GAHCHO KUÉ PROJECT
ENVIRONMENTAL IMPACT STATEMENT

REPONSES TO THE MARCH 17, 2011 DEFICIENCY STATEMENT
ISSUED BY THE GAHCHO KUÉ PANEL
ITEM 3

July 15, 2011 **11-1365-0001**

1.0 Introduction

The Mackenzie Valley Environmental Impact Review Board's Gahcho Kué Panel (the Panel) "Environmental Impact Deficiency Statement" dated March 17, 2011, for the Gahcho Kué Project (the Project) stated that a description of the long-term management plans for processed kimberlite with respect to permafrost, and a description of impact of climate change on frozen mine rock and processed kimberlite needs to be provided to address conformity-related deficiency Item No. 3. This requirement is in respect of the Environment Impact Statement (EIS) Terms of Reference (ToR) 5.2.6. This response has therefore been prepared to address Item No. 3 of the deficiency statement as identified by the Panel.

The subjects within the deficiency statement item No. 3 (i.e., permafrost and climate change) are discussed in the EIS in the sections outlined in Table 1.

Table 1 Relevant Environment Impact Statement Sections Pertaining to Permafrost and Climate Change

EIS Section	Title	Sub-section	Title
Section 3	Project Description	3.7	Mine waste management
Section 10	Key line of inquiry: long-term biophysical effects, closure, and reclamation	10.4.2	Long-term viability of the plan
Section 11.5	Subject of note: mine rock and processed kimberlite storage	11.5.2	Mine rock and processed kimberlite storage
Section 11.6	Subject of note: permafrost, groundwater, and hydrology	11.6.3	Permafrost
Section 11.13	Subject of note: climate change impacts	11.13.4	Climate Change Assessment: Secondary pathway - *Delay or prevention of permafrost development in the Fine PKC Facility, the Mine Rock Piles and the Coarse PK Pile*
Annex D	Bedrock geology, terrain, soil, and permafrost baseline	D7	Permafrost

EIS = Environmental Impact Statement; PK = processed kimberlite; PKC = processed kimberlite containment

The extent of the discussion of permafrost and climate change within the EIS was limited because the biophysical assessment of potential effects of the Project, including the mine rock piles, Coarse Processed Kimberlite (PK) Pile, and Fine Processed Kimberlite Containment (PKC) Facility, was completed without reliance on permafrost. These facilities, associated with waste and water management plans, have been designed to not rely on permafrost over the long-term to operate correctly. As a result, potential effects from climate change to these facilities were not anticipated to alter the classification of effects on the biophysical environment, and therefore were not assessed in the EIS.

This memorandum provides supplemental information to that included in the EIS to specifically address Item No. 3 of the deficiency statement. An overview of the permafrost conditions and climate change scenarios at the Project site are provided below in Sections 2.0 and 3.0, respectively. The long-term management plans and impact of climate change on the waste and water management facilities is detailed in Section 4.0. A summary follows in Section 5.0.

2.0 Overview of Permafrost Conditions

A detailed description of the permafrost conditions at the site is presented in Section 11.6 of the EIS. A summary is provided below.

The majority of the Project site includes glacial veneer and blanket with the mean annual permafrost temperatures of -0.5 to -2.5 degrees Celsius (°C). The highest soil temperatures (-0.5°C) correspond to regions that possess dense polar birch vegetation, while the lowest temperatures (-2.5°C) are encountered within glacial veneers or blankets with minimum snow cover, which correspond to areas with no shrub vegetation. Wet areas within peat bogs and peat veneers may have mean annual soil temperatures from -1.0 to -1.5°C, due to the low thermal resistance of saturated moss. The minimum mean annual permafrost temperature (approximately -3.5°C) within the Project site is encountered either in well-drained peat bogs and peat veneers (due to the maximum insulating effect of moss in summer time). Areas with a mean annual soil temperature above 0°C (up to +1.5°C) (i.e., permafrost-free) may be encountered within the tall shrub terrain along creeks in the glaciofluvial deposits and on lake banks. The development of positive temperatures is a result of snow accumulation in tall shrubs.

The maximum thickness of the active layer (3.7 to 4.0 metres [m]) is estimated to occur in exposed bedrock areas. Deep seasonal thaw in this terrain is a result of very low moisture retention within the bedrock. A deep active layer is also expected for the eskers, where the thickness of the active layer would be in the range of 3.0 to 3.4 m. The thickness of the active layer within the moraine veneer and blanket is expected to vary from 2.6 to 3.2 m and 1.6 to 2.5 m, respectively. Glaciofluvial sand and silt have the thinnest active layer thickness (1.0 to 2.0 m) of the mineral soils within the study area. The main factors that determine a relatively shallow active layer are the high moisture content and insulating effect of the moss cover. Organic soils (peat) have the shallowest active layers (0.4 to 0.9 m).

Seasonal frost penetration within the on-land taliks likely does not exceed 2 m due to a thick snow cover within tall shrubs.

In general, the mineral soils within the Project area have low ice content. No visible ice was observed in the majority of boreholes advanced at the moraine blanket and glaciolacustrine plain. The moisture contents of these materials were in a range of 3 to 20 percent (%), by weight. Glaciofluvial deposits have higher ice content. For instance, ice layers, up to 10 mm thick, were encountered in a borehole in the depth interval from 1.8 to 2.9 m. The soil consisted of fine-grained sand and silt with some fine gravel and had a moisture content of about 35%, by weight. Organic deposits were found to be extremely ice-rich. It was estimated that volumetric ice content of the peat could be about 40 to 50% (moisture content of peat was in a range of 500 to 800%). Ice layers in peat were up to 3 millimetres (mm) thick, occurring as horizontal or wavy layers. The ice layers were alternated with peat layers, several millimetres thick. Numerous ice lenses and pockets, up to 30 mm in size, were also recorded in the peat.

Based on measured soils temperatures from three deep boreholes, an estimated range of permafrost thickness within the Project area is 120 to 310 m. The high degree of variability in permafrost thickness between the boreholes can be explained by the locations of the boreholes. The boreholes with the shallower permafrost depths were located on islands within Kennady Lake at a distance of about 45 to 70 m from the shoreline. The shallow permafrost depth is therefore considered to be a result of the warming effect of Kennady Lake. The permafrost thickness of about 300 to 310 m observed in boreholes within the Project site is to be considered typical for the study area.

Taliks exist under deeper lakes, including Kennady Lake.

3.0 Overview of Future Climate Change

Climate change scenarios project that over the long term, the air temperatures will warm at the Project site. Recent estimates of climate change for the region have been developed by Environment Canada and are presented in Canadian Standards Association (CSA) (2010). Estimates of climate change for the location of the Project are provided in Section 11.13.2.3 of the EIS (Future Climate) based on climate projection data relative to the 1980 to 2009 baseline from various models and emissions scenarios. Future conditions within the EIS represented the 30-year period between 2011 and 2040; this represents a period near the end of the life of the Project and incorporates the post-operations management and closure period of the Project.

From the EIS, the annual average temperature in the Project area is projected to increase by 0.7°C to 1.6°C through the 2011 to 2040 period. The largest increase is expected to occur in the winter season, wherein temperatures may increase by 3.6 to 8.0°C. Additional future climate scenarios extending to 2100 have been projected and are included in Tables 2 and 3 for 'moderate' and 'high' emissions scenarios, respectively. These projections follow similar 30-year annual and seasonal trends to those described in the EIS.

Table 2 Mean Air Temperature Change (°C) from 1971 – 2000 Baseline under 'Moderate' Emissions Scenario (CSA 2010)

Future Scenario	Winter	Spring	Summer	Autumn	Annual
2041 – 2070	4.2	2.1	1.8	2.7	2.7
2071 – 2100	6.2	2.8	2.4	3.4	3.4

Note: °C = degrees Celcius

Table 3 Mean Air Temperature Change (°C) from 1971 – 2000 Baseline under 'High Emissions Scenario (CSA 2010)

Future Scenario	Winter	Spring	Summer	Autumn	Annual
2041 – 2070	4.9	2.0	1.8	2.8	2.9
2071 – 2100	8.9	3.5	3.0	4.7	4.7

Note: °C = degrees Celcius

4.0 Waste and Water Management

The waste and water management plans proposed for the Project exclude the use of frozen core dams or other similar designs that utilize permafrost conditions and frozen material as the principal barrier to prevent seepage. The design plans utilize natural terrains where possible, and water and waste (i.e., mine rock and PK material) control structures are restricted to the upper Kennady Lake watershed area (the controlled area).

Several of the dams and dykes are removed or lowered at the end of the mine life upon refilling of Kennady Lake. The dykes and dams remaining at the end of the mine life will form part of new landforms or part of permanent watershed diversions and associated fish habitat areas.

Regardless of potential variability in future climate change conditions, no changes would occur to the long-term stability and closure scenarios outlined for the Project. Additional details on the impact of climate change to the specific waste management plans are further described below.

4.1 Fine Processed Kimberlite Management

Fine PK will be deposited sub-aerially and sub-aqueously within Areas 1 and 2 (Fine PKC Facility) during the first seven years of the mine life. Fine PK will be placed into the mined out Hearne Pit when it is available. The fine PK in the

Hearne Pit will be submerged under the refilled Kennady Lake basin; therefore, it will ultimately be in an unfrozen condition within the Kennady Lake talik.

The majority of the fine PK in Areas 1 and 2 will be above the original lake level. Fine PK placed below lake level will initially be unfrozen. Fine PK placed above lake level is anticipated to contain layers of frozen and unfrozen fine PK, due to winter and summer placement. Over time, permafrost will penetrate into the fine PK and aggrade to the top of the fine PK layers. Given that the ground temperatures at site range from -0.5 to -2.5°C, it is conceivable that permafrost thaw will be initiated under the future climate change projections (Section 3.0).

The sub-aerial winter-placed fine PK in Areas 1 and 2 may contain entrained ice. The amount of entrained ice is expected to be relatively small given the thin layers of deposited fine PK and the annual seasonal thaw depths. Any entrained ice will thaw during warming associated with long-term climate change, although the thaw of the entrained ice is anticipated to be very slow. Excess entrained ice is anticipated to induce settlement of the fine PK surface layers, but it is not expected to result in unstable slopes on the surface of the facility.

Although the presence of frozen conditions in the fine PK provide an additional safety factor to the physical and chemical stability of the Fine PKC Facility, the design of the facility does not depend on permafrost conditions for its proper function, and has been designed based on the assumption that the fine PK will thaw over time to accommodate future climate change projections.

4.2 Mine Rock Waste Management

Two areas, one to the southeast of Area 6, and another on the south end of Area 5, were identified as areas for the South and West Mine Rock Piles. Mine rock will be deposited on the mine rock piles in the summer and winter, which means that mine rock placement will occur during unfrozen and frozen conditions. Most of the mine rock produced during Tuzo Pit development is planned to be placed in the mined-out 5034 Pit when it becomes available for deposition after Year 5. The projected yearly quantities of mine rock to be placed in each of the three locations are summarized in Table 4.

During the mine operation, it is anticipated that permafrost will develop in the mine rock piles, as has been observed at the EKATI Mine (EKATI). A thermal analysis of the EKATI mine rock piles (EBA 2006) provides an insight to the potential thermal conditions of the Project mine rock piles with climate change; however, the climatic differences between EKATI and the Project location must be considered. The nominal ground temperatures at EKATI ranged from -4 to -6°C, which are approximately 3°C colder than the Project site. The analysis showed that the mine rock piles generally sustained super-cooling below normal ground temperatures, although this was not observed at all locations. The super-cooling was attributed to convective heat transfer in the mine rock piles during winter months. The cooling was strongest in areas with coarse mine rock, as the convective currents and super cooling can be hampered by finer grained layers in the mine rock piles.

Table 4 Mine Rock Disposal Locations and Projected Yearly Quantities (Mt)

Mine Year	Mine Rock Disposal Location				
	South Mine Rock Pile	West Mine Rock Pile			5034 Pit
	Rock from 5034	Rock from 5034	Rock from Hearne Pit	Rock from Tuzo Pit	Rock from Tuzo Pit
-2	1.6	-	-	-	-
-1	16.0	-	-	-	-
1	27.2	-	-	-	-
2	24.7	-	-	-	-
3	2.3	15.5	-	-	-
4	-	10.5	1.9	-	-
5	-	2.9	10.0	-	11.6
6	-	-	11.9	-	13.3
7	-	-	3.6	-	27.2
8	-	-	-	-	31.5
9	-	-	-	9.9	-
10	-	-	-	4.0	-
11	-	-	-	1.0	-
Total	**71.7**	**71.2**			**83.6**

Note: "-" = no projected annual deposition; Mt = million tonnes

The EKATI study also evaluated the effects of future climate change of a magnitude of 9.7°C in 200 years. The results indicated that the Panda/Koala and Misery Waste Rock Piles, in addition to the underlying permafrost foundation, will remain mostly frozen for a period exceeding 200 years, largely due to enhanced cooling within the mine rock due to air convection. The perimeter of the Panda/Koala Waste Rock Storage Area (WRSA) is predicted to remain well frozen and will continue to retain moisture that percolates into the core of the pile. By contrast, the regional permafrost is expected to degrade over this same period, with a deepened active layer and ground temperatures close to 0°C. The mine rock piles at EKATI, especially those which currently exhibit convective cooling, are projected to likely retain remnants of permafrost in the EKATI area under long-term climate change projections. As the Project site is warmer than the EKATI area, permafrost remnants within the mine rock piles at the Project site are not expected to persist as long as they may at EKATI under long-term climate change projections.

The geochemical characterization study of the mine rock from the Project site is summarized in the EIS (see Appendix 8.II, Section 8). The mine rock has a low sulphur content, with only 1.4% of the samples for the Acid/Base Accounting (ABA) having a total sulphur concentration greater than 0.3 percent by weight (wt%) (0.3 wt% is generally considered the minimum sulphur concentration for potential acid generation). One-hundred and sixteen of 1,274 samples (9.1%) have a Neutralization Potential/Acid Potential (NP/AP) ratio less than one, and are considered to be potentially acid generating (PAG). Therefore, the PAG rock comprises only a small proportion of the overall mine rock tonnage that will be sourced from the operation.

While permafrost will enhance the performance of the mine rock piles in terms of seepage control, other mitigation features are associated with the design of the mine rock piles with respect to PAG mine rock. These include:

- PAG mine rock will be placed below an elevation of 418.7 m in the basins of both the South and West Mine Rock Piles, such that the portion of the mine rock will be completely submerged under water with a minimum of 2.0 m water cover when the original lake elevation of 420.7 m is restored after final mine site closure;
- PAG mine rock will be placed in the mined-out 5034 and Hearne Pits, where the mine rock pile will be limited to a top elevation of 418.0 m and be completely submerged with a water cover of about 2.7 m after the final mine site closure; and
- In the case that a small portion of the PAG mine rock cannot be placed below the elevation of 418.7 m in the basins of both the South and West Mine Rock piles or in the mined-out 5034/Hearne Pits, the excess portion of PAG mine rock would be encapsulated in the interior portions of either the South or West Mine Rock piles. The PAG mine rock would be placed in an interior zone at least 20 m away from the outer surfaces of the mine rock pile and the restored lake surfaces. The PAG mine rock within the mine rock piles will be enclosed with a minimum of 2 m thick till overburden fill to limit the potential for infiltration into and through the encapsulated PAG rock areas.

The stability of the mine rock piles has considered both permafrost and thawed conditions. The mine rock piles are configured to avoid covering ice-rich materials at the edge of the mine rock piles (i.e., within 30 to 160 m), and the slope of the first bench of the mine rock piles will be a relatively flat slope (3H:1V). The mine rock pile foundation soils are predominantly coarse grained.

If the foundation soils thaw due to climate change, the thaw rate will be slow enough such that thaw consolidation will not result in a stability issue. Overall, the mine rock piles have not been designed to rely on permafrost over the long term, although the benefits of permafrost will exist for many years during mine production and closure.

4.3 Coarse Processed Kimberlite Management

The coarse PK will be dewatered in the process plant and trucked to the deposition areas. It will be placed in a number of areas on site as listed in Table 5. Coarse PK will be placed during the summer and winter months; therefore, unfrozen and frozen zones will initially be present. Non-acid generating (non-AG) mine rock will be placed over exposed coarse PK prior to mine closure.

The waste management plan does not consider any potential benefits of permafrost in the Coarse PK Pile for long-term performance; however, it is anticipated that the permafrost may begin to form in the Coarse PK Pile during operations. Over the long term, the permafrost is anticipated to thaw due to future climate change projections.

Given the geotechnical properties of the coarse PK and the flat slopes (4H:1V) on the Coarse PK Pile, no adverse performance is anticipated due to permafrost formation or subsequent thaw.

Table 4 Coarse Processed Kimberlite Management Plan

	Planned Coarse Processed Kimberlite Deposition Location			
	On-land Coarse PK Pile	**Cover Over Fine PK in Areas 1 and 2 (Fine PKC Facility)**	**Dyke Construction**	**Co-Disposal with Mine Rock**
Approximate Time Period during Operations	Years 1 to 5	As needed from Year 4 to closure	Years 4 to 5	Year 6 to end of mine production
Estimated Total Volume of In-place Coarse PK (Mm^3)	5.2	1.7	0.2	4.6

Note: Mm^3 = million cubic metres

4.4 Dykes and Berms

The dyke and berm structures associated with the water and waste management plans have been designed to not rely on permafrost over the long term. The final design of the dykes will include a comprehensive evaluation of the foundation conditions in which they will be placed to determine if any additional design elements are required due to long-term climate change projections or thaw of the permafrost. All of the dykes in the water management plans for the mine development are located within the controlled area, or placed to prevent water from adjacent watersheds entering the controlled area.

The majority of dykes and berms will be breached at mine closure, or become non-water retaining structures. Several dykes will remain at the end of the Project life (i.e., dykes C, F, G, E1, H14, N18, A3, and N10). These dykes will become permanent water diversion structures to maintain the established drainage patterns and associated fish habitat upstream of these dykes after mine closure. The downstream face of Dyke C will be covered with a wide zone of settled fine PK during the early stages of mine operation. Additional till fill materials will be placed on the downstream side of dykes F, G, E1, N14, N18, A3, and N10 during the late stages of mine operation or early mine closure to limit potential excess seepage through the dykes if thermal evaluations during the final design stage indicate that the permafrost below the key trench will be thawed under more extreme (‘high’ emissions) climate change projections.

The dyke performance during the mine operation and early closure stages will be evaluated to address any potential issues, and to minimize the requirements of long-term maintenance and monitoring. Potential measures to be considered during the final design of these dykes for closure may include placing extra fill (till and mine rock) on the downstream side of each dyke and flattening slopes to shape each dyke into a very wide landform with low-gradient slopes. These measures will improve the long-term dyke performance and lower the risk and consequences of dyke failure.

5.0 Summary

The waste and water management facilities are designed to be physically stable even if any existing ground ice in the foundations of the structures thaws. The environmental performance of these facilities does not rely on freezing of the mine rock or PK materials or the cover materials. The rate of infiltration into the facilities assumes that the cover is thawed; frozen conditions would reduce the rate of infiltration. The biophysical assessment of the Project within the EIS has therefore been completed assuming no permafrost was present within the aforementioned structures. Permafrost establishment within the mine rock piles, Coarse PK Pile, and the Fine PKC Facility will limit seepage rates from these structures into Kennady Lake and therefore reduce loading and water quality projections for Kennady Lake and downstream waters as assessed in the EIS.

6.0 References

Canadian Standards Association (CSA). 2010. Technical Guide – Infrastructure Foundations in Permafrost – A practice guide for climate change adaptation, Canadian Standards Association.

EBA. 2006. Thermal Evaluation of Waste Rock Piles, EKATI Diamond Mine, NT Submitted to BHP Billiton Diamonds. Inc.