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MEMORANDUM

To:	**Nunavut Water Board**	**Fax No.:**	**Via email**
Attention:	**Dionne Filiatrault, P.Eng., Acting Executive Director**	**CC:**	**D. Hohnstein**
From:	**Holger Hartmaier, P.Eng.**	**Date:**	**January 17, 2008**
Subject:	**Executive Summary- Cape Dorset Sewage Lagoon, Review of Final Submissions**		
No. of Pages (including this page): 7		**Project No:**	**0308-003-03-01**

1.0 SCOPE OF WORK

BGC was requested by the NWB to review the following information posted on the NWB ftp site on November 13, 2007 by the Government of Nunavut Department of Community and Government Services (GNCGS), the proponent of the Cape Dorset Sewage Lagoon:

- The record (as-built) drawings of the construction.
- The Operation and Maintenance (O&M) Manual for the operation of the lagoon, prepared by Dillon Consulting Limited (Dillon), dated November 9, 2007.
- Memorandum Re: Additional Stability and Seepage Analysis for P-Lake Sewage Lagoon, Cape Dorset, NU, prepared by AMEC Earth and Environmental, a Division of AMEC Americas Limited (AMEC), dated November 15, 2007.
- Letter from GNCGS with table summarizing GNCGS's response to the list of specific geotechnical items requested by BGC, dated November 13, 2007.

Upon receipt of this documentation, BGC noted that the as-built detail of the berm differed significantly from the design drawings, as well as the details used in the geothermal model. The main differences are the configuration of the GCL within the berm, the cut-off trench excavation and the cut-off trench backfill. These discrepancies, in addition to other technical issues raised by BGC in previous reviews resulted in a recommendation by BGC to conduct an independent geothermal analysis of the berm as part of this review. Board representatives (D. Hohnstein, December 19, 2007) agreed that this additional work would be worthwhile and should be included in BGC's budget.

The purpose of the independent analysis was to satisfy the following objectives:

- To support BGC's intervention statement; -specifically to back up any comments or critique of AMEC's geothermal modeling to-date.
- To provide the Board with an independent assessment and improve the level of confidence that the permafrost conditions in the as-built liner, berm, foundation and lagoon configuration will provide the necessary water retention of lagoon contents, such that waste water treatment objectives are met.
- To identify sensitive or critical parameters/issues that must be addressed either by additional investigations, monitoring, engineering or construction (remediation) on the part of the proponent.
- To provide technical guidance for drafting the terms and conditions of the water licence to address the above identified issues.

In summary, therefore, the overall scope of work for the technical support of the NWB for the January 23-24 Public Hearing included the following tasks:

- Task 1: Review of documentation received by NWB on November 15, 2007 and provide a final intervention statement no later than January 8, 2008.
- Task 2: Conduct an independent geothermal analysis of the lagoon based on the as-built drawing details to support this intervention and subsequent Board decisions.
- Task 3: Attend the Public Hearing in Cape Dorset on January 23-24, 2008.

2.0 SUMMARY OF KEY COMMENTS

As- Built Drawings:

- The as-built drawings require a stamp by AMEC as the engineer responsible (Engineer of Record) for the geotechnical discipline.
- In general, there was no identification shown on the drawings indicating where field changes were made from the construction drawings. Normally these would be highlighted in some way, such as a revision "bubble", as well as a brief note in the revisions section of the title block.
- In Record Drawing 100, major revisions were made with respect to the alignment of the access roads on both side of the lagoon between the East and West Berms compared to Design Drawing 100. Also, the configuration of the West Berm at the north abutment has been altered from the original design. Further clarification on this is requested from Dillon, as noted under the comments for Drawing 109.
- Drawing 109 shows up to 1 m of unfrozen fill used to level the ground surface under both berms. There are no details provided on the drawings as to what this material is actually composed of.

- On Drawing 109, the berm contours at the north abutment of the West Berm include a widened crest (from 4 m to about 25 m) for a turnaround area on the downstream side. On the upstream side, there are two significant gullies or ditches indicated by the contours and it is not clear what this represents. BGC requests that the proponent provide additional cross sections and longitudinal sections of this area to clarify as- built conditions. The concern is that there may be insufficient fill thickness in this area to ensure that the GCL tie-in to the cut-off trench remains frozen.
- Record Drawing 110 shows typical road sections. On July 30, 2007, GNCGS provided a revised ditch detail for the road which does not seem to be included in as-built details on this Drawing. The Hamlet of Cape Dorset noted a problem with seepage into the lagoon through the active zone with the as-constructed detail in the October 1, 2007 Technical Pre-Hearing. Dillon is requested to provide further clarification on how this issue is being resolved.
- In Record drawing 112 the configuration of the GCL (geosynthetic clay liner) is different from the original design where the liner was placed on top of the original ground surface under the berm, upstream of the cut-off trench. The concern with the as-built configuration is that the saturated zone upstream of the liner is closer to the cut-off trench.
- Record Drawing 112 indicates that the material used to backfill the cut-off trench is a "Sand", the same material as used for the berm. At the October 1, 2007 technical pre-hearing, Hamlet representatives noted that water was observed to be seeping out of the downstream toe of the dam. Since the berm was constructed during the summer, on top of the thawed active zone, the berm foundation has not yet had a chance to freeze back. As a result, the water within the lagoon can seep under the berm, through the active zone, around the GCL through the sand backfill in the cut-off trench and through the thawed active zone under the downstream toe of the berm. As a result, the lagoon will not be useable until after the winter of 2007-08 at the earliest, when the foundation has had a chance to freeze back.
- It is important to note that AMEC's original design recommendation (October 13, 2005) was to backfill the cut-off trench with "compacted clayey material or grouted". This requirement was never reflected in the previous construction drawings issued by Dillon to date, and has been raised as a design issue by BGC in previous reviews. The modification requires the lagoon to remain dormant over the first winter season so that the foundation can freeze back. This conflicts with the original intended commissioning of the lagoon in October. Thermistors are therefore required to validate the freeze back as a licence condition.

- In Record Drawing 112, the as-built liner embedment details for the abutment areas of the East and West Berms are requested. The cut-off trench must extend sufficient distance into the abutment so that any "end-run" seepage through the active zone is prevented. It is not clear from the as-built information if the extent of the cut-off trench satisfies this criterion.
- Also in Record Drawing 112, the crest detail of the emergency overflow weir section was changed. This change notice was transmitted to the contractor by Dillon on July 21, 2007. The as-built detail now shows the geo-web and the GCL in one layer, with no granular or other material between the two. Dillon initiated this modification to address a previous concern raised by BGC that water could seep under the GCL in the emergency spillway and potentially lift the liner. It is still not clear how the above modification prevents this problem from occurring.

3.0 OPERATION AND MAINTENANCE MANUAL

- BGC recommends that the Board include a condition in the water licence requiring prior approval by the Board for any change in the lagoon waste water storage and decanting operations. This notification should trigger a geotechnical and geothermal review to assess the implications of year round water storage on permafrost conditions under the lagoon.
- Section 3.4.6 of the Operation and Maintenance Manual for the lagoon describes geothermal monitoring, but does not provide the number, locations, depths or bead locations of the thermistors that are proposed. Further details should be provided as a licence condition.
- Section 3.4.7 describes Geotechnical Reviews, but does not mention dam safety inspections. Inspections should be carried out more frequently than Dam Safety reviews. As a minimum, the lagoon should be subject to an annual inspection by a qualified geotechnical engineer. The O&M manual should also require operators to conduct a visual inspection of the berms whenever they are visiting the lagoon and record any observations in a log book that can be reviewed during the annual inspection. It is noted that weekly inspections of berms, dikes and drainage courses were recommended in Table 6 of the O&M manual. This is considered an adequate minimum frequency, similar to typical licence requirements for mining operations. It is recommended that these requirements be included as conditions in the water licence. The annual geotechnical inspection should be added under the "Yearly" frequency in Table 6.

4.0 STABILITY AND SEEPAGE ANALYSES

- Observations of the active zone in the cut-off trench were carried out by AMEC between July 2 and July 12, 2007. A 1 m thick working pad was placed over the natural ground surface, but depths were measured relative to the natural ground surface. Hard frozen soil was typically observed from about 1.5 m depth. This would suggest that the active layer (deepest in early October) is likely on the order of 2.0 to 2.5 m. AMEC should have commented on whether their geothermal model agreed with the active layer observations. In AMEC's August 21, 2007 geotechnical report that reviews the geothermal analysis, no mention is made of the assumed active layer thickness or of any calibration of the geothermal model to replicate these site conditions. Note that in bedrock areas, the depth of the active zone is typically much greater than in soil, say in the order of 3 to 4 metres deep.
- AMEC assumed that the native silt and clay and frozen soil were impermeable material, having low values of hydraulic conductivity. This assumption may be true for the ice-saturated frozen material, below the active zone. However, for the active zone materials, which have been disturbed by freeze-thaw cycles this is not the case, nor has it been substantiated by site observations. Hamlet officials reported water seeping into the sides of the lagoon under the roadways and exiting the lagoon under the berm at the completion of construction in August, 2007. Therefore it is clear that the GCL by itself is not an effective water barrier. Freezing of the foundation and the berm will be necessary to form an effective barrier to seepage. This major design criterion must be confirmed with thermistor readings.
- The major concern from a licensing perspective, is the water retention capability of the lagoon. Since the base of the lagoon is unlined, there is nothing preventing seepage losses (or gains) through the active zone along the sides and bottom of the lagoon. As noted above, it is also not clear from the record drawings if the cut-off trench extends far enough into each of the abutments to prevent end run seepage out of the lagoon through the active zone. The extent of the cut-off must also take into account global warming effects over the design life of the structure, which has not been included in the current geothermal analysis done by AMEC.
- The modelled cross sections used in the seepage and stability analyses do not realistically represent the as-built configuration of the liner. The modelled case assumes a vertical liner in the centre of the berm, that ties into a core of frozen soil. The as-built detail indicates that the GCL is inclined at 45° from the horizontal within the upstream shell.
- The active zone in the berm was assumed by AMEC to be 2 to 3 m deep. This appears low considering that the berm is composed of granular material, which was placed during the summer in a relatively dry and drained state.

- From a seepage analysis perspective, the differences between the modelled and actual liner configuration are not considered significant. From a stability perspective however, it seems that having the GCL as a low shear strength element that is oriented at the as-built slope of 45° would have a greater effect in reducing the factor of safety of the upstream slope, than the vertical liner. With the modelled case, the slip circle lies essentially within the granular berm material of the upstream slope. If the failure path was modelled along the inclined low strength GCL, a lower factor of safety for the upstream slope is expected. It is recommended that the stability analyses for the 1 and 2 m head difference for the rapid drawdown case include this assessment to demonstrate the stability of the upstream slope based on the as-built detail. BGC recommends that AMEC validate the stability of the upstream slope with the revised liner configuration for all expected stability cases in agreement with Factors of Safety recommended by the Canadian Dam Association (CDA).

5.0 CONCLUSIONS

- Based on field performance, the GCL on its own is not an effective seepage barrier. A GCL with overlapped sheets is an imperfect liner typically used for secondary containment. Freezing of the foundation is required to create an impermeable barrier to seepage under the berm. Within the berm itself, the upper 2-3 m is assumed to be within the seasonal active zone. In this area, the GCL has to act as the primary water retention barrier. It remains to be seen how effective this barrier is, since the lagoon has not yet been impounded.
- In general, the seepage analyses have indicated that there are no significant adverse effects on stability. The downstream slope however has slightly less than the required factor of safety for the conservative case of full seepage, assuming no liner is present. The effectiveness of the liner under full lagoon conditions remains to be confirmed, especially for seepage through the active zone in the berm as noted above.
- The upstream slope stability should be re-checked with an inclined, low shear strength element, representative of as-built conditions. It is expected that lower factors of safety than presented in the current analysis will result.
- AMEC has outlined potential mitigation strategies that could be implemented should factors of safety for the berm slopes not meet the required design criteria, including:
  - Additional drainage provisions,
  - Construction of support berms,
  - Modified operational procedures.

  Further details should be provided by AMEC regarding the event/trigger level when these contingency measures should be implemented. These details should be included in the O&M manual, as well as in water licence conditions.

6.0 PRELIMINARY RESULTS OF INDEPENDENT GEOTHERMAL ANALYSIS

Some initial conclusions based on the analytical assessment done to date by BGC, include:

- Assuming that the lagoon is filled after the first winter, the GCL liner is expected to freeze into the bedrock and seepage through the berm (mainly through the silt layer in the foundation) will not occur. Convection will only partially thaw the upstream side of the berm.
- A talik will not develop under the base of the lagoon.
- It may be difficult to thaw the water in the lagoon. When modelling the 0.45 m increments of filling, they freeze quite fast. The warm summer months might be too short to thaw the whole pond due to gravity driven natural convection. Even with high n-factors, the bottom of the pond stayed frozen which might cause new problems in terms of sewage management.
- Where the liner is embedded in bedrock, the active layer is much thicker than the depth of the core trench. If the bedrock is fractured, there may be a problem with seepage, unless there is sufficient cover provided to ensure permafrost aggradation. Additional modeling is still underway to assess this case. Confirmation that the GCL is keyed into permafrost should be carried out before filling the lagoon.
- It is critical to have thermistors installed in the berm to confirm that freeze-back has occurred within the foundation and the berm. Temperature data must be collected and reported in the annual inspection reports. BGC recommends that three deep (20-25 m) thermistors be installed from the berm crest as a licence requirement.