

# **BGC ENGINEERING INC.**

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## **PROJECT MEMORANDUM**

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<b>To:</b>	<b>Wolfden Resources/Gartner Lee/ Wardrop Engineering</b>	<b>Fax No.:</b>	<b>by email</b>
<b>Attention:</b>	<b>Andrew Mitchell/Eric Denholm/Phil Davis</b>		
<b>From:</b>	<b>Jim Cassie, P.Eng.</b>	<b>Date:</b>	<b>March 30, 2007</b>
<b>Subject:</b>	<b>Climate Change Design Criteria Proposed Tailings Dams, High Lake Project, NU</b>		
<b>No. of Pages (including this page):</b>	<b>13</b>	<b>Project No:</b>	<b>0385-003-19.3</b>

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### **1.0 INTRODUCTION**

Wolfden Resources Inc. (Wolfden) is proceeding with the permitting and potential development of their High Lake Project in Nunavut, situated about 550 km by air northeast of Yellowknife, NT. At the mine site, several tailings dams are proposed to be designed and constructed on continuous permafrost. As outlined in BGC (2006), these dams are designed to have the foundation under the dam remain frozen either for their operational life, and potentially into their closure phase as well.

Climate change, and more specifically, global warming, is an on-going phenomena in the world. For a variety of reasons, the effects of global warming are magnified at northern latitudes. In order for the design of the High Lake tailings dams to proceed, climate change design criteria and associated duration periods need to be selected.

The selection of appropriate design criteria for dams, including climate change parameters over some future time period, need to be made within the overall context of the "Precautionary Principle". Environment Canada (2005) outlines the tenets of the principle as follows:

"The precautionary approach/precautionary principle is distinctive within science-based risk management. It recognizes that the absence of full scientific certainty shall not be used as a reason to postpone decisions when faced with the threat of serious or irreversible harm. However, guidance and assurance are required as to the conditions governing the decisions that will be made. Guidance and assurance are particularly needed when a decision must be made regarding a risk of serious or irreversible harm about which there is significant scientific uncertainty. The precautionary approach/precautionary principle primarily affects the development of options and the decision phases, and is ultimately guided by judgement, based on values and priorities."

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Therefore, it is necessary to ensure that impacts from climate change, and more specifically, global warming, are accounted for in the design and the potential impacts of the High Lake Project. The application of the Precautionary Principle is specified within the Nunavut Impact Review Board (NIRB) Terms of Reference issued for Environmental Impact Statements.

Therefore, the following memo outlines some climatic information relative to the High Lake site, as context for some later interpretations regarding climate change design parameters. Global warming allowances for other recent northern projects are also reviewed. The memo also provides a recommended warming allowance for the High Lake site, where the critical engineered structures, the tailings dams, will be located. Related climate change topics such as the potential variation in precipitation and evaporation are also reviewed briefly.

## **2.0 NORTHERN LATITUDE CLIMATE CHANGE**

Recent pronouncements by the Arctic Climate Impact Assessment (ACIA), a four-year study of the Arctic by international scientists, noted some of the following conclusions:

- In Alaska, Western Canada, and Eastern Russia, average winter temperatures have increased as much as 3 to 4°C in the past 50 years and are projected to rise 4 to 7°C over the next 100 years.
- Arctic summer sea ice is projected to decline by at least 50 percent by the end of this century
- Many coastal towns and facilities around the Arctic face increasing risks from erosion and flooding due to rising sea levels, decreased sea ice and thawing coastal permafrost.
- Over the next 100 years, climate change is predicted to accelerate, contributing to major physical, ecological, social, and economic changes.

Within Canada, Environment Canada (1995) noted that mean annual temperatures within the Mackenzie Valley have increased by 1.7°C over the last century. Burn (2002) noted that near surface permafrost in the Mackenzie Delta has warmed rapidly in response to regional climate warming. Beilman et al. (2000) indicated that the southern limit of permafrost in Western Canada has moved northward by 39 km on average.

Alternatively, some records for the eastern Arctic and northern Quebec (Allard et al. 1995) showed cooling occurring over the same time period in which Mackenzie Valley warming had been documented. That observation has recently been superseded by Allard et al. (2002) that noted that permafrost warming is now occurring in northern Quebec, beginning with summer temperatures in 1993 and winter temperatures in 1995.

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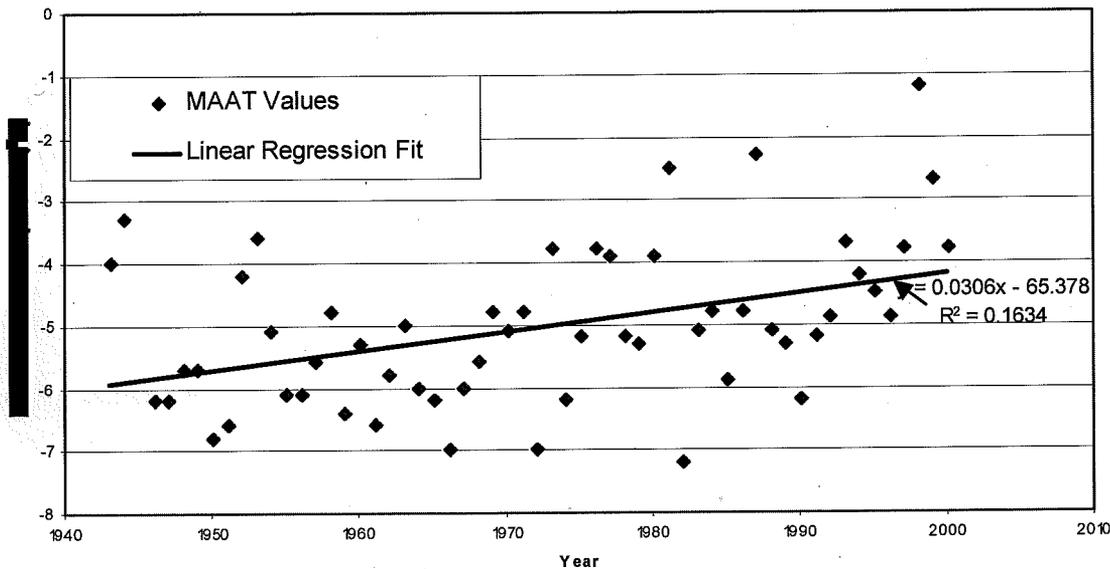
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There is still on-going debate in both the scientific and the public circles on whether climate change is a natural phenomena, is caused by anthropogenic (“man-made”) inputs to the atmosphere, or some combination of the two. Anthropogenic climate warming is caused by “greenhouse gases” such a carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and water vapour. These gases trap the Earth’s outgoing radiation, and hence, warm the planet. Both carbon dioxide and methane are generated by industrial activity and the use of fossil fuels. Anthropogenic contrarians, such as Baliunas et. al. (2002) and Patterson (2003), suggest that variations in the Sun’s energy output cause the increasing temperatures. The rising temperatures then raise the concentration of carbon dioxide in the atmosphere, rather than the other way around.

Regardless of the causes, warming air temperatures are occurring in the western Canadian Arctic. Figure 1 shows almost 60 years of recorded air temperatures at Yellowknife (62°27’N) along with a linear regression line fitting to the noted data points.

**Figure 1 60 Years of Yellowknife Temperatures**



A warming trend of approximately 0.3°C/decade is indicated over the long period shown on Figure 1. If the regression were limited to a later time period (post-1970 for example), then higher warming values may have been indicated.

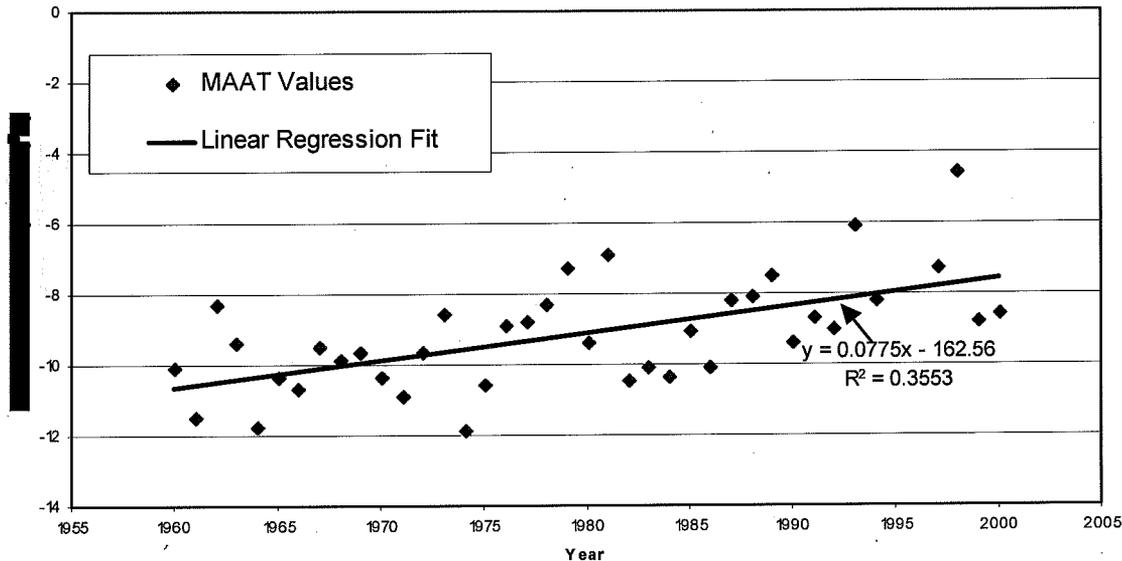
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Figure 2 displays the data for Inuvik, in the Mackenzie Delta at 69°18'N.

**Figure 2 40 Years of Inuvik Temperatures**



Based on 40 years of records, and a coefficient of determination of 0.36 (i.e. 36% of the data is explained by the linear fit model), a warming trend of 0.77°C/decade is indicated by the air temperature history. Regardless of the air temperature trends, warming in the underlying permafrost has been measured, as noted earlier in Burn (2002).

For the eastern Arctic, the warming indications are not quite so obvious. Linear regression of only 14 data points from the Nanisivik A Station (Baffin Island) provided a warming trend of 0.6°C/decade with a coefficient of determination of only 0.22 (i.e. only 22% of the data is explained by the linear fit). For the Resolute Station (Cornwallis Island), with 52 data points and hence a much larger sample population for statistical assessment, a warming of only 0.1°C/decade was indicated but the coefficient of determination was only 0.04. Hence, the Nanisivik and Resolute weather stations do not indicate any statistically significant warming within the data sets analysed (up to 2000). It is possible that eastern Arctic warming may be indicated on other Nunavut or northern Quebec locations or in more recent data (after 2000).

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### 3.0 HIGH LAKE PROJECT

The High Lake property site is located at 67°22'N latitude. No long term climate measurements are available for either site but Table 1 summarizes the mean annual air temperature (MAAT) data for nearby climate stations, in relation to the High Lake site:

**Table 1 - Summary of MAAT Data from Nearby Stations**

Station Name	Distance/Direction from High Lake	Period of Record	MAAT
Cambridge Bay	300 km NE	1929-2004	-14.7° C
Coppermine	200 km WNW	1933-1977	-11.4° C
Kugluktuk	200 km WNW	1978-2004	-10.4° C
Contwoyto Lake (65.48°N)	280 km S	1959-1981	-11.9° C
Lupin (65.76°N)	200 km S	1982-2005	-11.0° C

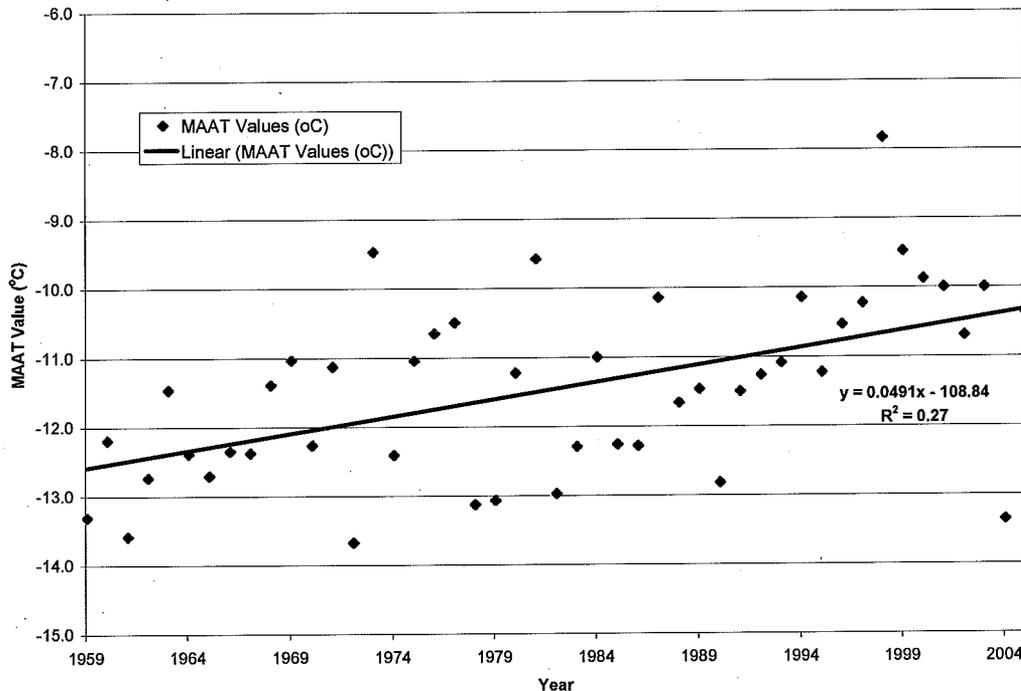
As a result, it is estimated that the MAAT values for the High Lake site will be approximately -11° to -12°C. RWDI (2006) estimated the MAAT for the High Lake as -11.8°C. In addition, RWDI (2006) estimated the 2 year return period total precipitation to be 309 mm/year (adjusted).

The climate data available from the Contwoyto Lake and Lupin are from two different, but relatively close stations. Both are located around the large lake and provide a long term climate station in relative proximity to High Lake. The MAAT values are similar (-11.9° versus -11.0°C) along with the standard deviation values from the data (1.16° versus 1.24°). If the data is combined from the two proximal stations, a 46 year period of record is available for potential assessment of climate warming; the results are displayed on Figure 3:

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**Figure 3 Long Term Temperatures for Combined Station**

The 46 years of data from the combined station indicates a potential warming amount of 0.49°C/decade, but again with a low correlation coefficient.

RWDI (2006) reviewed climate data from several proximal weather station (including Lupin and Contwoyto) and provided the following two conclusions regarding climate change observations for the High Lake "Project Area":

- Annual mean temperatures have increased by 0.01°C/year to 0.02°C/year between 1933 and 2002.
- Mean annual precipitation amounts have increased by about 0.7 mm/year in the same time frame.

In addition to climate change amounts, it is also necessary to discuss the relevant time periods relative to the mine phases in which to apply the various climate change parameters:

1. Construction – two years from 2008 to 2010.
2. Mining – 14 years from 2010 to 2024.
3. Reclamation and monitoring – 7 years from 2024 to 2031.
4. Closure – past 2031.

Both the amount and time period will be important as design criteria, along with the potential differing design intent of each dam structure within the operations and closure phases.

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#### 4.0 OTHER NORTHERN MINING PROJECTS

Numerous other new mine and closure projects in the north have been submitted for regulatory review and permitting within the last few years. As such, these projects had to undertake some form of climate change review and proposed global warming values in their regulatory submissions. As such, these other northern projects can provide some valuable information and context for the topic of allowances made to account for the precautionary principle. Table 2 therefore summarizes the climate warming values used for the variously noted projects:

**Table 2 Summary of Climate Warming Parameters for Northern Mines**

Project	Latitude	Mean Annual Air Temperature	Global Warming Allowances as Design Criteria	Project Status
Polaris Mine Closure, NU	76°N north of Resolute	-16.5°C	Best estimate MAAT increase; 3.0°C/100 years High sensitivity; 5.1°C/100 years	Permits received Closure work completed Active monitoring
Nanisivik Mine Closure, NU	73°N north end of Baffin Island	-15.1°C	Best estimate MAAT increase; 2.8°C/100 years High sensitivity; 5.0°C/100 years	Permits received Closure work almost completed
Doris North Mine, NU (2 year mine life)	67.5°N	-12.0°C	Discussed worst case of 5.3°C warming over the next century. Used simplifying assumption of 6.5°C over next century for thermal modelling of dams.	NIRB approval provided in September 2006.
Jericho Mine, NU (8 year mine life)	65.8°N	-11.1°C	High sensitivity value was used for final dam design	Mine now operating
Meadowbank Mine, NU (8 year mine life)	65°N north of Baker Lake	-11.3°C	5.5°C warming over 100 years	NIRB approval provided in August 2006.

As such, global warming amounts ranging from approximately 5° to 6°C/100 years have been selected for design and received regulatory approval on selected northern projects. The 100 year time frame from closure should also be noted as important.

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Some of High Lake's structures may be required to perform their design function for more than 100 years. Any climate predictions beyond a 100 year period, and some may argue a 50 year period, contain so much uncertainty as to be useless. Monitoring and design criteria reassessments would be required in the future for all noted structures.

## 5.0 CLIMATE CHANGE FORECASTS

Any selection of appropriate climate change parameters for the future is done on the basis of complex, atmospheric general circulation models (GCM's) that attempt to forecast future changes in greenhouse gases (based on proposed society's response) and their impact on the climate. These computer models are highly complex and require extensive amounts of computer power and time to simulate long time periods. In order to simplify the models, the horizontal resolution of the models is limited (Plummer et. al 2006). As such, finer scale resolution is provided through the use of limited-areas regional climate models (RCM's). It should be noted that these models are complex, but that does not necessarily imply accuracy in terms of all elements of the climate (e.g., temperature, precipitation, evaporation, etc.)

Environment Canada (1998) has published guidelines as a consistent basis for planning and impact assessment for long-term projects in the North. Based on increasing concentrations of greenhouse gases, and using GCM's, the IPCC (1995) estimates a range of estimated global warming values. Often quoted scenarios are the "Best Estimate" and the "High Sensitivity" values of 2.0°C and 3.5°C for the global temperature warming between 1990 and 2100. These global increases are then converted into regional warming values, based on the use of GCM's.

Environment Canada (1998) provides values for the expected temperature increases by season, latitude and decade. The following limitation is noted though with the temperature increase values provided:

"...they can be considered nominal temperature change scenarios for northern North America to the north and west of Hudson's Bay (emphasis by BGC). There is still considerable uncertainty on both the direction and magnitude of impact of global warming in the northeastern part of North America."

These guidelines, although noted as only appropriate for the Western Arctic, has been used for numerous projects in the Eastern Arctic as well.

Tables 3 and 4 therefore provide the interpolated temperature increase values proposed for High Lake site, based on the only currently published guidelines for temperature increases in the North.

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**Table 3 Best Estimate Global Warming Estimates for High Lake**

BEST ESTIMATE CASE											
	60°N Latitude					70°N Latitude					67.3°N Latitude
Year	DJF	MAM	JJA	SON	Annual	DJF	MAM	JJA	SON	Annual	Annual
2000	0.5	0.4	0.1	0.1	0.3	0.5	0.4	0.1	0.1	0.3	0.3
2100	5.0	3.9	1.5	1.2	2.9	6.0	4.2	1.0	1.1	3.1	3.0
Difference					2.6					2.8	2.8

**Table 4 High Sensitivity Global Warming Estimates for High Lake**

HIGH SENSITIVITY CASE											
	60°N Latitude					70°N Latitude					67.3°N Latitude
Year	DJF	MAM	JJA	SON	Annual	DJF	MAM	JJA	SON	Annual	Annual
2000	0.8	0.6	0.2	0.2	0.5	1.0	0.7	0.2	0.2	0.5	0.5
2100	8.8	6.9	2.6	2.0	5.1	10.5	7.2	1.8	2.0	5.4	5.3
Difference					4.6					4.9	4.8

As a result, the mean annual temperatures increases of 2.8°C and 4.8°C for the Best Estimate and the High Sensitivity cases respectively, would be applied to the "current" MAAT value of -11.8°C. As a result, the Best Estimate MAAT would be equivalent to -9°C and the High Sensitivity MAAT would be -7°C by 2100.

RWDI (2006) undertook a review of proposed climate change parameters from GCM's extracted from the Canadian Institute for Climate Studies (CICS) at the University of Victoria. It should be noted that results provided herein are results for a specific cell encompassing all of Nunavut and not for the High Lake area specifically. For four different scenarios and seven different models, the following climate change parameters were predicted, on average, by the Year 2080:

- 5.7°C total average change in the air temperature (0.076°C/decade).
- 23% total increase in precipitation (3%/decade).
- 0.21 mm/day increase in evaporation.

Again, these estimated values are representative of the entire territory and not just the High Lake site.

Plummer et al. (2006) presented the recent results from the Canadian RCM, which was broken down into 11 climatic regions. For the Eastern Arctic region (appears equivalent to Nunavut), the following climate change estimates were made for the climate means from 1971-1990 to 2041-2060 (70 year duration):

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- The air temperature was forecast to increase by 3.6°C (average) to 4.3°C (high amount) over the 70 year duration. This increase corresponds to 0.051°C/decade to 0.061°C/decade.
- The total annual precipitation (seasonally precipitation amounts were also variable) was estimated to increase by 12.75% (average) to 18.75% (high amount) over the modelled 70 year duration.

As such, two different models over similar time periods appear to provide different results.

Increasing precipitation resulting from global warming should increase the probability of greater snow cover. Increasing snow cover represents additional insulation on the ground and hence, permafrost warming would occur. It should be noted that climate models appear to have difficulty is accurately predicting precipitation changes in the future. Increasing air temperatures is expected to increase the evaporation in northern areas.

## 6.0 CONCLUSIONS

The currently available information provides five varying estimates of climate warming; 0.1°-0.2°C/decade to 0.49°C/decade from actual measured temperatures and 0.48°C/decade to 0.76°C/decade based on climate change models. Based on these values, and on the precedents with respect to the other northern mining projects, it is recommended that a warming allowance of 0.5°C/decade be applied as the "base case" and 0.65°C/decade for the "high case" for the High Lake Project. Some judgement will need to be applied to their application, based on the potential consequences and impacted predicted for this amount of warming. Thermal Factors of Safety will be employed during the design of the dams, and therefore, some additional conservatism will be applied to the noted warming value.

Two climate models estimated 18%, 26% and 33% precipitation increase over a 100 year period. As such, it is recommended that a total precipitation increase of 25% over 100 years be allowed for, including the increase in snowfall amounts by 25%.

## 7.0 LIMITATIONS AND CLOSURE

This memorandum provides a review of climate change information collected and modelling undertaken by third-parties, separate from BGC Engineering Inc. (BGC). As such, BGC has not independently verified the work and it is assumed accurate, although numerous assumptions (and associated limitations) are generally required to simplify natural complexity. As such, judgement has been applied to the information reviewed and the recommendations made herein. Variations from the noted conclusions are possible.

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This memorandum was prepared by BGC Engineering Inc. (BGC) for the account of Wolfden Resources Inc. The material in it reflects the judgement of BGC staff in light of the information available to BGC at the time of memorandum preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be based on it are the responsibility of such Third Parties. BGC Engineering Inc. accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this memorandum. All memorandums and drawings are submitted for the confidential information of our client for a specific project and authorization for use and/or publication of data, statements, conclusions or abstracts from or regarding our memorandums and drawings is reserved pending BGC's written approval.

We trust that the information contained within memorandum meets your present requirements. Should you have any questions regarding the information and recommendations contained herein, please contact BGC at your convenience.

Respectfully submitted;  
**BGC Engineering Inc.**  
per:

Reviewed by:



James W. Cassie, M.Sc., P.Eng.  
Specialist Geotechnical Engineer



Ron Coutts, M.Sc, P.Eng.  
Specialist Geothermal Engineer

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**REFERENCES**

- Allard, M., Fortier, R., Duguay, C. and Barrette, N. 2002. A trend for fast climate warming in northern Quebec since 1993: impacts on permafrost and man-made infrastructure. American Geophysical Union 2002 Fall Meeting, San Francisco, December 2002.
- Allard, M., Wang, B. and Pilon, J.A. 1995. Recent cooling along the southern shore of Hudson Strait, Quebec, Canada, documented by permafrost temperature measurements. Arctic and Alpine Research, Vol. 27, p. 157-166.
- Arctic Climate Impact Assessment 2004. <http://usinfo.state.gov/gi/Archive/2004/Nov/08-21489.html>. Web site accessed December 2005.
- Baliunas, S., Patterson, T. and MacRae, A., 2002. Climate change is natural. Article published in the Globe and Mail, November 19, 2002, page A21.
- Beilman, D.W., Vitt, D.H. and Halsey, L.A. 2000. Localized Permafrost Peatlands in Western Canada: Definitions, Distributions and Degradation. Arctic, Antarctic and Alpine Research, Vol. 33, No. 1, p. 70-77.
- BGC Engineering Inc. 2006. Supplemental Information on Tailings Dam Design, High Lake Project, NU. Memorandum submitted to Wolfden Resources Inc., October 13, 2006, 13 pages.
- Burn C.R. 2002. Recent permafrost warming in Northwest Canada. American Geophysical Union 2002 Fall Meeting, San Francisco, December 2002.
- Environment Canada 1995. The State of Canada's Climate; Monitoring Variability and Change. Environment Canada State of the Environment Report, Ottawa, Canada.
- Environment Canada 1998. Climate change impacts on permafrost engineering design. Published by the Environmental Adaptation Research Group, AES, Environment Canada. Funded by the Panel on Energy Research and Development (PERD). March 1998, 42 pages.
- Environment Canada 2005. [http://www.ec.gc.ca/econom/pp\\_e.htm](http://www.ec.gc.ca/econom/pp_e.htm). Web site accessed December 2005.
- IPCC 1995. Climate change 1995: the science of climate change – technical summary. Cambridge University Press, Cambridge, UK.
- Natural Resources Canada. 1995. Canada – Permafrost 1995. The National Atlas of Canada, 5<sup>th</sup> Edition. Published by the National Atlas Information Service, Canada Centre for Mapping, Geomatics Canada and the Terrain Sciences Division, Geological Survey of Canada, Natural Resources Canada 1995.
- Patterson, T., 2003. Kyoto science disputed. Article in the National Post, July 14, 2003.

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Plummer, D.A., Caya, D., Frigon, A., Cote, H., Giguere, M., Paquin, D., Biner, S., Harvey, R. and De Elia, R., 2006. Climate and Climate Change over North America as Simulated by the Canadian RCM. Journal of Climate, Volume 19, pages 3112 to 3132.

RWDI Air Inc. 2006. High Lake Climate Assessment. Report submitted to Gartner Lee Limited, March 7, 2006, 53 pages.

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