Report on responses to questions from the Nunavut Water Board
in regards to the Water Reservoir, Sewage Lagoon and Landfill
Improvements for the Municipality of Qikiqtarjuaq, Nunavut

February, 2007

1.0 Introduction

Upon completion of the Detailed Design Report, the GN submitted the documentation regarding the improvements to the municipal services to the NWB for licencing.

Comments regarding the submission were provided and are attached for reference. This report provides responses to the comments, which have been prepared by Nuna Burnside and AMEC Earth and Environmental.

Water Use and Understanding of Waste

i. *Has the Proponent undertaken an assessment of the water supply and its capacity to meet the demands of the Hamlet? For the next five years and the next 20 years?*

Currently, the Municipality takes a very small portion of the available capacity of the Tulugak River. The river is fed from snowmelt and runs for the summer months. Based on historical records the current taking is approximately 22,400 m^3. Based on the 20-year population projections, this will increase to 37,500 m^3 over the next 20 years. Based on the site review, capacity is not considered to be an issue.

ii. *The Proponent shall provide further details in the O&M plan on how the chemical and biological composition of the sludge will be determined and where the sludge will be stored, treated and eventually disposed of.*

The Proponent has access to an existing land farm facility to the south of the community. Sludge from the lagoon will be transported to the land farm and allowed to go through a natural dewatering process. Sludge samples will be submitted to an accredited laboratory for analysis to determine when the sludge can be used either for cover material at the landfill site or spread on the tundra. The community plan showing the location of these facilities is attached. The O&M plan will be updated accordingly.

iii. The Proponent shall provide the references for the assumptions in Tables 4 and 5.

A compendium of References is provided in Section 8 of the Detailed Design Report. The assumptions in Tables 4 and 5 were developed from these references.

iv. The Proponent shall provide the NWB with further information on the wetland treatment area, as it is an integral part of the facilities and required to meet the proposed effluent criteria and the provisions of Section 36 (3) of the Fisheries Act. The NWB requests further site specific description of the wetland, the processes involved within the wetland to achieve treatment, the limitations of the model used to predict the size of the wetland and how the Proponent will ensure that adjacent water bodies are not impacted by this treatment system.

The wetland is a gently sloping area downstream of the lagoon. Vegetation consists of mosses and grasses native to the area. The processes consist of uptake by the vegetation, dilution from runoff and melting permafrost, natural biological processes resulting from aeration of the effluent and sunlight during the summer months.

The Proponent will be monitoring the effluent quality during discharge and the quality of the water leaving the wetland treatment area, as per the requirements of the NWB, to confirm that the requirements of the license are being met.

Should annual monitoring indicate a potential issue, it is anticipated that the Proponent will be required to take additional steps as required by the license to ensure that the adjacent water bodies are not impacted.

The minimum wetland area required was calculated based on the area required to reduce the Total Phosphorus from 15.8 to 1.0 mg/l. This was shown to require 22 ha of wetland area. Based on the wetland model and the more stringent guidelines that may be implemented, the area is considerably larger than what would be required to meet the current guidelines and licencing limits.

v. The NWB requests further clarification on when the wetland will be capable of treating the effluent to meet the proposed effluent criteria in Table 8? Also what will be the estimated effluent qualities from years 0-5? 5-10? 10-15? 15-20?

The wetland in its current state is expected to provide the necessary treatment to meet the effluent quality for the existing flow. The wetland will continue to develop as the population and flow increase over the next 20 years, therefore providing the treatment necessary to meet the quality objectives for that period. The estimated effluent qualities for the next 20 years are estimated to be less than the current NWB Licence Limits as indicated in Table 8 of the Detailed Design Report.

vi. *Prior to developing the former landfill site for bulky waste disposal, the Proponent shall submit to the Board a plan to close the site that estimates the volume and depth of the wastes currently at the site and provides a plan to manage those wastes to reduce their impact on receiving waters.*

It is our understanding based on conversations with the Proponent that the former landfill site was located in close proximity to the water's edge immediately north of the community. The reference to the current Bulky Metals Disposal Area being a former landfill site needs to be verified with the Proponent. The existing Bulky Metals Disposal Area is currently being used for this purpose and the site review and evaluation recommends that it continue to be used for this purpose. If this area was used previously as a landfill, there was no evidence of this at the time of the site visit. The exposed refuse, at the time of the site visit, was bulky waste.

As indicated above, if there is any waste located at this site it has been capped and there was no evidence of exposed waste. This site is adjacent to the current landfill site and would be considered to be a natural attenuation site. Monitoring of both sites could be accomplished through the continuation of the proposed NWB monitoring program.

vii. *The Proponent shall confirm that the granular material used for construction of the perimeter berms shall be free of contamination.*

Testing shall be completed during the construction of the berms to ensure that the material is free of contamination.

viii. *The Proponent shall provide further information on the probability of a 100 mm storm event or snow runoff and the probability that the water retention area may overtop during the design life.*

The existing Qikiqtarjuaq landfill was evaluated in the summer of 2005. Site staff indicated the existing retention area never had to be drained and never retained water for any appreciable length of time. There was no evidence of sediment in the bottom, indicating it was filling in, and no evidence of erosion of the berms from being over topped.

The Qikiqtarjuaq landfill site is designed as a natural attenuation landfill. This means that the site is not lined and that there is the expectation that landfill derived contaminants will leach from the waste, and be mobilized in the seasonally active subsurface and migrate with the shallow groundwater away from the site. The direction of movement would be downhill towards the ocean through the same area used by the adjacent sewage lagoon as a wetland treatment area.

The typical quality of landfill leachate from small municipal landfills is usually elevated in such things as inorganic ions, metals, nitrogen species, dissolved organic carbon, and small quantities of hydrocarbons. Natural attenuation processes will reduce the environmental impact of these compounds through dilution, dispersion, and for some components breakdown by inorganic and microbial processes in the natural environment.

Landfill site impacts are expected to be reduced to non-detectable levels within a contaminant attenuation zone (CAZ). In the case of the Qikiqtarjuaq landfill, the CAZ extends approximately 1.0 km before reaching the nearest sensitive receptor (the ocean). Prior to reaching the ocean, some near surface groundwater may enter the surface water regime via base flow into the meandering creek system, also fed by the sewage lagoon discharge. Attenuation also occurs in the surface water environment.

The natural attenuation design for the Qikiqtarjuaq landfill is based on the current lack of impacts, the relatively low rate of filling, the seasonal limitations to groundwater and surface water flow, and the depth of the active layer (1.5 to 2.0 m maximum).

As the site fills, the permafrost will gradually entomb the deeper parts of the waste. In this way, only a limited amount of waste is even available to be leached, which is the depth of the active zone.

When rain falls on the site, it infiltrates the waste (when thawed) and generates leachate, which can seep out of the site via the seasonally active zone. This is diluted and attenuated in the down gradient CAZ.

In the case of a storm event, surface runoff over the exposed waste will mobilize some contaminants. The storm water retention pond has been sized to retain 780 m^3 of runoff from the site. The average annual rainfall received at Qikiqtarjuaq is 39 mm. Over the entire landfill (14,000 m^2) and retention pond (900 m^2) footprint, this is equivalent to 580 m^3 of water, which can be contained within the retention pond. Any water that is retained will infiltrate into the active zone and enter the CAZ and/or evaporate in place.
If the landfill is being operated according to the design there will be only a small area of exposed waste on the site. Surface run-off over the waste would generate impacted surface water; however, this will be diluted by the run-off from the majority of the site where there is no exposed waste to impact the surface water. This is typical for waste disposal sites designed based on natural attenuation and dilution of runoff and infiltration.

During spring run-off, the snow sitting on the landfill and in the storm water retention pond will melt prior to surface thawing. This creates overland flow across the tundra. The vast majority of the snow will not come into contact with exposed waste. At the time of run-off, the exposed waste will be mainly frozen and not conducive to leaching. Due to the volume of run-off that is not impacted and the low susceptibility of the frozen waste to be leached by surface flow, it is unlikely that spring run-off into the storm water retention pond will be significantly impacted. The dilution rate between impacted and non-impacted surface run-off is expected to result in no significant impacts to the water in the retention pond. The total snow volume that could melt from the site and enter the retention pond exceeds the capacity of the pond, which could result in a controlled discharge to the CAZ. The flow will be diluted and not cause a significant impact to the environment. The overland flow across the CAZ at this time will also provide an additional dilution factor.

Site staff indicated that they had not observed the pond to ever overflow, suggesting snow melting occurs at a rate, which does not cause the existing pond to fill and overtop.

The option to install a liner in the landfill was reviewed. It was not selected for this site because a liner would act to retain all water that entered the site. The water, whether it infiltrated waste and generated leachate, or flowed across waste and generated impacted surface water or infiltrated in non-waste areas or flowed across non-waste areas, would have to be contained and controlled. This would add significant operational issues to the site. The water would have to be controlled, tested, and pumped or drained from the site regularly.

If any water exceeded the discharge criteria, it would have to be treated prior to discharge. A lined site tends to act as a "bath tub", and by retaining water, accelerate the leaching of the waste. This usually results in the need for leachate collection, control, and treatment. Other than putting the leachate in the sewage lagoon for several months before discharging it to the surface environment, there is no practical leachate treatment option for the community. Based on this rationale, Nuna Burnside believes the design of the unlined landfill and the use of a contaminant attenuation zone in the same area as the sewage, wetland treatment system, is the most practical solution for Qikiqtarjuaq.

ix. The Proponent shall provide the NWB a discussion on monitoring the waste disposal facilities that shall include proposed monitoring.

The current license requires annual sampling from two locations in a drainage ditch that bisects the site; one upstream of the solid waste facility and one downstream. Since the existing facilities are to continue to be used to meet the 30 year requirements for the community, it is recommended that this program continue to monitor landfill impacts on the active zone down gradient of the landfill site.

The NWB may wish to include landfill leachate indicator parameters as part of the sewage wetland treatment system sampling that would provide monitoring of landfill impacts to the surface water regime.

x. *In the drawings submitted for the application, the following drawings requested in the supplementary questionnaire were not included: fuel and chemical storage for the community, traditional use and recreational areas, outline of the drainage basin for the water use and waste disposal facilities.*

Fuel storage and chemical storage at the Truck Fill Station is shown on the tender drawings. The GN has indicated that they will be providing the drawings requested in the supplementary questionnaire to the NWB.

xi. *The NWB recommends that the Proponent should review the comments provided by the GN-DOE.*

The Proponent has reviewed the comments provided by the GN-DOE. The proposed design of the upgrades to the municipal infrastructure has been completed in accordance with applicable GN-DOE regulations and guidelines.

Geotechnical Issues

xii(a) The optimum density and water content of construction materials were not tested on the construction soils.

i. *Why was this not completed during the site geotechnical assessment in additional to completing a sieve analysis?*

See xii (a) – ii below.

ii. *Does the proponent agree that optimum water content and density are important design parameters to engineer and construct a stable structure?*

The proponent agrees that the optimum water content and density are important parameters for the design and construction of a stable structure. The relationship between moisture content and soil dry density is established based on results of the Proctor Test. For the sand and gravel, proposed for the reservoir berm, the maximum dry density can be achieved within a relatively wide interval of moisture content (±2 to 3 percent of optimum moisture content). This moisture content is typically observed in stockpiled and drained sand-gravel mixtures. Depending on the composition of the fill material, the density of well-compacted sand-gravel material is generally between 19 kN/m^3 and 21 kN/m^3. The compaction level is expected to be tested (checked) during berm construction. It is expected that the sand cone method or equivalent method will be used together with proof rolling of the compacted lifts by a heavy loaded truck.

The density of the fill has an impact on slope stability and on the thickness of the active layer at the berm crest and downstream slope. In general, the factor of safety for slope stability slightly decreases with increasing soil density. However, the impact would be minor. The influence of soil density on the stability of the berm material is presented in xiii (a). The impact of the fill density on the thickness of the active layer is also insignificant, about 15 percent within the expected moisture content of the fill.

xii(b) *Drawing #10 within Engineering Drawings document depicts a typical cross-section of the lagoon berm with a caption that states that the berm material will be "placed in lifts and compacted to 95 % standard proctor density".*

i. What is the desired as-placed density; how will this be determined?

The Standard Proctor Maximum Dry Density (SPMDD) is defined as the ratio between the field dry density of the compacted material and the laboratory maximum dry density expressed as a percentage. In general, the material directly below a structural foundation requires neglected deformation due to compaction of soil particles after a concentrated load is applied. Therefore, 100 percent of the SPMDD is generally specified. However, minor deformation on a slope, such as a berm slope for a lagoon or reservoir, is considered to be acceptable and practical. Therefore, 95 percent of SPMDD is recommended in this design.

ii. What are the specifications for lift thickness?

All fill should be placed in lift thickness compatible with the compaction equipment being used, to the maximum thickness of 300 mm and uniformly compacted to at least 95 percent of the SPMDD at a moisture content ±3 percent of the optimum moisture content.

iii. Will these construction specifications be used for the other structures? If not, what are the details of construction specifications for the other structures?

The specifications may be used for all earthworks within this project. However, these specifications should be modified up to 100 percent of the SPMDD for materials directly under foundations and base and sub base courses for a pavement.

xiii The lagoon, landfill hazardous waste storage area and water reservoir each contain a perimeter berm in the design. Despite each structure containing a similar berm configuration the applied loadings for each structure may be unique. There is not a clear understanding of the stability of the perimeter berm from slope failure under the applied loads. Additional detail and discussion on the stability of the berms from slope failure are requested that provide a full description of:

(a) Method of analysis.

In order to determine the stability of the berm slopes for the proposed facilities, the most critical section is located at the downstream slope of the lagoon (Section B-B in design drawing No. 8). The upstream slope in this section is 3H:1V while the downstream slope is 2H:1V with a total slope height of approximately 8 m. The slope stability was assessed for the downstream slope of the lagoon berm because this slope is highest and steepest.

Three failure mechanisms were assumed in the stability analyses:

Case 1: Circular failure through berm material during first several months of the operation when the berm is still unfrozen.

Case 2: Planar failure of the active layer of the berm with a frozen core during summer periods of the berm operation.

Case 3: Berm stability against sliding along the interface of the berm and native material

Case 1

This case considers the berm slope under construction or shortly after construction. The strength of the berm fill after compaction governs the stability of berm slope. The pore water pressure within soil particles will reduce the effective overburden stress of soil and hence decrease the shear strength of soil at the failure slip. Considering that the materials to be used for berm construction will be coarse granular soils, the pore water pressure within soil particles may be assumed to be zero.

Commercial computer software SLOPEW (Geostudio 2004) was applied for assessment of the slope stability. Due to a various composition of the berm fill, a series of sensitivity analyses were performed, applying various strength parameters to the fill.

A potential failure surface with the lowest factor of safety was first determined by varying the radius of the slip circle and location of the failure axis associated with the mean values of the soil parameters (friction angle, cohesion and unit weight). The friction angle and unit weight were then held at the mean values, and safety factors were computed by varying the soil cohesion. This procedure was also used to assess the model sensitivity to the friction angle and unit weight while keeping other parameters at the mean values. The estimated mean values of the soil parameters and results of the analyses are summarized in Table 1.

Table 1 Input Parameters of Berm Fill and Results of Sensitivity Analyses

Input Parameters	Mean value	Range	Factor of Safety
Apparent Cohesion (kPa)	5	0 ~ 10	1.5 ~ 2.1
Friction angle°	33°	30° ~ 36°	1.65 ~ 2.0
Unit Weight (kN/m^3)	20	19 ~ 21	1.8 ~ 1.85

Figure 1 presents the sensitivity plots. For presentation purpose, the strength and unit weight are normalized to a value ranging between 0 and 1. Zero means the lowest value in the range and 1 means the highest value. The point, where the three sensitivity lines are crossing, is the deterministic factor of safety, corresponding to mean values of the analyzed soil. Figure 1 indicates that the safety factor against slope failure, is higher than 1.5 for any combination of soil parameters. The safety factor of 1.5 is acceptable in geotechnical practice. Figure 2 illustrates the factor of safety for a 2H:1V slope and a potential failure surface generated with all input parameters set to the mean values.

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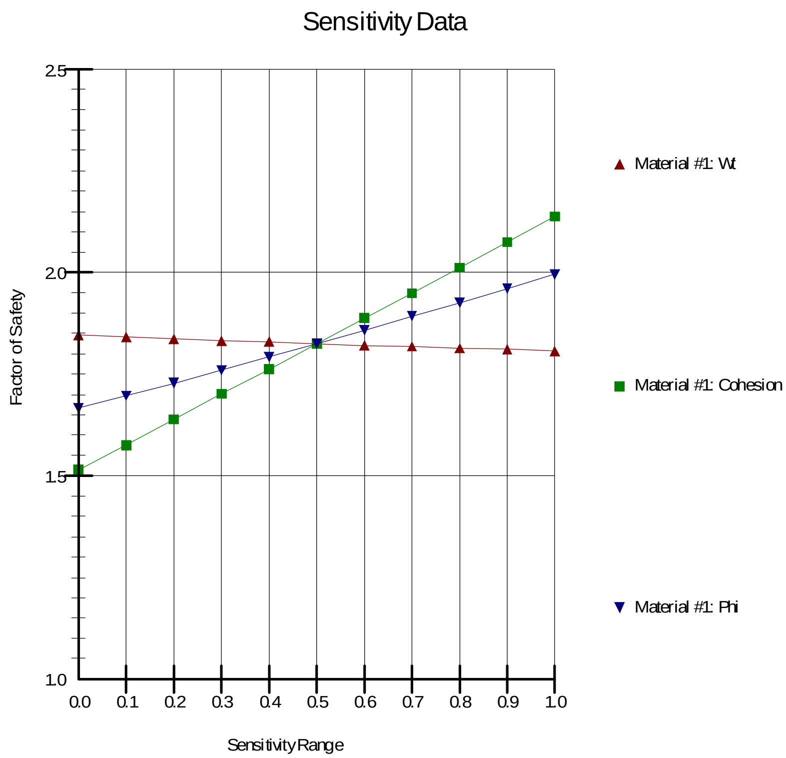

Figure 1 Sensitivity Plots for Slope Stability

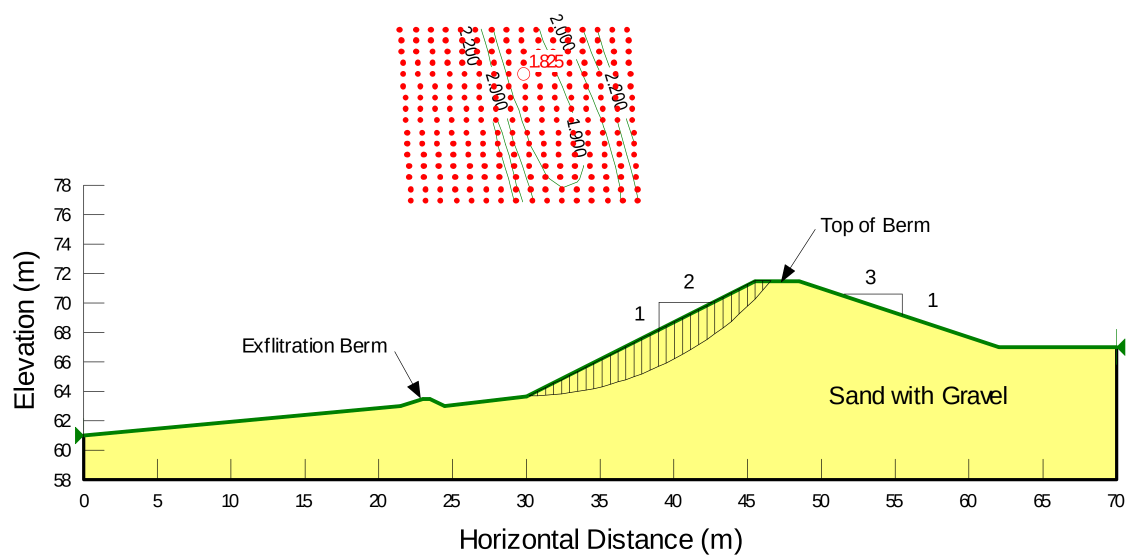

Figure 2 Factor of Safety for Lagoon Berm (Mean Value of Soil Parameters)

Case 2

The stability of thawed material (active layer) overlying the frozen slope during summer periods was assessed. The thaw depth on the berm slope was obtained based on results of a geothermal analysis. The maximum thickness of the active layer was predicted by geothermal analysis to reach 1.5 m by the end of the summer.

The factor of safety of the slopes was calculated using the limit equilibrium theory by comparing the total resistance force along a failure surface to the total driving force along the same failure surface. Dr. E. McRoberts developed the limit equilibrium theory, applicable to frozen slopes. In addition to the base resistance along the failure surface, the side shear resistance within the thawed materials also contributes to the total resistance, hence increasing the stability of the slope. Resistances along both sides of the failure zone were considered, applying a side factor of 0.7.

The analyses were carried out for an assumed failure slope 15 m long (based on the proposed berm section) and 20 m wide. Similar to case 1, sensitivity analyses were carried out using the same mean values and ranges of the soil parameters outlined in Table 1. The results of the analyses for a thaw depth of 1 m and 1.5 m are presented in Figure 3. The factors of safety against failure within the active layer are greater than unity, which suggests that the proposed slopes are in a stable condition. The factor of safety may decrease to about 1.3 when the apparent cohesion of the active material is close to zero. It is our opinion that coarse material generally tends to dilate during shearing under a low confined pressure. It is reasonable to assume a minimum apparent cohesion for dilating soil. Hence, the likelihood of zero cohesion is very low.

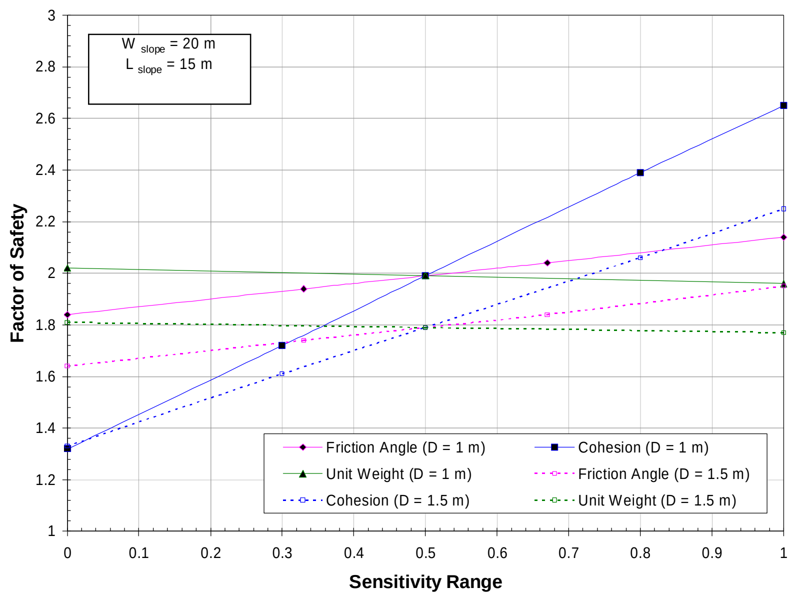

Figure 3 Sensitivity Plots for Stability of Active Zone

Figure 3 indicates also that the factor of safety of the active layer generally decreases by 10 to 15 percent with increasing of the active layer thickness from 1 m to 1.5 m. It was also found that the factor of safety decreases by 3 to 4 percent when the slope width is increased from 20 m to 50 m.

Case 3

The stability of the berm against sliding due to hydraulic pressure applied on the upstream side of the berm was assessed by assuming that the berm is a rigid retaining structure. A coefficient of friction of 0.5 was used at the interface between the berm fill and the native ground, as recommended in Canadian Foundation Engineering Manual (1992, 3^{rd}). The lateral pressure on the interior slope of the berm was estimated based on fluid pressure with a unit weight of 10 kN/m^3. It was found that the factor of safety against sliding along the interface is close to 4.

(b) *Any limitations in the method of analysis.*

The limit equilibrium analysis takes into account the equilibrium of forces and moments. The deformation that the slope will undergo during the service life of the structures and re-distribution of internal forces due to berm deformation are not considered. In general, the results obtained from limit equilibrium analyses are slightly conservative.

(c) *Values of assumed or known soil strength and density used in the analysis with justification for their use.*

All soil parameters for slope stability analyses were based on field observations and soil descriptions during the site reconnaissance, empirical relationships in the published design manuals (Canadian Foundation Engineering Manual, NAVFAC DM-7.01) and our geotechnical experience with similar soils.

xiv The Proponent is requested to provide additional detail and discussion to address each of the following points.

(a) *There are no details or discussion on the bearing capacity of the foundation soils under potentially thawing conditions or the expect amount of settlement for the berms. The geotechnical investigation did not establish the ground ice content in the foundation soils which could lead to differential settlements and foundation instability.*

i. Does the Proponent agree that bearing capacity and settlement are important geotechnical considerations in the design, stability, and containment of these structures? If not, why not?

AMEC agrees that the bearing capacity of frozen/thawed soils and potential settlements are important issues for geotechnical consideration in the design. The geothermal analysis has shown that during operation, the berm will be founded on frozen medium to coarse sand and gravel with varying amounts of cobbles and boulders. In frozen conditions, such soils have compressive strength greater than 250 kPa. Minor thawing occurs only near the toe of the berm’s upstream slope covered with water (see results of the geothermal analysis). The allowable bearing capacity of compacted unfrozen sand and gravel is generally higher than 175 kPa while the allowable bearing capacity of frozen sand, as was mentioned above, is not less than 250 KPa.

Both values (175 kPa and 250 kPa) are greater than the vertical stress induced by the proposed berm. Long term creep settlement for frozen sand under a minimal load will be negligible.

A review of AMEC project files indicated that the thickness of the overburden in the Qikiqtarjuaq community is about 10 m to 15 m. The moisture content of predominantly sandy deposits ranges from 8 percent to 26 percent (average moisture content is about 15%). This amount of water in the soil is not enough to fill up the pores (porosity 0.3) with ice, resulting in a minimum settlement of thawing soil (sand). It is estimated, based on our experience that the settlement strain of the overburden can be in an order of 0.01. This means that if the thaw depth under the reservoir impoundment is greater than the overburden thickness (15 m), then the thaw settlement will be in an order of 15 cm maximum. The thaw settlement of the berm upstream slope would be considerably less (about 4 cm to 5 cm, see results of geothermal analysis).

ii. *Have any thermistors been installed to provide site specific temperature data for design purpose?*

The site-specific temperature data was not available for design purposes. The initial temperature conditions are only important during the initial first years of the berm operation. During subsequent years of operation, the temperature conditions of the impoundment and berm change dramatically due to a warming effect from water over the impoundment and minimal thickness of snow over the raised berm. The geothermal analysis has shown that it takes more than 20 years for the soil temperatures under the water and within the berm to stabilize. At that time, the soil temperatures will differ considerably from the initial soil temperatures. However, we agree that the initial soil temperature is an important parameter to predict the berm and impoundment temperature during the first years of the berm/reservoir/lagoon operation.

For assessment of the permafrost temperature at the site prior to construction, a 1D geothermal analysis was undertaken to predict the permafrost temperature over the site. The model includes all parameters that determine the soil temperature: soil thermal conductivity, heat capacity and latent heat, snow cover and snow density, air temperature, and water temperature. It was modeled that the mean annual permafrost temperature at the site is in an interval of -4 ^{o}C to -6 ^{o}C and the thickness of the active layer, depending on soil moisture content and ground vegetation can be in a range from 0.5 m (mossy ground vegetation) to about 1.5 m (bared ground surface). Moreover, AMEC experience in geothermal modeling shows that variations of soil thermal properties within a reasonable range of values, provides insignificant changes to soil temperature. The boundary conditions have considerably more impact on the resulting berm temperature throughout the years of the reservoir/lagoon operation. On this basis, AMEC considers that the soil thermal properties and applied boundary conditions used in the analysis have resulted in an adequate assessment of the berm temperature regime.

AMEC recommends the implementation of a temperature-monitoring program within the berm as described in xv below (thermal monitoring). If actual berm/ground temperatures differ considerably (i.e., are warmer than predicted) or warming trends are noted, then a contingency plan should be implemented. Currently, it is considered that an appropriate contingency plan would be to install thermosyphons to reduce berm temperatures.

iii. Has settlement been considered in the calculations for volume capacity of the reservoir and lagoon, and what are the details of the analysis? If settlement has not been considered, why not?

Settlement on the reservoir/lagoon ground surface will be minimal (see explanation above). Therefore, it can be considered that the volume capacity of the reservoir and lagoon will not change noticeably during the operation.

xv There is limited to no details into the construction methods and specifications for the lagoon, landfill, hazardous waste storage area, or water reservoir. For example, in Section 7.1 Appendix B Geotechnical Evaluation, it is stated that "soil around the potential new reservoir identified sufficient suitable overburden material to create the berms, and provide the raw material that could be crushed and sorted to provide the needed sand and gravel"; however, there is no quantifiable measure to describe what material specification is required, or what grain size and distribution is required. Details and discussion of this nature are also not provided for the lagoon or landfill construction.

a. Additional detail and description into the quality control and quality assurance(i.e., quality assurance program) of, but not limited to, soil type, material characteristics, moisture content, and density, used in construction each structure is requested.

b. A detailed monitoring plan, which includes, but not limited to, soil property testing methods (e.g., sieve density, moisture content, etc) and frequency of testing during construction is requested.

c. Detail and description into soil and material specifications acceptable for construction, as well as, specifications for as-placed conditions like moisture content, density, and standard proctor are also requested.

d. Will construction, quality assurance, and quality control monitoring be overseen by a qualified geotechnical engineer" If not, why not? How does the Proponent propose to report this information to the NWB?

Characterization and analysis of materials available on site and suitable for berm construction was carried out for three borrow sources, located near the existing sewage lagoon, proposed waste water lagoon and proposed water reservoir. Three samples were derived from test pits, excavated at the borrow source sites. The methodology used for analysis of the granular materials from the test pits is provided below.

Sieve analyses were performed on selected samples by Alston Associates Inc. The results of all sieve analyses are presented in the Geotechnical Evaluation Report prepared by Nuna Burnside. The grain size distribution curves of these materials were then compared to upper and lower bound gradation envelopes for 25 mm minus gravel material typically used for foundation subgrade, embankment and road construction. The results of comparisons are presented in Figure 4. The solid lines, shown in Figure 4 demonstrate the upper and lower bound of gradation envelopes for the specified gravel material, and the dashed lines represent the gradations of the granular materials obtained in the test pits.

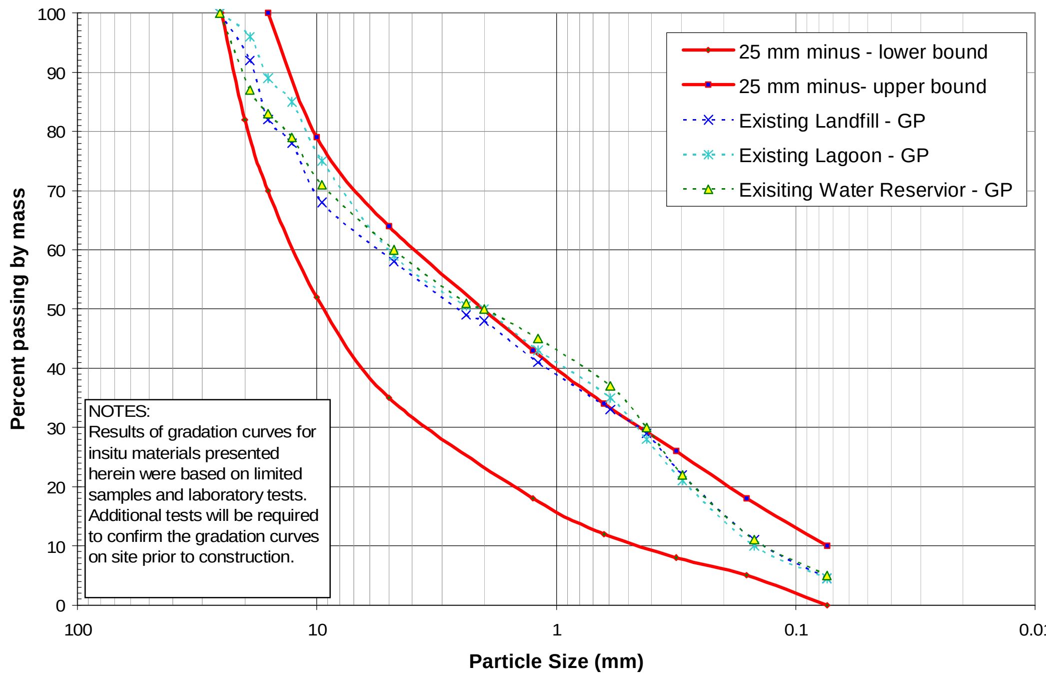

Figure 4 Comparison of Gradations of In-situ Material to 25 mm minus Crushed Gravel

It was found that the particle size distribution, for the sampled materials, practically falls within the specification envelope for 25 mm minus gravel. The minor discrepancy of the grain size distribution within the particle size from 0.4 mm to 2 mm should not have a noticeable impact on performance of these materials as a material for berm construction if the gravel is properly compacted. Therefore, materials obtained from these sites are considered to be acceptable as a 25 mm minus gravel resource.

For (a), (b), (c), (d)
A geotechnical allowance has been included in the tender contract for the services of a field geotechnical engineer or technologist to be onsite during the entire time of the berm construction to provide proper quality control and quality assurance. His responsibility would include the following:

- Inspection of engineered fill, including such fill parameters as gradation, moisture content, unfrozen state, inclusions of boulders;
- Estimation of lift thickness corresponding to capacity of available compaction equipment;

- Inspection of compaction level with the use of sand cone method, proof rolling or equivalent for each lift;
- Record all activities on the site and direct these activities if they contradict to the earth work specifications;
- Review of design drawing and specifications prior the construction is commenced;
- Provide recommendations if unforeseen site conditions will be encountered, including specify drainage conditions and permafrost conditions.

The following are the main requirements for the engineered fill placement and compaction. The material used for berm construction should be unfrozen at the time of placement and placed in lift thickness compatible with the compaction equipment being used, to a maximum thickness of 300 mm and uniformly compacted to at least 95 percent of Standard Proctor Maximum Dry Density (SPMDD) at moisture content within three percent of optimum. Any cobbles and boulders within the berm fill should be removed. The Proctor tests should be carried out on stockpiled material prior to construction. The achieved density of the berm materials will be assessed on a regular basis. The minimum test requirements are provided in Section No. 01410 of the construction specifications. Additional tests will be performed where necessary, as determined on site by the field engineer.

It is recommended that the GN and the Hamlet consider the implementation of the following monitoring program after completion of construction:

- Thermal monitoring: Thermistors would be installed to monitor ground temperatures. Two thermistors strings would be installed in drill holes through the crest of each berm structure, extending a minimum of 5 m into the native materials. Temperature readings would be taken twice per year for the first 5 years of operation, after which the monitoring frequency would be reviewed.

- Movement monitoring: Survey monuments would be installed along the interior and exterior crest of the berm. Design and depth of the monuments should provide that they are not subjected to frost heave forces. The monuments would be surveyed for vertical and horizontal movements twice during the first year of operation, after which the monitoring frequency would be reviewed.
- Seepage monitoring: If any seepage is detected downstream of the berm, a remediation program would be developed. Water quality samples would also be taken weekly and analyzed for critical constituents.

All field observations, recommendations and monitoring data including field testing results obtained in conjunction with any approved monitoring programs would be documented and submitted to the NWB.

xvi *The Proponent is requested to provide additional detail and description to address each of the points provided below:*

(a) *There are no details provided regarding the construction of perimeter of interior berms. Additional detail and discussion is requested to address what equipment will be used to construct the berms.*

All construction requirements relating site grading, excavation and backfilling (construction of berm) are detailed in Section 02210 and 02220, Construction Specifications. The Contractor should propose the appropriate equipment that will be used for construction and to meet the design criteria.

(b) *The depth to permafrost during the geotechnical assessment as about 2 m below ground surface.*

i. *Are the foundation conditions competent for the expected soil loadings and potential foundation thawing conditions?*

Please see xiv (i).

ii. *Does the Proponent agree that the landfill and lagoon perimeter berms, which do not contain a liner, could have seepage through and under the berm? If seepage could migrate beneath the berm through the proposed design what impacts will this seepage have on waters contained in the soil proximal to the facility?*

Seepage analyses for the proposed lagoon berm were carried out using the SEEP/W commercial finite element computer software. The purpose of the analyses was to assess the safety of downstream slope against piping shortly after construction if liner is not provided on the upstream slope, while frozen core has not formed yet in the berm material (one year after completion of berm construction) and the water level on upstream slope was raised to the maximum elevation. In this case, water will infiltrate through berm materials and may daylight on the downstream slope. The critical section (west side of the proposed lagoon) used in slope stability analysis was also used for the seepage analyses. The width of berm at the crest was 3 m. The maximum water level at the upstream slope was assumed to be at El. 71 m. Berm materials and native materials were assumed to have similar hydraulic properties.

The saturated hydraulic conductivity (K_{sat}) of in-situ materials were referenced to works performed by D. Swanson (1991) on poorly graded sand and the hydraulic conductivity functions were estimated using a method proposed by Green and Corey (1971). Since coarse material was encountered on site, the hydraulic conductivity was increased by a factor of 50%. It is understood that the K_{sat} has insignificant impact on the results of the seepage gradient. AMEC considers that this assumed parameter results in an adequate assessment of the seepage. Figure 5 presents the contour plot of total pressure head for the proposed berm under a steady flow condition. Figure 6 shows the contour plot of x-y gradient. It was found that the maximum gradient near the toe of downstream slope varies between 0.35 and 0.45.

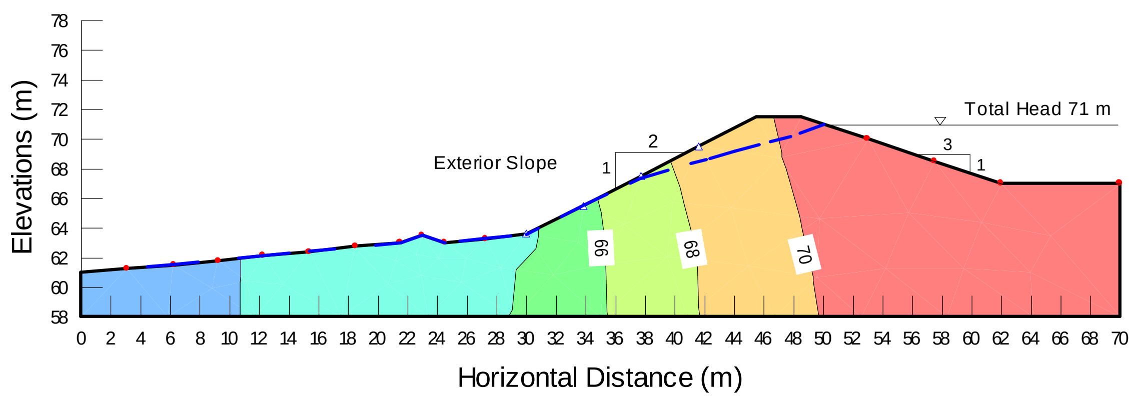

Figure 5 Total Pressure Head within Lagoon Berm due to Seepage

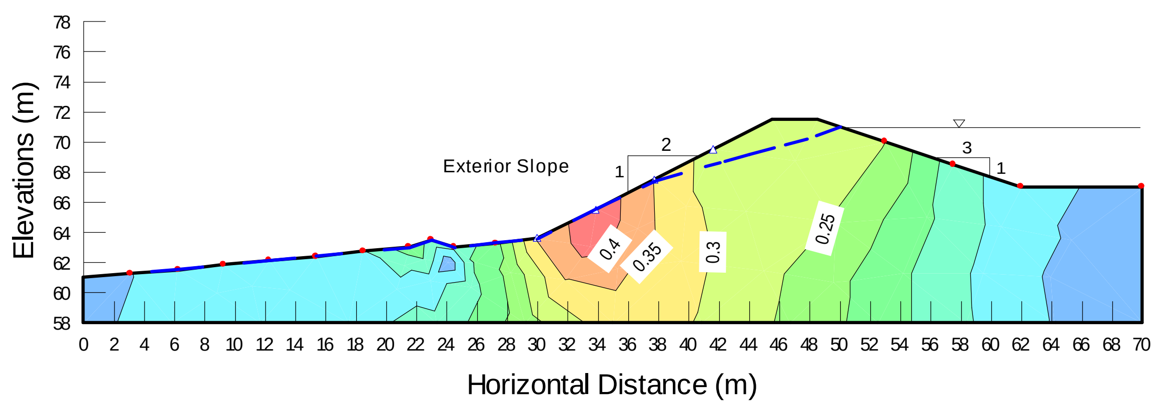

Figure 6 X-Y Gradient within Lagoon Berm due to Seepage

The factor of safety against piping can be defined as the ratio of i_{cr} to i_{exit} where i_{cr} is the critical hydraulic gradient of berm material and i_{exit} is the estimated maximum gradient. The i_{cr} may be evaluated using void ratio (*e*) and specific gravity (G_s) of soil and generally varies within a range of about 0.85 and 1.1 (Das, 1983). The factor of safety against piping was calculated to be approximately 2, which is acceptable for short term period prior to the berm material being frozen.

As mentioned before, the pore water pressure within soil particles will reduce the effective overburden stress of the soil, and hence decrease the shear strength of the soil at the failure surface. The stability of berm slope was re-assessed by considering the pore water pressure within the berm due to seepage. The results of analyses, using mean value of soil parameters and the sensitivity plots are given in Figure 7 and Figure 8, respectively. The results indicated that the stability of berm slope is more sensitive to the cohesion of the compacted soil than other parameters. If the lower bound of this parameter was assumed, the factor of safety may decrease to less than unity. However, it is our experience that a mean value of cohesion shown in Table 1 should be warranted if the granular material for berm fill could be compacted to the specified density. Monitoring compaction during construction is required to ensure that the specified density is attained. Alternatively, if full time monitoring is not to be provided, it is recommended that a liner be installed on the inside slope of the downstream berm for the lagoon.

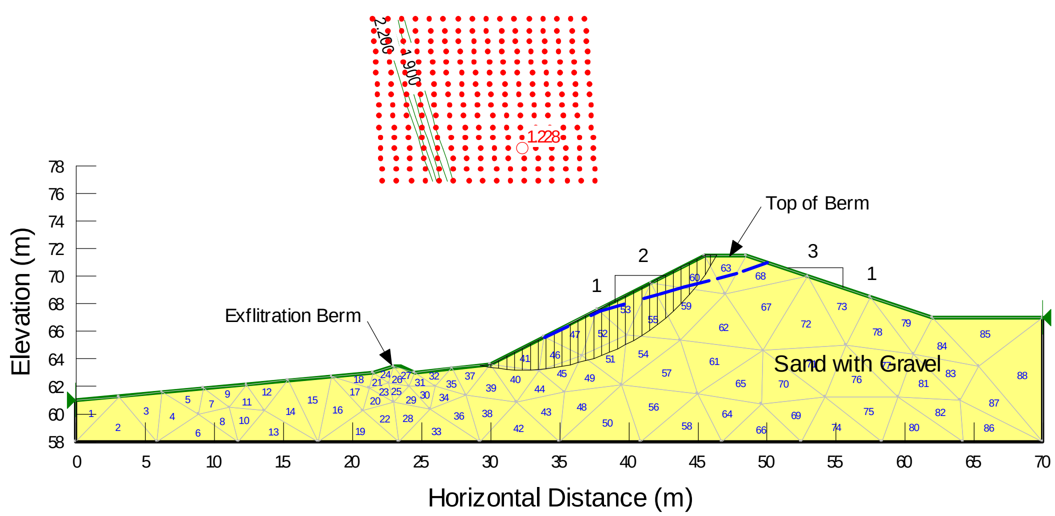

Figure 7 Factor of Safety for Lagoon Berm (Mean Value of Soil Parameters)

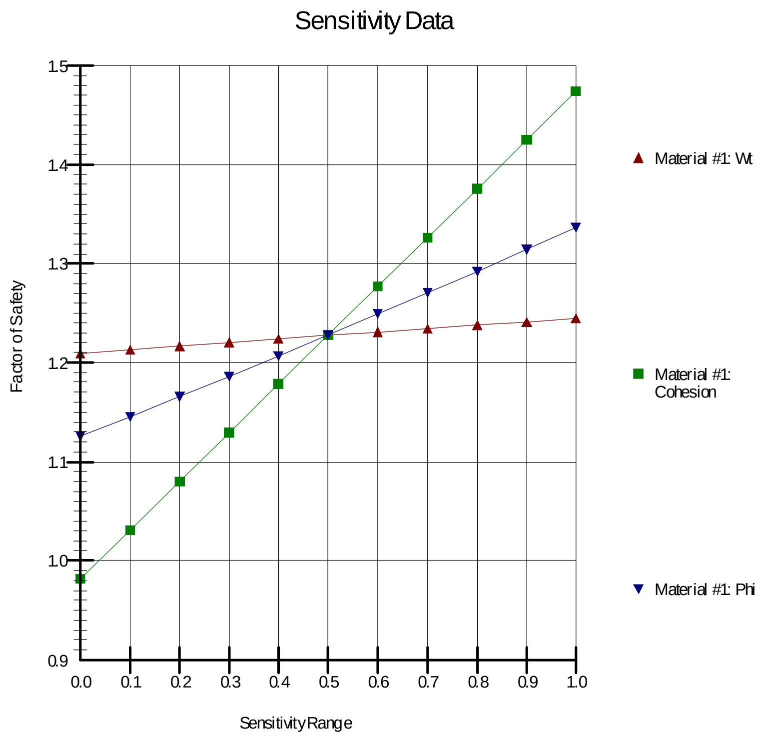

Figure 8 Sensitivity Plots for Factor of Safety

iii *Has the potential for seepage through the landfill and lagoon berms and piping failure been considered in the design? If so, additional detail and discussion is required. If not, is the Proponent relying on permafrost aggregation into the berms.*

Seepage analysis for the lagoon berm has confirmed that there is a potential of seepage through the berm during the first year of the berm operation, assuming that the lagoon is filled to the top immediately after construction. Since the lagoon will be placed into service at the end of August, no seepage is expected during the first winter following the completion of the berm construction. It was further understood, that each summer, the sewage effluent will be discharged from the lagoon in July and August. If the effluent level in the lagoon is lower than the thaw depth, then consideration can be made to not use a liner to prevent seepage of the water through the upper portion of the berm. Recommended maximum levels of the water are provided below.

May – any water level.
June - 0.5 m below berm crest.
July – 1.2 m below berm crest.
August – 1.7 m below berm crest.

September – 2 m below berm crest.

If water levels will be above the maximum levels, then a liner should be installed to prevent the seepage. The seepage analysis completed by AMEC was based on a freeboard within the lagoon of 0.5 m. The actual freeboard included in the design is 1.0 m below the berm crest. Therefore in reality the water levels will be 0.5 m or more lower that what was used in the evaluation and therefore a liner would not be required assuming that the required compaction in the berms is attained during construction.

iv If permafrost aggregation is relied upon in the design, does the Proponent have an understanding of the thermal regime with time and what are these details?

The geothermal modeling program SIMPTEMP, 2D version (developed in-house by AMEC) was used to analyze the geothermal regimes for the water reservoir and lagoon berms. The geothermal simulator uses the finite element method to compute a numerical solution of the heat transfer problem. Physical/mathematical algorithms used in the SIMTEMP model have been published, and the simulation process has been verified both against well-known analytical solutions of the heat transfer problem, and as compared with numerical solutions produced by other commercial/non-commercial geothermal software. AMEC has successfully used the SIMPTEMP program for a variety of geothermal applications over a ten year period.

The analysis considered the following geometry for the lagoon:

- Height of dyke is 5 m (upstream).
- Width of crest is 3 m.
- Upstream slope is 3H:1V and downstream slope is 2H:1V
- Local soil (sand and gravel) is proposed for the dyke core construction.

Table 2 below provides surface temperatures that were applied at the berm, downstream terrain beyond the berm, ice surface and also reservoir water temperatures in summertime.

Table 2 Surface Temperatures and water temperatures Applied in Geothermal Model

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Berm	-27.6	-27.6	-24.5	-11.9	-7.1	0.8	6.4	6.2	2.3	-4.8	-11.1	-17.6
Downstream Terrain	-21.5	-21.5	-19.1	-9.2	-5.5	0.8	6.4	6.2	2.3	-3.7	-8.6	-13.6
Ice Surface	-21.5	-21.5	-19.1	-9.2	-5.5	---	---	---	---	-3.7	-8.6	-13.6
Water	---	---	---	---	---	0.6	4.9	4.8	1.8	---	---	---

The provided temperatures were derived by application of various n-factors to the mean monthly air temperatures at Qikiqtarjuaq weather station for the period from 1971 to 2000.

The initial temperature of the berm material and active layer was taken to be 2 ^{o}C, while the frozen soil below the active layer was appointed to be -5 ^{o}C. The soil profile consisted of 15 m thick overburden (sand and gravel at moisture content of 12%), overlying bedrock (moisture content of bedrock 2%). It was assumed in the analysis that the berm material properties are the same as properties of the overburden. The water level in the reservoir was at the maximum elevation, beginning from October 1. The model ran for 30 years.

Figure 9 shows that after the first year of the berm operation, the majority of the berm core has a temperature in a range above 0 ^{o}C. One can see that due to the warming effect of the reservoir water a portion of the berm at the upstream slope has a positive temperature about 1 ^{o}C to 2 ^{o}C. Figure 10 to Figure 13 present the estimated temperatures from the fifth to thirtieth year of the berm operation.

The numerical simulation suggests that a frozen core within the lagoon berm will be located at 2.0 m to 2.5 m below the crest of berm after one year of operation. The potential of percolation of water/effluent through the berm will depend on the water level inside the lagoon during operation. If water levels will be higher than the maximum levels (see Response to XVI –b-iii), then a liner will be required. If the operation scenario with high water level (higher than maximum) will be used, AMEC recommends installation of the geomembrane liner in the lagoon berm for seepage protection. A typical section for the liner layout is provided in Figure 14. The cut-off trench, at least 2 m deep into the native soil, should be excavated at the position of the upstream slope crest. The liner should be placed vertically in the cut-off trench and then backfilled with compacted clayey material or grouted. The liner curtain should then follow the ground surface to the toe of the upstream slope and then cover the upstream slope to an elevation higher than the expected maximum water level, as shown in Figure 14. The liner should be covered with 0.5 m thick armour layer (riprap). An alternative liner option is shown in Figure 15. It is understood that the constructability of the alternative option is more complex however the liner is almost twice shorter.

No geothermal analysis was carried out on the landfill section where the height of the berm fill is approximately 2 m. Based on results of the geothermal analysis for the lagoon berm, it is our opinion that the majority of the berm will be unfrozen at the end of summer and seepage can occur through the berm if a considerable amount of precipitation accumulates in the retention area. Please refer to comments provided under item viii, for an explanation of natural attenuation.

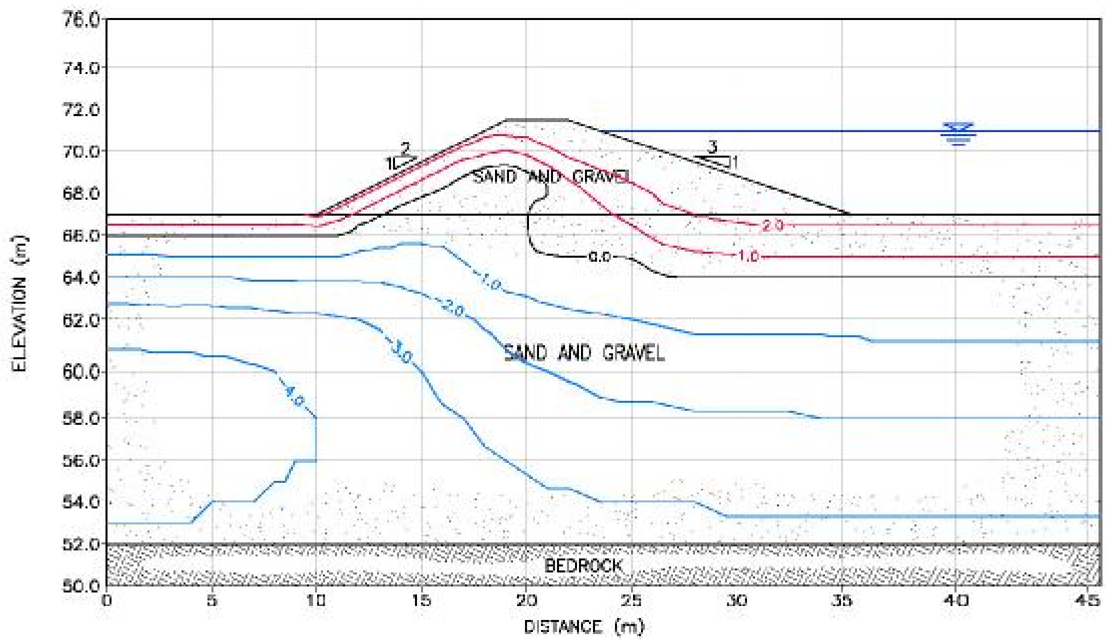

Figure 9 Berm Temperatures after 1 year of Operation

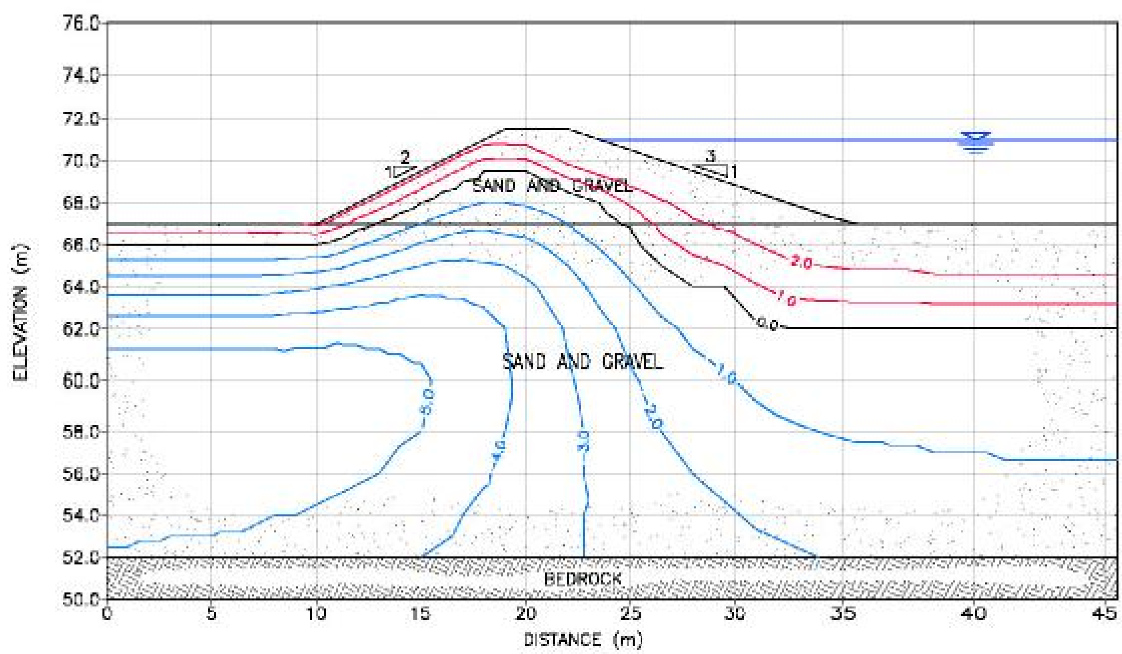

Figure 10 Berm Temperatures after 5 years of Operation

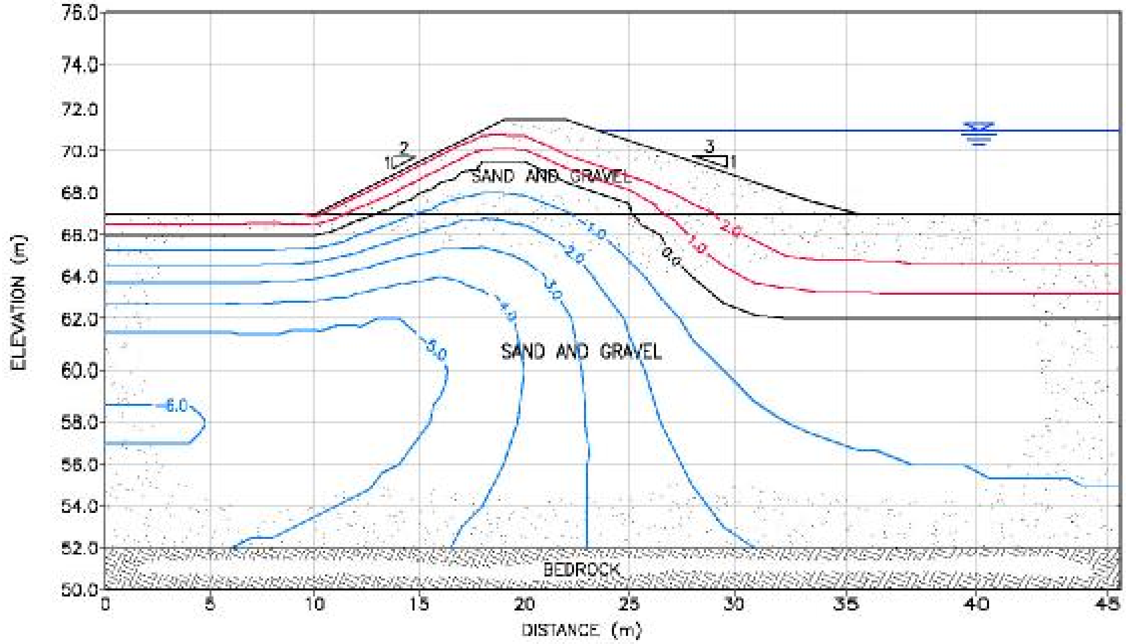

Figure 11 Berm Temperatures after 10 years of Operation

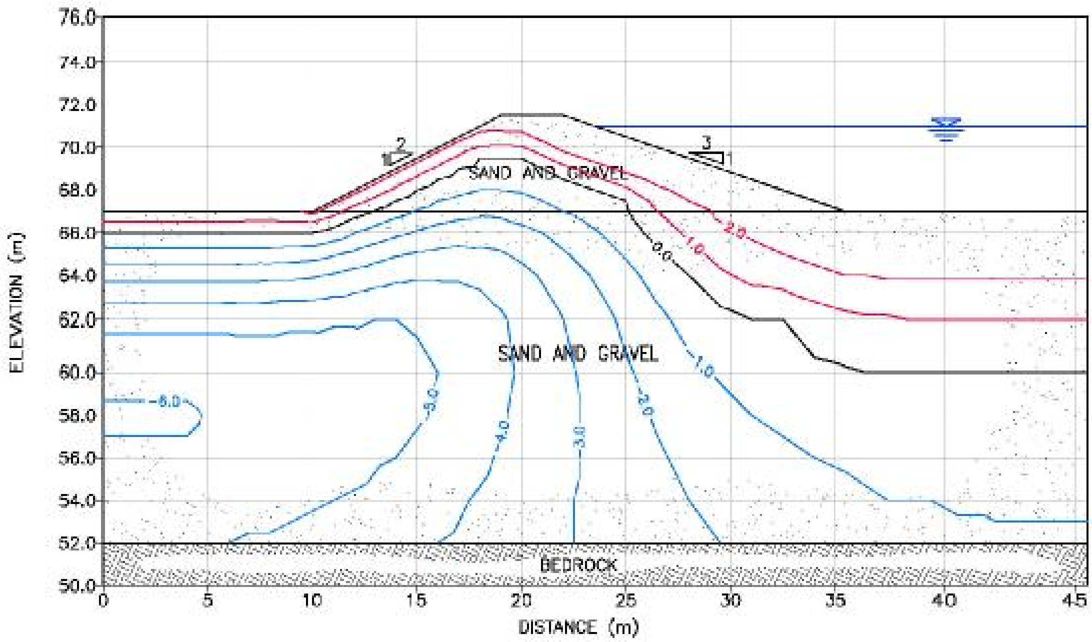

Figure 12 Berm Temperatures after 20 years of Operation

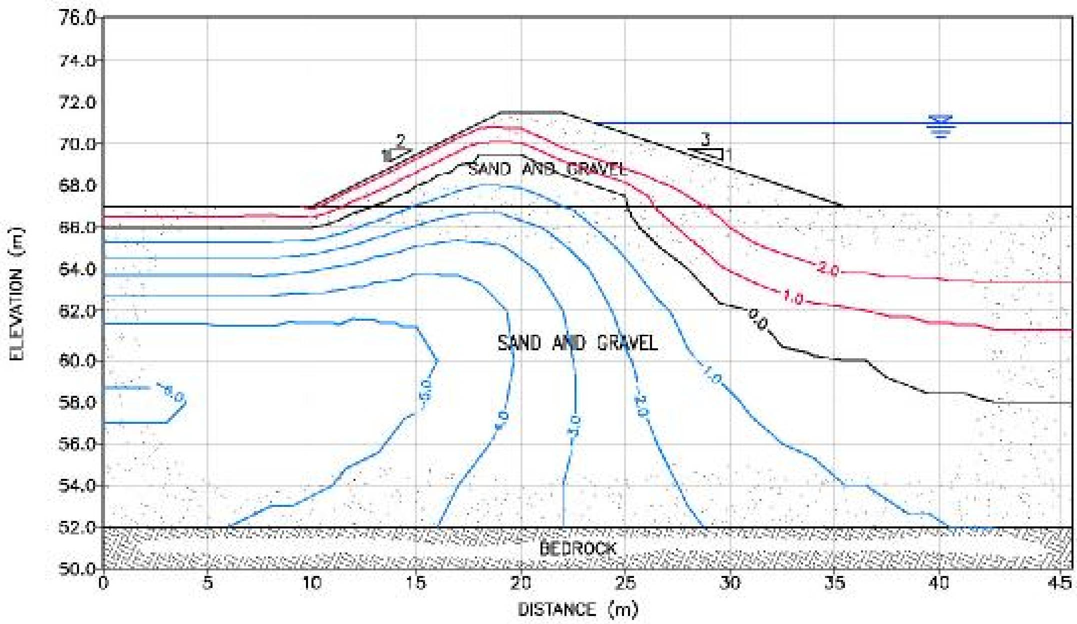

Figure 13 Berm Temperatures after 30 years of Operation

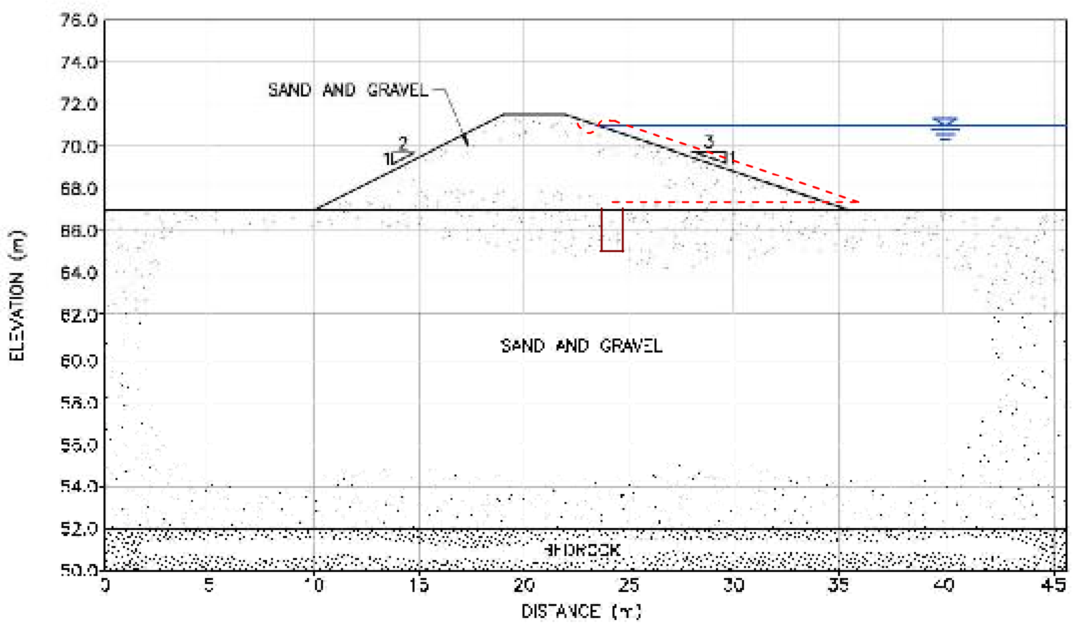

Figure 14 Proposed layout of HDPE Liner (Option 1)

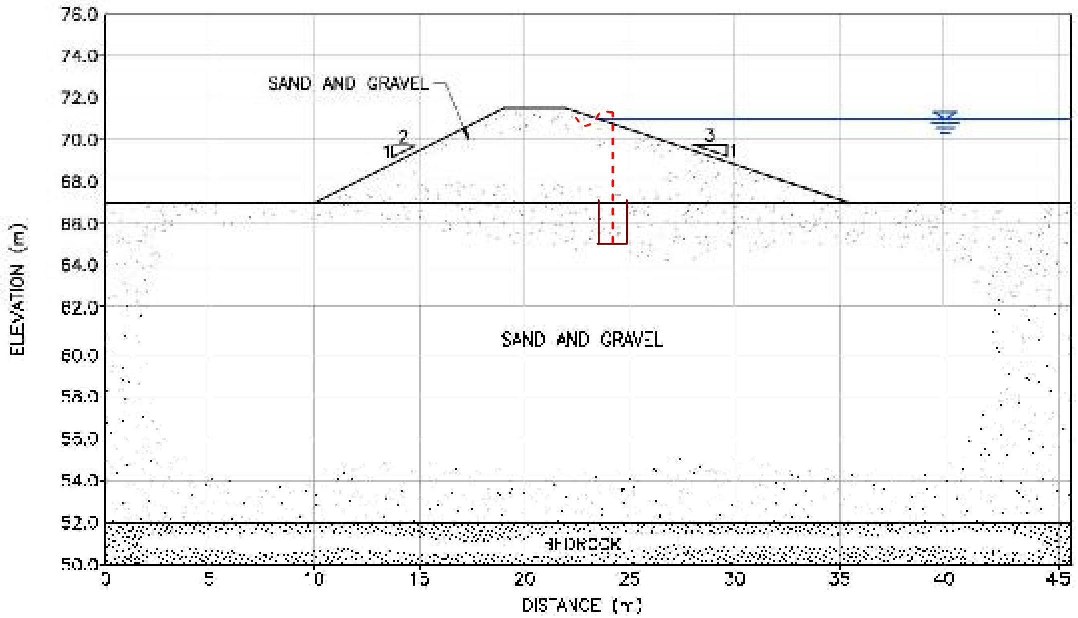

Figure 15 Proposed layout of HDPE Liner (Option 2)

v *What, if any, site/foundation prep work is required before berm development occurs, or will they be constructed on top of ground surface without removing the active zone?*

Prior to the construction of the berms, any topsoil or vegetation should be cleared and grubbed as specified in Section 02210, construction specifications. Excavation to permafrost is not required. However, the exposed native coarse material after site stripping should be compacted to the satisfaction of the field engineer using a vibratory roller.

vi *If the berms are not lined or have permafrost aggregation, how will seepage be prevented through the active zone?*

Please see results of geothermal analyses.

xvii *No slope protection on the inside slope of the berms was specified. Is there a concern to protect the inside slope of berms from wave, ice, or wind erosion? If not, why not?*

Based on field performance of the existing facilities over the last 17 years, there was no evidence of erosion caused by wave, ice or wind on the slope. However, AMEC recommends that a layer of 500 mm thick riprap (class 1) be placed on the upstream slope of water reservoir and lagoon for erosion protection.

As stated above the existing lagoon does not have a riprap layer on the upstream slope of the lagoon and there were no signs of erosion of the berm. Based on the above, the design does not include riprap on the upstream slope of the berm.

With regards to the water reservoir, the liner has been shown to be exposed. The operation of the water reservoir is different from a typical lagoon. A lagoon is filled slowly over the winter period, whereas the reservoir level is depleted over the winter. As the water level in the reservoir drops, ice that has formed over the surface of the water also drops. Placing a riprap layer over the liner in this situation would not work. Ice would form around the riprap and when the ice shifted as the water level dropped it would be dragged down the face of the liner. This is evident in the existing reservoir, where the sand layer that had been placed over the existing liner appears to have been dragged down into the bottom of the reservoir. Based on this, it has been recommended that a heavy liner be used and that the liner be exposed to provide a surface that the ice can move over without restriction.

xviii *The refuse is to be contoured to obtain a slope of 3:1. Within Figure 12 of the detailed Design Report there is a caption that states "site operators may elect to install an additional vertical berm if construction wastes with 3;1 slope is problematic." This statement suggests that a 3:1 slope may not be stable.*

(a) *What is the level of confidence does the Proponent have that a 3:1 slope will be stable?*

As shown on Figure 11 (Detailed Design Report), the operator constructs a berm that is used to push the waste against during compaction operations. Figure 13, shows what the face would look like once the first cell was completed. Figure 12, shows that if the operator is having difficulty compacting and maintaining a 3:1 slope constructed from refuse, then he could construct an intermediate berm to help contain the refuse and make his job easier.

(b) *What evidence or justification is there to suggest that a slope of this angle will be stable?*

See response to (a)

(c) What quantifiable markers are in place to define "problematic" in the Proponent's statement?

If the operator is having difficulty with garbage blowing around or cannot obtain compaction on the face, he may elect to construct an intermediate berm.

xi An interior berm is to be constructed within the landfill to support the refuse and separate stages of construction. The interior berm will have a waste load applied to one side and no load applied to the other during landfilling.

(a) *What is the stability of the interior berms from slope failure and sliding along the foundation soil for the applied loads?*

Please see xix (b) below.

(b) *What method of analysis as well as what soil and waste strength and density values with justification on their selection, were used to assess stability of the interior berms?*

The potential for failure of the landfill berm is addressed in the response to xiii (a) slope stability of a berm.

The stability of the landfill berm against sliding, due to a waste load being applied on one side of the berm, was assessed by assuming the berm to be a rigid retaining structure. A coefficient of friction (μ) equal to 0.5 was used at the interface between berm fill and native ground. The lateral pressure on interior slope of the berm was estimated based on fluid pressure with a unit weight of 15 kN/m^3. This value is considered to be conservative. It was found that the factor of safety against sliding along the interface is close to 4.

xx Will a cover be placed over the landfill? If so, what are the geotechnical engineering design and details, function, and characteristics of the final cover proposed?

The final cover over the landfill will consist of native granular material, which meets the type 5 outlined in Section 02220, construction specifications. The thickness of the cover should be at least 2 m.

xxi *Within Section 6.0 of Appendix B Geotechnical Evaluation, the following statements are provided: " From a geotechnical point, the site can be rehabilitated fairly easily as there are no significant land availability and cover availability constraints.", and "From the geotechnical view point the site can be effectively redeveloped and managed to serve the long term needs of the Hamlet." Additionally, within Section 9.0 of Appendix B Geotechnical Evaluation, the following statement was provided "The geotechnical evaluation found the existing wastewater lagoon site, landfill site, and water reservoir site to be suitable for rehabilitation and/or expansion. No compelling geotechnical reasons were found to relocate the landfill or wastewater lagoons."*

(a) T*he Proponent is requested to further detail and describe what geotechnical considerations were assessed to justify each of these statements?*

The geotechnical considerations were based on a visual site investigation, review of geological mapping, and results of the gradation analysis and were confirmed by the geotechnical review completed with respect to the comments received.

(b) *From the phasing used in these statements, the geotechnical considerations include land and cover availability. Does the Proponent agree that there are other geotechnical considerations like slope stability, bearing capacity, construction quality control and assurance, settlement, etc. are important geotechnical considerations in the design of these structures?*

Yes these are important and have been included in the above discussion.

(c) *How were the geotechnical considerations listed in bullet point b) accounted for in the geotechnical statements provided in Section 6.0 and 9.0 of Appendix B geotechnical Evaluation?*

Additional information in support of the design has been provided.

xxii *There were minimal details regarding the design and construction of the exfiltration berm for the wetland. The Board requests complete details regarding the size, shape, extent, material characteristics, specifications for construction, and engineering drawings of the exfiltration berm.*

The berm is to be constructed of native material and, as shown on the drawings, is to be constructed approximately 300 mm high and 1.8 m wide (3:1 side slopes). The berm is to extend for the length of the 300 mm effluent pipe as shown. The purpose of the berm is to encourage sheet flow of the effluent from the lagoon across the wetland area. The berm is to be constructed using the same material as that used for the lagoon berm.

xxiii Section 5.5 within the Design Report stated that the existing ditching in the northeast corner of the Bulky Metals Disposal Area will be improved "so that surface erosion of the area is minimized". It was further stated that corrective action for this issue was to add additional cover material to the affected area.

(a) The Board requests additional detail on the thickness and material type, as well as, specifications of the cover material required for this corrective action.

Where necessary, the existing ditches will be re-graded to provide better hydraulic gradient and to redirect the drainage paths around the site rather than over it.

The access area to the bulky metals disposal site and the part of the site that has already been covered, showed signs of erosion due to runoff cutting channels across the site. These channels are to be filled in as part of the proposed upgrades at the site. Erosion will be controlled by improving the drainage around the site so that this doesn't occur again in the future.

(b) *How will the addition of cover material prevent future erosion concern?*

The intent is to replace the cover material lost due to the erosion. . Improvements to the site ditching are intended to prevent future erosion concerns.

(c) *Are the ditches around the others structures prone to erosion damage? If not, why not? What has been done to prevent erosion in the other ditches at this site?*

Ditching did not appear to be prone to erosion damage. The problem at this site wasn't erosion damage to the ditching, it was the lack of ditching in this area that allowed surface runoff to travel directly across the site.

(d) Will monitoring of the structures and ditching for erosion damage be completed and what will be done for corrective action? If so, what is the frequency of monitoring and reporting to the Board?

Ditching will be improved and maintained by the Proponent. It is recommended that annual inspections be completed and reported to the NWB as part of the annual report.

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xxiv. The Proponent is requested to provide additional detail and description to address each of the point provided below with regards to the water reservoir liner.

Response to a), b), c) and d) is provided below.

During the construction document phase, the proposed reservoir construction method was modified. A revised Design Report is provided. The reservoir construction was revised to include the construction of the berms, supply and placement of a 300 mm layer of 19 mm gravel on top of the inside berm face, supply and placement of a 16 oz geotextile liner which would provide additional protection for the liner and a 80 mil HDPE welded liner. The 19 mm granular layer is provided as a support layer between the native material used in the berm construction and the geotextile and liner.

The construction process will be monitored by the onsite inspector and the soils consultant to ensure liner integrity during construction. The liner material is UV resistant. Liner and geotextile specifications are included in Section 02072 and 02075 of the Construction Tender Specifications.

xxv. The Proponent is requested to provide additional detail and description to address each of points provided below with regards to the hazardous waste storage area liner.

a) A complete set of the tender drawings has been provided in electronic format. The liner thickness was changed during the preparation of the design drawings and specifications to 80 mil from 40 mil. The drawings submitted for tender do not contain the inconsistencies noted. The protection layer as stated on Dwg 13 covers the liner and will protect the liner from damage under normal operating conditions.

b) The berm around the hazardous waste storage area is 0.33 m. The 1.0 m height indicated in the Design Brief was an error and should have read 0.33 m.

xxvi. The Proponent is requested to provide additional detail and description to address each of points provided below with regards to the lagoon and landfill liner.

a) i) Please refer to the responses provided previously which indicate that liners are not required for the landfill and lagoon.

ii) no

iii) yes

iv) & v) & vi) & vii) & viii) & ix) see results of analyses provided above.

b) The installation requirements are outlined in the Specifications Section 2072 and 2075. Any problems encountered with the liner during the maintenance period will be the responsibility of the contractor. Following this the Proponent will be responsible to monitor the liner.

xxvii *Within Section 3.1 of the Design Report, it stated that there was evidence of damage to the existing water reservoir. Specicically, "numerous areas where the liner had failed", and "slumping of the material under the liner was occurring, as well as the sand cover material over the liner had been eroded away" . The reasons for why these damages occurred were not provided. What provisions have been made to ensure that damages of this type will not occur with the construction of the water reservoir, lagoon, hazardous waste storage area, and landfill?*

It appears that the existing liner in the water reservoir may have been damaged by ice or stretching of the liner. It was also noted that the sand cover that was provided over the liner in the original design had either been scraped away by ice movement or erosion. It was also noted that the sand material under the liner had shifted over the last 27 years. The proposed design incorporates a 19 mm gravel layer on top of the native material to reduce the impacts of freeze and thaw cycles and ice damage. It was also decided to use a bare liner as this may assist with melting of the ice in the spring. It was also noted that there did not appear to be any leaks from the existing reservoir, which would suggest that permafrost had reaggraded into the berm. The liner was recommended for the reservoir to assist with the reaggradation of the permafrost, as it would be filled with water immediately following construction.

The other facilities, however, would not be filled immediately following construction they would be filled slowly providing an opportunity for the reaggradation of permafrost into the berms.