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Project No: 0308-005-01

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

Dear Sir:

Re: NWB 3BM-CLY0308 CLYDE RIVER 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 Clyde River's water license (NWB 3BM-CLY0308). BGC submitted to the Nunavut Water Board (NWB), a review of geotechnical and geothermal documents in a letter report dated June 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 August 8, 2008, the NWB notified BGC that the Designers had prepared a letter response (Response) to the intervenors' comments (including BGC) and revised the geotechnical investigation 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 June 5, 2008.

2.0 GEOTECHNICAL SITE INVESTIGATION

BGC pointed out a number of deficiencies in the original geotechnical investigation report, including:

a) Inconsistencies between measured moisture contents and soil descriptions

b) Lack of pore water salinity measurements

c) No distinction between natural and fill materials in boreholes drilled through existing lagoon embankment in borehole logs

d) No description of local surficial geology

e) No boreholes drilled west of existing lagoon

f) Limited value of subsurface information of borehole logs given shallow borehole penetration depths

g) Lack of information describing geotechnical design of existing facility

The Designer's revised geotechnical investigation report and Response letter addresses and clarifies many of these issues. However, BGC believes the Designer still misunderstands two issues, (b) and (f):

- Pore water salinity: BGC maintains that high pore water salinities can be expected within the permafrost soils, as was encountered at the Quluak School (Nixon, 1988); BGC stated that lower salinities can be expected *within the active layer*. The Designers applied conservatism in salinity values for geothermal analyses, but not for slope stability analyses.
- Shallow borehole penetration depths: BGC concurs with the Designers that sampling frozen soils and rock in remote arctic sites is challenging, particularly for small municipal projects. The fact remains that one borehole, BH-6, encountered ice up to over 5 m depth, although this ice layer was not intercepted in any of the remaining boreholes. Secondly, the Designer's comment that "the ice content in the soil generally decreases with depth" cannot be wholly supported because only this one borehole encountered massive ice and there may be areas beneath the lagoon that have even thicker layers of ice. A better characterization of the local surficial geology (issue d) may improve the delineation of the ice-rich areas; although the Designers reported in their Response letter that they discussed the surficial geology in the revised geotechnical report, BGC found no such descriptions.

BGC has reviewed the geotechnical investigation report for the existing lagoon (Thurber, 1991). As the Designers reported, Thurber's investigation was based on four shallow test pits and the recommended berm design configuration was based on experience from other arctic sites rather than site-specific detailed analyses. Thurber's report does contain some useful information, which will be described in more detail in the following section.

3.0 GEOTHERMAL REGIME

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

a) Predicted active layer of 0.5 m from geothermal modeling was less than what was observed

b) Proposed thermistor depth penetrating 2 m below containment berm was considered too shallow for monitoring purposes

c) Cost of installing thermosyphons as a rehabilitation measure was not fully addressed

d) Use of permeable soils as embankment fill material does not fully explain observed seepage through existing lagoon berm

e) Initial ground temperatures may be warmer than assumed in geothermal model

f) No details were provided regarding soil and ground surface input parameters used in geothermal modeling

g) No geothermal analysis was performed for rehabilitation of the existing lagoon, including the inner berm.

The Designers believe that an active layer of 0.5 m is appropriate in undisturbed terrain at this latitude. BGC concurs that active layer thicknesses can be variable, depending on moisture content, organic cover, and summer climate, among other factors. However, Thurber (1991) indicated that the four test pits were excavated to the top of the permafrost, to depths of 0.8 m to 1.1 m. This reinforces BGC's position that the predicted active layer thickness of 0.5 m is not conservative.

The Designers have indicated that the thermistor casings will extend to a depth of 5 m below the base of the berm. BGC is satisfied that extending the thermistor casing to at least this depth will provide much more useful data for monitoring the geothermal performance of the containment berms than the originally-planned 2 m. The design of the facility is based on the premise that the liner and permafrost foundation are impermeable barriers to seepage and that the liner will be keyed into permafrost. Therefore, it is recommended that additional thermistors be installed within the liner key trench to confirm that the liner is keyed into frozen soils.

BGC had not stated that installing thermosyphons as part of initial construction is preferred. BGC simply pointed out that installing thermosyphons as a remediation measure can be substantial, especially if required around the entire lagoon perimeter, because thermosyphons are better suited at maintaining permafrost foundations frozen rather than refreezing thawed materials.

The Designers have revised their explanation for the problem of seepage through the existing lagoon berm as a combination of using permeable soils for berm construction, potentially poor compaction practices, and slope aspect. This is a more plausible

explanation than what was described in the original geotechnical investigation report, where the use of permeable soils for construction was the sole reason cited.

Issues (e) and (f) above were not addressed by the Designers.

The Designers suggest that the results of the geothermal modeling for the proposed new lagoon berm could be extrapolated to the rehabilitation of the existing berm. BGC strongly disagrees with this approach and recommends that specific geothermal analyses be conducted for this case because, as outlined in BGC's review letter, the permafrost foundation in the vicinity of the existing lagoon berm has been strongly affected (i.e., become warmer) by the lagoon, a condition which the Designers already acknowledge ("Construction of the lagoon has resulted in degradation of the permafrost and thawing of the underlying ice rich soils…"). Re-freezing of the rehabilitated berm and permafrost foundation is not only influenced by climatic conditions but also by the thermal regime of the permafrost foundation. As such, geothermal analyses of the rehabilitated berm will tell two things: i) if the berm and permafrost foundation will re-freeze to the design thermal "dynamic steady-state" within the required time frame following berm rehabilitation (or require artificial cooling), and ii) if the location and burial depth of the vertical portion of the liner keyed into the permafrost foundation remains appropriate. It is also recommended that specific geothermal analyses be carried out to confirm that the proposed design of the inner berm is appropriate.

4.0 SLOPE STABILITY

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

a) Location of analyzed cross-section AA
b) Derivation and representativeness of design stratigraphic section for stability analyses
c) Derivation of cohesion for the ice layer
d) Details related to the design peak ground acceleration
e) Disconnect between geothermal and geotechnical analyses
f) Assessment of potential thaw settlement on liner integrity
g) Stability analyses not carried out for the design berm crest width (4 m)
h) Rapid drawdown analyses were performed, yet the conclusions of the analyses were not considered in the final design configuration

Issue (a) was not addressed in the Response or revised geotechnical report.

The Designers contend that the design stratigraphic section used in stability analyses is conservative. BGC disagrees. As shown in the Designer's stability analyses results, slope stability is strongly influenced by the depth of the upper ice layer. The design upstream slip

surface penetrates approximately 2 m into the surficial silty sand layer while the design downstream slip surface appears to be in contact with the interface between the surficial silty sand layer and the upper ice layer. The Designer's initial stratigraphic section (Trow, 2008a) had the surficial silty sand layer varying in thickness from approximately 1 m below the downstream berm toe and 3 m below the upstream berm toe, and becoming even thicker further upstream. The revised stratigraphic section showed the surficial silty sand layer as uniformly approximately 3 m thick. In Borehole BH-6, which shows the ice layer, the top of the upper ice layer is at a depth of 1.7 m below ground surface. Furthermore, Thurber (1991) reported that excess ground ice was encountered at the top of the permafrost in the four test pits excavated, ranging in depths from 0.8 m to 1.1 m. The basis for deriving the design stratigraphic section should be described.

The Designers have argued that the ice layers are likely low-saline "freshwater" ice as a result of salt extrusion during the freezing process. While this fact is debatable (e.g., sea ice), the Designers still have not explained how they derived the cohesion values of 100 to 125 kPa for the ice layers, and whether or not these values are consistent with the results of the geothermal modeling.

The Designers described how they derived the peak ground acceleration in the Response. BGC appreciates that this has been clarified and would suggest that this be included in the geotechnical investigation report.

The Designers elaborated on the anticipated response of the berm liner to thaw settlement in their Response. The Designers did not address the effects of creep strain.

The Designers conducted stability analyses comparing the effects of the berm crest width and showed practically no difference in the computed factor of safety between a 4 m crest width and 5 m crest width. BGC is satisfied that the analyses confirmed the expected factor of safety.

The Designers explained that the rapid drawdown analyses were conducted when unlined berms were originally envisioned and because liners are now being proposed, the berm would not be subjected to the rapid drawdown condition. Given the proposed rate of decanting at the end of each year (approximately 0.1 m/day) and the proposed use of silty sand as berm fill materials (as assumed in the stability analyses), excess pore pressures may remain in the fill materials upstream of the liner during decanting.

The Designers have indicated that a settlement monitoring program will be carried out. BGC is satisfied that this has been recommended. The proposed instrumentation and monitoring plan should be forwarded to the NWB for review.

5.0 SUMMARY AND RECOMMENDATIONS

The Designers have responded to BGC's review letter to the NWB dated June 5th, 2008. Most of the issues brought up by BGC were addressed or elaborated in the Designers' Response to Comments letter and/or in the revised geotechnical investigation report. BGC remains in disagreement with the Designers over two main issues:

- the appropriateness of extrapolating the results of the geothermal analyses for the new lagoon to the rehabilitation of the existing berm. It is BGC's opinion that the warmer subgrade soils beneath the existing containment berms will retard natural re-freezing of the containment berm and permafrost foundation to the design thermal "dynamic steady-state" predicted for the newly-constructed berm. This could affect the timing for when the lagoon is able to provide effluent containment as well as the design of how and where the liner should be anchored to the permafrost foundation.
- As the stability of the containment berm is partly governed by the assigned strength and depth to the upper ice layer, the revised design stratigraphic section used in stability analyses is not considered conservative. The Designers have not elaborated how the strength of the ice layer was derived, nor if the assigned strength were consistent with the geothermal modeling predictions. Furthermore, the site investigations of 1991 and 2007 have reported depths to the upper ice layer shallower than assumed (approximately 3 m depth).

On the basis of these outstanding design issues, BGC still considers the Trow submission for the water license amendment of the Clyde River sewage lagoon inadequate and recommends further geotechnical and geothermal assessments to confirm the suitability of the proposed design.

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:

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LISTING OF DOCUMENTS REVIEWED

Thurber Engineering Ltd., 1991. Clyde River Sewage Lagoon Geotechnical Investigation. Report submitted to the Government of the Northwest Territories, Municipal and Community Affairs, File 15-23-47, October 18, 1991.

Trow Associates Inc., 2008a. Geotechnical Investigation, Proposed Sewage Lagoon, Hamlet of Clyde River, Nunavut. Report prepared for Mr. Richard Caronnier, CGS Projects – GN, Project OTGE00019055B, January 16, 2008.

Trow Associates Inc., 2008b. Design Brief, New Sewage Lagoon and Rehabilitation of Existing Sewage Lagoon for the Hamlet of Clyde River. Report prepared for Department of Community Government and Services, Government of Nunavut, Project OTCD00019055A, February 2008.

Trow Associates Inc., 2008c. Construction Drawings – GN, Project OTCD00019055A, February 22, 2008.

Trow Associates Inc., 2008d. Geotechnical Investigation, Proposed Sewage Lagoon, Hamlet of Clyde River, Nunavut. Revised Report prepared for CGS Projects – GN, Project OTGE00019055B, August 6, 2008.

Trow Associates Inc., 2008e. Response to Comments, Clyde River Sewage Lagoon, Nunavut. Letter report submitted to Mr. Bhabesh Roy, CGS Projects – GN, Project OTCD00019055A, August 5, 2008.

Naviq Consulting Inc., 2008. Geothermal Analysis of Proposed Sewage Lagoon, Clyde River, NU. Report Prepared for Trow Associates Inc., Project J008, February 2008.

Nixon, J.F., 1988. Pile load tests in saline permafrost, Clyde River Northwest Territories, Canadian Geotechnical Journal, 25(1), pp. 24-32.