Appendix 2-C

Geotechnical Evaluation New Sewage Lagoon (2008)

GEOTECHNICAL EVALUATION
NEW SEWAGE LAGOON FACILITY
COLVILLE LAKE, NORTHWEST TERRITORIES

Submitted To:

Dillon Consulting Limited.
Calgary, Alberta

Submitted By:

AMEC Earth & Environmental
Calgary, Alberta

December, 2008

AMEC File No. YX00803

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1.0 INTRODUCTION

AMEC Earth & Environmental, a Division of AMEC Americas Limited (AMEC), has been retained by Dillon Consulting Limited (DCL) to conduct a geotechnical evaluation for a proposed new sewage lagoon facility located near the community of Colville Lake, NT. The objective of the evaluation was to analyse soil samples provided by DCL and provide geotechnical design parameters and recommendations for construction of the new sewage lagoon facility. Authorization to carry out this work was received from Mr. Keith Barnes, P. Eng. with DCL by returning a signed copy of AMEC's Professional Service Agreement, dated September 26, 2008.

2.0 BACKGROUND INFORMATION AND SCOPE OF WORK

The community of Colville Lake is currently in a design stage for construction of the new sewage lagoon facility, which will be located about 2.5 km southeast of the community, as shown on Figure 1, Appendix A. It is understood that the proposed sewage lagoon facility will consist of a lagoon, approximately 1190 m^2 in size, bounded by four berms. The lagoon impoundment is proposed to be excavated to between 1 m to 2 m depth into native soil. It is also understood that the lagoon berm is expected to be designed on the basis of a frozen core berm with a bentomat liner. No liner is expected for the base of the lagoon impoundment area, or on the submerged slopes of the lagoon..

Based on AMEC's Professional Service Agreement and subsequent discussions with Mr. Barnes, the scope of work for the evaluation was to:

- Conduct a review of the climatic data, and geological and permafrost conditions of the community.
- Conduct soil testing on five samples provided by DCL, including Atterberg Limits, hydrometer, and permeability. Following discussions with Mr. Barnes, the hydrometer test was changed to a Standard Proctor Maximum Dry Density test.
- Undertake a geothermal analysis to estimate thaw depth under the lagoon impoundment area and temperatures within and below the lagoon berms.
- Prepare this geotechnical report that summarizes the results of the geotechnical evaluation that includes:
    - o discussion of inferred subsurface conditions;
    - o recommendations for the development of the lagoon berms, based on the geothermal analysis;

3.0 REVIEW OF EXISTING DATA

AMEC and predecessor companies (AGRA Earth & Environmental Limited, HBT AGRA Limited, and Hardy BBT Limited) have completed several geotechnical projects in the community of Colville Lake. One AMEC report and a Paper from the Geological Survey of Canada was reviewed for this project. A summary of the subsurface conditions presented within these reports is presented below:

The AMEC report titled ***"Foundation Soil Investigation for Proposed Assembly Building and Wellness Center, Colville Lake, NWT"*** was prepared for the Government of Northwest Territories in 1997. The report provides data on three boreholes advanced at the assembly building site. Within the 9 m depth investigated, the general soil profile was observed to consist of peat overlying fine to medium grained sand overlying clay till. The thickness of the peat was found to be about 0.6 m. The peat was ice rich with moisture contents varying from about 140 percent to over 400 percent. The thickness of the sand was up to 1 m. Underlying the sand was low to medium plastic clay till with varying amounts of silt and fine-grained sand. Moisture contents in the sand and clay till varied from 10 percent to over 40 percent, indicating that considerable excess ice could be encountered in the mineral soils. The permafrost temperature at a depth of 8 m was reported to be approximately -2°C.

The Paper 70-12 ***"Geology, Colville Lake Map-Area and part of Coppermine Map-Area (96 NW and NE, Part of 86 NW) Northwest Territories"*** by D.G. Cook and J.D. Aitken was published by the Geological Survey of Canada in 1971. The article provides detailed data on the bedrock geological settings from the Proterozoic to Cretaceous age. The bedrock geology consists of an extensive sequence of sedimentary formations of Paleozoic age underlain by the Proterozoic basement. The deposits are mainly of sedimentary origin and comprised of dolomite, limestone, shale and sandstone. The thickness of the Paleozoic sediments exceeds 1000 m.

In addition to the above noted report, surficial geology reports and published climatic data (long term averages) were reviewed. Information obtained during this review and other available documentation is presented in the following sections.

4.0 INFERRED SURFACE AND SUBSURFACE CONDITIONS

Subsurface soil conditions at the proposed sewage lagoon site were inferred from analysis of the above mentioned report, paper and results of the laboratory test program for five samples derived at the site down to a depth of about 2 m by a backhoe excavator.

4.1 Site Location and Terrain

The community of Colville Lake is located on the south shore of Colville Lake at approximately 67°2' N latitude and 126°5' W longitude. The proposed sewage lagoon facility site is located about 2.5 km southeast from the community. The ground surface in the vicinity of the community is flat to gently rolling with occasional wetlands. Based on the analysis of aerial photographs of the area, it can be concluded that the new lagoon site is sparsely treed with a well developed ground vegetation cover consisting of moss and lichen.

4.2 Climate and Permafrost

Climate records for Colville Lake are not readily available, therefore a tentative assessment of the mean monthly air temperatures and snow cover thickness were based on averaging of climate data from Climate Normals (1970 to 2000) for two weather stations: Inuvik, located approximately 320 km northwest from Colville Lake, and Norman Wells, positioned some 200 km south from the community. Table 1 presents mean monthly air temperatures and snow cover thickness for Colville Lake obtained as the arithmetic mean for the weather stations at Inuvik and Norman Wells. The estimated mean monthly air temperatures and snow cover for Colville Lake were used to assess the mean annual permafrost temperature at the sewage lagoon site.

Table 1: Mean Monthly Air Temperatures and Snow Cover Thickness

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temp., °C	-27.0	-25.8	-20.8	-9.3	3.4	13.2	15.6	12.4	5.2	-6.8	-20.2	-25.4
Snow Thickness, m	0.37	0.44	0.46	0.38	0.0	0.0	0.0	0.0	0.0	0.08	0.22	0.26

The community of Colville Lake lies near the southern limits of the continuous permafrost zone. The depth of the active layer has been reported to vary from 0.3 m (peat) to about 2 m in relatively dry mineral soils. Calculations using the data from Table 1 indicate that the expected thickness of the active layer at the sewage lagoon site is in the order of 1.7 m. Mean annual permafrost temperature has been reported in a range of -1.0°C to -3.0 °C. This is consistent with the results of analysis based on the data in Table 1, which indicate that the mean annual permafrost temperature at the site would be in the order of -1.5 °C.

4.3 Stratigraphy and Properties of Marine Deposits

The general soil profile, based on analysis of the DCL samples and the reviewed reports, consists of marine silty clay over clay till. The marine silty clay was brown with some black organic inclusions down to about a 0.5 m depth, trace of fine gravel and inclusions of coarse gravel, up to 60 mm in size. The silty clay was soft, and the plasticity index varied from 7.2 to 9.2.

The Standard Proctor Maximum Dry Density (SPMDD) test indicated an optimum moisture content of 11.5 percent at a dry density of 1950 kg/m^3. Results of the laboratory testing program are provided in Appendix B. The samples were not securely sealed when they arrived at the laboratory, therefore no moisture content tests were performed on any of the samples. The expected thickness of the marine silty clay is expected to be in a range of several metres.

Clay till may be present below the marine silty clay. In accordance with the borehole log data provided in the reviewed AMEC report, the clay till may generally be classified as ice-rich. However no visible ice inclusions were observed during investigations for the Assembly Building and Wellness Centre. The moisture content of the clay till ranged from 30 percent to 40 percent.

5.0 GEOTHERMAL ANALYSIS

A detailed geothermal analysis has been carried out to assess the present and future thermal regime within the proposed sewage lagoon berm and the associated berm/impoundment area foundation soils. Based on a review of DCL general suggestions, and drawings numbered 101, 102, and 103, the analysis considered the following berm details and geometry:

- *Height of berm is 2.5 m.*
- *Width of crest is 3 m.*
- *Upstream and Downstream slope of berms are 1V:2H, above the design water level.*
- *Granular fill consisting of sand and gravel is proposed for the berm construction.*
- *Sewage lagoon floor is at a depth of 1 m below the existing ground surface.*
- *Sewage lagoon impoundment slopes are 1V: 4H, below the design water level.*

The geothermal modeling program SIMPTEMP, 2D version, (developed by AMEC) was used to analyze geothermal regimes for the berm. The simulator uses finite element analysis 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 following section briefly describes the initial geothermal conditions assumed for the berm subgrade, the model setup, input parameters and the result of the SIMPTEMP analysis.

5.1 Boundary Conditions for Geothermal Modelling

The air temperature and snow depth data used for the present analysis where averaged using weather station data from Inuvik and Norman Wells as discussed in Section 4.2. The mean monthly air temperatures and snow thicknesses used for the SIMPTEMP model are presented in Table 1, in Section 4.2.

Mean monthly surface temperatures were applied over the exposed berm surface, ground surface beyond downstream slope of the berm and over water surfaces beyond upstream slope of the berm. To obtain the mean monthly surface temperatures, various n-factor coefficients were used over the berm, downstream ground surface beyond the berm and water surface.

<u>Berm Slopes and Crest.</u> It was assumed that reduced snow thickness would be accumulated on the dyke slopes and crest. Therefore, an n-factor of 0.8 was applied to the mean monthly air temperatures to obtain the mean monthly winter temperatures on the berm surface. An n-factor of 1.2 was applied to the mean monthly air temperatures to obtain the berm surface temperature in summertime. An n-factor of 1.2 corresponds to bare rockfill surface, meaning that the rockfill surface is warmer than the corresponding air temperature.

Downstream Terrain Beyond Berm. It was assumed that snow could accumulate beyond the toe of the berm. Based on 1D geothermal analysis, it was estimated that n-factors for the terrain type, would be 0.46 and 0.7 for the winter and summer air temperatures, respectively. These n-factors represent the insulating/warming effect of snow cover in the winter, and the cooling effect of the peat/lichen vegetation in the summer.

Water (Upstream Beyond Berm). It was assumed that snow would accumulate on the lagoon surface in the winter. Similar to the downstream terrain area, an n-factor of 0.46 was applied to the mean monthly air temperatures for the winter months (October through April). From May through September, it was assumed that the water temperature over the entire depth of the water column was the same as the mean monthly air temperatures. Table 2 provides data on the mean monthly surface temperatures that were applied over the upper boundary of the geothermal models.

Table 2: Mean Monthly Surface Temperatures on Model Mesh

Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Berm Crest and Slopes	-21.6	-20.6	-16.6	-7.4	4.1	15.8	18.7	14.9	6.2	-5.4	-16.2	-20.3
Downstream Surface	-12.4	-11.9	-9.6	-4.3	2.4	9.3	10.9	8.7	3.7	-3.1	-9.3	-11.7
Water	-12.4	-11.9	-9.6	-4.3	Water temperature equals air temperature (see Table 1, Section 4.2).					-3.1	-9.3	-11.7

5.2 Physical and Thermal Soil Properties

Estimates of physical soil properties for various typical soils expected to be encountered within the berm and berm foundation were based on published information (see Section 3.0) and the samples provided by DCL. Thermal properties of the materials (thermal conductivity and heat capacity) were selected based on available published data, and on previous experience with similar materials. Table 3 summarizes the material physical and thermal properties applied for the geothermal analyses.

Table 3: Physical and Thermal Soil Properties

Soil Type	Dry Density, kN/m³	Moisture Content, %	Thermal Conductivity, W/m/°C		Heat Capacity, MJ/m³/°C	
			Frozen	Unfrozen	Frozen	Unfrozen
Granular fill	20	7	2.90	2.73	2.26	2.68
Silty clay	16	20	1.74	1.63	2.14	2.80
Water	10	---	2.20	0.58	1.95	4.19

5.3 Grid and Initial Temperature Description

The geothermal model grid extended 152.5 m below the crest of the berm and contained 4536 finite elements and 2365 nodes. The berm and active layer initial temperatures were taken as +5 °C, corresponding to the assumed berm material temperature and active layer temperature at the end of summer. The initial soil temperature from the base of the active layer and to a depth of 10 m was taken to be -1.5 °C; the soil temperature was then taken to warm gradually down to the bottom of the grid with a geothermal gradient of 0.02 °C/m.

Zero heat flux was applied at lateral boundaries of the grid, while the heat flux at the mesh bottom corresponded to the geothermal gradient of 0.02 °C/m.

5.4 Results of Geothermal Modelling

Figure 2, Appendix A shows that after the first year of lagoon operation (end of summer), the berm has temperatures above 0 °C, ranging from 1.0 °C to 6.0 °C, and the zero isotherm is located at a depth of about 0.5 m below the berm base. The talik thickness under the lagoon impoundment is about 3 m.

Figures 3 through 6 show that no considerable change in the berm temperature is observed during thirty years of facility operation. At the end of summer, the entire berm temperature remains positive, ranging from 1.0 °C to 6.0 °C after 5, 10, 20, and 30 years of the operation. It can be observed that the thickness of the talik under the lagoon floor increases to 14 m after 30 years of lagoon operation.

The analyses did not include any component of climate warming over the expected life of the lagoon and following decommissioning. Typical climate warming values could be in the range of 0.1 °C/year (1 °C/decade). Applying a climate warming scenario to the analysis would result in warmer berm temperatures.

It can be concluded based on the geothermal analysis, that the concept of a frozen core berm to provide the primary containment of lagoon water should not be considered for the current berm configuration in the Colville Lake area. It is estimated that a frozen core can be created only within a relatively high, (6 m to 7 m) berm.

6.0 GEOTECHNICAL RECOMMENDATIONS

The following sections provide general recommendations pertaining to the design and construction of the sewage lagoon berm and lagoon impoundment based on the results of the geothermal modelling and laboratory analysis.

6.1 Berm Design

The following paragraph provides recommendations for four alternative berm design options.

The first design option proposes construction of the berm and cut-off trench with the use of the compacted silty clay similar to that tested in the AMEC soil laboratory. It is estimated that the cut-off trench should be about 4 m deep to ensure that the lower 1 m portion of the trench will remain in a frozen state. The trench should be backfilled with compacted silty clay fill at 98 percent of SPMDD. It should be noted that the thickness of the silty clay available in an unfrozen state will likely be limited to an about 2 m depth or less during the summer construction season. Previous drilling within the Coleville Lake area has indicated that the silty clay may be ice rich, having a high moisture content when thawed. Due to the relatively short construction season and comparatively cool summer temperatures, it may be not practical or impossible to dry out the silty clay fill sufficiently to achieve the proper compaction level. This design option can be implemented with a synthetic liner if hydraulic conductivity of the compacted silty clay material will be considerably greater than that obtained in the AMEC soil laboratory (see Appendix B). If a synthetic liner will be used, then only a lower portion (about 1 m) of the trench should be compacted to 98 percent of SPMDD. Above this layer, the trench can be filled up with silty clay compacted at the natural moisture content.

The second design option proposes construction of the berm with the use of the compacted silty clay, and with the cut-off trench backfilled with silty clay fill mixed with cement. Grout can also be used for backfilling of the cut-off trench. The cement additive will assist in stabilization of the native silty clay for the well above optimum moisture content. Although mixing 3 percent to 7 percent cement by weight with the soil can be effective in stabilizing wet fill, the process must be done with specialized mixing/metering equipment to be effective. Such equipment would likely have to be sourced in Edmonton. This design option also can be implemented with a synthetic liner.

The third design option proposes construction of the berm with compacted granular fill, and cut-off trench backfilled with bentonite or grout. A synthetic liner installed in the cut-off trench and extended into the berm is the mandatory requirement for the given option. The liner could be either a hydrocarbon based or a bentonite based geomembrane. Some overbuilding of the lagoon berm would be required to allow for some additional settlement of the bentonite backfill. The volume of material (grout or bentonite) required to backfill the cut-off trench makes this very costly.

The fourth design option proposes construction of the berm with compacted granular fill, and a synthetic liner installed over the entire lagoon floor and extending onto the berm. This option will not require construction of a cut-off trench. The liner could be either a hydrocarbon based or a bentonite based geomembrane. The liner should be placed with creases that provide slack in the liner to avoid rupture as thawing of permafrost under the lagoon impoundment area occurs. If this option will be chosen it is recommended that, one borehole be drilled within the lagoon impoundment to assess ice content and potential for thaw settlement over a depth of about 15 m to 20 m.

The upper layer of the berm, about 0.5 m thick, should consist of granular fill, protecting the berm slopes against water erosion. Upstream and downstream slopes of 1V:2H, corresponding to slope angle of about 26.5 degrees, were applied in the geothermal analysis. However, additional slope stability analyses should be undertaken to confirm stability of the berm slopes for the proposed design options.

6.2 Excavating and Backfilling

Prior to excavating the cut-off trench, all organic material should be stripped over the entire berm footprint. The exposed subgrade should be inspected, and all soft materials and materials with organic inclusions should be removed and replaced with engineered fill. The subgrade then should be scarified down to 200 mm, moisture conditioned and compacted to 98 percent of SPMDD.

It is estimated that the cut-off trench should be about 4 m deep to ensure that the lower 1 m portion of the cut-off trench will remain in a frozen state. Depending on the design option, the trench should be backfilled with compacted silty clay, bentonite or grout. If the silty clay will be used as the backfill it is recommended that the material be free of organics, and moisture conditioned to ±1percent of the optimum moisture content and be compacted to 100 percent of Standard Proctor Maximum Dry Density (SPMDD). The silty clay should be spread evenly and placed in lifts no more than 200 mm in compacted thickness. Fill placement should be undertaken during frost-free seasons since required degree of compaction cannot be achieved if the fill materials are frozen or are at near-freezing temperatures.

The silty clay excavated at the lagoon impoundment or alternative clayey material from a borrow pit can be used to construct the berm core and cut-off trench. However the alternative borrow material should have similar hydraulic conductivity as the original silty clay. The laboratory test has demonstrated that the hydraulic conductivity of the compacted silty clay is in the order of 10^{-8} cm/sec.

6.3 Impoundment Floor Design

It is recommended that the impoundment area be excavated to 1.2 m below grade with sideslopes not steeper than 1V: 4H, assuming that the excavation will be undertaken in soft clayey material. The exposed clay subgrade should then be scarified, moisture conditioned and re-compacted to 100 percent of SPMDD. A gravel layer, 200 mm in compacted thickness (95 percent to 98 percent of SPMDD) should be placed over the re-compacted clay subgrade at the impoundment floor. The thickness of the compacted gravel on the impoundment slopes should be increased to 1 m.

7.0 CLOSURE

The engineering recommendations presented herein are based mainly on the results of a geothermal analysis and the laboratory test program conducted on five soil samples. No drilling was undertaken at the proposed location to observe subsurface conditions below 2.2 m depth. It is recommended that a drilling program/investigation be carried out along the berm alignment and over the lagoon impoundment area to ensure that there is a sufficient thickness of native clay material and to confirm the presence or absence of ice rich soils.

It should be stated that the results of modelling are valid for the boundary conditions and soil properties described in Sections 5.1 and 5.2. If actual boundary conditions and soil properties differ considerably from the assumed/calculated parameters, then the actual soil temperatures within the berm and impoundment could vary from the predicted temperatures.

AMEC recommends that seepage and slope stability analyses be conducted for the chosen design berm configuration. These analyses were not included in the present geotechnical scope of work.

This report has been prepared for the exclusive use of Dillon Consulting Limited and its agents for the specific application described in this report. The use of this report by third parties is done so at the sole risk of those parties. It has been prepared in accordance with generally accepted permafrost and foundation engineering practices. No other warranty, expressed or implied, is made.

Respectfully submitted,

AMEC Earth & Environmental
a division of AMEC Americas Limited

REGISTERED PROFESSIONAL ENGINEER
D. DUMSKY
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Dmitry Dumsky, B.Sc., P.Eng.
Geotechnical and Permafrost Engineer

PERMIT TO PRACTICE
AMEC Earth & Environmental, a Division of AMEC Americas Limited
Signature
Date December 18, 2008
PERMIT NUMBER: P 047
The Association of Professional Engineers, Geologists and Geophysicists of the NWT / NU

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Associate Geotechnical and Permafrost Engineer

Reviewed by:
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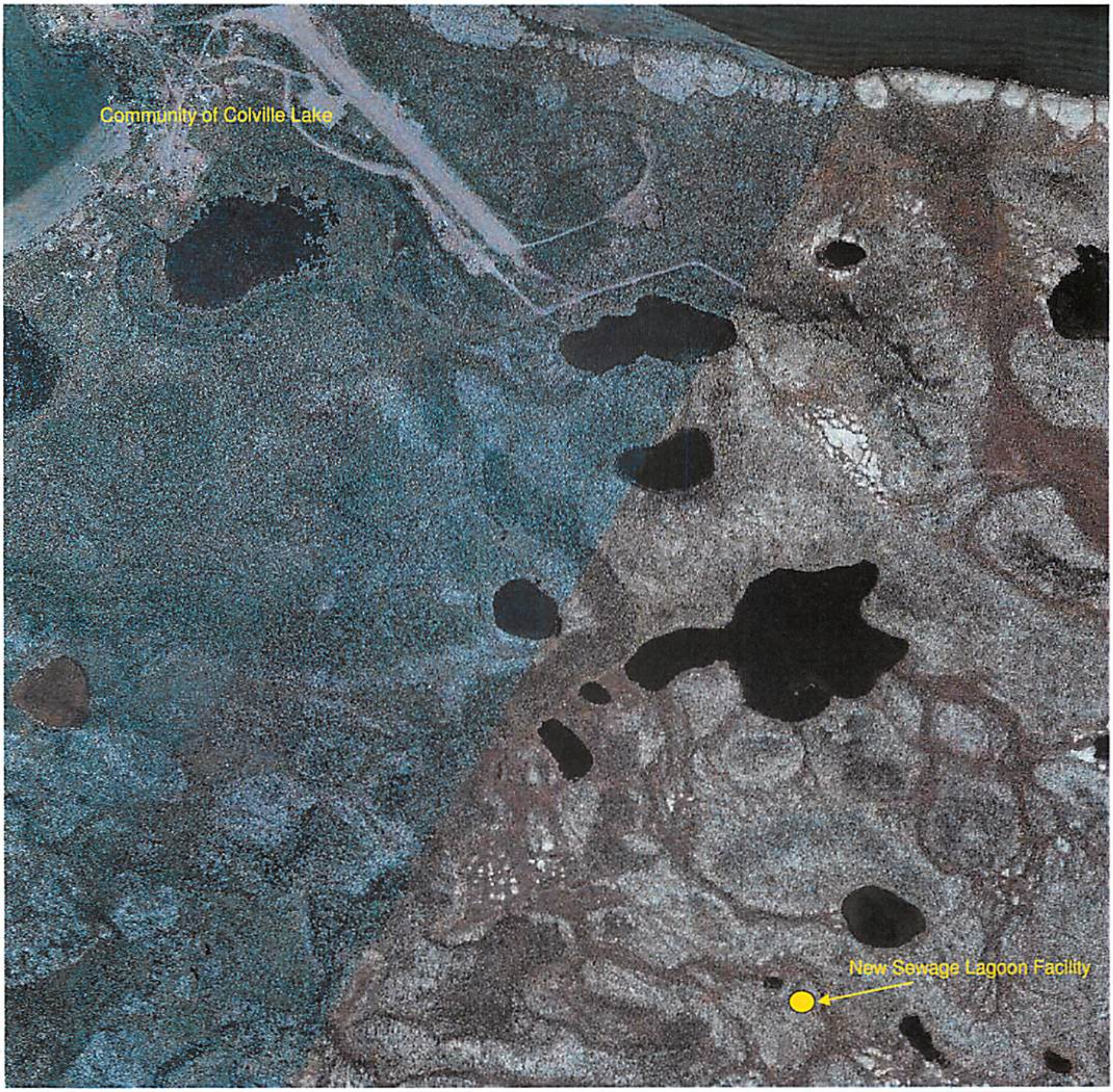
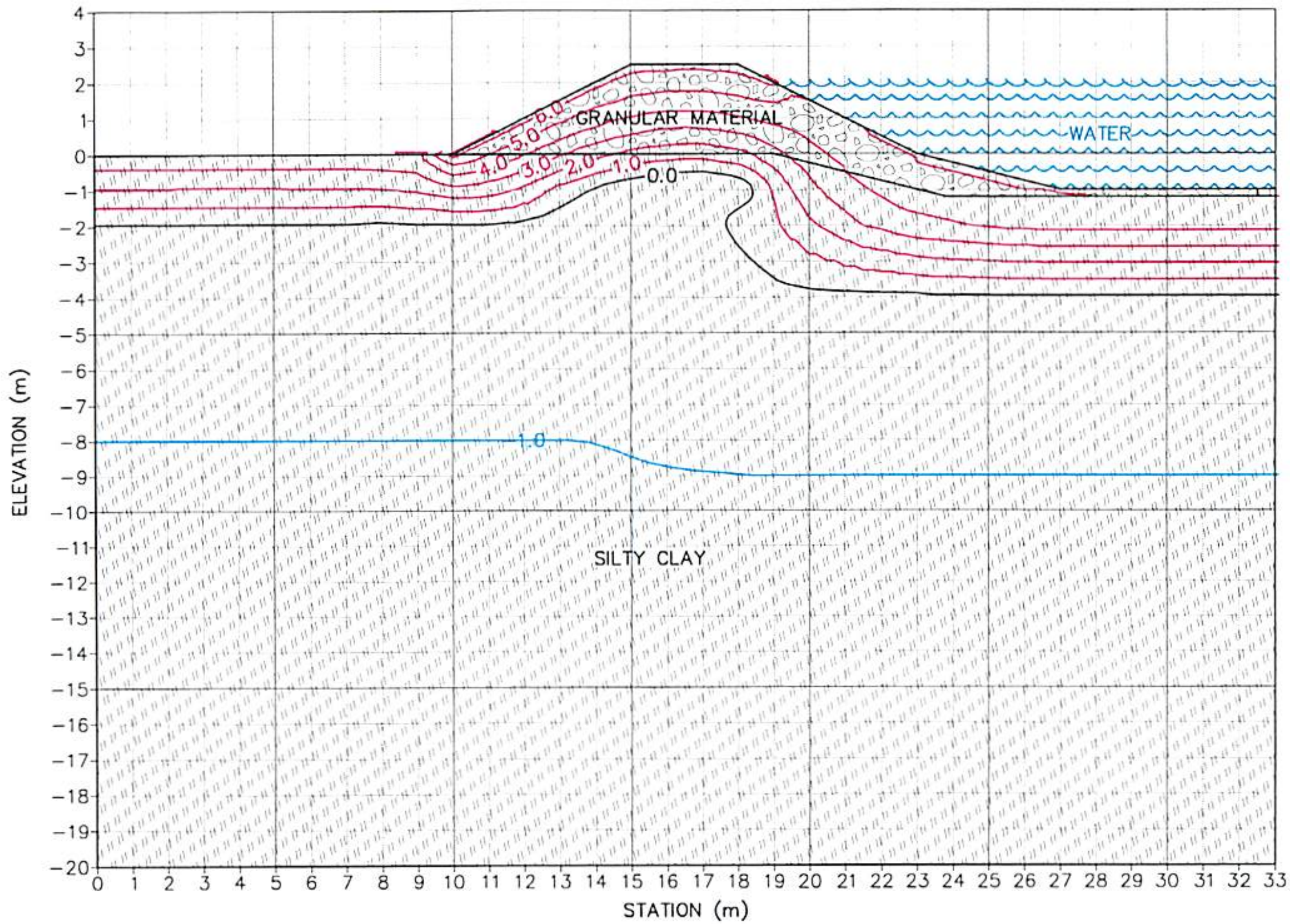
Associate Geotechnical Engineer

APPENDIX A



Client:	Dillon Consulting Limited	Figure 1		amec
Project:	New Sewage Lagoon Facility Colville Lake, NT.	Date: Nov. 2008	N ↑	
Title:	Sewage Lagoon Location	Job No. YX00803		
		File No.: Figure 1.xls		



LEGEND:

GRANULAR MATERIAL

SILTY CLAY

WATER

SCALE

1:200 0 1 2 3 4 m

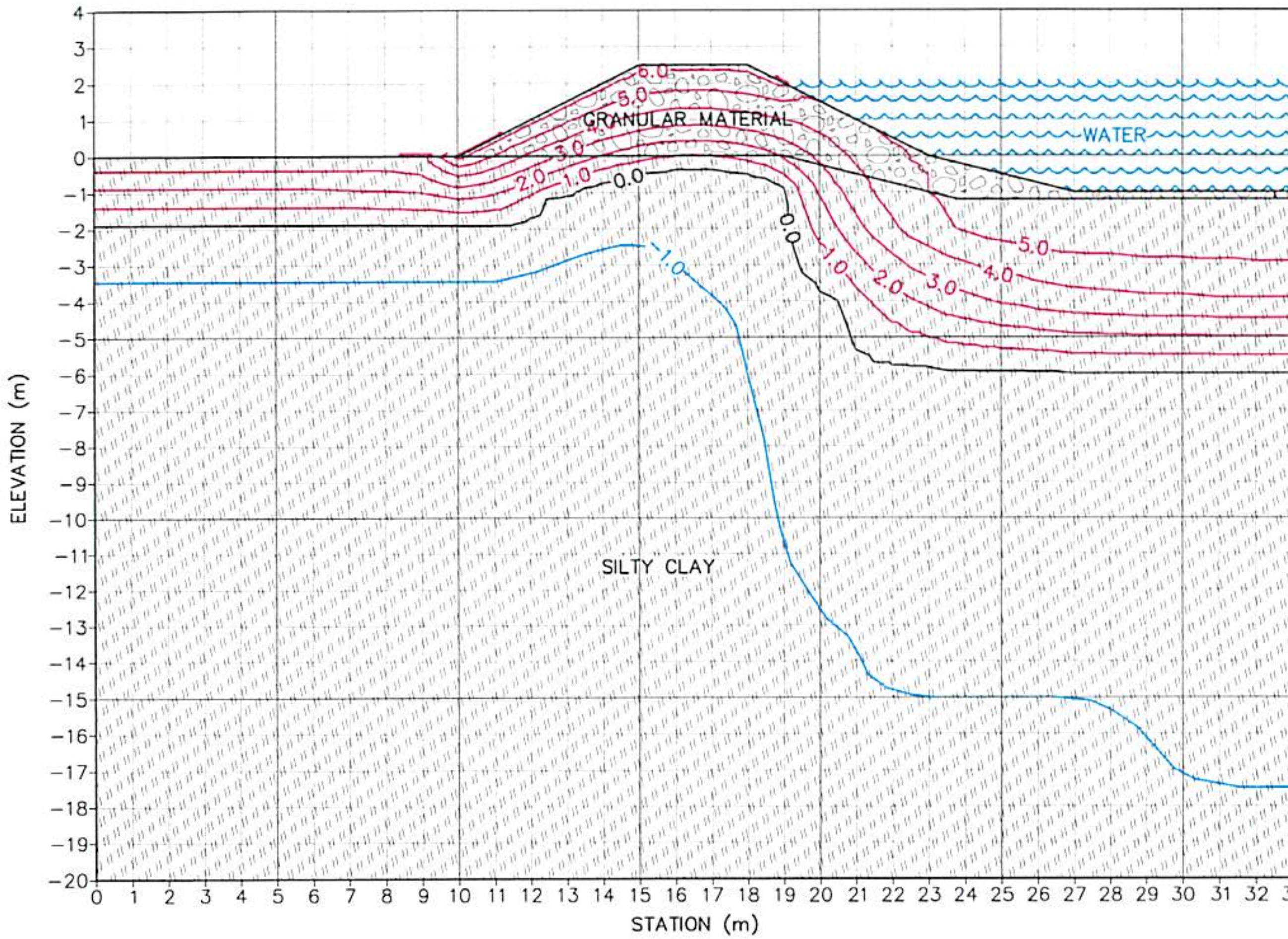
amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

PROJECT: NEW SEWAGE LAGOON FACILITY, COLVILLE LAKE, NT

TITLE: BERM TERMPERATURE AFTER 1 YEAR

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
NOVEMBER 2008	YX00803	00803N00.dwg	FIGURE 2	A



LEGEND:

GRANULAR MATERIAL

SILTY CLAY

WATER

SCALE
1:200 (0 1 2 3 4 m)

amec Earth & Environmental

CLIENT: DILLON CONSULTING LIMITED

PROJECT: NEW SEWAGE LAGOON FACILITY, COLVILLE LAKE, NT

TITLE: BERM TEMPERATURE AFTER 5 YEARS

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
NOVEMBER 2008	YX00803	00803N00.dwg	FIGURE 3	A

*PLOT 1:1=A (P)

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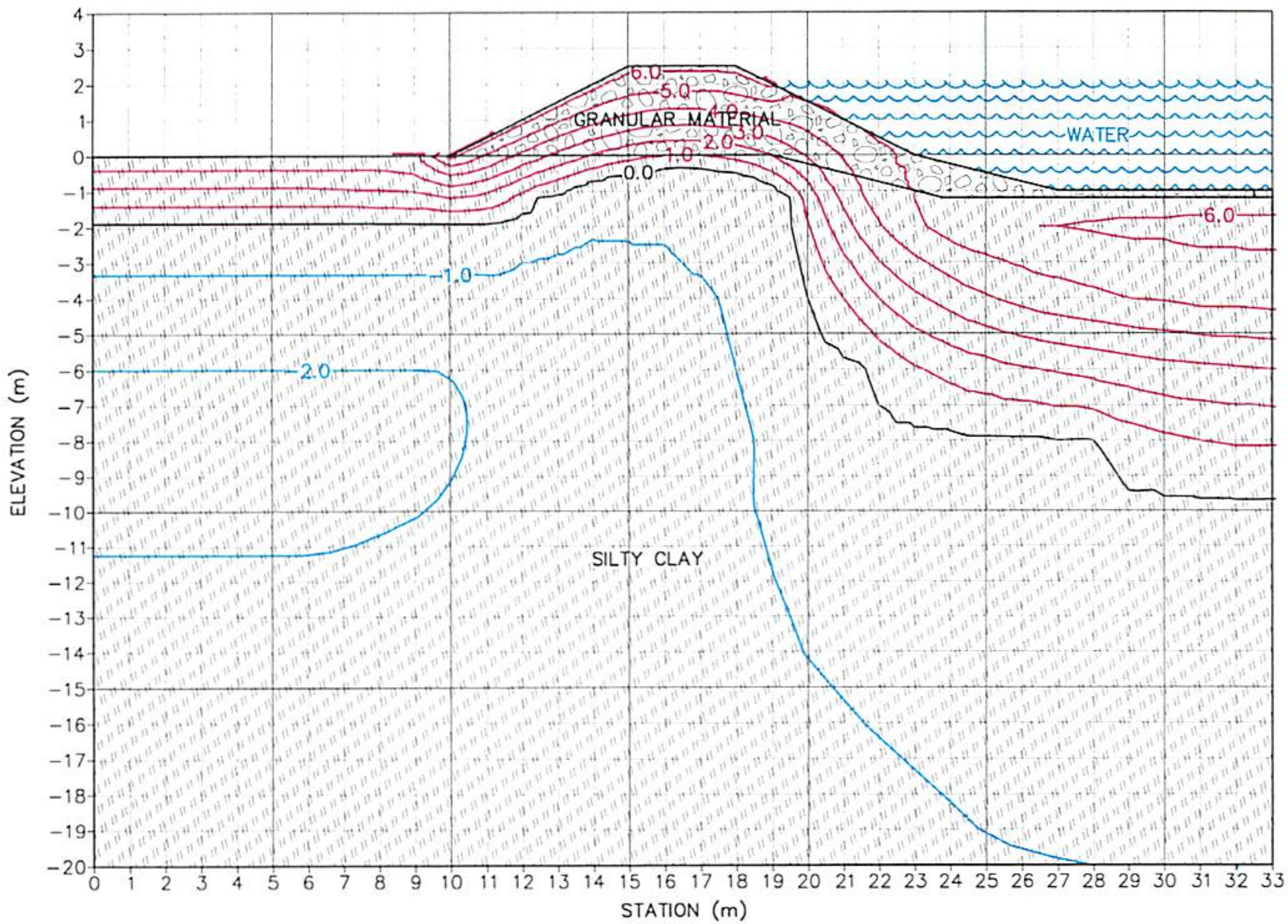


LEGEND:

- GRANULAR MATERIAL
- SILTY CLAY
- WATER

SCALE
1:200 0 1 2 3 4 m

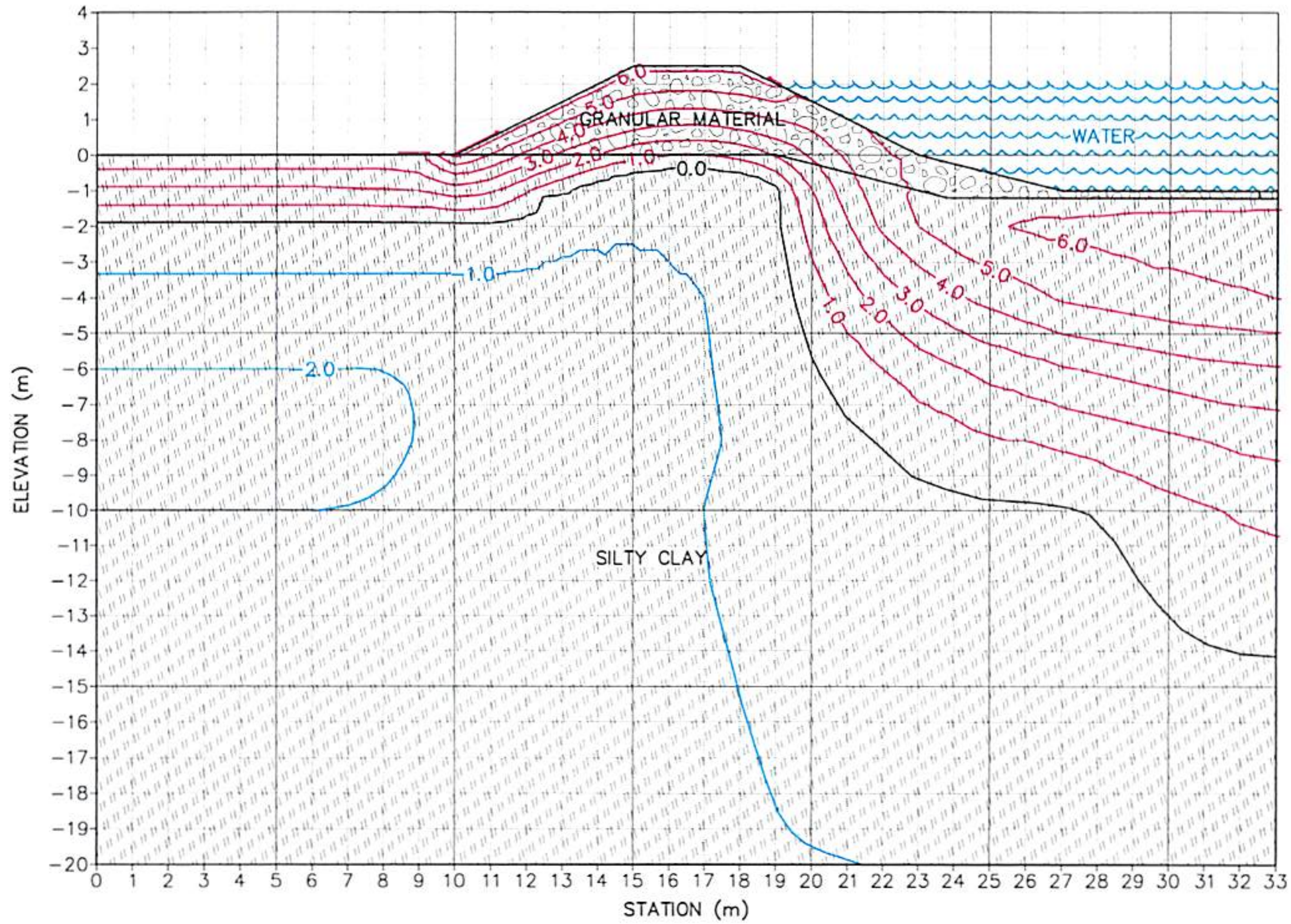
amec Earth & Environmental

CLIENT: **DILLON CONSULTING LIMITED**

PROJECT: **NEW SEWAGE LAGOON FACILITY, COLVILLE LAKE, NT**

TITLE: **BERM TEMPERATURE AFTER 10 YEARS**

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
NOVEMBER 2008	YX00803	00803N00.dwg	FIGURE 4	A



LEGEND:

GRANULAR MATERIAL

SILTY CLAY

WATER

SCALE

1: 200

0 1 2 3 4 m

amec Earth & Environmental	PROJECT: NEW SEWAGE LAGOON FACILITY, COLVILLE LAKE, NT
	TITLE: BERM TEMPERATURE AFTER 20 YEARS
CLIENT: DILLON CONSULTING LIMITED	DATE: NOVEMBER 2008 / JOB No.: YX00803 / CAD FILE: 00803N00.dwg / FIGURE No.: FIGURE 5 / REV.: A

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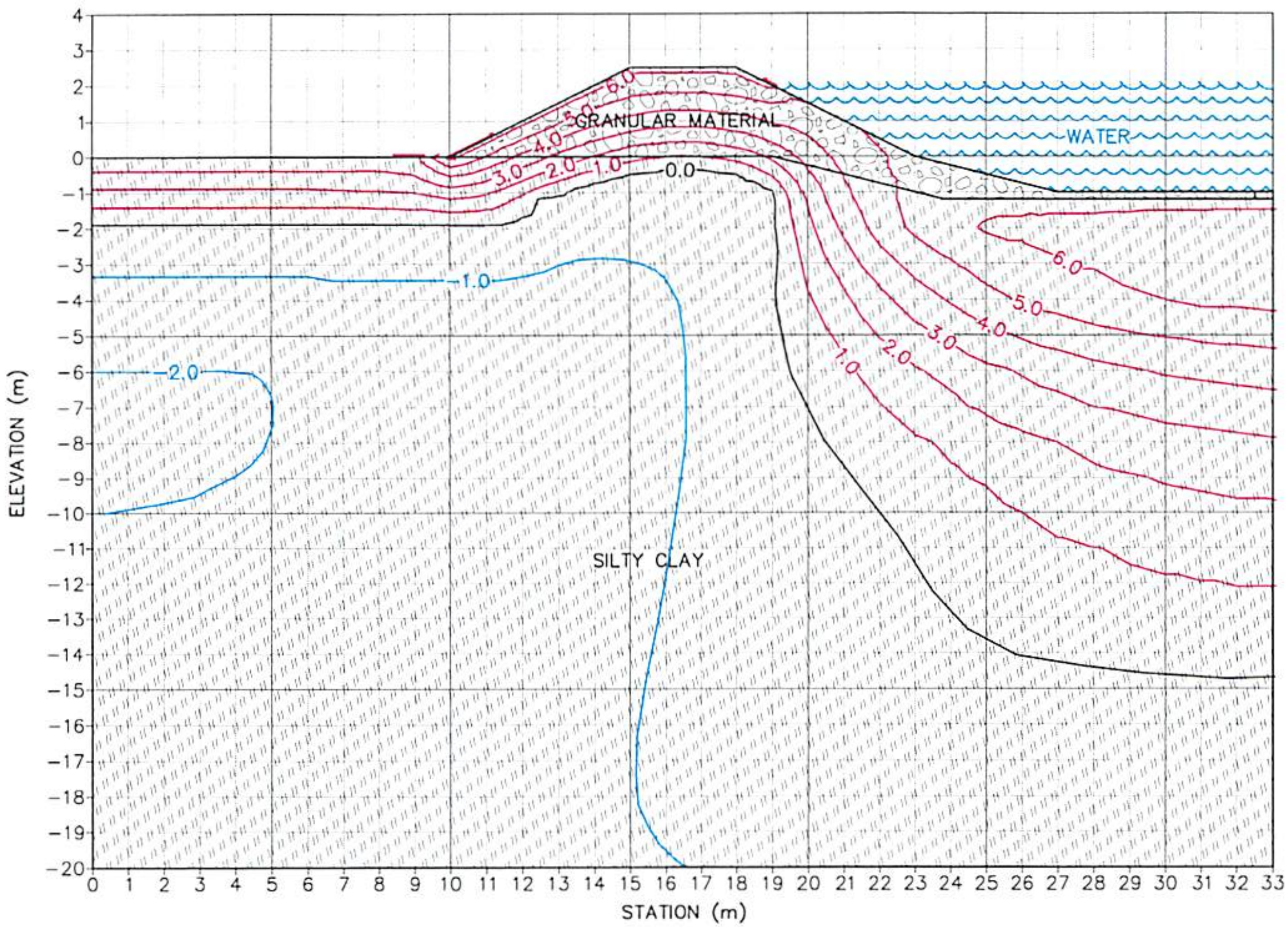


LEGEND:

- GRANULAR MATERIAL
- SILTY CLAY
- WATER

SCALE
1:200
0 1 2 3 4 m

amec Earth & Environmental

CLIENT: **DILLON CONSULTING LIMITED**	PROJECT: **NEW SEWAGE LAGOON FACILITY, COLVILLE LAKE, NT**
	TITLE: **BERM TEMPERATURE AFTER 30 YEARS**

DATE:	JOB No.:	CAD FILE:	FIGURE No.:	REV.
NOVEMBER 2008	YX00803	00803N00.dwg	FIGURE 6	A

APPENDIX B

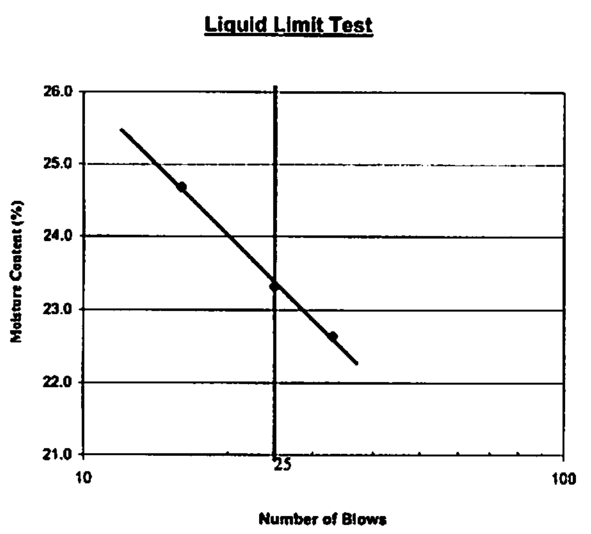
Atterberg Limits Test

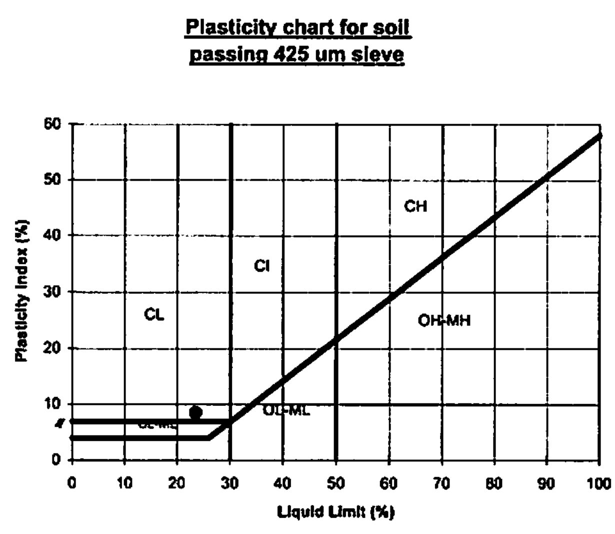
AMEC Earth & Environmental
a Division of AMEC Americas Limited

amec

Project No: YX00803
Project:
Request No:
Sample ID: 0.5m
Date: Sept. 25, 2008
Technician: DMM

Liquid Limit Test				Plastic Limit Test		
# of Blows	33	25	16			
Tare #	T30	T76	T17	Tare #	T31	T97
Wet Wt + Tare	20.11	19.74	18.29	Wet Wt + Tare	11.04	10.91
Dry Wt + Tare	17.98	17.63	16.37	Dry Wt + Tare	10.72	10.59
Wt of Tare	8.57	8.58	8.59	Wt of Tare	8.57	8.48
% Moisture	22.6	23.3	24.7	% Moisture	14.9	15.2





Liquid Limit 23.5 **Plastic Limit** 15.0 **Plasticity Index** 8.5

Classification CL

Reporting of these results constitutes a testing service only. Engineering interpretation or evaluation of these test results is provided only on written request. The data presented is for the sole use of the client stipulated above.

P:\Projects\Yellowknife\YX00803 - Colville Lake Sewage Lagoon\Report\Lab data\Atterberg Limits 0.5m.xls

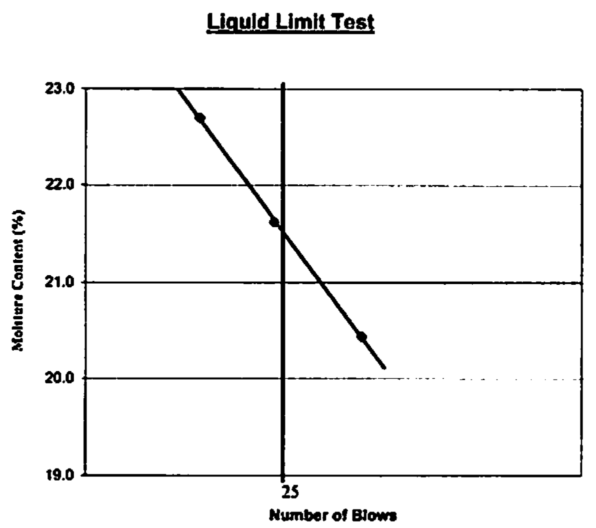
Atterberg Limits Test

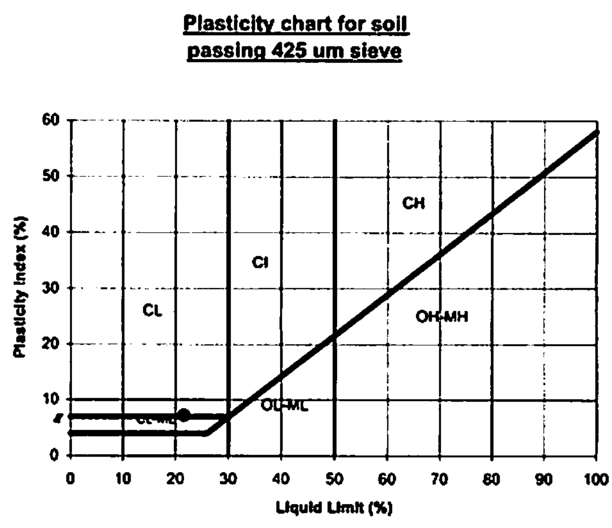
AMEC Earth & Environmental
a Division of AMEC Americas Limited

amec

Project No: YX00803
Project:
Request No:
Sample ID: 1.0m
Date: Sept. 25, 2008
Technician: DMM

Liquid Limit Test				Plastic Limit Test		
# of Blows	36	24	17			
Tare #	T51	T87	BE	Tare #	T25	T9
Wet Wt + Tare	21.22	19.42	18.53	Wet Wt + Tare	11.50	11.75
Dry Wt + Tare	19.08	17.50	16.68	Dry Wt + Tare	11.14	11.34
Wt of Tare	8.61	8.62	8.53	Wt of Tare	8.58	8.55
% Moisture	20.4	21.6	22.7	% Moisture	14.1	14.7





Liquid Limit 21.6 **Plastic Limit** 14.4 **Plasticity Index** 7.2

Classification CL

Reporting of these results constitutes a testing service only. Engineering interpretation or evaluation of these test results is provided only on written request. The data presented is for the sole use of the client stipulated above.

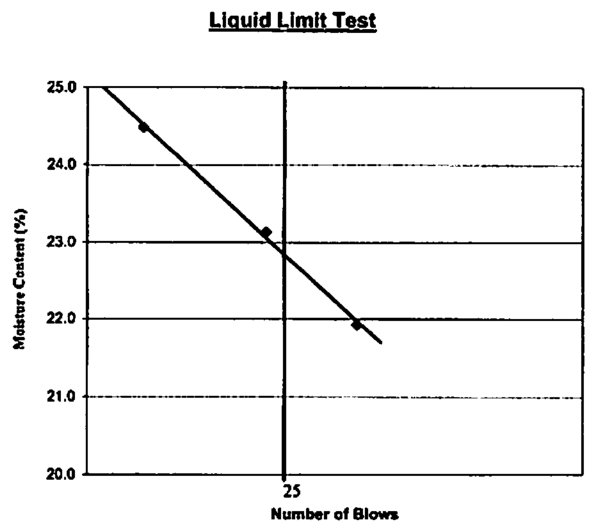
P:\Projects\Yellowknife\YX00803 - Colville Lake Sewage Lagoon\Report\Lab data\Atterberg Limits 1.0m.xls

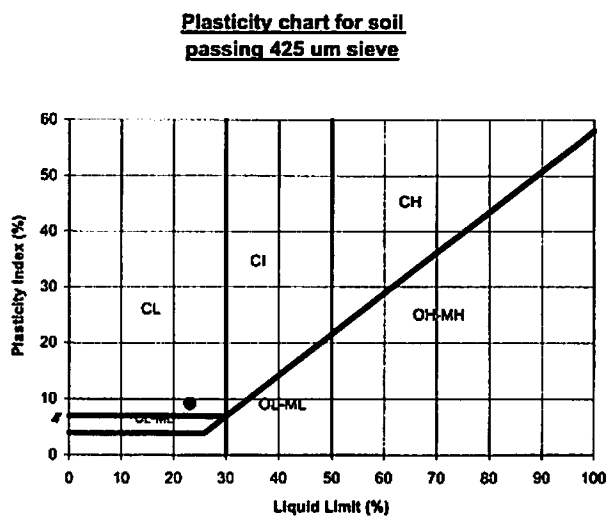
Atterberg Limits Test
AMEC Earth & Environmental
a Division of AMEC Americas Limited

amec

Project No: YX00803
Project:
Request No:
Sample ID: 1.5m
Date: Sept. 25, 2008
Technician: DMM

Liquid Limit Test				Plastic Limit Test		
# of Blows	35	23	13			
Tare #	T44	T47	T10	Tare #	T28	T65
Wet Wt + Tare	18.27	19.00	20.04	Wet Wt + Tare	11.72	12.16
Dry Wt + Tare	16.54	17.05	17.79	Dry Wt + Tare	11.33	11.72
Wt of Tare	8.65	8.62	8.60	Wt of Tare	8.53	8.60
% Moisture	21.9	23.1	24.5	% Moisture	13.9	14.1





Liquid Limit 23.2 **Plastic Limit** 14.0 **Plasticity Index** 9.2

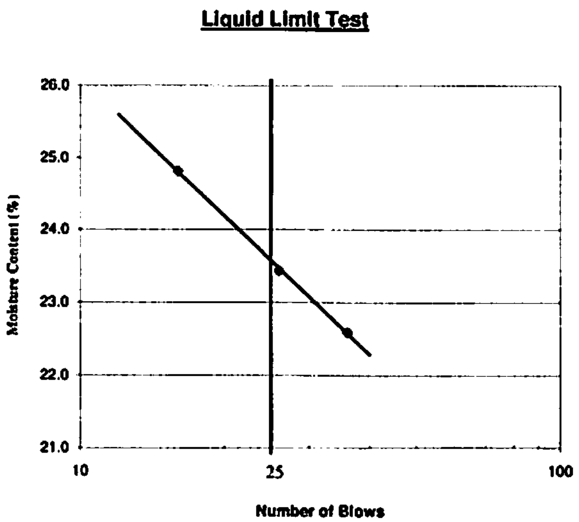
Classification CL

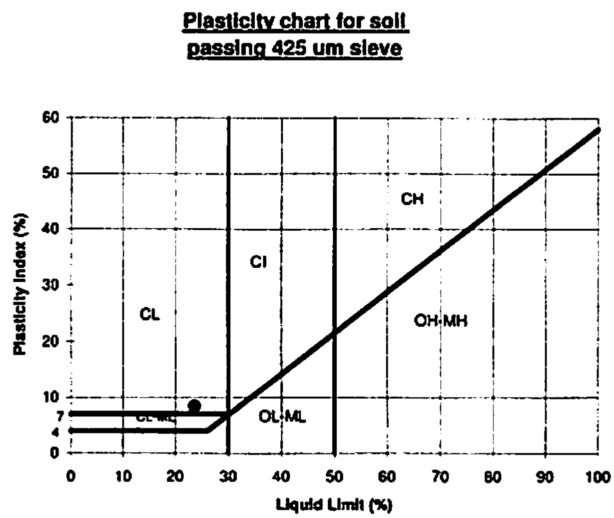
Atterberg Limits Test

AMEC Earth & Environmental
a Division of AMEC Americas Limited

Project No: YX00803
Project:
Request No:
Sample ID: 2.0m
Date: Sept. 25, 2008
Technician: DMM

Liquid Limit Test				Plastic Limit Test		
# of Blows	36	26	16			
Tare #	T108	T73	T114	Tare #	T75	T520
Wet Wt + Tare	19.28	18.94	18.70	Wet Wt + Tare	11.50	11.62
Dry Wt + Tare	17.31	16.95	16.69	Dry Wt + Tare	11.11	11.23
Wt of Tare	8.59	8.46	8.59	Wt of Tare	8.57	8.62
% Moisture	22.6	23.4	24.8	% Moisture	15.4	14.9





Liquid Limit 23.6 **Plastic Limit** 15.1 **Plasticity Index** 8.5

Classification CL

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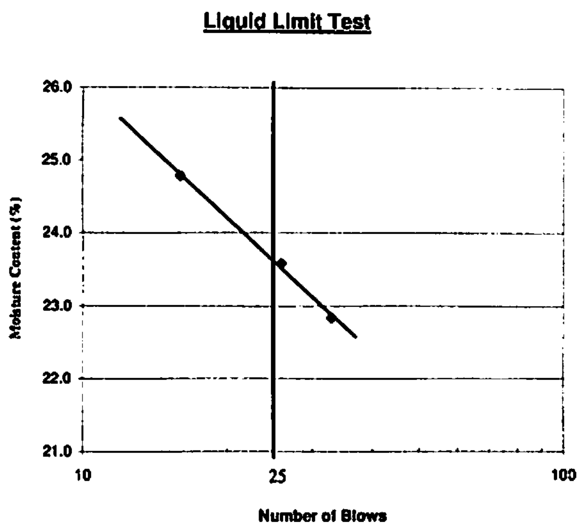
P:\Projects\Yellowknife\YX00803 - Colville Lake Sewage Lagoon\Report\Lab data\Atterberg Limits 2.0m.xls

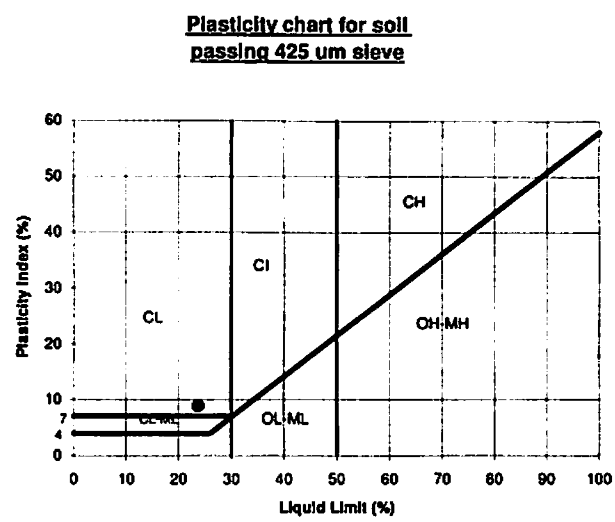
Atterberg Limits Test

AMEC Earth & Environmental
a Division of AMEC Americas Limited

Project No: YX00803
Project:
Request No:
Sample ID: 2.2m
Date: Sept. 25, 2008
Technician: DMM

Liquid Limit Test				Plastic Limit Test		
# of Blows	33	26	16			
Tare #	T83	T27	T92	Tare #	T68	T3
Wet Wt + Tare	18.08	18.32	18.78	Wet Wt + Tare	11.37	11.56
Dry Wt + Tare	16.31	16.45	16.76	Dry Wt + Tare	11.00	11.18
Wt of Tare	8.56	8.52	8.61	Wt of Tare	8.53	8.61
% Moisture	22.8	23.6	24.8	% Moisture	15.0	14.8





Liquid Limit 23.7 **Plastic Limit** 14.9 **Plasticity Index** 8.9

Classification CL

FLEXIBLE WALL PERMEABILITY TEST - REPORT SHEET
ASTM D5084 - CONSTANT HEAD METHOD A

PROJECT No. YX00803
CLIENT Dillon Consulting Ltd.
BOREHOLE No. n/a
DEPTH 1 m.
PROJECT ENGINEER Alexandre Tchekhovski

DATE October 28, 2008
PROJECT LOCATION Colville Lake Sewage Lagoon
TEST TYPE Remoulded
SAMPLE No. n/a

PERMEANT TYPE Tapwater
SOIL DESCRIPTION Silty Clay Trace Gravel

Flexible Wall Permeability Test

Elapsed Time	Incremental Time	Effective Head	Gradient (i)	Incremental Volume Out	Incremental Volume In	Ratio outflow vs inflow	Cumulative Volume Out	Cumulative Volume In	Permeability Based on Incremental Flow Out of Sample	Permeability Based on Incremental Flow into Sample	Cumulative Vol (out) / Vol.of voids	Cumulative Vol (In) / Vol. Of voids	Temperature
(s)	(s)	(kPa)		(cm³)	(cm³)		(cm³)	(cm³)	(cm/s)	(cm/s)			(°C)
0	0	20.7	28	0.0	0.0	1.10	0.0	0.0	0	0	0.000	0.000	20
83700	83700	20.7	28	3.2	2.9	1.10	3.2	2.9	3.3E-08	3.0E-08	0.035	0.032	20
170220	86520	20.7	28	2.7	2.6	1.04	5.9	5.5	2.7E-08	2.6E-08	0.065	0.061	20
256500	86280	20.7	28	2.5	1.9	1.32	8.4	7.4	2.5E-08	1.9E-08	0.093	0.082	20
516600	260100	20.7	28	7.7	8.2	0.94	16.1	15.6	2.6E-08	2.7E-08	0.178	0.173	20
610200	93600	20.7	28	2.5	2.5	1.00	18.6	18.1	2.3E-08	2.3E-08	0.206	0.201	20
690000	79800	20.7	28	2.2	2.2	1.00	20.8	20.3	2.4E-08	2.4E-08	0.231	0.225	20
776400	86400	20.7	28	2.2	2.2	1.00	23.0	22.5	2.2E-08	2.2E-08	0.255	0.249	20
862800	86400	20.7	28	2.9	2.9	1.00	25.9	25.4	2.9E-08	2.9E-08	0.287	0.282	20
1207500	344700	20.7	28	11.4	11.3	1.01	37.3	36.7	2.9E-08	2.9E-08	0.413	0.407	20

FINAL PERMEABILITY VALUE 2.61E-08 cm/sec.

AMEC Earth & Environmental

Per: ____________

P:\Projects\Yellowknife\YX00803 - Colville Lake Sewage Lagoon\Report\Lab data\Perm for sample @ 1.0m Depth.xls

AMEC Earth & Environmental Limited
221 - 18th Street S.E.
Calgary, Alberta
Canada, T2E 6J5
Tel: (403) 248-4331
Fax: (403) 569-0737

MOISTURE-DENSITY RELATIONSHIP REPORT

Dillon Consulting Limited

Project No: YX00803

Test Date: September 30, 2008

Client P.O.:

Attention:

CC:

Project: Colville Lake Sewages Lagoon

Type Of Construction: Fill Material

Applicable Standard: ASTM D698-91

Method: A

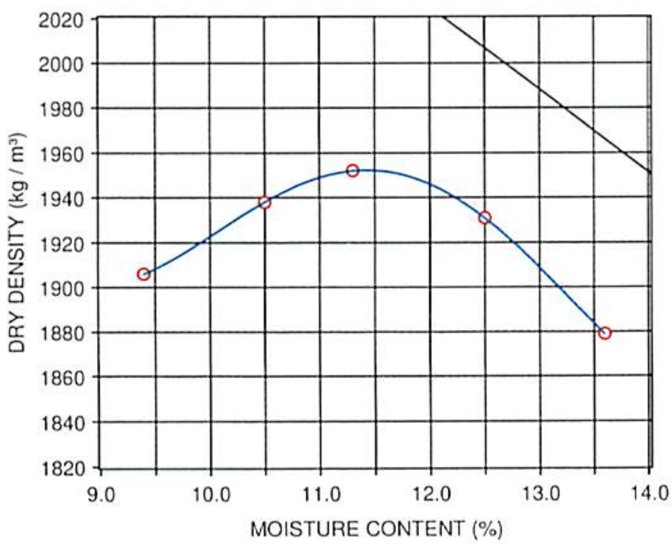
Wet Density (kg / m³):	2085	2142	2173	2172	2135		
Dry Density (kg / m³):	1906	1938	1952	1931	1879		
Moisture Content (%):	9.4	10.5	11.3	12.5	13.6		

Maximum Dry Density: 1950 kg / m³

Optimum Moisture: 11.5 %

Source: Depth 1.0m

MOISTURE-DENSITY RELATIONSHIP



Date Sampled: September 29, 2008

Sampled By: AMEC

Date Received: September 29, 2008

Tested By: Siraj

Proctor No: 1

Rammer Type: Auto

Preparation: Moist

Percent Retained 4.75 mm screen: 15.7 %

Soil Description: Silty Clay Tr. Gravel

Approved By: Jonathan