X1A 1N5

Report Submitted - February, 2003 - by:

MacDonald Environmental Sciences Ltd.
Suite 24 - 4800 Island Highway North
Nanaimo, British Columbia
V9T 1W6

1.0 Introduction

MacDonald Environmental Sceinces Ltd. (MESL) has been retained to review and evaluate certain elements of the ***Environmental Assessment (EA) Report*** and associated documentation that was submitted to the Mackenzie Valley Environmental Impact Review Board (MVEIRB) by DeBeers Canada Mining Incorporated (DCMI) in support of the proposed Snap Lake diamond project. This review of the EA report focussed on several key topic areas, including:

- Baseline Environmental Information;
- Development of Site-Specific Water Quality Benchmarks;
- Selection of Impact Assessment Criteria;
- Design and Capacity of the Water Treatment Plant;
- Accuracy of the Predicted Concentrations of COPCs in Snap Lake;
- Accuracy of the Phosphorus Model;
- Secondary Effects of Lake Eutrophication;
- Potential Effects of Total Dissolved Solids on Snap Lake; and,
- Cumulative Effects Assessment.

Specific comments on each of these issues are provided the following sections of this report. These comments are offered to INAC to support the preparation of its technical report to the MVEIRB on behalf of the responsible minister (i.e., the Minister of INAC).

2.0 Specific Comments

As indicated above, MESL has identified a number of issues related to the proposed Snap Lake diamond project that were not been adequately addressed in the EA report, in the responses to information requests, or in the MVEIRB Technical Sessions (i.e., the information provided was insufficient to resolve the issue). Each of these issues are discussed in the following sections of this report.

2.1 Baseline Environmental Information

Baseline environmental information is required to support two main environmental assessment initiatives, including prediction of the impacts of mining activities and evaluation of those predictions during mining activities (i.e., assessing the actual impacts of the project. Accordingly, sufficient data are needed to characterize both the spatial and temporal variability of the various metrics that are used to characterize baseline environmental conditions in the vicinity of the mine site.

DCMI has generated a substantial quantity of baseline data in the vicinity of the proposed Snap Lake mine site, including information on water quality, sediment quality, and biological conditions. While the available water quality and sediment quality data presented in the EA report and associated documentation are generally sufficient to support the EA, the data will not be sufficient for evaluating the impact hypotheses that are presented in the EA. That is, the data may not be sufficient to support statistical analyses to determine in changes in the physical, chemical, and/or biological characteristics of Snap Lake or to evaluate the severity of any changes that have occurred.

Importantly, biological data that have been collected to date may not be sufficient to support the EA and unlikely to support subsequent evaluations of the impact hypotheses. Fisheries and Oceans Canada and other participants in the Technical Sessions have pledged to identify information shortfalls that need to be addressed in the near-term. In the long-term, additional pre-development water quality, sediment quality, and biological data will need to be collected to fully characterize temporal and spatial variability in baseline conditions in Snap Lake and associated water bodies. This additional information must be collected prior to construction and will be used together with the results of an aquatic effects monitoring program (AEMP) to evaluate the impact hypotheses that are presented in the EA report (i.e., to assess the nature, magnitude, and extent of environmental effects associated with the development).

2.2 Development of Site-Specific Water Quality Benchmarks

DCMI has developed site-specific benchmarks for assessing the potential effects of mining activities on water quality conditions in the vicinity of Snap Lake. However, the methods that were used to derive the benchmarks were not consistent with the procedures that have been established by the Canadian Council of Ministers of the Environment. Rather, the procedures that were established by the U.S. Environmental Protection Agency (USEPA) were used to develop the site-specific benchmarks. As the Snap Lake project is located in Canada, it seems more reasonable to apply the procedures that have been developed for use in Canada for deriving site-specific water quality benchmarks.

During the Technical Sessions, DCMI indicated that they have no intention of developing alternate water quality benchmarks for the EA. Therefore, INAC should derive benchmarks using the procedures that have been developed by the CCME and apply them to evaluate the effects associated with discharges of treated wastewater into Snap Lake. It is recommended that a single benchmark be established for each chemical of potential concern (COPC) that represents the chronic toxicity threshold (CTT) for the most sensitive receptor group in the lake (i.e., typically zooplankton).

To facilitate this process, DCMI should be asked to provide the results of water quality modelling activities for Snap Lake under worst case conditions (i.e., when the concentrations of COPCs are expected to be highest; i.e., later in mine life under ice cover). More specifically, DCMI should be asked to provide maps of Snap Lake which show concentration isopleths radiating from the diffuser for key COPCs, including total suspended solids (TSS), turbidity, total ammonia, nitrate, phosphorus (i.e., total phosphorus, dissolved phosphorus, and ortho-phosphate - TP, DP, and OP), chloride, total dissolved solids (TDS), copper, cadmium, and chromium (III and IV). These modelling results should reflect the need to incorporate more conservative assumptions, as specified by participants at the recent Technical Sessions. DCMI will likely require further guidance to ensure that the maps that are produced meet the needs of participants in the EA process.

2.3 Selection of Impact Assessment Criteria

DCMI has developed criteria for assessing the potential impacts of mining activities (i.e., as negligible, minor, moderate, or major) based on areal extent of exceedances of various effects thresholds (e.g., HC20 values). However, the impact assessment criteria that were selected by DCMI tend to minimize the potential for rating predicted effects as high because COPC concentrations in the whole lake must exceed the levels that would adversely affect 20% of the aquatic species in Snap Lake before the effects would be considered to be high. Negligible, low, or moderate impacts were predicted if the severity or areal extent of the effects was lower.

The approach that was selected by DCMI is flawed because ignores that fact that zooplankton tend to be the most sensitive group of aquatic organisms and that impacts on these sensitive species could destabilize the aquatic community. In my opinion, this possibility is greater in the north because the structure of aquatic communities tends to be simpler than is the case in aquatic ecosystems located further south (i.e., because the level of functional redundancy is likely lower in the north, the loss of a few species could create voids in the ecosystem that might not be easily filled by other species). Those fish species that rely on zooplankton for food at key times of their life history would necessarily be adversely affected by such changes in the zooplankton community. Therefore, more conservative impact assessment criteria need to be applied in the EA of the proposed project.

Because zooplankton tend to represent the most sensitive taxa to the COPCs that will be discharged into Snap Lake, it is recommended that alternate impact assessment criteria be established that consider the potential for effects on these organisms. More specifically, it is recommended that the following, more conservative criteria by applied in the EA:

- Exceedance of the CTT in <1% of Snap Lake - Negligible Impact;
- Exceedance of the CTT in 1 to 10% of Snap Lake - Low Impact;
- Exceedance of the CTT in 10 to 20 of Snap Lake - Moderate Impact; and,
- Exceedance of the CTT in >20% of Snap Lake - High Impact;

Application of more conservative criteria for assessing the impacts associated with releases of individual COPCs is likely to provide INAC and other participants in the EA process with more confidence that the effects of the project are not being underestimated in the EA.

2.4 Design and Capacity of the Water Treatment Plant

INAC has expressed concerns regarding the design, capacity, and operation of the water treatment plant for the proposed Snap Lake diamond project. More specifically, INAC is concerned that the water treatment plant is designed to facilitate the removal of suspended solids only. However, further evaluation of the information provided by DCMI suggests that certain metals, phosphorus, and major ions may occur at concentrations sufficient to adversely affect aquatic organisms in all or a portion of Snap Lake. That is, the levels of COPCs in mine water could be higher than predicted. As a consequence, further water treatment may be needed to ensure that releases of COPCs does not adversely affect the aquatic communities of Snap Lake. The results of further analyses by DCMI and INAC will provide the information needed to determine if the proposed level of wastewater treatment is likely to be sufficient.

In addition, INAC has expressed concerns that the water treatment plant may not have sufficient capacity if inflows of groundwater into the mine are substantially higher than anticipated. To resolve this issue, INAC's expert on hydrogeology should review the results of the Technical Sessions on this topic and determine if DCMI's estimates of groundwater inflows are sufficiently conservative. It should be noted, however, that the water treatment plant is designed in modules and, hence, is amenable to expansion if required. Furthermore, DCMI has identified various contingencies (e.g., use of the water treatment pond, flooding the mine, etc.) which, if included in a water licence, would largely mitigate concerns regarding the capacity of this facility.

2.5 Concentrations of COPCs in Snap Lake

The results of the INAC evaluation of the information contained in the EA and supplemental reports suggest that the levels of several water quality variables (e.g., TDS, TP, DP, OP) could be higher than predicted in connate groundwater. In addition, the lack of mixing under ice-covered conditions and the negative buoyancy of the effluent could result in higher than anticipated levels of COPCs in water at the bottom of Snap Lake during the winter. As deep lake water is likely to represent an important source of inflow water to the mine, the concentrations of COPCs in mine water could be higher than anticipated by DCMI. As a result, it is possible that the concentrations of COPCs in effluent from the water treatment plant could be higher than those predicted in the EA, particularly in deeper portions of the lake. Consequently, it is possible that the effects on sensitive environmental receptors that were predicted in the EA report are underestimated.

During the Technical Sessions, a work group met on Tuesday evening to discuss the results of the North Lakes study and the potential implications of these results for water quality modelling. Although that work group did provide some further insights into the applicability of the predictions of mine water quality, INAC's technical expert on hydrogeology was unable to attend the meeting. Therefore, it is essential that INAC's expert hydrogeologist review the findings of the work group and provide further comments on the validity of the current predictions of mine water quality, particularly for TDS, chloride, other major ions, and phosphorus. This input will be essential for conducting sensitivity analyses to assess the potential effects of effluent discharges to Snap Lake.

2.6 Accuracy of the Phosphorus Model

Based on evaluations ofthe data contained in the North Lakes study, it is possible that the concentrations of phosphorus in mine water could be underestimated in the EA. In addition, the evaluations of the effects of phosphorus in the EA did not fully consider the potential availability of the dissolved phosphorus that will be released from the mine. Furthermore, the baseline concentrations of phosphorus in Snap Lake may be overestimated due to limitations on the availability of data on the concentrations of phosphorus during the open-water growing season for algae. Together, this information suggests that increases in the concentrations of potentially bioavailable forms of phosphorus in Snap Lake could be higher than anticipated.

During the Technical Sessions, the possible limitations of the assessment of the effects of phosphorus releases on the trophic status of Snap Lake were identified. In an evening meeting of a task group on this topic, it was recommended that DCMI conduct further analyses to evaluate the potential effects on phosphorus releases on Snap Lake. More specifically, it was recommended that the results of phosphorus modelling be re-evaluated using the following additional assumptions:

- The concentrations of orthophosphate (OP) in mine water could be higher than anticipated in the EA. Therefore, the levels of OP in mine water plus one standard deviation should be used to evaluate the potential effects of phosphorus additions on the trophic status of Snap Lake;
- All of the dissolved phosphorus (DP) in mine water is available to aquatic plants in the EA. Therefore, the levels of DP in mine water should be used to evaluate the potential effects of phosphorus additions on the trophic status of Snap Lake; and,
- The concentrations of DP in mine water could be higher than anticipated in the EA. Therefore, the levels of DP in mine water plus one standard deviation should be used to evaluate the potential effects of phosphorus additions on the trophic status of Snap Lake.

Because the results of phosphorus modelling could be sensitive to baseline concentrations of phosphorus in Snap Lake, it was also recommended that both average concentrations and average concentrations minus one standard deviation of DP be used to establish baseline concentrations for the purpose of modelling.

2.7 Secondary Effects of Lake Eutrophication

DCMI evaluated the effects of nutrient releases from the mine site on the trophic status of Snap Lake. In addition, the secondary effects of eutrophication were evaluated by considering the effects of enhanced algal production and subsequent settling of algae on the lake bottom on dissolved oxygen (DO) concentrations under ice. The results of this assessment indicated that DO levels under ice could decrease by 1 to 3 mg/L and approach levels of concern for lake trout. Because the phosphorus modelling that was presented in the EA report may underestimate effects in Snap Lake, it is important for DCMI to re-evaluate the secondary effects of lake eutrophication after more conservative assumptions have been applied in the phosphorus modelling.

2.8 Potential Effects of TDS on Snap Lake

Although the effects of chloride releases were assessed in the EA report, the potential effects of TDS were not fully evaluated. More specifically, the potential effects of TDS releases on the structure of aquatic communities due to changes in the osmolarity of lake water were not assessed. Currently, Snap Lake has low levels of TDS. As such, aquatic communities are likely to be dominated by those species that are tolerant of osmotic stress (i.e., dealing with substantial inflows of low ionic strength water into their tissues). Increases in the ionic strength of water in Snap Lake could favour a transition toward species that thrive at higher levels of dissolved ions and, as a result, alter the structure of one or more aquatic communities (i.e., algae, zooplankton, etc.). DCMI should be encouraged to undertake the analyses needed to more fully assess the potential effects of TDS releases on Snap Lake.

2.9 Cumulative Effects Assessment

Although DCMI has included a section in the EA report on cumulative effects assessment, it does not provide a basis for fully evaluating the effects of the proposed Snap Lake diamond project nor the interactive effects between the project and other anthropogenic activities that could influence aquatic resources in the Lockhart River Basin. First, the results of the Technical Sessions reinforce the INAC evaluation that the EA currently underestimates the effects of the various mining activities and associated discharges of COPCs on aquatic organisms (i.e., the effects of releases of phosphorus, TDS, and possibly metals have likely been underestimated). Second, the interactive effects of multiple COPCs have not been adequately addressed in the EA report (although the implementation of whole effluent toxicity tests mitigates this concern to a certain extent). Third, the interactive effects of the Snap Lake project with other land and water use activities in the Lockhart River Basin (e.g., exploration activities, sport and subsistence fishing, etc.) have not been fully evaluated. Finally, the interactive effects of the project with other human activities (e.g., long-range transport of atmospheric pollutants, global climate change, etc.) have likewise not been assessed. While the terms of reference of the EA do not explicitly require DCMI to conduct a broader assessment of cumulative effects, it is reasonable to expect the EA to assess the interactive effects of project activities and interactions between project activities and activities that occur elsewhere in the Lockhart River Basin.

3.0 Preliminary Screening References

4.0 Outstanding Information Requests

5.0 Summary of Recommendations

Please note that I did not take part in any of the technical discussions regarding the North Pile or various other geotechnical issues. Therefore, other INAC experts will need to be consulted to determine if the issues that were identified in the Technical Sessions have been adequately resolved. Please do not hesitate to call if you would like to discuss any aspect of this review in more detail.

Sincerely,

Don MacDonald,
R.P.Bio, C.F.P.

ATTACHMENT II **February 14, 2003**

INDIAN AND NORTHERN AFFAIRS CANADA LAND ADMINISTRATION DIVISION'S TECHNICAL REPORT OF THE ENVIRONMENTAL ASSESSMENT OF THE PROPOSED SNAP LAKE DIAMOND PROJECT

1. Organization's mandate

The mandate of the Land Administration Division is the management of land in the Northwest Territories under the control, management and administration of the Minister of INAC by virtue of the *Territorial Lands Act* and in particular through the Territorial Land Regulations and the *Federal Real Property and Federal Immovables Act* and subsequent Regulations as they apply to Territorial Lands.

In the case of the De Beers Canada Mining Inc. (DCMI) Snap Lake Diamond Project, it will be wholly located on Crown Lands, for which land tenure pursuant to the above-noted legislation would be required. DCMI has taken steps to secure land tenure, with the submission of Crown Land Applications to the Land Administration Division, which were received on November 26th, 2002. The land applications include all infrastructure of the mine site, including access roads and have now been distributed for comment according to our standard procedures. Pending completion of the Environmental Assessment, our review of the land applications will be placed on hold.

2. Our Role

For the purposes of this Environmental Assessment, Land Administration's role is that of a Regulatory Authority, for the purposes of issuing land tenure documentation and as an expert advisor on general land management considerations, such as reclamation/restoration requirements. We are also able to provide some expertise in assessing and mitigating potential impacts from the project to the land itself.

3. Terms of Reference Reviewed

In the course of our assessment and review of the Snap Lake Diamond Project, we have utilized the following specific sections of the Terms of Reference. This list represents those topics Land Administration considers to fall within our mandate and have a bearing on Crown Lands:

Section 2.2.1 Public Consultation, Lines 23 to 43
Section 2.3 Scope of Development, Lines 58 to 151
Section 2.4, Related Considerations, Lines 153 to 157, 161 to 163
Section 2.4.3, Closure and Reclamation, Lines 164 and 170
Section 2.5.1, Alternatives to Carrying out the Development, Lines 187 to 207 as it relates to Lines 190, 191, 194, and 197
Section 2.5.2, Description of the Existing Environment, Lines 213 to 219 as it relates to Lines 231 & 232
Section 2.5.3, Spatial and Temporal Boundaries, Lines 239 to 249
Section 2.6.2, Terrain, Lines 293 to 295, as it relates to Lines 311-312, 319 to 320 and 327 to

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Section 2.6.2, Terrain, Lines 322 to 325
Section 2.6.6, Wildlife and Wildlife Habitat, Line 414 to 417 as it relates to line 427
Section 2.7.2, Land and Resource Use, Lines 443 to 449 as it relates to Lines 452 to 455
Section 2.7.5, Government, Lines 500 to 503
Section 2.9, Cumulative Impact, Lines 541 & 542
Section 2.10, Abandonment and Restoration, Lines 560 to 572
Section 2.13, Regulatory Regime, Lines 582 to 584

4. Summary

INAC's review has been based upon the information provided in the Project Description, Environmental Assessment Report prepared by DCMI or presented in Information Requests, meetings with DCMI and the Technical Sessions held during November and December of 2002. Overall, from a land administration perspective, impacts from the described project are felt to range from minor to negligible and can be addressed through the mitigation actions outlined by DCMI or implementation of the following general comments and recommendations on the overall project and the noted specific comment respecting Abandonment and Reclamation.

Where there are any land management issues or land tenure requirements with the project, they can be addressed through the issuance of land documentation and through the regulatory phase provided for in the issuance of other authorizations (i.e. Land use permits, and water licenses). For example, specific leases would be issued for specific components of the project, such as an airstrip lease, a mine site lease, an explosives storage lease, a waste disposal lease and a lease for the development on the north Shore of Snap Lake. These leases would include clauses specific to the particular activity.

- In general, INAC found the policies and guiding principles of DCMI for land use to be consistent with accepted Crown land management practices and requirements for land use. INAC would also acknowledge the efforts DCMI has made in lessening the area of impacted land by developing a compact mine development and smaller footprint with a total underground operation.

- The proposed development is within an area that is remote and use by the public for recreation and traditional uses appears to be minimal. There are several tourism operations at the limit of the Regional Study Area for the project, however, they do not have Crown land interests that are directly impacted by the proposed development.

- Usage of the Tibbitt to Contwoyto Winter Road falls within projected traffic volumes set out in the recent document package supplementing the renewal request for the Tibbitt to Contwoyto Lake Winter Road License of Occupation administered by INAC. The access road to the proposed DCMI mine site follows the routing used to date for advanced exploration activities for which there are no Crown land conflicts. INAC recommends that the access road to the mine site be monitored and limited to usage and volumes outlined in DCMI project description and the EA Report.

- INAC recommends approval of the project be limited to the use of the project lands for only those activities directly associated with development, mining and reclamation of the Snap Lake kimberlite dyke as described in the project description and the EA Report. This will ensure unforeseen or new impacts resulting from the construction of additional facilities, mine extensions or the use of this land for purposes other than the development, mining and reclamation of the Snap Lake kimberlite dyke (i.e. Custom milling, exploration base, etc.) are minimized.

- There is a requirement to establish a clear trigger for when an additional review/approval is required, resulting from proposed changes to the project that were not considered or identified in what would be approved in this EA process that would normally not trigger a requirement for a regulatory approval. Additionally, any changes as a result of the new development should be assessed prior to the actual development occurring; (i.e. custom or test milling for activities originating outside the Snap Lake Project, etc.).

- Development and operation of the project should be carried out in a manner, which lessens or removes the potential for safety or environmental failures or accidents during short or long term temporary closures. INAC recommends all activities whose successful and safe operation is dependent on some type of mitigation action, be carried out in a manner to reduce the dependence or requirement for ongoing maintenance, (i.e. the development and operation of the North Pile needs to maintain and ensure its stability). Completing abandonment and reclamation activities as soon as possible and monitoring site development for potential safety and environmental situations would also accomplish this.

- INAC recommends the development and use of standard monitoring programs to validate, support and improve upon projected and operational project expectations and assumptions.

5. Outstanding Issue

Topic:

Closure and Reclamation Activities

Terms of Reference:

Section 2.4.3, Closure and Reclamation, Lines 164 and 170

DCMI shall explain its closure and reclamation approach and to what standards it <u>will</u> reclaim (i.e. stable land forms, revegetation, return to previous ecological productivity?) Based on proposed closure and reclamation intentions DCMI shall report the present day Canadian dollar value of reclamation costs associated with the closure and reclamation, including alternative approaches considered, of the proposed development as reported in section 2.3 Scope of Development.

Section 2.10, Abandonment and Restoration, Lines 560 to 572

DCMI should provide a description of regulations (regulatory framework), industry standards and government agreements that are needed with respect to the closure phase of the proposed development including plans for mitigating the social and economic impacts of mine closure. Where regulatory requirements, industry standards or government agreements exist, their minimum standards, criteria, etc. should be reported.

DCMI shall provide a clear (visual and textual) description of the proposed development site at closure, and after restoration. Abandonment & Restoration (A&R), components and activities should be listed. Rationale and alternatives that have been discarded should be listed, e.g., the removal of all material from site versus partial or total burial, including costs and details concerning the methods and location of material disposal, both on and off-site, including the structural foundations in the bottom of the mine water clarification pond.

Developer's Response:

Sections 3.10, 2.11, 5.3.2.2.1, 5.3.2.2.2, 5.3.2.2.3, 5.3.2.3.4, 10.2.2.2.2, 10.3.2.2.2, 10.4.2.2.2, Appendix III.1, Appendix III.11 and IR responses 1.19 and 2.4.4

Issue

Assess the proposed closure and reclamation activities, including objectives in relation to Crown Land Management principles and policies.

Developer's Conclusion:

Decommissioning and reclamation activities will form an integral part of the mine operating plan, and will be completed in a progressive manner during the life of the project. The mining, mine waste management, and site water management plans have been developed to facilitate progressive reclamation during operations. The objectives of the D/R plan are as follows:

- To protect public health and safety
- To establish conditions that will allow the land to return to a stable state that will reflect the surrounding environment; and,
- To minimize the need for long-term monitoring and maintenance by establishing physical and chemical stability of the disturbed areas.

6. Outstanding Information Request

INAC's IR request, numbered 2.4.4 requested DCMI provide further detailed information, including the research and rationale for the components comprising of the Abandonment and Restoration (A&R) activities. It also asked to see more detail in all A&R areas, especially disposal scenarios/options considered, associated costs, implications and rationale for their use or rejection. DCMI was referred to Lines 567 to 572 of the Terms of Reference that articulated the substance of INAC's request. Disposal methods other than underground and within the landfill site were also asked to be considered in the analysis. Gartner Lee Limited's (GLL) IR request numbered 1.18 also asked for a breakdown of the A&R cost estimate ($25 million) including assumptions and basis and INAC asked that the response be expanded to include the linkage of the cost to the life cycle of the project, the alternatives and a clear indication of the intended disposal method(s).

DCMI's IR response numbered 2.4.4, to our request for further information states "The linkage of the costs to the life cycle of the project, alternatives to disposal, and final decisions on intended disposal methods are not available at this time. Once detailed engineering is complete, further information and plans will become available." At the time of this writing, the information has not been received by INAC.

7. Conclusion and Rationale

The information presented to date in this project review has not allowed INAC to adequately assess the implications from the project vis a vis A&R work to obtain a level of confidence in the description of the area upon closure and whether there is a potential for long term environmental, safety or atheistic issues. Without a clear and concise understanding of the Closure and Reclamation activities, INAC is unable to ascertain whether DCMI's goals and rationale are justified and will satisfy our A&R requirements.

As noted above, INAC has requested the information needed to complete our analysis through the IR process and during the Technical Sessions held in November and December of last year. To date, the level of detail required has not been forthcoming from DCMI, other than to suggest it can be dealt within the regulatory phase of the project.

In support of our position, INAC would reference DCMI's Environmental Assessment Report, which states that closure activities are expected to cost a total of twenty-five million, while in their response to an IR request from GLL costs for closure activities is stated to now be estimated at thirty-five million dollars, which is based upon more detailed reclamation costing. Subsequent to this IR response, our IR for additional information on this aspect of the project was responded to as follows:

"A breakdown of the costs related to the Decommissioning and Reclamation plan was provided in Table 1.19.1 in the MVEIRB Information Request [GLL response]. The linkage of the costs to the life cycle of the project, alternatives to disposal, and final decisions on intended disposal methods are not available at this time. Once detailed engineering is complete, further information and plans will become available."

A&R costs should also reflect the various intervals of the life cycle of the project and the individual components of the work to be undertaken. This would facilitate the full and complete review of the proposed A&R activities including progressive reclamation work, the alternatives, and how they were incorporated into the decision making process used to develop the A&R plan. It is not clear from information presented in the EA Report, how the disposal method(s) will be utilized to complete the A&R work. For example, Section 2.11 states the preferred method for disposal of improvements would be decided during final closure activities, while other sections of the EA Report, including, Appendix III.11 (A&R plan), refers to disposal underground and/or within the site landfill or possible removal from site. Salvage value is also stated to be a consideration in the determination of final closure options, however the process to determine this value is not provided.

Within Ap pendix I II.11 o f D CMI's E nvironmental As sessment R eport, t here is no indication how materials will be handled based upon common reuse and recycling principles. In fact, within DCMI IR response numbered 1.19, it states, "For the purposes of the estimate it was assumed that equipment and material will have no residual or salvage value at the completion of the project life." Without further information on how residual value or salvage value is determined, alternate closure/disposal options may be more appropriate.

INAC considers this issue to be a fundamental aspect of the environmental assessment process and not a regulatory issue, as it is not a function of the approval of an A&R plan which is guided by agreed upon goals, but a principle or common objective and understanding from which to base the development of a future Abandonment and Reclamation plan. Fine-tuning of elements of the A& R w ork c an and s hould be addressed thru the regulatory phase and be ongoing throughout the life of the project. Without DCMI and regulators having a clear understanding of the objective in this area, Land Administration, as the Land Mangers, must take a conservative approach to the A&R review.

INAC would further draw attention to the disposal option of materials underground, which would imply there is underground space, which could also be considered for the disposal of additional processed kimberlite. Information pertaining as to why this option was not considered is requested. Disposal of processed kimberlite underground versus above ground would be desirable from a land administration perspective.

In section 1.2 of Appendix III.11.1 a stated objective of DCMI's decommissioning and reclamation activity is "to establish conditions that will allow the land to return to a stable state that will reflect the surrounding environment." It is not clear whether this statement implies that upon final closure, the land will have been reclaimed to a stable state, or if it may be some time before a stable state is naturally achieved. A minimum reclamation goal would be to return the land to a "stable" state that allows for its eventual reversion to a condition that is functionally similar to the way it was prior to development. Anything less would require DCMI to justify and rationalize it as a reclamation option. This has not been provided and without this information there is uncertainty in what the final A&R goal is and whether it can be achieved.

8. Recommendation

In the absence of specific information to support, rationalize and provide a clear and concise understanding of the project upon closure, INAC would recommend DCMI be required to commit to reclaim the land to a stable condition which would facilitate the return of the land to a functionally similar condition to the way it was prior to development. INAC would further recommend that instead of the proposed disposal options (burial within the North pile and/or underground in the mine workings), that DCMI be required to commit to the removal of all materials and infrastructure comprising the project development upon final decommissioning and closure.

Abandonment and reclamation plans should be reviewed and updated throughout the life of the project with the objective to better facilitate final closure objectives and activities and lessen the requirement for long term monitoring or follow-up actions by DCMI. INAC would also encourage the exploration of alternatives, which may further facilitate these goals.