INDEPENDENT ENVIRONMENTAL MONITORING AGENCY
P.O. Box 1192, Yellowknife, NT X1A 2N8 ▪ Phone (867) 669-9141 ▪ Fax (867) 669-9145
Website: www.monitoringagency.net ▪ Email: monitor1@monitoringagency.net

February 14, 2017

Violet Camsell-Blondin
Chair, Wek'eezhii Land and Water Board
#1-4905 48th St, Yellowknife, NT
X1A 3S3

Dear Ms. Camsell-Blondin,

Re: Waste Rock Storage Area Closure Ecological Risk Assessment – Agency Review

The Independent Environmental Monitoring Agency (Agency) has reviewed the Waste Rock Storage Area (WRSA) Closure Ecological Risk Assessment (Closure ERA) composed of three separate documents: Thermal Modelling Report (Tetra Tech EBA May 2016), Water Quality Modelling Report (Golder Associates October 2016), and Ecological Risk Assessment (ERM October 2016). The Agency retained the services of Dr. Kevin Morin from Minesite Drainage Assessment Group (MDAG). He attended the workshop and his review of the Closure ERA has been provided to all society members (available on Agency Website: www.monitoringagency.net). The Agency has used his report to inform the comments below.

In general, the Agency is pleased that Dominion Diamond Ekati Corporation (DDEC) has attempted to address the WRSA seepage uncertainties at closure and beyond. The Closure ERA provides a good starting point for discussion and highlights some of the uncertainties which can be used to inform the next consolidated versions of the Interim Closure and Reclamation Plan and the Reclamation Research Plan. The Agency's main concerns result from the lack of measured data used as input variables in the thermal and water quality models. This results in a large amount of uncertainly in the output or conclusions drawn. Until this uncertainty is reduced with measured Ekati-specific data, the predicted outcomes will remain questionable. Considering the importance of this work and the time remaining until planned closure of the mine site in 2034, the Agency believes that DDEC can, and should, focus efforts on collecting the required data needed to reduce the uncertainty in the thermal and water quality predictions upon which the Closure ERA is based.

The following comments outline in greater detail the rationale for our concerns and recommendations.

Section 1: Thermal Evaluation of Coarse Processed Kimberlite (PK) and WRSAs

1.1 One-Dimensional Model

The one-dimensional model does not adequately account for thermal convection and internal heat generation. These factors are particularly important since they have direct impacts on the existing and predicted thermal conditions of the Coarse PK and WRSAs at Ekati. In the Closure ERA, DDEC concludes that the storage areas will freeze at some point. Based on the limitations inherent with a one-dimensional model, the validity of the thermal predictions remain questionable. This could be addressed by using a two or three-dimensional model and confirming the inputs required using Ekati-specific data.

The recent request from DDEC to add approximately 1 million m^3 of Potentially Acid Generating (PAG) and heat generating schist to the top of the Misery WRSA further highlights the need for two or three-dimensional modeling that considers internal heat generation. The actual measured thermal conditions of the WRSA need to be measured and used as data input into future WRSA thermal evaluations.

1.2 Thermal conductivity

Thermal conductivity, or the rate at which heat moves through a given material, was the only parameter used in the thermal model. As described above, other important parameters such as internal heat generation and convection were not considered. The equation used to determine thermal conductivity in the model was $k_{dry} = 0.039\ n^{-2.2}$, where k is thermal conductivity (Watts/mCK) and n is porosity. Porosity is the only variable and therefore has a major impact on the calculated thermal conductivity in the model. As such, determining porosity of the WRSA materials is very important to the reliability of the results. Porosity of waste rock piles is very difficult to determine as it changes considerably throughout the pile due to the heterogeneity of the pile. While porosity is difficult to measure onsite, thermal conductivity of various rock types can readily be measured under laboratory and field conditions.

1.3 Lack of Active Thermistor Data

Appendix A Table A1 of the Tetra Tech EBA 2016 report provides a summary of ground temperature cable installations. This table, combined with Figures 2, 5, and 8 which show the locations of the cables, indicate that most of the data used in the models are from side slopes, which are colder, and not the center of the piles. Our concern is that this may give the false impression that the piles are colder than they actually are. The following is a list of thermistor cables and their approximate location within the pile.

Panda/Koala:

- 5 ground temperature cables (GTC) in WRSA and 4 in toe berm.

- 1 in the center of the pile.
- 4 in benches of the pile.

Course Kimberlite Reject Pile (CKRP):

- No current GTC
- Last recorded data July 2014

Misery:

- 6 GTC in total.
- 3 centrally located:
    - 1606 – inconsistent readings and damaged beads
    - 1466 - stopped functioning September 22, 2007
    - 1467 – Missing data no readings after 2014
- 3 close to side slopes:
    - 2 are providing consistent readings.

Fox:

- 11 GTC installed in 2015 to address the lack of information.
- 6 GTC in Kimberlite dump and toe berms
- 5 in the WRSA the majority are centrally located.

As with any model the GEOTHERM Model is reliant upon the quality of the input data. Considering the lack of functioning cables and cable placement, the Agency is concerned that the current level of thermal data is insufficient to provide reliable results with which to predict future thermal conditions and ultimately to inform the Risk Assessment. More data needs to be collected in order to reduce the level of uncertainty regarding the current and future thermal conditions of the WRSAs. The rationale provided for not installing additional thermistor and geotechnical instrumentation into the WRSAs is because it cannot be done during operations. At the January 24, 2017 workshop the Golder presentation indicated that operations will end for the Panda/Koala, CKRP, Misery and Fox WRSAs sometime in 2018.

1.4 Bead Malfunction

For the centrally located thermistor cables, warming trends or warmer temperatures than expected were noted at both Panda/Koala and Misery WRSA. These results were dismissed in the Thermal Model Report as bead malfunction. For the Panda/Koala results, Tetra Tech hypothesized that "*If the beads at GTC 1534 were assumed to be in good condition, a ground temperature warming trend would have been noticed over the last 10 years. In consideration of the non-reactive nature of granite waste rock and the malfunction of many beads in GTC 1534 since 2005, it is highly likely that the measured warming trend in GTC 1534 is the result of bead malfunction.*" (Section 4.1 p-5). For the Misery Pit, the report stated that "*If the measured temperatures were believed to reflect the actual field conditions (not due to a malfunction of beads), these observations could indicate that internal heat (possibly due to sulphide oxidation) may be generated in localized areas (possible schist layers) in the pile.*" (Section 4.3 p-6). Keep in mind that this is before the addition of 1 million m^3 of schist, which will likely worsen the issue.

1.5 Thermal Evaluation Recommendations

Recommendation 1-1: Expand the one-dimensional thermal model to at least two dimensions. The side slopes of the WRSAs are particularly important, because their freezing-thawing could lead to thick reactive active layers. WRSAs are three-dimensionally complex and variable. Water and pore-gas movements within mining waste rock are not reliably simulated in one dimension, so heat transport and freezing should not be simulated that way either.

Recommendation 1-2: Include at least two-dimensional thermal convection, which can substantially affect heat transport and freezing in three dimensions. Thermal convection with pore-gas movement is important for more reliable predictions of freezing in Ekati waste rock.

Recommendation 1-3: Include internal heat generation, which can substantially reduce freezing in three dimensions. The lack of any internal heat generation in the thermal modelling means that the current predictions of freezing in Ekati WRSAs are unrealistic best-case scenarios.

Recommendation 1-4: If there are insufficient verifiable data with which to complete at least two-dimensional thermal modelling, conduct research required to ensure the data is collected.

Recommendation 1-5: Update the thermal modelling of the Misery WRSA by including the proposed addition of one million m^3 of PAG and potentially heat generating schist.

Recommendation 1-6: Based on the Workshop, incorporate the findings of the reported unfrozen water within the core of the Fox WRSA into future modelling of thermal characteristics and water quality.

Recommendation 1-7: DDEC install new instrumentation in 2018 or 2019 into all of the WRSA that are no longer in operation. This will allow enough time for accurate measured data that can be used to inform future predictions.

Section 2: Water Quality Modelling

2.1 GoldSim Model

The GoldSim model was used by Golder Associates for water quality modeling. The first primary factor in GoldSim is how the “objects or elements” in the model were defined for Ekati. GoldSim considered Ekati lakes as single objects. Thus, any contaminated water entering through one inlet portion would be mathematically diluted down in GoldSim by the remaining lake water. As a result, any local toxic effects at that inlet would not be predicted by the GoldSim model.

2.2 Thermal Prediction and Water Quality Modelling

The Thermal Model prediction by Tetra Tech EBA that the WRSAs will develop a frozen core plays a very significant role in the water quality model predictions. The Water Quality Model Report states that "*The frozen core is assumed not to contribute load to seepage water due to a number of factors: 1) a lower rate of mineral reaction due to the temperature of this material, and 2) coating of mineral particles by ice which both impedes oxygen ingress and prevents the transport of load through the core."* (Section 3.2 p-6). The Agency believes this is not a conservative approach. This assumption is a dangerous one based on the thermal model uncertainties discussed above. Assuming that there will be no seepage water due to freezing conditions when the water balance of the WRSAs have not been determined is at best overly optimistic and adds significant uncertainty to the model predictions and closure Ecological Risk Assessment. A more appropriate conservative approach would be to assume different levels of freezing such as total freezing, partial freezing and no freezing. This would better frame the potential risks for the Risk Assessment.

2.3 Water Balance of WRSA

Based on the meteorological data routinely collected on site, the volume of precipitation on the WRSAs can be accurately determined. Unfortunately, what happens to the water once it enters the pile is not well understood. The only information currently collected to inform the water balance is the biannual surface seepage surveys. The surveys show that only a small percentage of the water entering the pile is being released as surface seepage. Therefore, there are two possibilities. First, all the remaining water not accounted for by surface seepage must be held within the core of the pile, an unknown volume that is increasing annually. The second possibility is that there are additional pathways in which water is leaving the WRSAs. This could be through subsurface seepage that is flowing out of the pile into the receiving environment within the active layer. This possibility is acknowledged in the Water Quality Report "*It is anticipated the flow at the seepage monitoring locations does not represent the total WRSA and CKRSA discharges due to very low flow conditions. Furthermore, it is expected that shallow groundwater flows (interflow) are traveling under the monitoring locations. As such, it was not possible to calibrate the water balance model discharge volumes to measured seepage volume monitoring data*." (Section 4.2.2 p-9). This unknown volume of water results in more uncertainty. This uncertainty could be reduced by monitoring ground water flows (interflow) from the storage areas to the adjacent receiving environment.

2.4 Infiltration Rates

Two infiltration scenarios were considered in the Water Quality model, the high and low flows. High seepage was based on the highest infiltration rates from the Diavik test piles. The low seepage rates, which due to low dilution result in the most contaminated seepage, used the average infiltration rate from the Diavik test results. This low seepage value is carried over into the Risk Assessment as a conservative approach. However, since it was calculated using the average infiltration rates there will be times (roughly half the time) when the actual infiltration rates will be lower than this 'conservative approach'. This again adds to the uncertainty of the Water Quality model and ultimately the Risk Assessment.

Test piles do not accurately represent actual infiltration rates for large scale WRSAs. The large scale and heterogeneity of the actual WRSAs result in areas with varying degrees of infiltration. Some parts of the pile will behave like the test piles at Diavik, however others will have areas or channels of coarse rock that have dramatically higher infiltration rates. This rapid infiltration is not considered in the model.

2.5 Contaminant Accumulation Within the Pile

As discussed above, an unknown volume of water is infiltrating into the WRSAs and only a small amount is being released as surface seepage. The Water Quality Report states "[When unfrozen*], it is assumed that 5% of the load prior to pile saturation and 10% of the load following pile saturation reports to the toe of the storage area. This is likely a conservative assumption. Given the dimensions of the storage areas it is likely that most of the load is stored in the core and/or in the underlying permafrost*." (Section 5.6 p-29). This is a very disturbing statement.

If it is true that most of the load is stored in the pile, this is a major concern and should certainly be considered specifically as part of the Risk Assessment. If the majority of contaminants are being held in the frozen core of the pile then the potential future release of this large volume of contaminants needs to be considered and factored into the Risk Assessment. Considering the concerns detailed above with the thermal models conclusion that the WRSAs will freeze, there remains a very real possibility that at some point this contaminant load building within the pile could overwhelm the mechanism that is holding it within the pile and release it into the environment. Without a better understanding of the water balance and mechanisms involved in holding the contaminants in the pile it is not possible to accurately determine if, how or when these contaminants could be released. The recent Fox borehole drill results could provide some insight.

2.6 Scaling Factors

Comparing 1 kg lab sample results to a full scale WRSA would be difficult and unreliable as there are many unknowns that need to be considered. Instead of trying to determine this number Golder Associates simply multiplied or scaled the 1 kg sample up to full scale WRSA, thereby introducing additional uncertainty in the predictions. The MDAG report (section 3.5.3 page 14) warns that:

> *Golder (2016) conducted this huge scaling up for the Ekati closure ERA, simply by multiplying the small laboratory mass loadings by single values called "scaling factors" (Golder Section 5.4.3). These scaling factors were applied to the lowest rates obtained from the humidity cells ("the last five weeks"), minimizing all predicted contaminant concentrations and heat generation from the start.*

Therefore, the lowest possible laboratory rates were scaled upwards. Moreover, these last-five-week cell rates were not stable (Golder Section 5.6), and could thus increase substantially any time later. This instability could lead to higher, unpredicted contamination at Ekati through closure, and unexpected ecological damage.

2.7 Model Calibration with Seepage Data

Seepage can vary considerably throughout the year. When comparing measured seepage data to predicted values there is agreement with the measured data. However, the current model predicts much higher seepage between the monitoring events which introduces significant uncertainty into the model results. The model could be further calibrated or confirmed by doing additional seepage sampling.

2.8 Water Quality Recommendations

Recommendation 2-1: Instead of using the 1:1 dilution model, predict contaminant concentrations using other, more typical full-scale relationships as a valuable sensitivity analysis.

Recommendation 2-2: Set up monitoring locations to best capture surface and ground water flows coming off the WRSAs.

Recommendation 2-3: Identify the predicted accumulation of contaminants within the core of WRSAs at Ekati in any future Risk Assessments or closure scenarios.

Recommendation 2-4: Provide greater details of predicted contaminant accumulation within the core of WRSAs including clarification and numerical examples so that all stakeholders understand the corresponding environmental liability.

Recommendation 2-5: Review details of the unfrozen water found within the core of the Fox WRSA (reported during the workshop) and incorporate them into the water-quality modelling. This includes the effect on the modelling assumption that all WRSAs will freeze and not release any contamination.

Recommendation 2-6: Use the actual low infiltration rates to calculate the low seepage infiltration.

Recommendation 2-7: Create time-series plots of daily measurements of precipitation, superimposed on daily measurements of seepage flows, to show how much water passes through Ekati WRSAs quickly. This would be in contrast to the current assumption that water only moves relatively slowly through finer-grained materials, and then seeps from WRSAs only after the finer material becomes saturated. Creating these plots would reduce the need for such uncertain assumptions.

Recommendation 2-8: Determine the ratio of measured flow (from seepage) to predicted flows (Appendix A) to reduce the uncertainty. This could provide some indication of how much flow is not being detected.

Recommendation 2-9: Provide the scaling factors used with a justification for their inclusion.

Section 3: Ecological Risk Assessment:

3.1 General

The Risk Assessment as a whole is well laid out and conducted in a logical rationale manner using the information available at the time of development. However, the reliability and accuracy of any risk assessment is dependent on the inputs and assumptions used. The Agency is concerned that the key inputs upon which the Risk Assessment is based were developed using limited measured data, simplistic models and questionable assumptions. The result of this 'daisy chain effect' is a high degree of uncertainty.

The Agency's review is intended to highlight the main causes of uncertainty and recommend ways in which it can be reduced for future analyses. Currently, the Agency is of the opinion that reliable conclusions regarding the long-term impacts of the WRSAs on the receiving environment cannot be made without more information, due to the level of uncertainty.

Recommendation 3-1: Moving forward, begin to consider the recommendations made and start to collect the data necessary to reduce the uncertainty in order to inform future discussions regarding reclamation research and closure and reclamation.

Recommendation 3-2: Repeat the thermal evaluation, water quality modeling and closure screening ecological risk assessment in 2022 (five years) using relevant site-specific data.

Should you have any questions concerning these comments, the Agency would be pleased to discuss these at your convenience.

Sincerely,

Jaida Ohokannoak
Chairperson

Cc: DDEC – April Hayward
Tlicho Government - Sjoerd van der Wielen
Yellowknife Dene First Nation – Alex Power
Lutsel K'e Dene First Nation – Lauren King
North Slave Metis Alliance – Shin Shiga

Kitikmeot Inuit Association – Jared Ottenhof
Government of the Northwest Territories – Laurie McGregor
Indigenous and Northern Affairs Canada – Jennifer O'Neil