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December 10, 2008

Project No: 0308-006-01

Mr. David Hohnstein
Acting Director, Technical Services
Nunavut Water Board
P.O. Box 119
Gjoa Haven, NU

Dear Sir:

RE: NWB 3BM-ARC0810 ARCTIC BAY SEWAGE LAGOON WATER LICENSE AMENDMENT –GEOTECHNICAL AND GEOTHERMAL REVIEW

1.0 INTRODUCTION

Further to your request, BGC Engineering Inc. (BGC) has completed a review of geotechnical and geothermal issues from documents filed for an amendment application for the Hamlet of Arctic Bay's water license (NWB 3BM-ARC0810). BGC submitted to the Nunavut Water Board (NWB), a review of geotechnical and geothermal documents in a letter report dated September 5, 2008 (BGC, 2008). BGC recommended to the NWB that the water license amendment submission be rejected as the geotechnical assessment was judged to be inadequate; additional analyses and clarification were recommended to confirm the appropriateness of the proposed design.

On November 13, 2008, the NWB notified BGC that the Designers had prepared a letter response (Response) to the intervenors' comments (including BGC) and revised the geothermal design report. BGC has reviewed these documents in conjunction with the original application design documents.

The geotechnical design of the facility was carried out by Trow Associates Inc. (Trow). Naviq Consulting Inc. (NCI) was subcontracted by Trow to conduct geothermal analyses to support the geotechnical design.

This letter has been written to supplement BGC's original review letter dated September 5, 2008.

2.0 SITE DESCRIPTION

BGC asked for clarification on several issues in the original geotechnical investigation report, including:

a) The surficial geology of the proposed wastewater lagoon site was not described and the extent of the ice-rich permafrost foundation was not delineated.

b) The potential impact of taliks beneath an ephemeral stream and existing pond within the proposed wastewater lagoon site has not been fully described.

c) NCI (2008) had commented that the ground temperature measurements from the two borehole locations were divergent; BGC recommended additional ground temperature measurements to further calibrate the geothermal model, particularly given the short installation depths of the thermistor strings.

d) The validity of using climate data from Nanisivik, which is over 500 m higher in elevation than Arctic Bay, for geothermal modeling was questioned.

Items (a) and (c) were not addressed by the Designers.

The Designers provided further information about the ephemeral stream and the existing pond. They acknowledged that a talik will form within the lagoon basin, but containment would be provided by bedrock at the bottom in addition to a large frozen zone all around. In two boreholes drilled along the berm alignments (Boreholes 6 and 12), the top of the bedrock was characterized as poor quality, with Borehole 12 having an RQD of 0% over the upper 2 m of the rock (drilling did not penetrate further into the bedrock, so it is possible that poor quality rock extends deeper into the bedrock). There was no description as to whether or not the fractures were ice-filled. The premise for a permafrost and/or bedrock foundation providing containment is that the bedrock is sound or the pores/fractures are ice-saturated; there is the possibility that the fractured bedrock could act as a conduit for seepage, particularly if thawed. Such a risk has not been specifically addressed by the Designers.

The Designers reviewed climatic normal air temperature data from some eastern Arctic meteorological stations and concluded that mean annual air temperature is controlled more by latitude than by elevation. BGC is of the opinion that there are still some uncertainties regarding the geothermal modeling, which are affected by the climate input, among others. Without further correlation between measured ground temperature data and inferred site climate data, BGC feels that the selected climate data is appropriate for current design, but should be reviewed in conjunction with ground temperature monitoring around the wastewater lagoon.

3.0 GEOTHERMAL ANALYSES

BGC raised several concerns related to Designer's evaluation of the geothermal regime:

a) Discrepancies were found in the geothermal modeling results.

b) No details were provided in the geothermal analysis regarding soil and ground surface input parameters.

c) The potential for thick snow pack developing at the toes of the berms was not addressed.

d) Proposed thermistor strings should extend more than 2 m into the subgrade soils.

e) Additional thermistor strings should also be installed within the liner key trench.

f) The location of the key trench from the toe of the berm as recommended based on NCI's geothermal modeling results differed from that shown on the design drawings.

In response to comments (a) and (b), NCI revised the geothermal analyses and reissued the geothermal design report. In their previous report, the geothermal model calibration appeared to be conservatively based on the warmer of the two measured thermistor strings. In the revised report, the geothermal model was calibrated against the colder of the two measured thermistor strings. There was no specific discussion about the measured ground temperatures, other than they were noted as divergent. BGC notes that the predicted active layer thickness (depth of 0^{o}C isotherm) in Figure 3-3 of NCI's report appears to be approximately 0.3 m, which is less than the range of 0.6 m to 1.7 m reported in Trow's geotechnical investigation report. Therefore, the geothermal model predictions may not be conservative. BGC also notes that in Section 3.1.1 of NCI's report, typical snow cover is reported to be 350 mm. This statement is inconsistent with what was input in the geothermal model, as described in Table 3-2 of NCI's report (approximately 20 cm); the reduced snow cover would result in colder ground temperatures, other climatic inputs being equal.

Issues (c), (d), and (f) were not addressed by the Designers. BGC requests that the Designers explain why the location of the liner key trench differs from that recommended from the geothermal analyses.

The Designers indicated that they are not opposed to the installation of thermistors within the key trench, provided that they are installed in a manner that does not compromise the integrity of the liner. Below is a sketch illustrating how BGC thinks that this could be done. This should be done for each station where there is a vertical thermistor string.

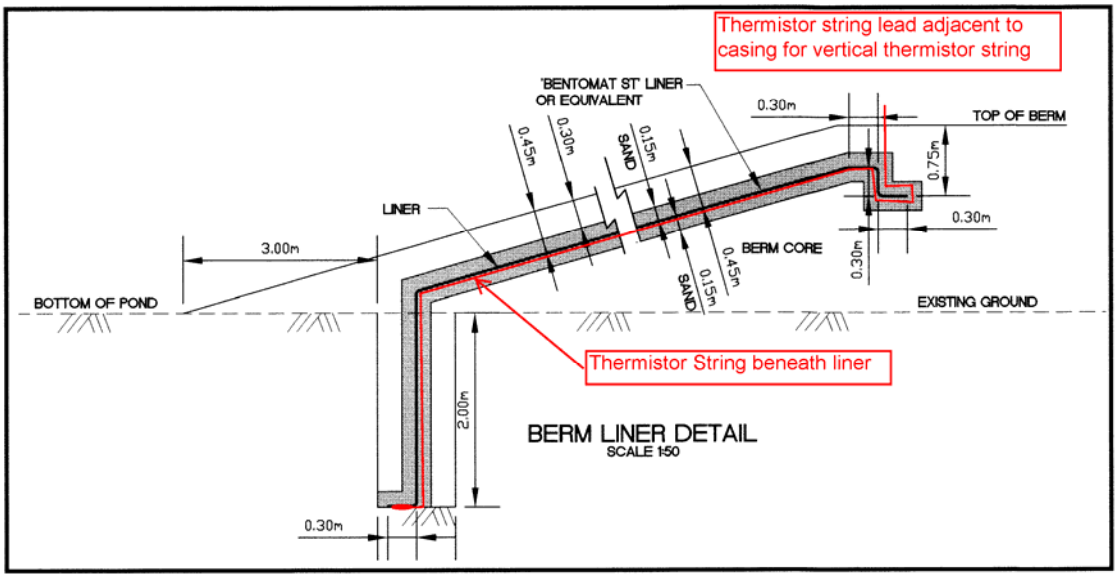

Figure 1. Sketch of Thermistor String in Key Trench Detail (not to scale, meant for illustrative purposes only).

4.0 GEOTECHNICAL ASSESSMENT

BGC reported several missing pieces of information in the Designers' geotechnical investigation report related to the stability analyses, including:

a) Design intent of granular cover over sludge for decommissioning.

b) Derivation of cohesion for the ice layer and testing sensitivity of cohesion value on slope stability.

c) Stability analyses not carried out for the design berm crest width (4 m)

d) Assessment of deformations due to thaw settlement and creep deformation.

e) Implementation of a settlement and displacement monitoring program.

f) Specifications for construction fill materials.

g) Design for keying in liner along side valleys and abutments of lagoon impoundment.

Issue (a) was not addressed in the Response.

The Designers elaborated on the derivation of long-term cohesion of the ice layer and carried out sensitivity slope stability analyses for lower cohesion values for the ice layer. Stability analyses were conducted for the design berm crest width of 4 m and the ground surface was modified to a 1 percent grade instead of being considered horizontal (it is noted that BGC previously made no comment about the ground surface grade). The results of the stability

analyses indicated that these changes did not significantly affect the computed factor of safety. BGC is satisfied that the additional analyses confirmed the expected factor of safety.

The Designers presented detailed thaw settlement calculations, based on thaw strain estimates for silty sand; the calculations ignored settlement due to thawing of ice layers in the permafrost foundation. BGC notes that thaw settlement will be substantially greater at those locations where ice layers were encountered (e.g., Boreholes 5 and 11). Thaw settlements exceeding 0.5 m could arise beneath the upstream toe if these layers ultimately thaw as predicted by NCI. Such displacements could jeopardize liner integrity. The Designers did not address the effects of creep strain.

The Designers have indicated that settlement of the upstream and downstream toes of the berm should be monitored, and that some maintenance of the berms may be required. No details were provided. The proposed instrumentation and monitoring plan should be forwarded to the NWB for review.

The Designers indicated that specifications for the fill material will be provided for review prior to tendering. BGC is satisfied with the Designers' response.

The Designers responded that the proposed liner key trench depth of 2 m is appropriate, as the thermal regime would be monitored. BGC's issue was more with transplanting the key trench liner detail from the berm design to the length of the side valleys without specific analyses. It is BGC's opinion that the 2 m key trench depth should be considered a *minimum* value and will depend on foundation conditions, i.e., it should penetrate into sound rock or ice-saturated mineral soils or rock.

5.0 SUMMARY AND RECOMMENDATIONS

The Designers have responded to BGC's review letter to the NWB dated September 5th, 2008. Many of the issues brought up by BGC were addressed or elaborated in the Designers' Response to BGC letter and/or in the revised geothermal design report. The following lists the issues that BGC previously raised but were not addressed in the Designers' Response:

- The surficial geology of the proposed wastewater lagoon site was not described and the extent of the ice-rich permafrost foundation was not delineated.
- NCI (2008) had commented that the ground temperature measurements from the two borehole locations were divergent; BGC recommended additional ground temperature measurements to further calibrate the geothermal model, particularly given the short installation depths of the thermistor strings.
- The potential warming influence from thick snow pack developing at the toe of the berms was not addressed.

- Proposed thermistor strings should extend more than 2 m into the subgrade soils.
- The location of the key trench liner from the toe of the berm as recommended from NCI's geothermal modeling results differed from that shown on the design drawings.
- The impact of displacements due to thaw settlement and creep strain on liner integrity was inadequately explained.
- The design intent of a granular cover over sludge for the existing wastewater lagoon for decommissioning was not explained.

Of the above issues, the key ones are the location of the key trench liner and the potential impact of berm displacements on liner integrity. BGC's recommends that the location of the liner key trench horizontally from the upstream toe of the berm be as recommended in NCI's geothermal design report. The Designers have indicated that the berms will be monitored and maintained, if required, but have not provided specific details.

Furthermore, BGC recommends that the proposed 2 m penetration depth of the lined key trench be considered a *minimum* and that the construction specifications indicate that it be keyed into sound rock or ice-saturated permafrost mineral soils or rock.

BGC is satisfied that the engineering analyses to date are adequate, but recommends that a detailed instrumentation monitoring and surveillance plan be provided to, and accepted by, the NWB, as part of the water license amendment. This plan should include details of the proposed instrumentation plan, describe frequency of measurements, and identify trigger values or observations for remedial action.

6.0 LIMITATIONS AND CLOSURE

BGC Engineering Inc. (BGC) prepared this letter for the account of the Nunavut Water Board. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of report preparation. Any use which a third party makes of this letter, or any reliance on decisions to be based on it are the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this letter.

Trow are the Engineers of Record for this project and are wholly responsible for the design and performance of the noted project and its components. None of the review comments and recommendations provided herein by BGC absolves Trow of that responsibility and again, BGC accepts no responsibility for any damages suffered by third parties based on the comments provided herein.

As a mutual protection to our client, the public, and ourselves, all reports and drawings are submitted for the confidential information of our client for a specific project. Authorization for any use and/or publication of this report or any data, statements, conclusions or abstracts

from or regarding our reports and drawings, through any form of print or electronic media, including without limitation, posting or reproduction of same on any website, is reserved pending BGC’s written approval. If this report is issued in an electronic format, an original paper copy is on file at BGC Engineering Inc. and that copy is the primary reference with precedence over any electronic copy of the document, or any extracts from our documents published by others.

We trust that the information contained in this letter meets your current requirements. Should you have any questions, please contact BGC at your convenience.

Respectfully submitted,
BGC Engineering Inc.
Per:

Reviewed by:

Original Stamped & Signed by

Jack T.C. Seto, M.Sc., P.Eng.
Senior Geotechnical Engineer

Orignal Stamped & Signed by

Kevin W. Biggar, Ph.D., P.Eng.
Senior Geotechnical/Geoenvironmental Engineer

JTCS/syt

LISTING OF DOCUMENTS REVIEWED

Naviq Consulting Inc., 2008a. Geothermal Analysis of Proposed Sewage Lagoon, Arctic Bay, NU. Report Prepared for Trow Associates Inc., Project J008, April 2008, Revision 1.

Naviq Consulting Inc., 2008b. Geothermal Analysis of Proposed Sewage Lagoon, Arctic Bay, NU. Report Prepared for Trow Associates Inc., Project J008, October 2008, Revision 2.

Rowan Williams Davies & Irwin Inc., 2008. Snowdrift Assessment, Proposed Wastewater Lagoon, Arctic Bay, Nunavut, Final Report. Report submitted to Trow Associates Inc., Project 08-1032A, April 14, 2008.

Trow Associates Inc., 2008a. Geotechnical Investigation, Sewage Lagoon, Hamlet of Arctic Bay, Nunavut. Report prepared for Government of Nunavut, Department of Community and Government Services, Project Management Division – Baffin Region, Project OTGE00019054B, April 24, 2008.

Trow Associates Inc., 2008b. Design Brief, New Sewage Lagoon for the Hamlet of Arctic Bay. Report prepared for Department of Community Government and Services, Government of Nunavut, Project OTCD00019054A, April 2008.

Trow Associates Inc., 2008c. Design Drawings – Arctic Bay Wastewater Lagoon, Project OTCD00019054A, April 25, 2008.

Trow Associates Inc., 2008d. Arctic Bay Sewage Lagoon Decommissioning. Report prepared for Government of Nunavut, Department of Community and Government Services, Project Management Division – Baffin Region, Project OTGE00019054C, April 2008.

Trow Associates Inc., 2008e. Response to BGC Letter of September 5, 2008, Geotechnical Ivestigation, Arctic Bay Sewage Lagoon, Arctic Bay, Nunavut. Letter report to Mr. Bhabesh Roy, CGS Projects – GN, Reference OTCD00019054B, October 27, 2008.

Trow Associates Inc., 2008f. Response to Comments, Arctic Bay Sewage Lagoon, Nunavut. Letter to Mr. Bhabesh Roy, CGS Projects – GN, Reference OTCD00019054A, November 10, 2008.