Trow

Geotechnical Investigation

Liquid and Solid Waste Management
Hamlet of Igloolik, Nunavut

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CANADA'S 50 BEST MANAGED COMPANIES

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Summary

A geotechnical investigation was undertaken at the site of the existing sewage lagoons and proposed sewage lagoon and at the site of the solid waste facility in the Hamlet of Igloolik, Nunavut. This work was authorized by Government of Nunavut on November 27, 2008.

It is proposed to rehabilitate the existing lagoons (Lagoons 1 to 4 inclusive) and to construct a new lagoon (Lagoon #5). In addition, a new solid waste disposal facility is to be constructed.

The investigation comprised the drilling of eleven boreholes at the site to 2 m to 5 m depth. Continuous standard penetration tests were performed in the boreholes in the upper levels and soil samples obtained by split barrel sampler. Subsequent to meeting refusal with the split spoon sampler in permafrost, the boreholes were advanced by core drilling techniques and continuous soil core obtained. All the soil samples and rock cores were visually examined, logged, preserved in plastic containers or core boxes and identified. Water level observations were made in the boreholes during the course of the fieldwork.

Three boreholes (Boreholes L1 to L3 inclusive) drilled in the vicinity of the existing lagoons revealed that beneath some surficial fill or topsoil, sandy silt to silty sand till and sand and gravel extends to 2.1 m to 3.4 m depth (Elevation 20.4 m to 24.2 m). These soils are underlain by siltstone bedrock.

Boreholes L4 to L9 were drilled in the vicinity of the proposed lagoon. In this area as well, beneath some fill or topsoil, the predominant surficial soil is sandy silt to silty sand till and/or sand and gravel which extends to 1.4 m to 3.7 m depth (Elevation 17.6 m to 21.8 m). The till in Borehole L9 is underlain by clayey silt to 3 m depth (Elevation 19.6 m). These soils are also underlain by siltstone bedrock.

Borehole 1 and 2 drilled at the proposed solid waste disposal site revealed a surficial topsoil or sand and gravel layer which extended to 0.5 m to 1.2 m depth. These soils are underlain by clayey silt till to 2 m to 3.6 m depth. The clayey silt till and Borehole 1 is underlain by sandy silt to 2.5 m depth (Elevation 26.7 m) beneath which siltstone bedrock was encountered.

Field observations and laboratory testing has revealed that the on-site soils are ice poor and are low in salinity.

The proposed Lagoon #5 is to be constructed along an existing slope by building berms on three sides. The maximum height of the berms would be 6.5 m. Since numerous problems are being experienced with existing lagoons which have been designed as exfiltration lagoons, it is recommended that the new lagoon should be designed as impervious lagoon. Since the berms are to be constructed with granular materials, it would be necessary to line the lagoon. The liner for the lagoon may consist of needle punched Bentofix Geosynthetic liner or equivalent.

Computerized stability of slope analysis was undertaken to determine the steepest stable berm slopes. The analysis has revealed that a 3H:1V upstream slope and a 3.25H:1V down stream slope would satisfy the requisite factors of safety for static and seismic loading conditions. The use of these slopes is therefore recommended.

The crest width of the berms of the existing lagoons is narrow and cannot accommodate vehicular traffic. In addition, these lagoons have been constructed with steep slopes and are experiencing slope failures and require extensive maintenance. It is proposed to rehabilitate these lagoons. It is recommended that rehabilitated lagoons should be constructed as impervious lagoons instead of exfiltration lagoons in order to minimize problems associated with slope failures etc. Since the materials available to construct the berms are essentially granular, the lagoons would have to be lined. The liner may consist of needle punched bentofix Geosynthetic Liner or equivalent.

In addition, the inside and outside slopes of these lagoons should be constructed at the same inclination as that recommended for the new lagoon i.e. inside and outside slopes of 3H:1V and 3.3H:1V respectively. It is recommended that 300 mm of cover material consist of on-site gravel should be provided on top of the slopes of all the berms as erosion protection.

The above and other related considerations have been discussed in greater detail in the report.

1.0 Introduction

The project under consideration is the optimizing of the Liquid and Solid Waste Management for the Hamlet of Igloolik (Hamlet). This will include expanding the existing liquid waste facility, assessing the current condition of the existing facility, addressing any issues identified, relocating the solid waste facility and decommissioning the existing solid waste sites (domestic and metallic).

The investigation was undertaken to:

(1) Establish the geotechnical and groundwater conditions at the site of the existing exfiltration lagoons, at the location of the proposed lagoon and at the location of the proposed solid waste facility;

(2) Review of the stability of the slopes of the berms of the existing lagoons and suggest remedial measures, if required. The impact of these modifications on the performance of these lagoons as exfiltration lagoons will be assessed in the geotechnical report;

(3) Provide geotechnical design guidelines for the proposed new lagoon including stable berm slope inclinations, need for a liner and other construction related issues; and,

(4) Provide geotechnical design parameters for construction of the new solid waste facility.

The comments and recommendations given in this report are based on the assumption that the above-described design concept will proceed into construction. If changes are made either in the design phase or during construction, this office must be retained to review these modifications. The result of this review may be a modification of our recommendations or it may require additional field or laboratory work to check whether the changes are acceptable from a geotechnical viewpoint.

2.0 Procedure

2.1 Drilling and Soil Sampling

The fieldwork for the geotechnical investigation was undertaken between September 29 and October 5, 2009 and on November 3 and 4, 2009 with a Hilti drill rig. The fieldwork was supervised by a representative of Trow Associates Inc. (Trow) on a full time basis.

The fieldwork consisted of drilling eleven (11) boreholes (Boreholes L1 to L9 and BH1 and BH2) to depths varying between 2.0 m and 5.0 m. The locations of the boreholes are shown on Site Plan, Figure 1.

All the boreholes except Borehole L5 were initially advanced by performing continuous standard penetration tests and retrieving the soil samples by the split spoon sampler. However, the boreholes could only be advanced by this method in unfrozen soil to a depth of 0.8 m to 1.7 m below which frost was encountered. The boreholes were then cased and advanced by core drilling techniques with the Hilti drill rig. Some of the boreholes were partly advanced using dry coring whereas water was used as flushing medium for others. During core drilling a careful record of colour of wash water, wash water return and any sudden drops of the drill rods was kept.

Thermisters were installed in Boreholes L2 and L7 to monitor the ground temperatures.

Water level observations were made in the boreholes during the course of the fieldwork. All the soil samples were visually examined in the field for textural classification, preserved in plastic bags or containers and identified. The boreholes were logged. Similarly, the rock cores were placed in the core boxes, identified and logged. On completion of drilling, all the soil samples and rock cores were transported to the Trow laboratory in the City of Ottawa, Ontario.

The locations and elevations of the boreholes were established by representatives of Trow Associates Inc. using a Global Positioning System (GPS). The elevations of the boreholes refer to the Geodetic datum.

All the soil samples and rock core were visually examined in the laboratory by a geotechnical engineer and borehole logs prepared. The engineer also assigned the laboratory testing. The laboratory testing consisted of performing natural moisture content on all the samples and grain size analysis, salinity and unit weight tests on selected soil samples. In addition, unconfined compressive strength of the rock cores was also determined.

3.0 Ground Temperatures

Thermisters were installed in Boreholes L2 and L7 to monitor the ground temperatures. The observations made have been documented in Table I. The readings indicate that the ground temperature varies from -2.8ºC to -6.0ºC at the ground surface to -4.8ºC at 4.3 m depth.

Table 1 – Results of Ground Temperature Monitoring

Borehole L7			Borehole L2		
Date	**Depth (m)**	**Temperature**	**Date**	**Depth (m)**	**Temperature**
Nov 3/09	+ 1.0	-24.5ºC	Nov 4/09	+ 1.0	-18ºC
Nov 3/09	- 0.3	-2.8	Nov 4/09	- 0.6	-6.0
Nov 3/09	- 1.3	-7.8	Nov 4/09	- 1.6	-1.8
Nov 3/09	- 2.3	-2.4	Nov 4/09	- 2.6	-2.8
Nov 3/09	- 3.3	-3.8	Nov 4/09	- 3.6	-3.6
Nov 3/09	- 4.3	-4.8			

It is considered that the ground temperature had not stabilized during the short time interval over which the observations were made. It is recommended that additional readings should be undertaken in order to determine reliable ground temperature readings.

4.0 Site and Soil Description

The existing liquid waste disposal system for the Hamlet comprises of four exfiltration lagoons located approximately 1.6 kms north of the community. The domestic waste and metallic waste disposal sites are located adjacent to the sewage lagoons. It is understood that the original two cells were built with slopes of 1.5H:1V whereas a third cell built in 1998 was constructed with side slopes of 2.5H:1V.

The existing sewage lagoons operate as exfiltration lagoons which in essence means that as the berms thaw during the summer months, the sewage is allowed to seep through the berms and drain across the existing wetlands to the ocean. A review of the photographs provided as part of the Request for Proposal and satellite images of the Igloolik lagoons on Google Earth has revealed that there is evidence of local piping through the sewage lagoons. From a geotechnical and geothermal perspective, it is difficult to predict the performance of exfiltration berms. Decanting of the lagoons through exfiltration has a tendency to lead to localized blocking of berms and localized areas of piping. Either of these can be contributory factors to failure of the berms and need for continuous maintenance of the berms.

The ground surface in the vicinity of the existing lagoons slopes down from Elevation 27.0 m approximately 750 metres from the ocean to Elevation 0 m at the waters' edge. The slope to the ocean is approximately at an inclination of 7.9H:1V for the initial 150 m, at an inclination of 30H:1V for the next 450 m approximately and then at an inclination of 11.5H:1V to the waters' edge. The existing lagoons have been constructed on the middle flatter slope utilizing the natural ground surface at Elevation 26.0 m approximately as the south boundary of the lagoons and constructing berms on the three other sides (east, north and west sides). These berms are approximately 3.5 m to 4 m high and have been constructed with a crest width of 2 m to 4 m approximately. The upstream and downstream slopes of the berms vary from 1H:1V to 1.9H:1V.

A detailed description of the subsurface and groundwater conditions encountered in the eleven boreholes drilled at the site have been given in Borehole Logs, Figures 2 to 12 inclusive. The boreholes logs and related information depict subsurface conditions only at the specific locations and time indicated. Subsurface conditions and water levels at other locations may differ from conditions at the locations where sampling was conducted. The passage of time also may result in changes in the conditions interpreted to exist at the locations where sampling was conducted. Boreholes were drilled to provide representation of subsurface conditions as part of a geotechnical exploration program and are not intended to provide evidence of potential environmental conditions.

4.1 Existing Lagoons (Boreholes L1, L2 and L3)

Boreholes L1 to L3 were located in the vicinity of the existing four lagoons. Borehole L1 was located on top of the existing berm of one of the lagoons whereas the other two boreholes were drilled approximately 10 m away from the outside toes of the berms.

Fill was encountered in Borehole L1 and extended to 2.3 m depth (elevation 25.3 m). The fill consists of sandy gravel. A grain size analyses performed on the fill indicated a composition of 2 percent clay, 8 percent silt, 26 percent sand and 64 percent gravel (Figure 13). The natural moisture content of the fill varies from 5 to 8 percent. The permeability of the fill was estimated to be in the order of 2.5 x10^{-3} cm/sec.

Topsoil and tundra was encountered in Boreholes L2 and L3 to a depth of 0.3 m to 0.6 m.

The fill in Borehole L1 and the tundra in Boreholes L2 and L3 are underlain by a layer of sandy silt/silty sand which extends to 2.1 m to 3.4 m depth (elevation 20.4 m to 24.2 m). Two grain size analyses performed on this stratum (Figures 14 and 15) indicate that this stratum comprises of 8 percent clay, 20 to 40 percent silt, 16 to 29 percent sand and 23 to 56 percent gravel. Its moisture content varies from 6 to 15 percent. The permeability of this stratum was estimated to vary from 4 x10^{-6} cm/sec to 6.3 x 10^{-6} cm/sec.

The sandy silt/silty sand (till) in Borehole L1 is underlain by a layer of sand and gravel which extends to 4.8 m depth (Elevation 22.8 m). The natural moisture content of this stratum is 10 percent.

It is noted that ice rich soils were not encountered in any of the boreholes. The overburden soils in all the three boreholes were underlain by siltstone bedrock below 2.1 m to 3.4 m depth. A total recovery of 50 to 100 percent was obtained when core drilling the bedrock. The Rock Quality Designation of the siltstone bedrock was zero. On this basis, the bedrock is considered to be of poor quality.

4.2 Proposed New Lagoon (Boreholes L4 to L9)

The surficial soil in Borehole L6 to L8 is silty sand and gravel with some organics which extended to 0.6 m to 1.2 m depth (Elevation 21.4 m to 24.0 m). The fill has a moisture content of 5 to 22 percent. A grain size analysis performed on this stratum from Borehole L7 yielded a soil composition of 6 percent silt, 12 percent sand and 82 percent gravel (Figure 16).

Topsoil and/or tundra was encountered in Borehole L3, L4 and L5 which varied in thickness from 150 mm to 600 mm. The surficial soil in the vicinity of Borehole L9 is sandy silt/silty sand till which also underlies the sand and gravel in Borehole L6 and L8, the fill in Borehole L7 and the tundra/topsoil in Borehole L4 and L5. This stratum extends to 1.4 m to 3.7 m depth (Elevation 17.6 m to 21.8 m). Four grain size analyses performed on this stratum are given on Figures 17 to 20 inclusive. A review of these figures indicates that the till varies in composition and contains 9 to 18 percent clay, 33 to 42 percent silt, 15 to 38 percent sand and 20 to 28 percent gravel. The natural moisture content and unit weight of the till are 6 to 28 percent and 21.6 to 24.2 kN/m^3 respectively.

The sandy silt/silty sand till in Borehole L9 is underlain by a layer of clayey silt to 3 m depth (Elevation 19.6 m). This stratum comprises of 30 percent clay, 46 percent silt, 20 percent sand and 4 percent gravel (Figure 21). It has a natural moisture content of 22 to 24 percent.

Field examination of the soil cores recovered during drilling and determination of moisture content of the soil cores has revealed that the on-site soils are not ice rich. Ice layers/seams were not encountered in any of the boreholes.

The sandy silt/silty sand till and the clayey silt in all the boreholes except Borehole L6 are underlain by siltstone bedrock which extends to the entire depth investigated i.e. 2.9 m to 4.7 m depth (Elevation 16.5 m to 21.2 m). A total core recovery of 50 to 100 percent was encountered when core drilling the bedrock. It was not possible to establish the Rock Quality Designation of the rock core due to frequent machine breaks during drilling.

4.3 Solid Waste Landfill Site (Boreholes 1 and 2)

Boreholes 1 and 2 were drilled at the location of the proposed landfill site. Borehole 2 encountered topsoil and tundra which extended to 0.5 m depth. The surficial soil in the vicinity of Borehole 1 was sand and gravel which extended to 1.2 m depth (Elevation 28.0 m). A grain size analysis performed on this stratum yielded a soil composition of 8 percent clay, 24 percent silt, 35 percent sand and 33 percent gravel (Figure 22). The moisture content of the sand and gravel varied from 9 to 16 percent.

The sand and gravel in Borehole 1 and the tundra in Borehole 2 are underlain by clayey silt till which extends to 2 m depth in Borehole 1 (Elevation 27.2 m) and to the entire depth investigated in Borehole 2 (3.6 m depth, Elevation 24.0 m). This stratum contains 12 percent clay, 83 percent silt, 3 percent sand and 2 percent gravel (Figure 23). Its natural moisture content is 13 to 24 percent.

The clayey silt till in Borehole 1 is underlain by sandy silt to 2.5 m depth (Elevation 26.7 m). Siltstone bedrock underlies the sandy silt to 2.8 m depth (Elevation 26.3 m).

4.4 Salinity of On-site Soils

Salinity tests were performed on some of the soil samples. The test results are given on Table II. A review of this table indicates that the salinity of the on-site soils varies from 0.14 to 2.31 parts per thousand (ppt). On this basis, the on-site soils are considered to be low in salinity.

Table II – Salinity of On-site Soils

Borehole #	Depth (m)	Salinity (ppt)
L2	1.35 – 1.93	1.26
L3	0 – 0.6	0.21
L5	0.33- 0.96	0.14
L9	2.57 – 3.18	2.31
L9	1.07 – 1.55	1.69

4.5 Permeability of On-site Soils

In order to estimate the permeability of the on-site soils, eleven grain size analyses were performed on selected soils samples. The test results are given on Figures 13 to 23 inclusive and have been summarized on Table III. Based on the grain size analyses, the permeability of the on-site soils was estimated to vary from less than 1 $x10^{-6}$ cm/sec to 3.6 $x10^{-1}$ cm/sec.

Table III – Estimated Permeability of On-site Soils

Borehole #	Depth (m)	Soil Description	Estimated Permeability cm/sec
L1	0.6 – 1.2	Silty sand and gravel	1×10^{-4}
L2	1.0 – 1.24	Sandy silt till	9×10^{-6}
L2	2.26 – 2.5	Clayey/sandy silt	6.3×10^{-6}
L8	0.6 – 0.8	Sandy gravel	3.6×10^{-1}
L7	1.2 – 1.65	Sandy silt, slightly cohesive	$<1 \times 10^{-6}$
L7	2.8 – 3.2	Clayey silt	$<1 \times 10^{-6}$
L4	0.6 – 1.32	Sandy silt with gravel	1×10^{-6}
L9	0.63 – 1.1	Sandy silt, some gravel	4×10^{-6}
L9	2.11 – 2.57	Clayey silt, trace sand	$<1 \times 10^{-6}$
BH1	0.6 – 1.2	Silt sand, some gravel	9×10^{-6}
BH2	1.6 – 3.6	Silt, trace sand	2.5×10^{-6}

Based on the estimated permeabilities, it is concluded that the on-site soils are not impervious. Consequently, if these soils are to be used for construction of the berms, the berms would have to be lined.

5.0 Construction of New Lagoon

It is understood that a new lagoon (Lagoon #5) is to be constructed at the site. This lagoon will be located adjacent to and on west side of the existing Lagoon #4. This lagoon will measure approximately 240 m by 125 m. The site of the proposed and existing lagoons is located on ground which slopes down towards the north to the ocean. As for existing lagoons 1 to 4, the natural slope on the south side will be used as the south berm of the lagoon. The new lagoon will be constructed by extending the west berm of Lagoon #4 in northerly direction and construction of new berms along the south and west sides. The berms of the new lagoon are to be constructed with a crest width of 4 m. The design crest of the berms will be at Elevation 27.5 m. Consequently, the height of the berms will vary from negligible at the south end to a maximum of 6.5 m for the north berm.

6.0 Design Considerations

6.1 Lagoon Type

The new lagoon will be constructed with permeable soils. The investigation has revealed that the on-site soils are not ice rich. Ice layers or seams were not encountered at the site in the soil cores retrieved from the boreholes. In addition, the natural moisture content of the on-site soils was determined to vary from 5 to 28 percent. Based on laboratory tests on the soil cores, the unit weight of the various soils was established to vary from 21.6 kN/m^3 to 24.8 kN/m^3. Therefore, the on-site soils are considered NOT to be ice rich. Salinity tests performed on selected soils samples have also revealed that the on-site soils are non-saline.

As indicated earlier, the existing exfiltration berms are leaking. In addition, localized slope failures are taking place resulting in increased maintenance of the lagoons. It is difficult to construct exfiltration lagoons which will perform satisfactorily when constructed with heterogeneous materials such as what were encountered at the site. Construction of the berms with heterogeneous materials invariably results in areas of preferential flow where soils are more permeable and blockage of other areas where the soils are less permeable. This leads to problems associated with piping of the soil in some areas and build up of pore pressures in other areas. The build up of pore pressures results in localized failures of the berms. It is therefore recommended that the proposed lagoon should be designed as impervious lagoon. In order to achieve this, it would be necessary to line the lagoon.

6.2 Liner Requirements

It has been recommended that the proposed lagoon should be designed as impervious lagoon. For this purpose, the lagoon would have to be lined since the berms will be constructed with permeable materials. Installation of the liner in the lagoon is expected to perform satisfactorily since ice rich soils were not encountered at the site and the settlements of the berms are expected to be very small.

The liner for the lagoons may consist of needle-punched Bentofix Geosynthetic Clay Liner or equivalent. The liner should be placed on a sand cushion at least 300 mm thick. It should be covered with at least 150 mm of sand fill. In addition, 300 mm of cover material consisting of on site gravel should be provided on top of the sand as erosion protection. The liner should be installed in accordance with the manufacturer’s recommendations. Installation of the liner should be supervised by experienced personnel to ensure that it has been installed according to the project specifications since satisfactory performance of the liner is dependant on its proper installation.

It is noted that synthetic liners, such as High Density Polyethylene (HDPE), Reinforced and Unreinforced Chlorinated Polyethylene (CPE) and Chlorosulphonated Polyethylene (hypalon) are also available and have been used in the Arctic environment. However, these liners are expected to be more costly compared to the Geosynthetic Clay Liner.

7.0 Design Slopes

It has been recommended that the lagoons should be fully lined. Theoretically, a lined lagoon will not be subjected to buoyant or seepage forces. However, these conditions could develop if the liner is damaged or if any of the joints in the liner fail. Therefore the berms of the lined lagoon were designed on the assumption that they would be subjected to buoyancy and seepage forces.

The stability of the berm slopes was analyzed by using Bishop’s Modified Method. Slope/W. Geoslope office, Version 4.23 Computerized system was used to assess stability of the slopes. Cross-sections of the north and west berm (Cross-Section AA and BB) of the proposed Lagoon #5 were analysed. The locations of the cross-sections are shown on Figure 1.

The following assumptions were made in the slope stability analyses:

(1) The crest of the berm is at Elevation 27.5 m. The crest width of the berm is 4 m. The inside slope of the berm was analysed for a slope of 3H:1V and 3.5H:1V. The outside slope of the berm was analysed for an inclination of 3H:1V to 3.25H:1V.

(2) The berms will be constructed with on-site materials comprising of silty sand and gravel with some cobbles, sandy silt and clayey silt to sandy silt till. The berms would be founded on silty sand to sandy silt soils which are ice poor.

(3) The engineering properties of the various layers were assumed to be as follows:

Table IV: Assumed Soil Properties

Soil Type	Unit Weight (kN/m^3)	Effective Cohesion c’ (kPa)	Effective Angle of Internal Friction ϕ(degrees
Silty Sand and Gravel Fill	22	0	34
Silty Sand	20	0	27
Sandy Silt	18	0	27
Sandy Silt to Silty Sand Till	22	0	30

(4) The water level in the pond would be at Elevation 26.5 m approximately or lower and that the berms would not be overtopped at any time. Also, the berms would not be subject to rapid drawdown condition.

The inside slopes were analysed for a fully submerged condition whereas the outside slopes were analysed for steady state seepage condition. The analysis was performed for static as well as seismic loading conditions.

The results of the analyses are given on Figures 24 to 33 inclusive and have been tabulated on Table V.

Table V - Computed Factors of Safety of North Berms of Lagoon #2 and #4

Lagoon # and Cross-section Identification	Slope Identification	Loading Condition	Computed Factor of Safety	Figure #
Section A-A Inside	3H:1V	Fully submerged	2.12	24
		Fully submerged with seismic loading	1.82	25
Section A-A Outside	3H:V	Steady state seepage condition	1.42	26
		Steady state seepage with seismic loading	1.31	27
	3.25:1V	Steady state seepage condition	1.55	28
		Steady state seepage condition with seismic loading	1.42	29
Section B-B Inside	3H:1V	Fully submerged condition	2.07	30
		Fully submerged with seismic loading	1.78	31
Section B-B Outside	3H:1V	Steady state seepage condition	1.53	33
		Steady state seepage condition with seismic loading	1.39	33

Based on current practice in the industry, a minimum factor of safety of 1.5 is required for static loading conditions and a factor of safety of 1.1 for seismic loading conditions. A review of Table 3 indicates that a 3H:1V upstream slope and 3.25H:1V downstream slope would satisfy the requisite factors of safety. Therefore, these slopes may be used in the design.

It is noted that the computed slopes would be stable provided that the berms are not overtopped and they are not subjected to rapid drawdown conditions.

8.0 Berm Construction

Prior to commencement of construction of the berms, any vegetation and surficial organic soils should be stripped from the area. The material to be used for construction of the berms should preferably conform to the following gradation:

Sieve Size (mm)	Percentage Passing
200 mm	100
26.5 mm	50 – 100
4.75 mm	20 – 100
1.18 mm	10 – 100
300 µm	5 – 95
150 µm	2 – 65
75 µm	0 - 25

The material should be placed in 300 mm lift thicknesses and each lift should be compacted to at least 95 percent of standard Proctor maximum dry density. In-place density tests should be performed on each lift to ensure that the specified degree of compaction is being achieved. This work should be undertaken under the full time supervision of a geotechnician working under the direction and supervision of a geotechnical engineer.

9.0 Causes of Failure of Existing Lagoons

The existing lagoons have been designed as exfiltration lagoons. These lagoons are experiencing a number of problems as follows:

(1) The crest width of the berms of lagoons 1 to 3 is narrow. It varies from 1.5 m to 2.5 m. As a result, these lagoons are not accessible to vehicular traffic which leads to maintenance difficulties.

(2) The existing berm slopes are very steep. They vary from 1 horizontal to 1 vertical to 1.9 horizontal to 1 vertical. As a result, these slopes are prone to localized failures and require extensive maintenance. (see next section for Slope Stability Analysis).

(3) The berms have been constructed with locally available materials which vary from sand and gravel clayey silt, sandy silt to sandy silt till. The heterogeneous nature of the available materials has resulted in pockets which are more permeable. As a result, these pockets become preferred paths for flow of the effluent. This results in erosion of the soil. As a result these conduits become larger with time and may lead to eventual failure of the berms due to piping.

(4) The seepage of effluent through the berms results in filtration of the effluent. As a result, the fines in the effluent are deposited in the voids of the soil. Gradually these voids filled with fines and prevent further seepage of the effluent. This results in build up of excessive pore pressures which eventually result in localized slope failures.

(5) Given the prevailing environmental conditions, the discharge of the effluent from the lagoons can take place during 2 to 3 months of the year only i.e. during the summer months, approximately from June to August. As a result, all the effluent is not discharged from the lagoons which results in greater reduction in the available capacity of the lagoons for storage of the effluent.

For the above reasons, design of the lagoons as exfiltration lagoons is not recommended.

10.0 Slope Stability Analysis of Existing Berm Slopes of Lagoon #2 and #4

In order to assess the stability of the existing lagoons, the north slopes of Lagoon #2 and #4 were analysed using Bishop's Method as described previously. The locations of the sections analyzed (Section CC, Lagoon #4 and Section DD, Lagoon #2) are shown on Site Plan, Figure 1. The following assumptions were made in the slope stability analyses.

(1) The cross-sections of the berms were obtained from drawings prepared by Trow Associates Inc. Infrastructure Division (Figure 2, Profile View of Lagoon #2 and Profile View of Lagoon #4). It is understood that the cross-sections were established based on a recent survey of the berms.

(2) The engineering properties of the various soils encountered at the site listed previously for slope stability analyses of the new lagoon berm slopes were also used for this analyses.

(3) The inside slopes of the berms were analysed for fully submerged conditions whereas the outside slopes of the berms were analysed for steady state seepage conditions.

The results of the analyses are given on Table VI:

Table VI - Computed Factors of Safety for Existing Upstream and Downstream Berm Slopes (Existing)

Slope Identification	Slope Inclination	Loading Condition	Computed Factor of Safety	Figure #
Upstream Slope (inside) Section C-C Lagoon #4	1.7H:1V	Completely submerged	1.46	34
	1.7H:1V	Completely submerged with seismic loading	1.30	35
Downstream Slope (outside) Section C-C Lagoon #4	2.1H:1V	Steady state seepage	1.08	36
	2.1H:1V	Steady state seepage with seismic loading	0.90	37
Upstream Slope (inside) Section D-D Lagoon #2	1.16H:1V	Completely submerged	1.25	38
	1.16H:1V	Completely submerged with seismic loading	1.15	39
Downstream Slope (outside) Section D-D Lagoon #2	1.06H:1V	Steady state seepage	0.95	40
	1.06H:1V	Steady state seepage with seismic loading	0.83	41

A review of Table VI indicates that the factor of safety of the existing slopes of the berms of Lagoon #2 and Lagoon #4 is less than 1.5 under static conditions. In addition, factors of safety of the downstream slopes of the berms are less than 1.1 under seismic conditions. It is therefore considered that these slopes are inherently unstable as they have been constructed at steep inclinations. It is recommended that these slopes should also be flattened to the inclinations established for the proposed Lagoon #5 i.e. construct inside and outside slopes at an inclination of 3.0H:1V and 3.25H:1V respectively.

11.0 Remediation of Existing Lagoons

The remediation of the existing lagoons would necessitate widening the crest of these berms so that they are accessible to vehicular traffic and constructing the berms with stable side slopes. In addition, these lagoons should be converted from exfiltration lagoons to impervious lagoons. This would necessitate lining of the lagoons.

It is recommended that the minimum crest width of the rehabilitated berms should be 4 m to enable access to vehicular traffic. These berms should be designed with stable side slopes. Stability of slope analysis undertaken for the design of proposed Lagoon #5 has revealed that the berms would be stable with requisite factors of safety if constructed with inside and outside slopes of 3.0 horizontal to 1.0 vertical and 3.25 horizontal to 1.0 vertical respectively. It is recommended that the rehabilitated berms should be constructed with stable side slopes as recommended previously for the proposed new lagoon. Rehabilitation of the existing lagoons may be commenced by flattening the inside slopes to the stable slope of 3.0H to 1V. The material excavated may be placed on the outside of the existing berms to widen the berms and to achieve stable side slopes. It is noted that additional material would be required for rehabilitation of the berms.

Prior to commencement of the excavation work, any vegetation and organic soils in the crest and faces of the berms should be stripped and discarded. The outside slopes of the berms should be stepped with 0.6 m wide by 0.3 m high steps so that the joint between the existing and the widened portion of the berm is at a slope of 2H:1V. The material for widening of the berms should be placed in 300 mm lift thicknesses and each lift compacted to at least 95 percent of standard Proctor maximum dry density. In-place density tests should be undertaken on each lift to ensure that specified degree of compaction is achieved. This work should be carried out under full time supervision of a geotechnician working under the direction and supervision of a geotechnical engineer.

12.0 Erosion Protection

It is noted that the computed upstream slopes of 3.0H:1V and downstream slope of 3.25H:1V will be stable provided that the berms are not overtopped and are not subjected to a rapid drawdown condition. Potential exists for considerable erosion and possibly failure of the berms if overtopped. Overtopping of the berms may be prevented by construction of a proper spillway structure which is capable of handling the overflow.

It is recommended that 300 mm of cover material consisting of on-site gravel should be provided on top of the sand fill and along the outside slopes of the berms as erosion protection. In addition, erosion protection should be provided at the toes of the existing berms in the vicinity of the spillways to prevent undermining of the berms by erosion at these locations.

13.0 Additional Comments

All earthwork activities including subgrade preparation, placement and compaction of fill for construction of berms, sand cushion, installation of geosynthetic clay liner and erosion protection should be inspected by qualified geotechnicians to ensure that rehabilitation of the lagoons and construction of the new lagoon proceeds according to the specifications.

14.0 General Comments

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc., would be much greater than has been carried out for the design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

The information contained in this report is not intended to reflect on environmental aspects of the soils. Should specific information be required, including for example, the presence of pollutants, contaminants or other hazards in the soil, additional testing may be required.

We trust that the information contained in this report will be satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.

Yours truly,

Trow Associates Inc.

REGISTERED PROFESSIONAL ENGINEER
March 16/10
S.K. AGGARWAL
LICENSEE
NWT/NU

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Figures

NOTES :
1. THE BOUNDARIES AND SOIL TYPES HAVE BEEN ESTABLISHED ONLY AT BOREHOLE LOCATIONS. BETWEEN BOREHOLES THEY ARE ASSUMED AND MAY BE SUBJECT TO CONSIDERABLE ERROR.
2. SOIL SAMPLES AND ROCK WILL BE RETAINED IN STORAGE FOR THREE MONTHS AND THEN DESTROYED UNLESS THE CLIENT ADVISES THAT AN EXTENDED TIME PERIOD IS REQUIRED.
3. TOPSOIL QUANTITIES SHOULD NOT BE ESTABLISHED FROM THE INFORMATION PROVIDED AT THE BOREHOLE LOCATIONS.
4. BOREHOLE ELEVATIONS SHOULD NOT BE USED TO ESTABLISH GRADES.
5. THIS DRAWING FORMS PART OF THE REPORT PROJECT NUMBER AS REFERENCED AND SHOULD BE USED ONLY IN CONJUNCTION WITH THIS REPORT.
6. BASE PLAN OBTAINED FROM TROW ASSOCIATES INC. PROJECT OTCD00019838A DRAWING SP-1 DATED MARCH 2010.

NOTES

THE POSITION OF ALL POLE LINES, CONDUITS, WATERMAINS, SEWERS AND OTHER UNDERGROUND AND OVERGROUND UTILITIES AND STRUCTURES IS NOT NECESSARILY SHOWN ON THE CONTRACT DRAWINGS, AND WHERE SHOWN, THE ACCURACY OF THE POSITION OF SUCH UTILITIES AND STRUCTURES IS NOT GUARANTEED. BEFORE STARTING WORK, DETERMINE THE EXACT LOCATION OF ALL SUCH UTILITIES AND STRUCTURES AND ASSUME ALL LIABILITY FOR DAMAGE TO THEM.

PRELIMINARY

NOT FOR CONSTRUCTION

NO.	REVISION DESCRIPTION	DATE	BY	APPD

NO.	REVISION DESCRIPTION	DATE	BY	APPD
1	ISSUED FOR REPORT	04/03/10	MEB	IT

SCALE
HORZ 1:1500
CONTOUR 1.0m
0 15m 30m 60m
HORIZONTAL 1:1500

DESIGNED BY

REVIEWED BY

CLIENT
HAMLET OF IGLOOLIK
NUNAVUT

Trow Associates Inc.
154 COLONNADE ROAD SOUTH
OTTAWA ON. K2E 7J5
PHONE 613.225.9940
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BASEPLAN TROW
DESIGN
CHECKED
CAD M.BERRIGAN
PROJ. MAN S.BURDEN
APPROVED

PROJECT
INFRASTRUCTURE IMPROVEMENTS
SOLID WASTE
SEWAGE LAGOONS

TITLE
BOREHOLE LOCATION PLAN
SLOPE STABILITY ANALYSES CROSS–SECTION

PROJ NO. OTGE00019838A
SURVEY BERRIGAN
DATE MARCH, 2010
DRAWING NO. FIGURE 1

Filename: r:\19000\19800\19838 liquid-solid waste mgt igloolike - temp working drawings
Last Saved: 3/10/2010 10:40:29 AM
Last Plotted: 3/10/2010 11:20:08 AM Plotted by: berriganm
Pen Table:: ---
References:

Notes On Sample Descriptions

1. All sample descriptions included in this report follow the Canadian Foundations Engineering Manual soil classification system. This system follows the standard proposed by the International Society for Soil Mechanics and Foundation Engineering. Laboratory grain size analyses provided by Trow Associates Inc. also follow the same system. Different classification systems may be used by others; one such system is the Unified Soil Classification. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.

ISSMFE SOIL CLASSIFICATION

CLAY	SILT			SAND			GRAVEL			COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE		

0.002	0.006	0.02	0.06	0.2	0.6	2.0	6.0	20	60	200

EQUIVALENT GRAIN DIAMETER IN MILLIMETRES

CLAY (PLASTIC) TO SILT (NONPLASTIC)	FINE	MEDIUM	CRS.	FINE	COARSE
	SAND			GRAVEL	

UNIFIED SOIL CLASSIFICATION

2. Fill: Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

3. Till: The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Log of Borehole L1

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 2

Page. 1 of 1

Date Drilled: 'October 3rd, 2009

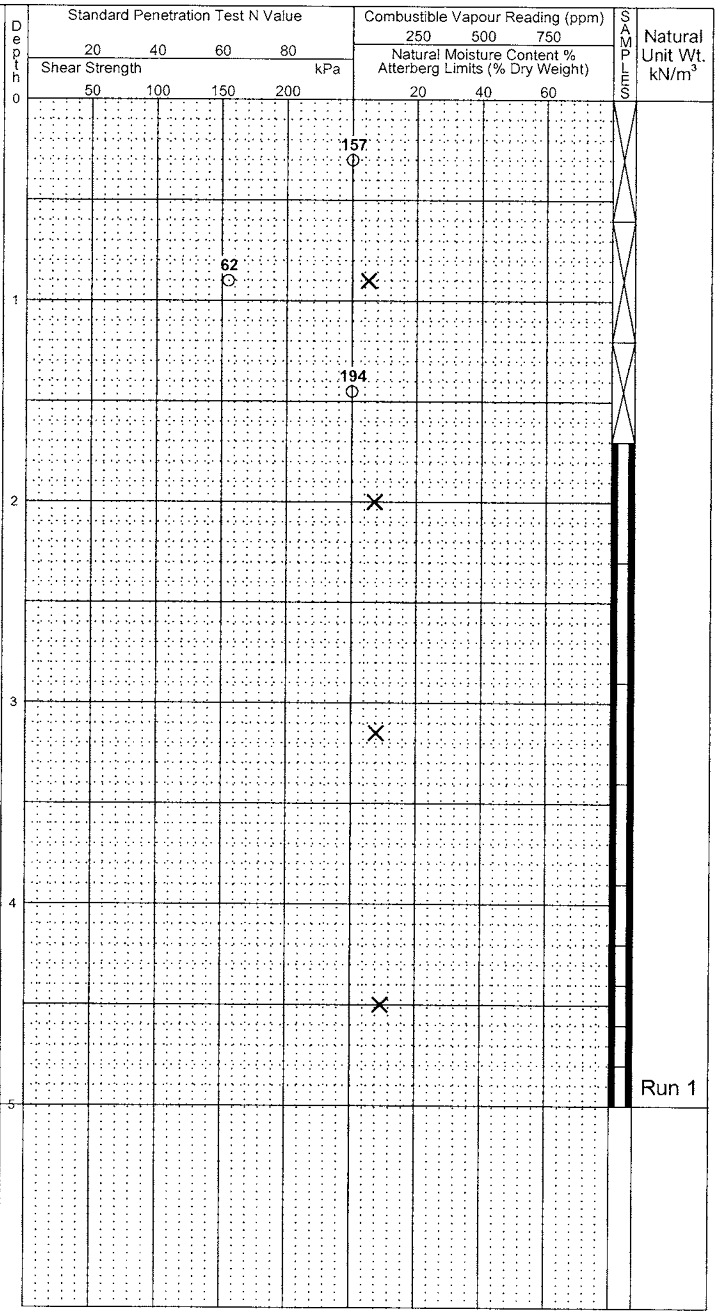
Drill Type:

Datum: Estimated Elevation from Contour Lines (Approx)

Logged by: Checked by:

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◨	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	──	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■	Shear Strength by Penetrometer Test	▲
Shear Strength by Vane Test	+ S		

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic Elevation m
		FILL Sandy gravel, fine to coarse gravel with some fine to coarse silt, occasional cobbles and boulders, brown, moist Frozen below 1.2 m depth	27.6
		SANDY SILT Trace to some gravel, light grey, moist	24.8
		SILTY SAND AND GRAVEL Occasional cobbles, thin siltstone seams, grey brown.	24.2
		SILTSTONE BEDROCK Fractured, grey	22.8
		Terminated @ 5.0 m depth	22.6



LOG OF BOREHOLE BOREHOLE LOGS.GPJ TROW OTTAWA.GDT 3/10/10

NOTES:
1. Borehole/Test Pit data requires interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	4.83 - 4.98	83	

Log of Borehole L2

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 3

Page. 1 of 1

Date Drilled: 'October 4th, 2009

Drill Type:

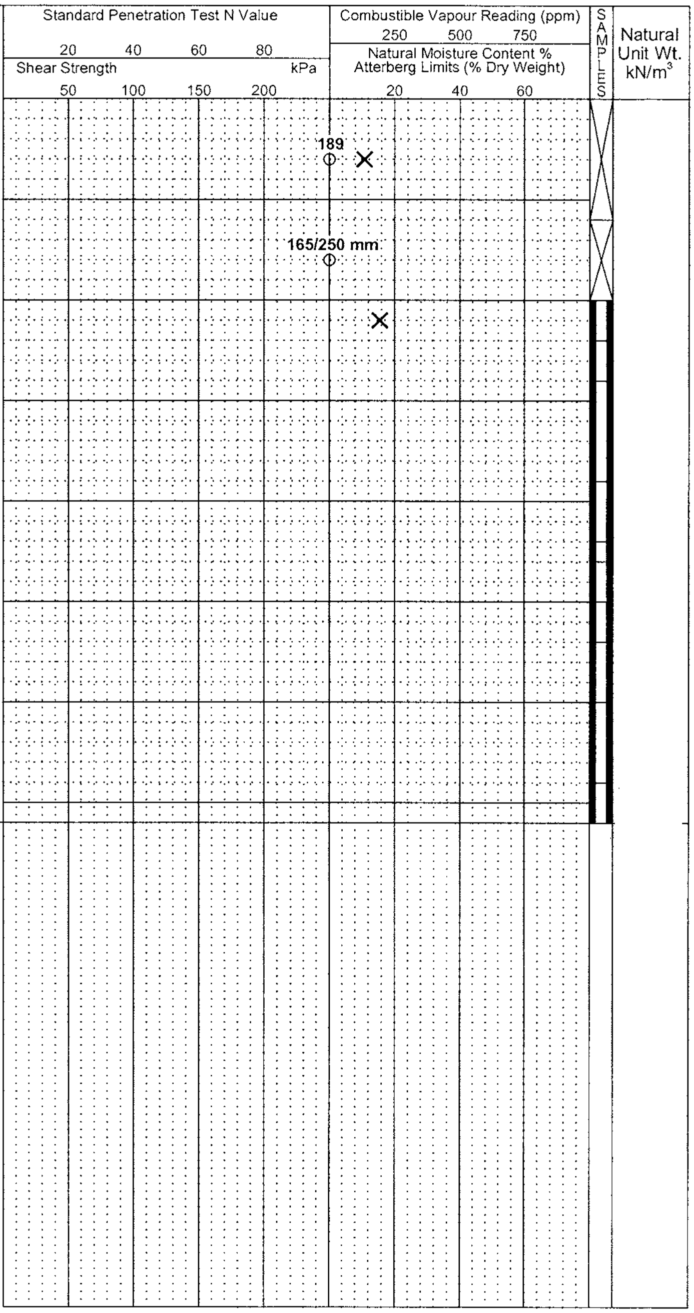
Datum: Estimated Elevation from Contour Lines (Approx)

Logged by:

Checked by:

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◫	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├──○
Dynamic Cone Test	──	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■	Shear Strength by Penetrometer Test	▲
Shear Strength by Vane Test	+ S		

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic Elevation m	Depth
			22.7	0
		TOPSOIL AND TUNDRA		
			22.4	
		SANDY SILT TILL Black staining in uper levels, occasional to some gravel, occasional cobbles and boulders, yellow brown Frozen at ground surface		
				1
				2
			20.4	
		SILTY GRAVEL Some sand, brown		
			20.2	
		SILSTONE BEDROCK Fractured, grey		
				3
			19.1	
		Terminated @ 3.6 m depth		



NOTES:

1. Borehole/Test Pit data requires Interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	2.49 - 2.72	78	
2	2.72 - 3.02	75	
3	3.02 - 3.35	54	
4	3.35 - 3.58	100	

Log of Borehole L3

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 4

Page. 1 of 1

Date Drilled: 'October 5th, 2009

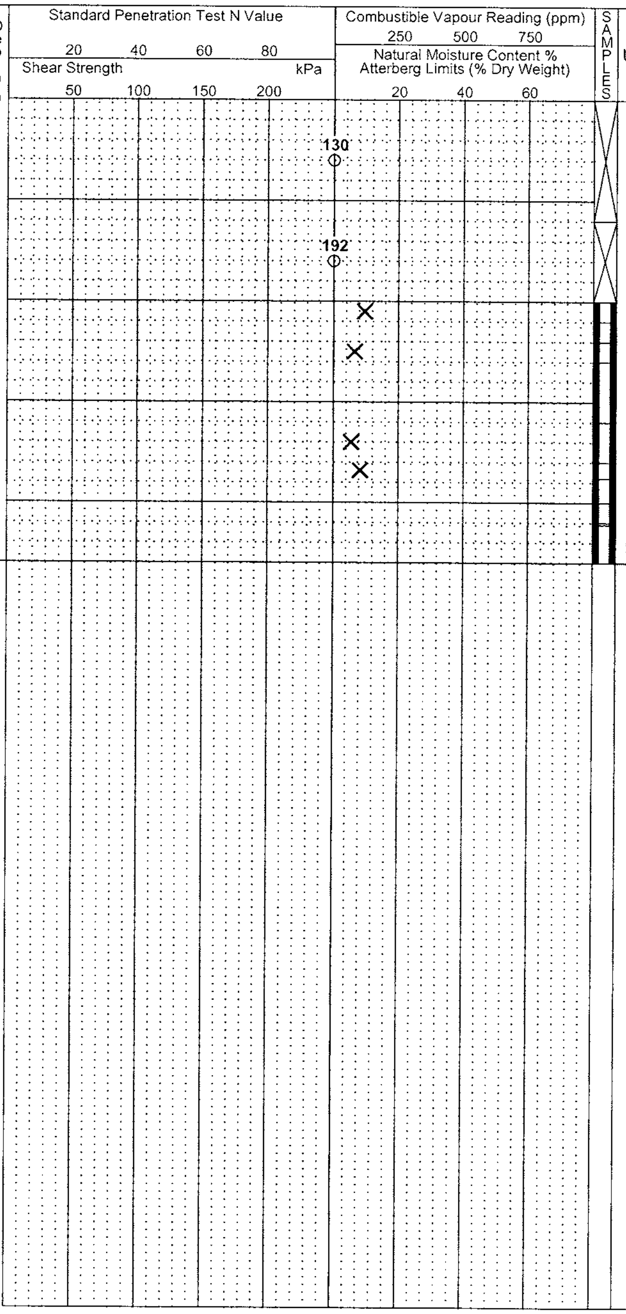
Drill Type:

Datum: Estimated Elevation from Contour Lines (Approx)

Logged by: Checked by:

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◨	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├──○
Dynamic Cone Test	──	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic Elevation m	Depth	SAMPLES	Natural Unit Wt. kN/m³
		TOPSOIL AND SILTY SAND Some fine gravel, black (frozen)	22.5	0	☒	
		SILTY SAND Fine to medium gravel, occasional cobbles, grey to brown	21.9	1	☒	23.3
	× ×	**POSSIBLE WEATHERED SILTSTONE BEDROCK** Grey	20.4 20.2	2		Run 1
		Terminated @ 2.3 m depth				



NOTES:
1. Borehole/Test Pit data requires interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	2.11 - 2.29	86	

Log of Borehole L4

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Date Drilled: 'October 1st, 2009

Drill Type:

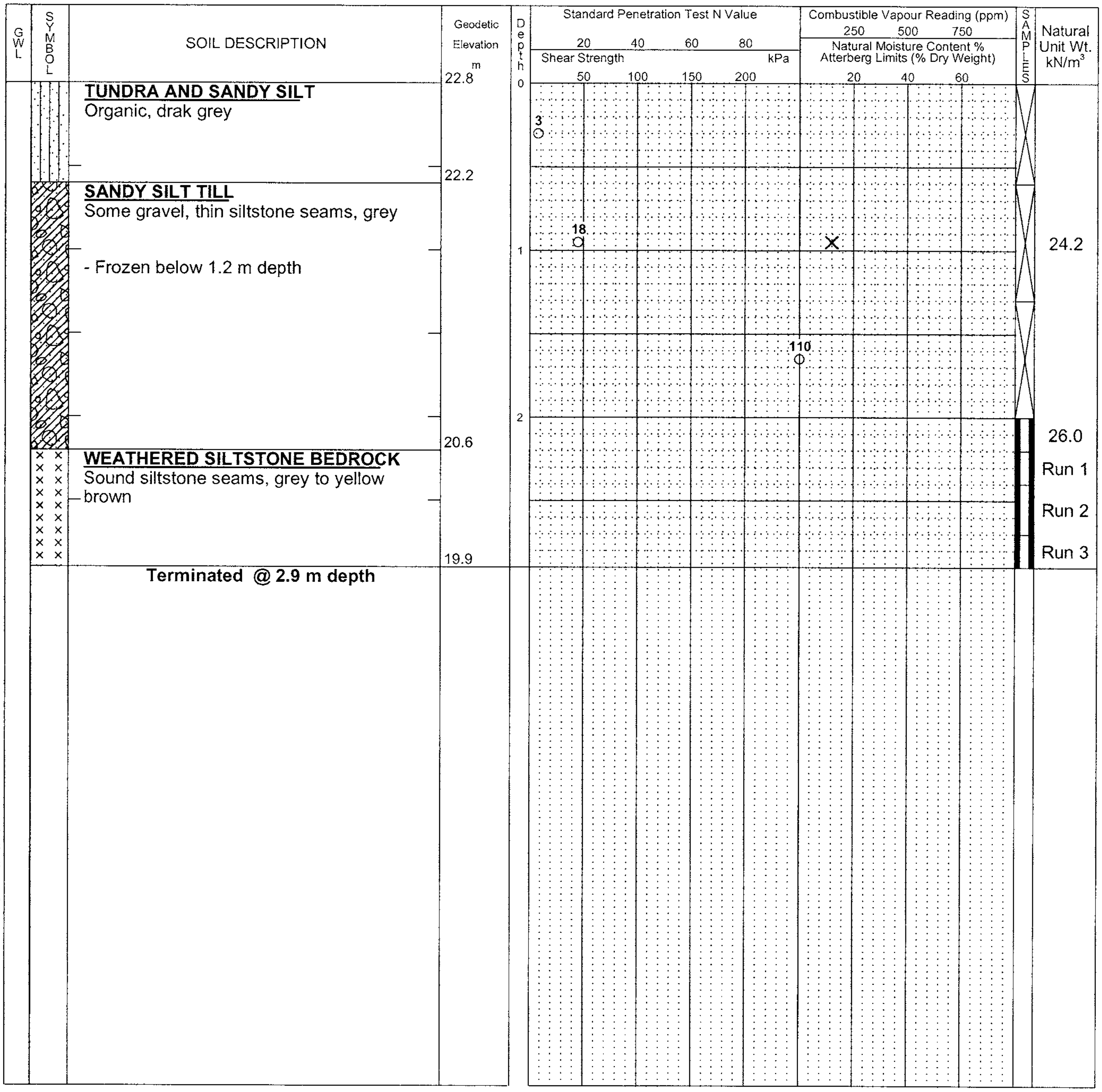
Datum: Estimated Elevation from Contour Lines (Approx)

Logged by: Checked by:

Figure No. 5

Page. 1 of 1

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◨	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	───	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲



Geodetic Elevation m	SOIL DESCRIPTION	Natural Unit Wt. kN/m³
22.8	**TUNDRA AND SANDY SILT** Organic, drak grey	
22.2	**SANDY SILT TILL** Some gravel, thin siltstone seams, grey - Frozen below 1.2 m depth	24.2
20.6	**WEATHERED SILTSTONE BEDROCK** Sound siltstone seams, grey to yellow brown	26.0 Run 1 Run 2 Run 3
19.9	**Terminated @ 2.9 m depth**	

NOTES:
1. Borehole/Test Pit data requires interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	2.18 - 2.36	83	
2	2.36 - 2.72	50	
3	2.72 - 2.87	100	

Log of Borehole L5

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 6

Page. 1 of 1

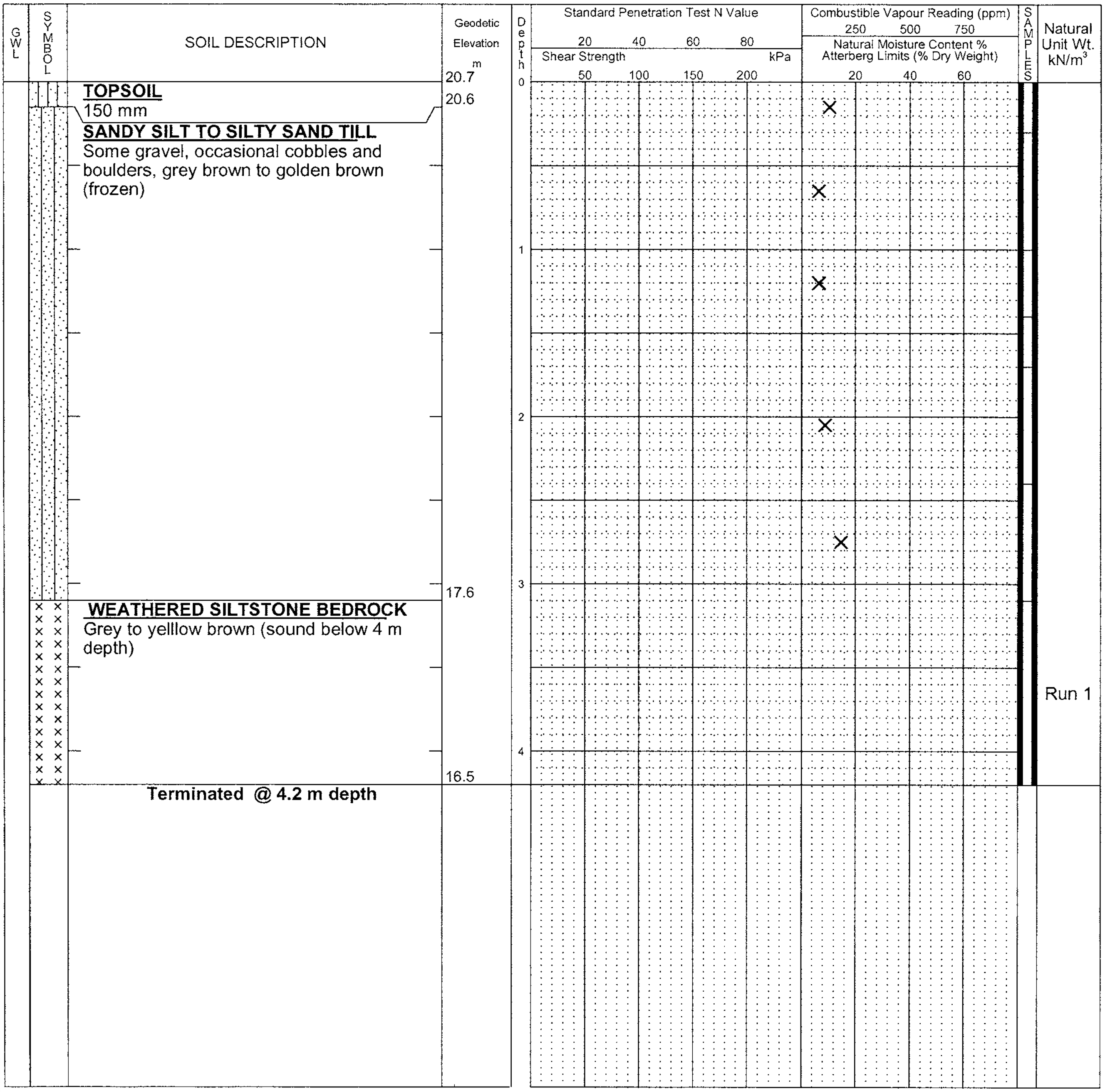
Date Drilled: 'November 4th, 2009

Drill Type:

Datum: Estimated Elevation from Contour Lines (Approx)

Logged by: Checked by:

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◫	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	⊢⊖
Dynamic Cone Test	—	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲



20.7

TOPSOIL
150 mm

20.6

SANDY SILT TO SILTY SAND TILL
Some gravel, occasional cobbles and boulders, grey brown to golden brown (frozen)

17.6

WEATHERED SILTSTONE BEDROCK
Grey to yelllow brown (sound below 4 m depth)

16.5

Terminated @ 4.2 m depth

NOTES:
1. Borehole/Test Pit data requires Interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	3.13 - 4.24	100	

Log of Borehole L6

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 7

Page. 1 of 1

Date Drilled: 'September 30, 2009

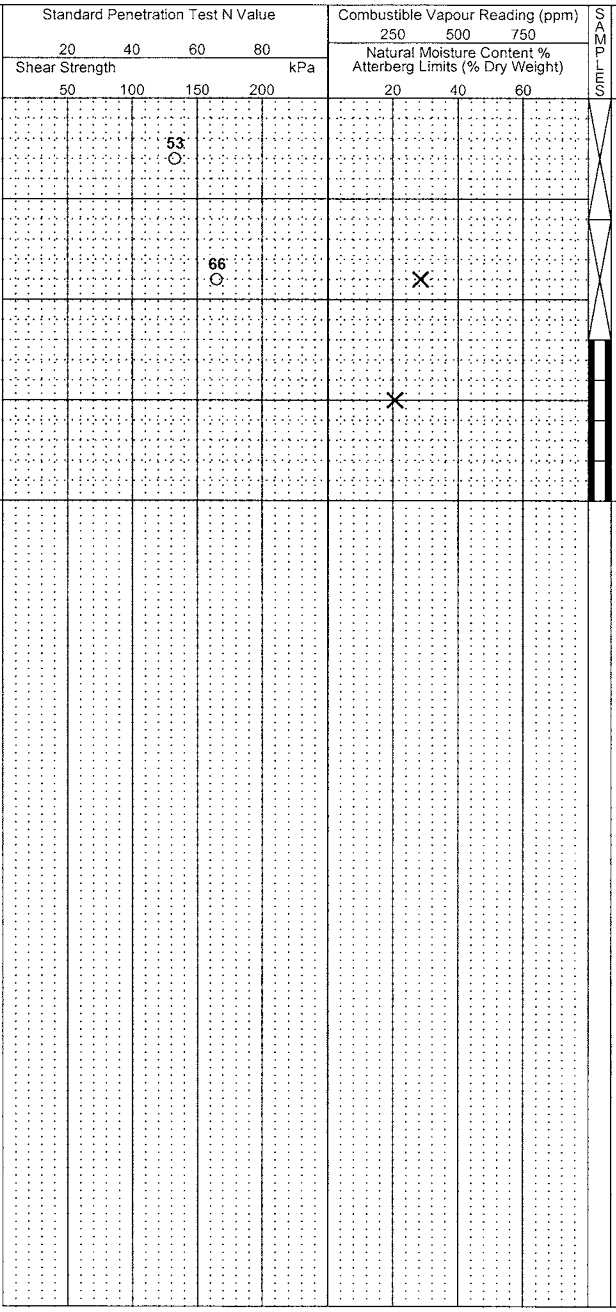
Drill Type:

Datum: Estimated Elevation from Contour Lines (Approx)

Logged by: ________ Checked by: ________

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◨	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├─○
Dynamic Cone Test	──	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic Elevation m	Depth	Natural Unit Wt. kN/m³
			23.7	0	
		SAND AND GRAVEL 250 mm frost at surface. fine to coarse, some silt, brown.	23.1		
		SANDY SILT TILL Scattered gravel, slightly cohesive, grey Frozen below 1.0 m depth	22.3	1	21.6
		SANDY SILT Occasional gravel, siltstone seams below 1.6 m depth, brown	21.7	2	
		Terminated @ 2.0 m depth			



NOTES:
1. Borehole/Test Pit data requires Interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Log of Borehole L7

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 8

Page. 1 of 1

Date Drilled: 'September 29, 2009

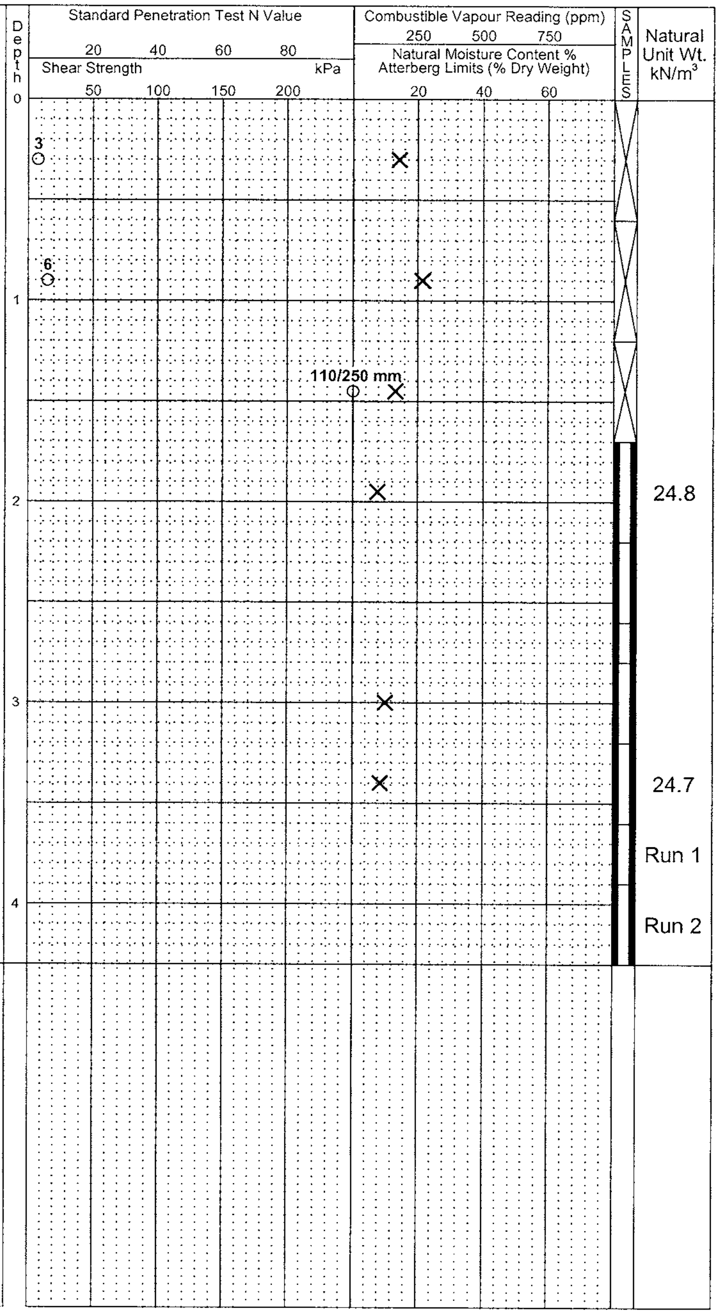
Drill Type:

Datum: Estimated Elevation from Contour Lines (Approx)

Logged by: Checked by:

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◫	Natural Moisture Content	✕
SPT (N) Value	○	Atterberg Limits	⊢—○
Dynamic Cone Test	—	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲

SOIL DESCRIPTION	Geodetic Elevation m
	22.8
FILL Silty sand, some organics, occasional cobbles, light brown	
	21.6
SANDY SILT TILL Some sand and gravel, occasional cobbles and boulders, light grey - becoming clayey below 3.5 m depth. Frozen below 1.5 m depth.	
	19.1
SILTSTONE BEDROCK Weathered seams, light grey to brown	
	18.5
Terminated @ 4.3 m depth	



NOTES:
1. Borehole/Test Pit data requires interpretation by Trow before use by others
2. A thermister was installed in the Bottom of the borehole
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	3.58 - 3.91	62	
2	3.91 - 4.27	86	

Log of Borehole L8

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 9

Page. 1 of 1

Date Drilled: 'September 30, 2009

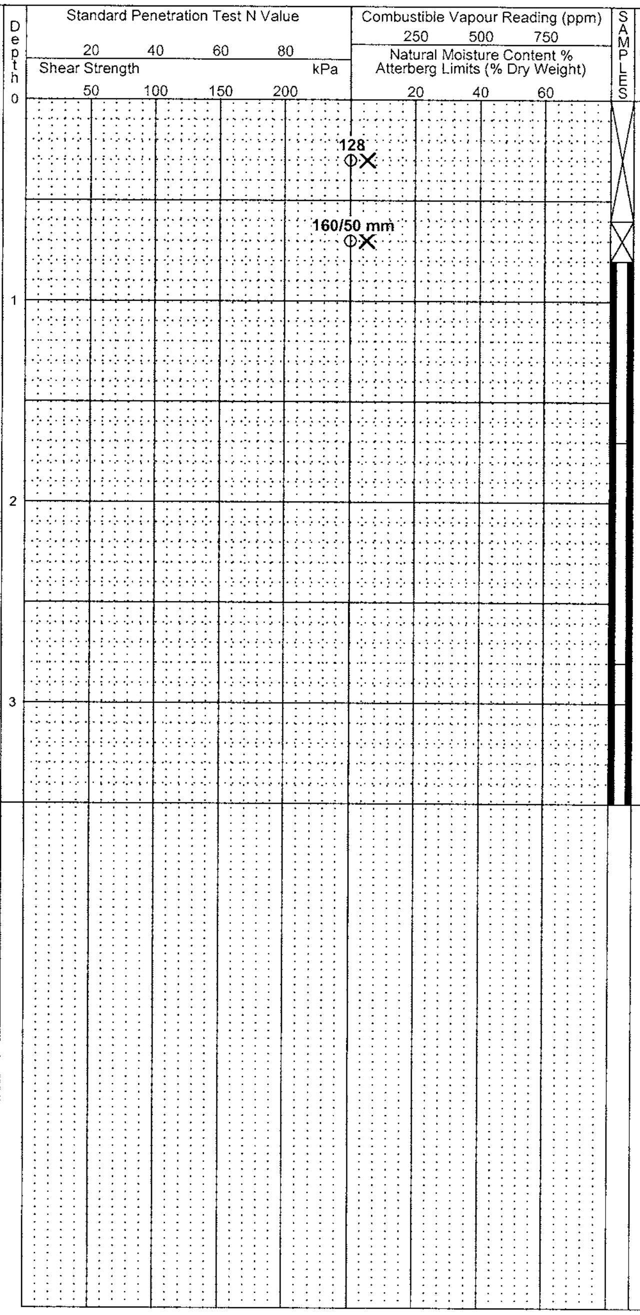
Drill Type:

Datum: Estimated Elevation from Contour Lines (Approx)

Logged by: Checked by:

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◨	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├──○
Dynamic Cone Test	──	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic Elevation m	Depth	SAMPLES	Natural Unit Wt. kN/m³
		GRAVEL Sandy and silty, occasional cobbles, brown	24.6	0	☒	
		SANDY SILT TILL Some gravel, siltstone seams or cobbles, yellow brown Frozen below 1.4 m depth	24.0	1 2	☒	
		SILTSTONE BEDROCK Grey to yellowish brown	21.8	3		Run 1 Run 2
		Terminated @ 3.5 m depth	21.1			



NOTES:
1. Borehole/Test Pit data requires Interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	2.84 - 3.05	75	
2	3.05 - 3.45	81	

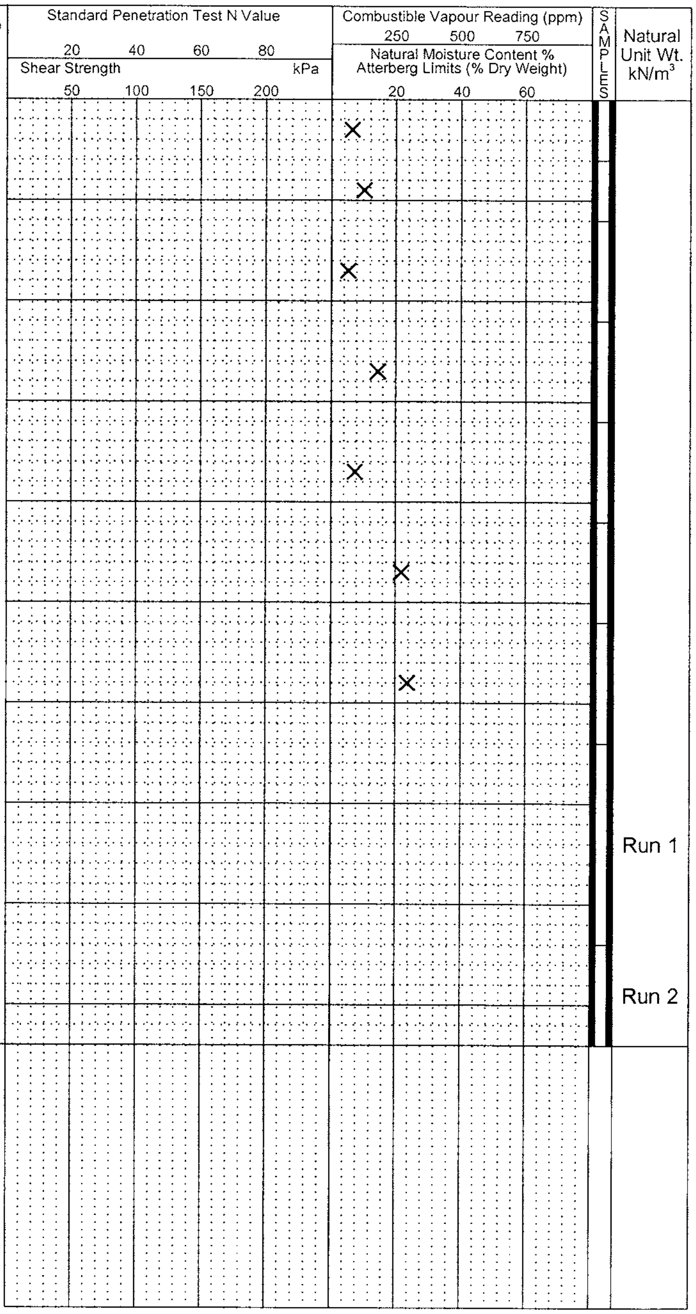
Log of Borehole L9

Project No: OTGE00019838B
Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility
Location: Hamlet of Igloolik, Nunavut
Date Drilled: 'November 3rd, 2009
Drill Type:
Datum: Estimated Elevation from Contour Lines (Approx)
Logged by: Checked by:

Figure No. 10
Page. 1 of 1

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◨	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├──○
Dynamic Cone Test	───	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■	Shear Strength by Penetrometer Test	▲
Shear Strength by Vane Test	+ S		

GWL	SYMBOL	SOIL DESCRIPTION	Geodetic Elevation m	Depth
		SANDY SILT TO SILTY SAND TILL Trace to some gravel, occasional siltstone pieces, brown, moist to very moist (frozen)	22.6	0
				1
		CLAYEY SILT Trace sand, golden brown, very moist	20.5	2
		SILTSTONE BEDROCK Weathered to sound, horizontally stratified, yellowish brown	19.6	3
				4
		Terminated @4.7 m depth	17.9	



NOTES:
1. Borehole/Test Pit data requires Interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	3.18 - 4.17	54	
2	4.17 - 4.67	80	

Log of Borehole BH 1

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 11

Page. 1 of 1

Date Drilled: 'October 2 2009

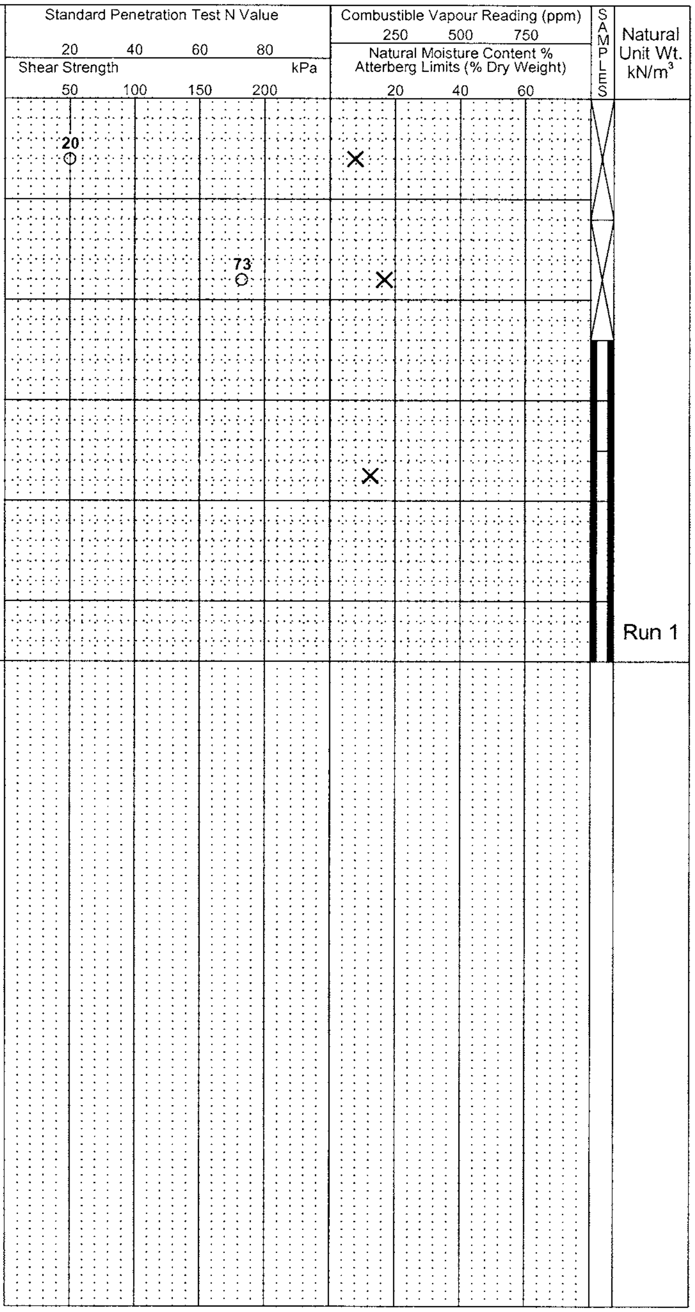
Drill Type:

Datum: Estimated Elevation from Contour Lines (Approx)

Logged by: Checked by:

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◨	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├──○
Dynamic Cone Test	───	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■	Shear Strength by Penetrometer Test	▲
Shear Strength by Vane Test	+ S		

GWL	SOIL DESCRIPTION	Geodetic Elevation m	Depth
		29.2	0
	SAND AND GRAVEL Silty, trace clay, fine to coarse, brown, moist Frozen below 0.9 m depth		
			1
		28.0	
	CLAYEY SILT TILL Fine to medium gravel, brown, moist		
		27.2	2
	SANDY SILT Trace fine to medium gravel, yellowish brown.		
		26.7	
	SILTSTONE BEDROCK Yellow brown		
		26.4	
	Terminated @ 2.8 m depth		



NOTES:
1. Borehole/Test Pit data requires Interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	2.54 - 2.84	50	

Log of Borehole BH 2

Trow

Project No: OTGE00019838B

Project: Geotechnical Investigation, Liquid and Solid Waste Management Facility

Location: Hamlet of Igloolik, Nunavut

Figure No. 12

Page. 1 of 1

Date Drilled: 'October 2 2009

Drill Type:

Datum: Estimated Elevation from Contour Lines (Approx)

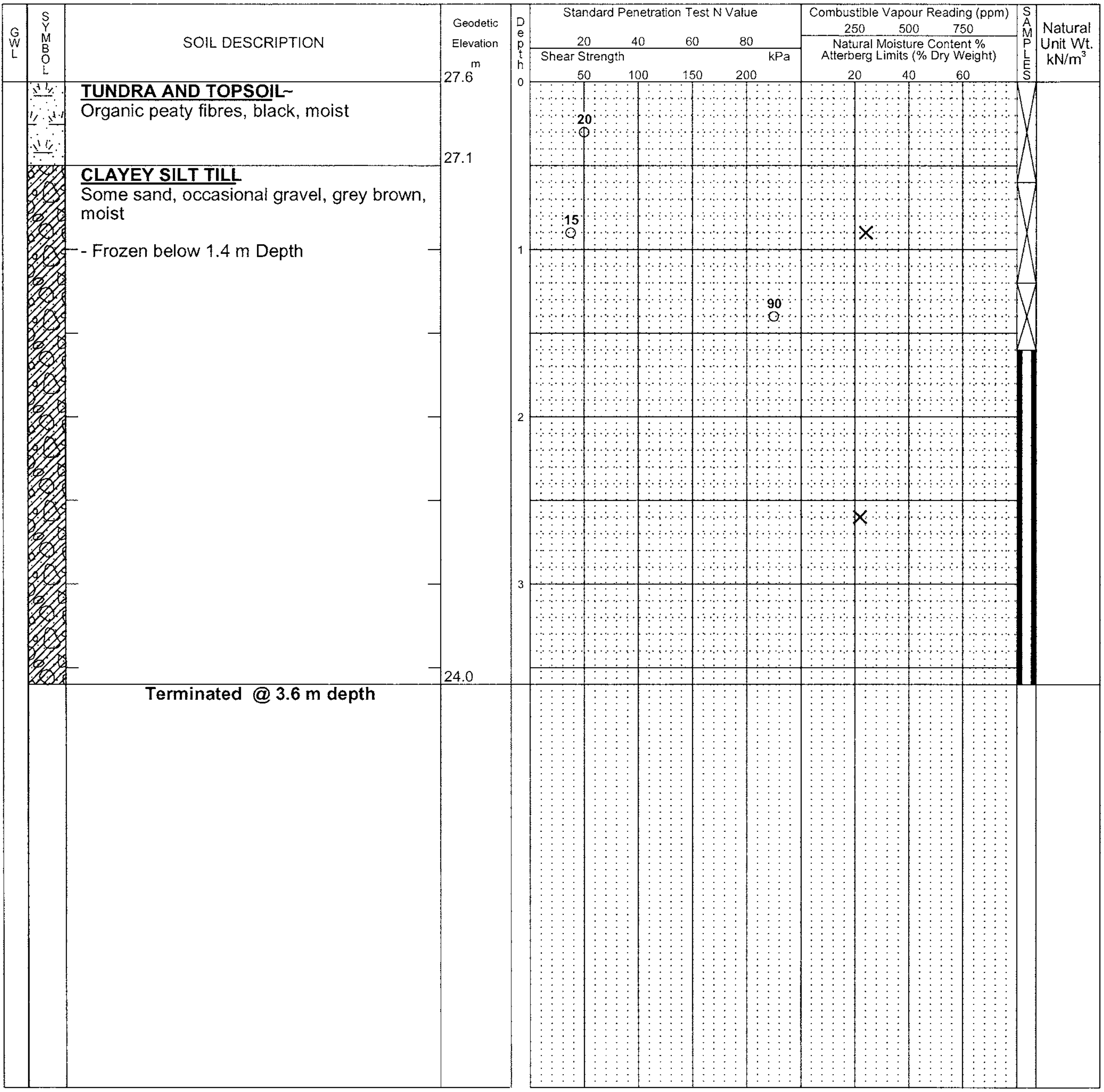
Logged by:

Checked by:

Split Spoon Sample	☒	Combustible Vapour Reading	☐
Auger Sample	◫	Natural Moisture Content	×
SPT (N) Value	○	Atterberg Limits	├──○
Dynamic Cone Test	───	Undrained Triaxial at % Strain at Failure	⊕
Shelby Tube	■		
Shear Strength by Vane Test	+ S	Shear Strength by Penetrometer Test	▲

GWL	SOIL DESCRIPTION	Geodetic Elevation m	Depth
		27.6	0
	TUNDRA AND TOPSOIL~ Organic peaty fibres, black, moist		
		27.1	
	CLAYEY SILT TILL Some sand, occasional gravel, grey brown, moist - Frozen below 1.4 m Depth		1
			2
			3
		24.0	

Terminated @ 3.6 m depth



NOTES:
1. Borehole/Test Pit data requires interpretation by Trow before use by others
2. Borehole backfilled upon completion of drilling
3. Field work supervised by a Trow representative
4. See Notes on Sample Descriptions
5. This Figure is to read with Trow Associates Inc. report OTGE00019838B

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %

Trow Associates Inc.
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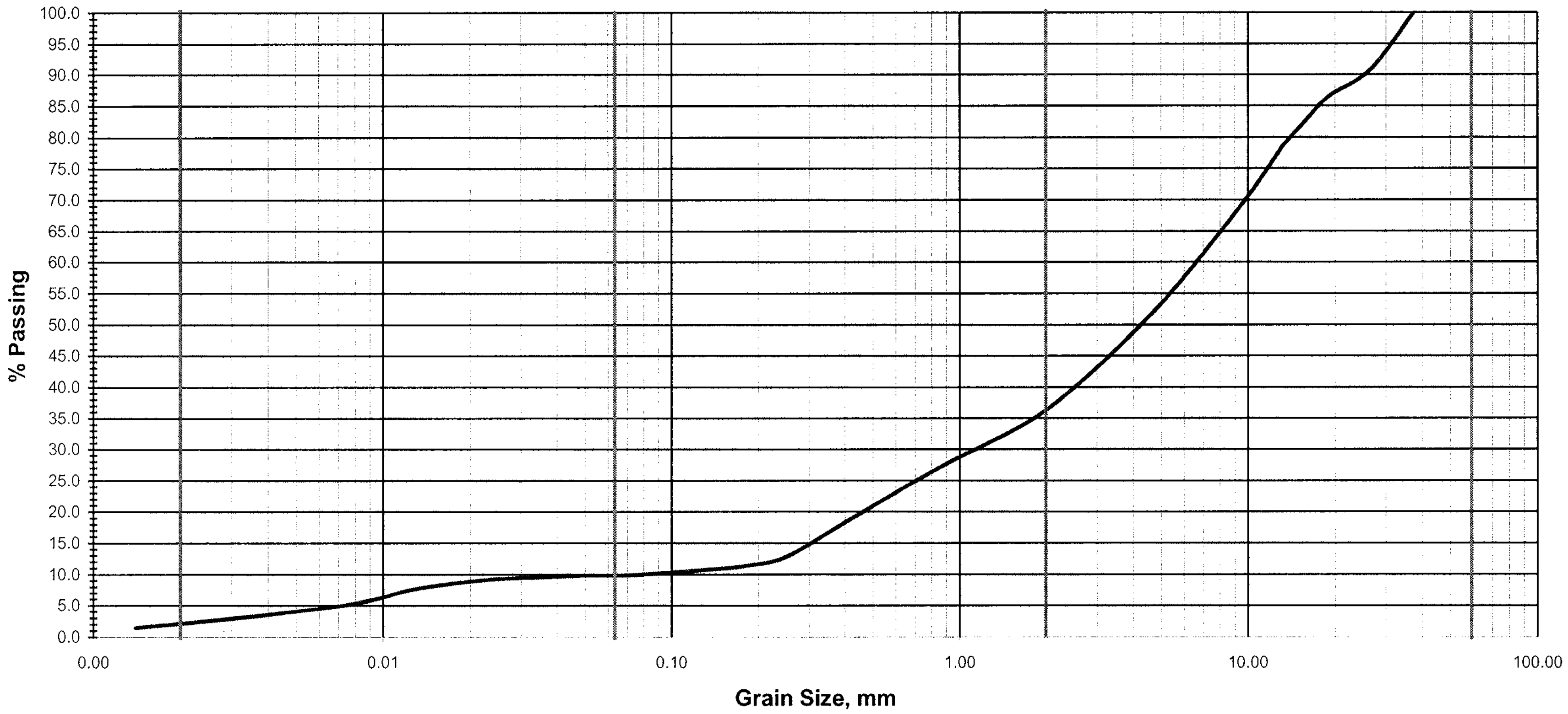
Ottawa, ON K2E 7J5

Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



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<tr><td colspan="3">SILT</td><td colspan="3">SAND</td><td colspan="3">GRAVEL</td></tr>
<tr><td colspan="11">Modified M.I.T. Classification</td></tr>
</table>

Trow Project No.:	**OTGEO0019838B**	**Project Name :**	**Geotechnical Investigation Liquid and Solid Waste Management**		
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet, Igloolik, Nunavut**		
Date Sampled :	**November 3, 2009**	**Borehole No.:**	**BH L1**	**Sample No.: SS 2**	**Depth (m) : 0.6 to 1.2**
Sample Description :		**Sandy Gravel, trace Silt and Clay**			**Figure : 13**

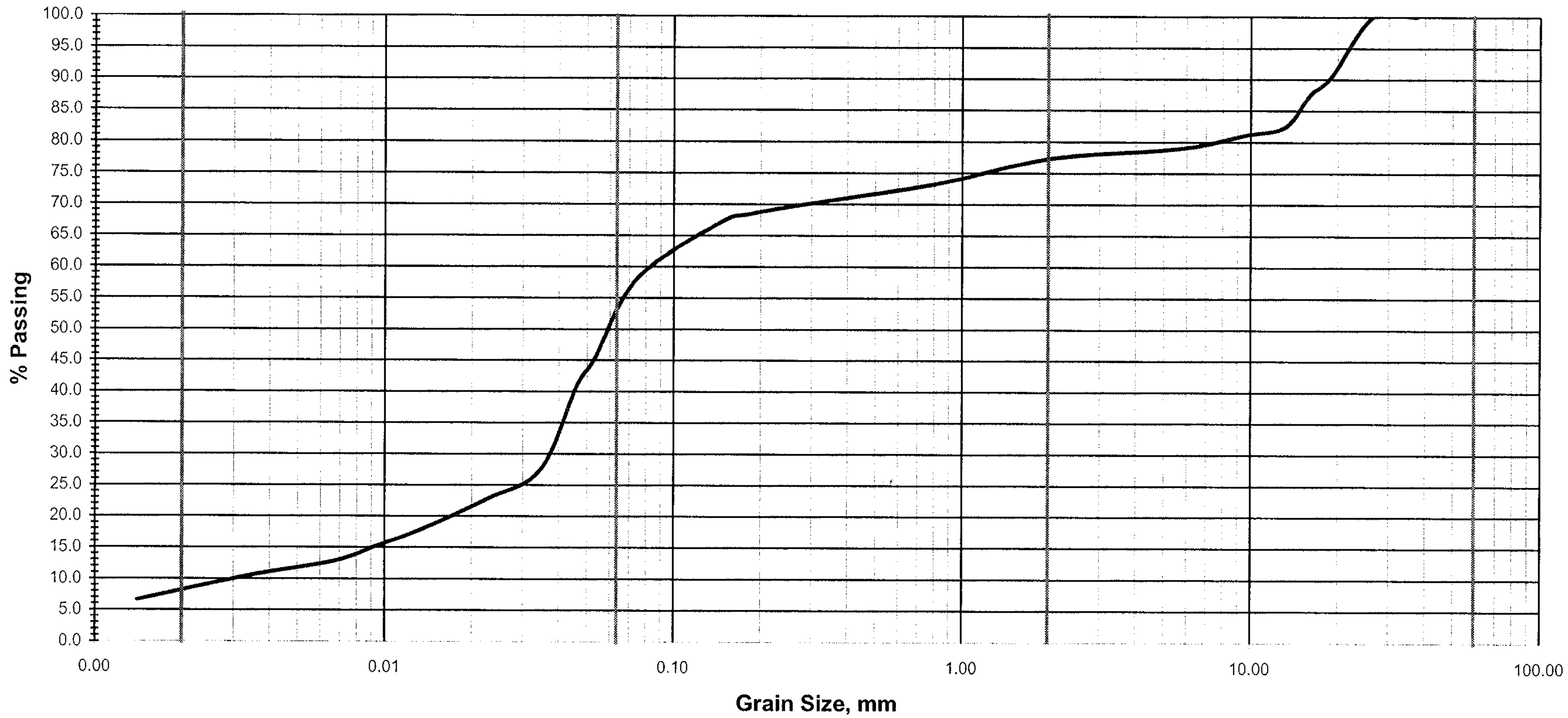
Trow

Trow Associates Inc.
154 Colonnade Road South
Ottawa, ON K2E 7J5

Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



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<tr><td colspan="11">Modified M.I.T. Classification</td></tr>
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Trow Project No.:	**OTGEO0019838B**	**Project Name :**	**Geotechnical Investigation Liquid and Solid Waste Management**				
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet, Igloolik, Nunavut**				
Date Sampled :	**November 3, 2009**	**Borehole No.:**	**BH L2**	**Sample No.:**	**SS 3**	**Depth (m) :**	**1.0 to 1.2**
Sample Description :		**Sandy, Gravelly Silt,trace Clay**				**Figure :**	**14**

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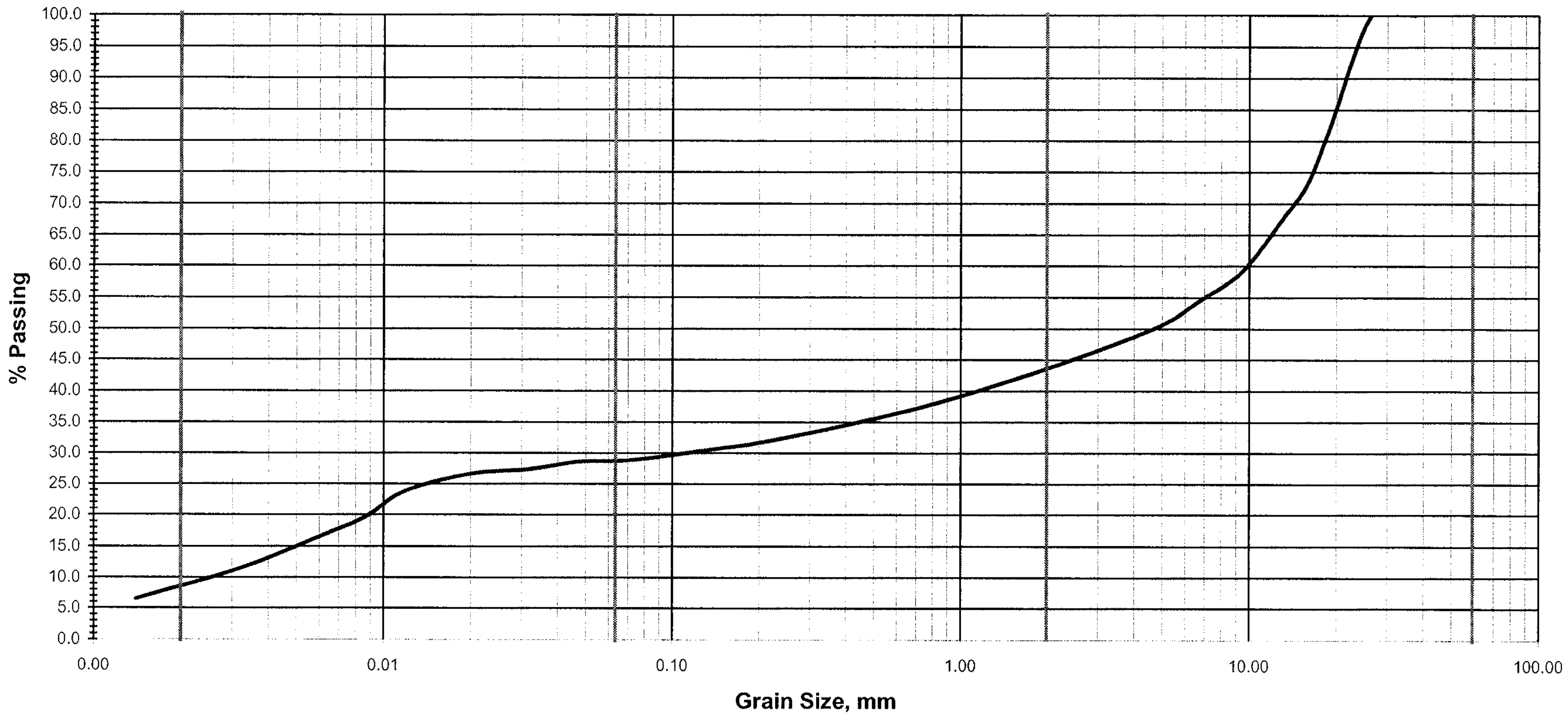
Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



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<tr><td colspan="11">Modified M.I.T. Classification</td></tr>
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Trow Project No.:	OTGEO0019838B	Project Name :	Geotechnical Investigation, Liquid and Solid Waste Management		
Client :	Government of Nunavut	Project Location :	Hamlet, Igloolik, Nunavut		
Date Sampled :	November 3, 2009	Borehole No.:	BH L2	Sample No.: SS 8	Depth (m) : 2.3 to 2.5
Sample Description :		Silty, Sandy Gravel, trace Clay			Figure : 15

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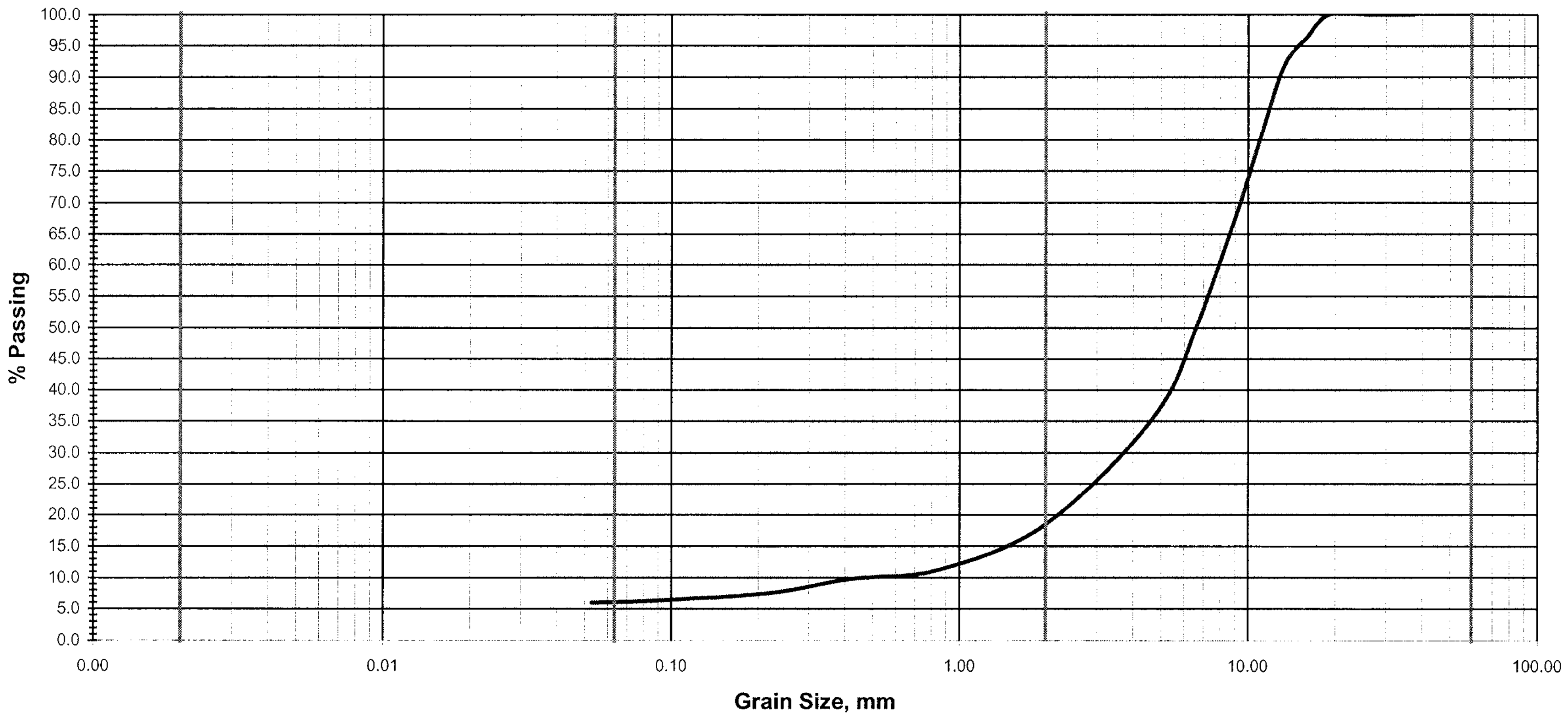
Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
	SILT			SAND			GRAVEL			
Modified M.I.T. Classification										

Trow Project No.: OTGEO0019838B	Project Name : Geotechnical Investigation, Liquid and Solid Waste Management				
Client : Government of Nunavut	Project Location : Hamlet, Igloolik, Nunavut				
Date Sampled : November 3, 2009	Borehole No.:	BH L8	Sample No.: SS 2	Depth (m) :	0.6 to 0.8
Sample Description :	Sandy Gravel			Figure :	16

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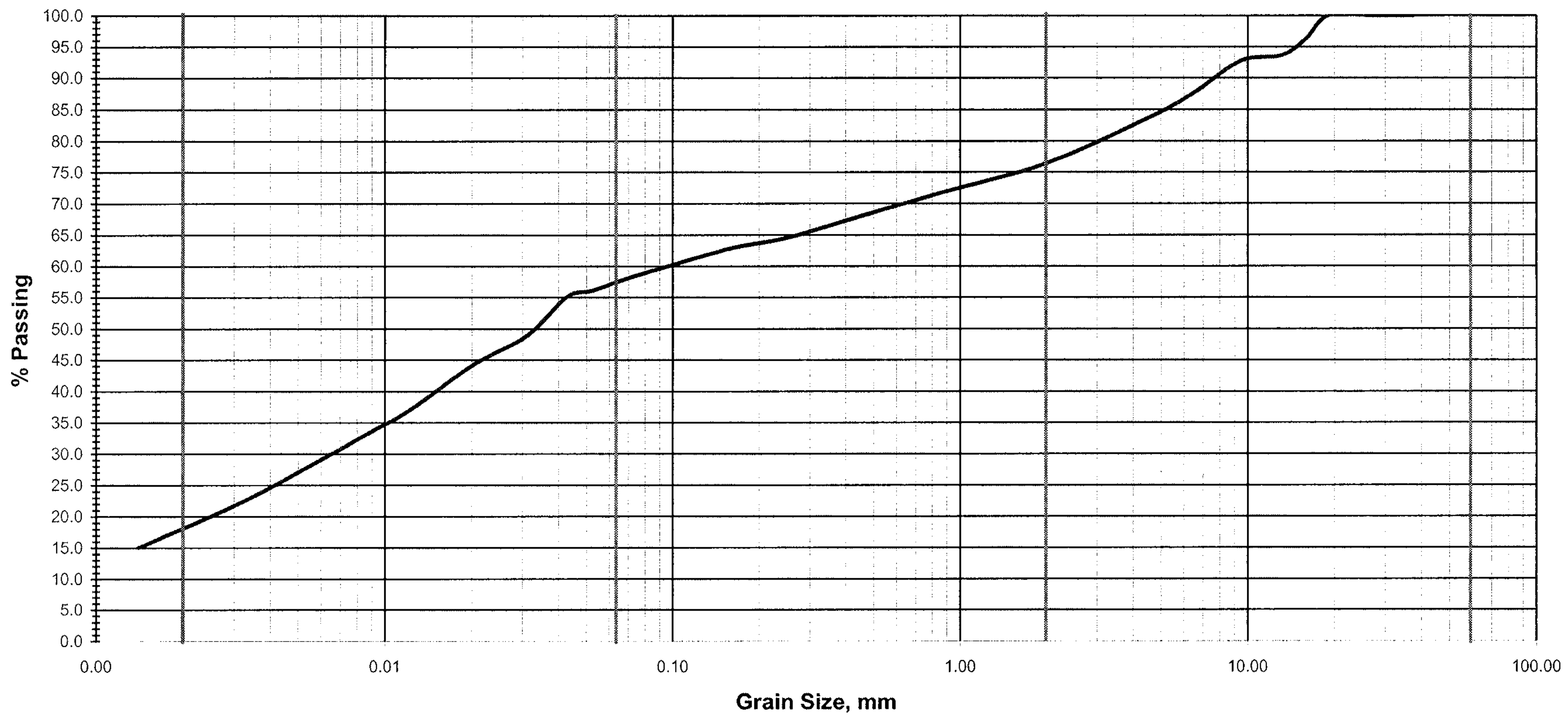
Ottawa, ON K2E 7J5

Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
	SILT			SAND			GRAVEL			
Modified M.I.T. Classification										

Trow Project No.:	OTGEO0019838B	Project Name :	Geotechnical Investigation, Liquid and Solid Waste Management				
Client :	Government of Nunavut	Project Location :	Hamlet, Igloolik, Nunavut				
Date Sampled :	November 3, 2009	Borehole No.:	BH L7	Sample No.:	SS 3	Depth (m) :	1.2 to 1.6
Sample Description :		Sandy Silt, some Clay and Gravel				Figure :	17

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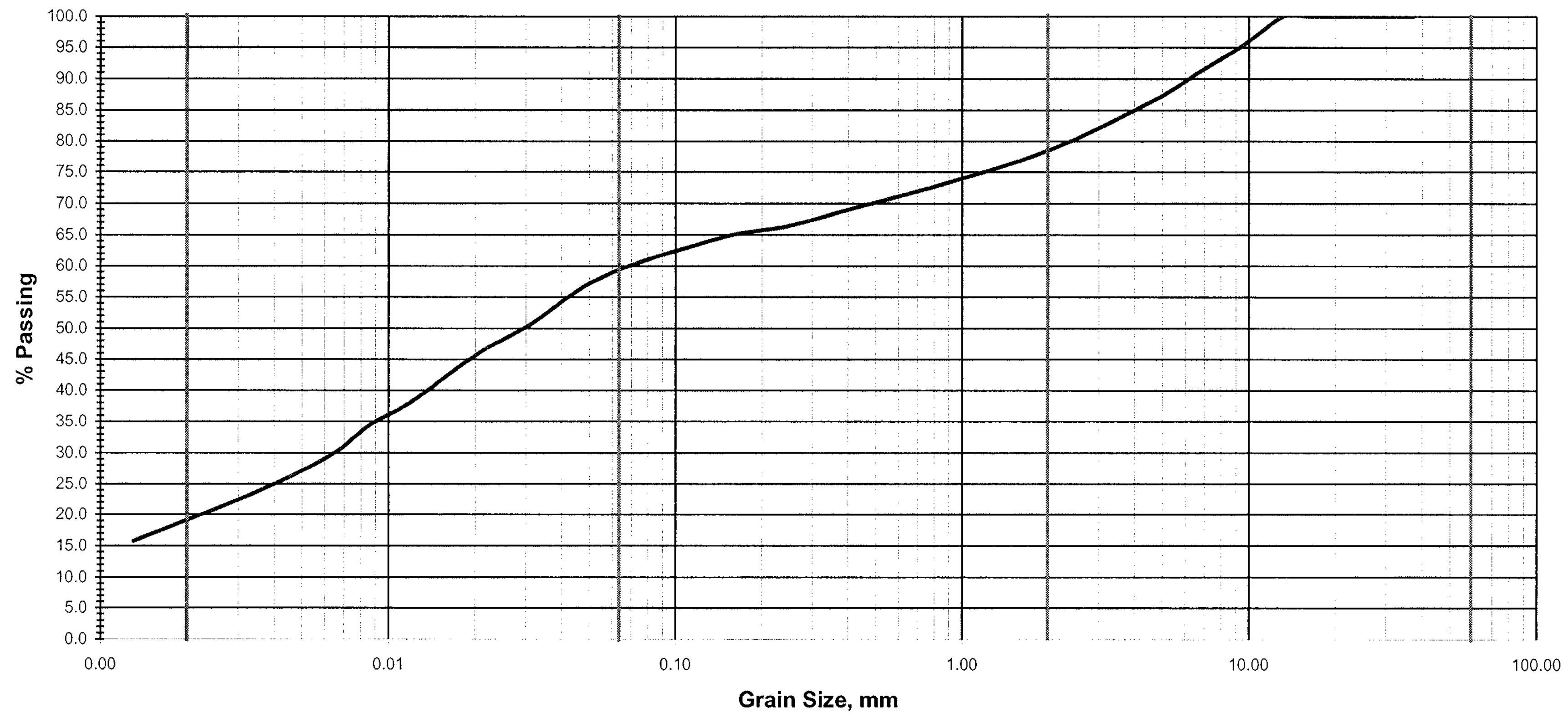
Ottawa, ON K2E 7J5

Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



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<tr><td colspan="3">SILT</td><td colspan="3">SAND</td><td colspan="3">GRAVEL</td></tr>
<tr><td colspan="11">Modified M.I.T. Classification</td></tr>
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<tr><td>Date Sampled :</td><td>November 3, 2009</td><td>Borehole No.:</td><td>BH L7</td><td>Sample No.: SS 7</td><td>Depth (m) :</td><td>2.8 to 3.2</td></tr>
<tr><td>Sample Description :</td><td colspan="4">Sandy Silt, some Clay and Gravel</td><td>Figure :</td><td>18</td></tr>
</table>

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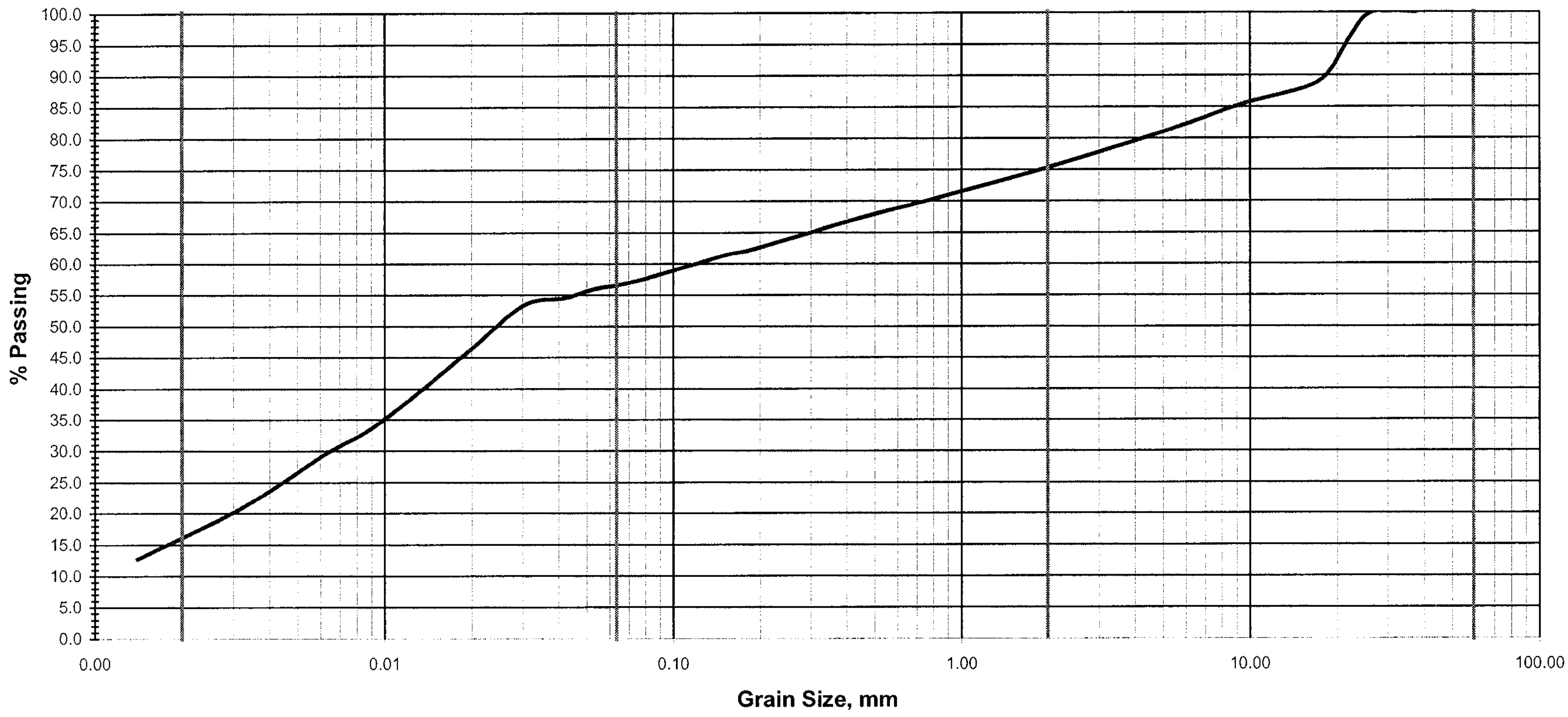
Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
	SILT			SAND			GRAVEL		
Modified M.I.T. Classification									

Trow Project No.:	**OTGEO0019838B**	**Project Name :**	**Geotechnical Investigation, Liquid and Solid Waste Management**		
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet, Igloolik, Nunavut**		
Date Sampled :	**November 3, 2009**	**Borehole No.:** **BH L4**	**Sample No.:** **SS 2**	**Depth (m) :**	**0.6 to 1.3**
Sample Description :	**Sandy Silt, some Gravel and Clay**			**Figure :**	**19**

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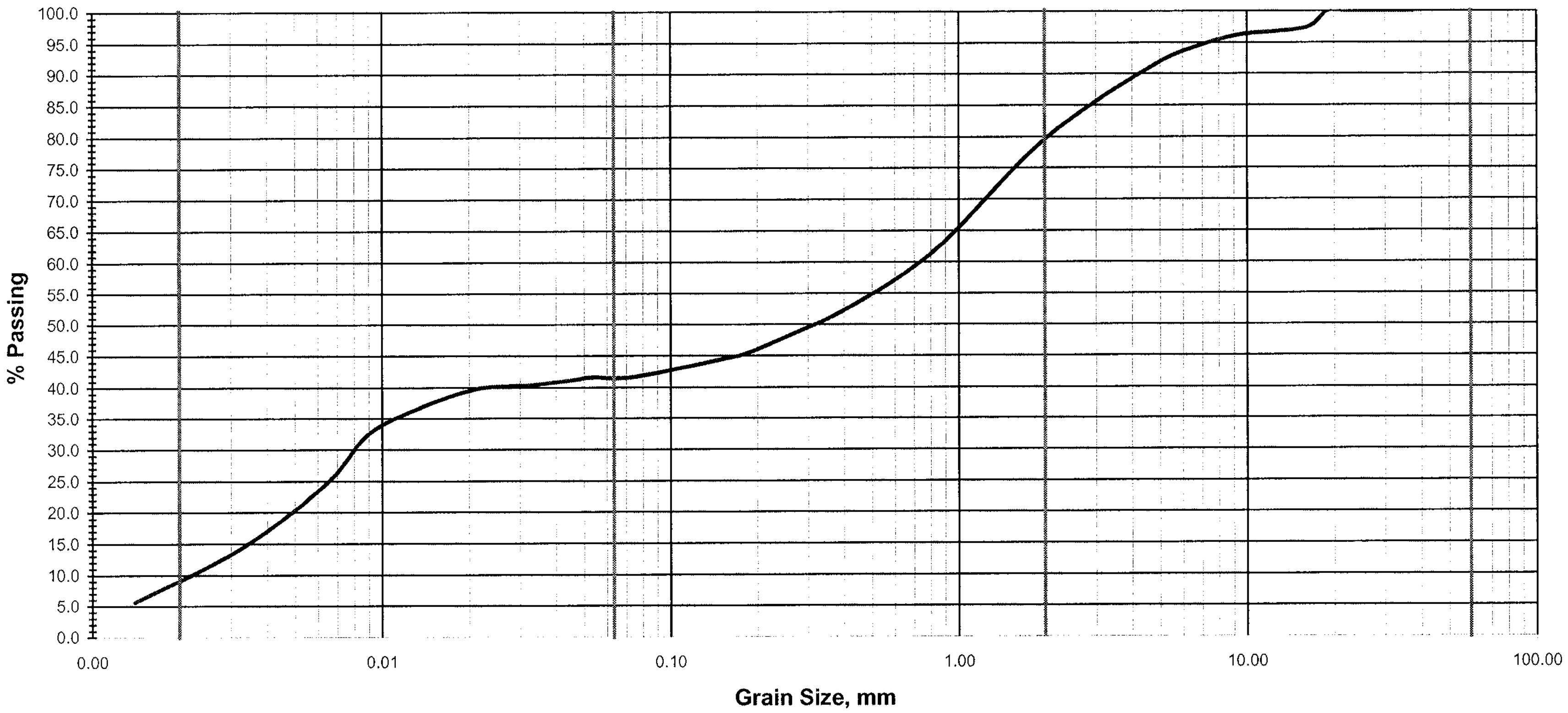
Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
	SILT			SAND			GRAVEL		
Modified M.I.T. Classification									

Trow Project No.:	**OTGEO0019838B**	**Project Name :**	**Geotechnical Investigation, Liquid and Solid Waste Management**		
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet, Igloolik, Nunavut**		
Date Sampled :	**November 3, 2009**	**Borehole No.:** **BH L9**	**Sample No.:** **SS 3**	**Depth (m) :**	**0.6 to 1.1**
Sample Description :		**Silty Sand, trace Clay and Gravel**		**Figure :**	**20**

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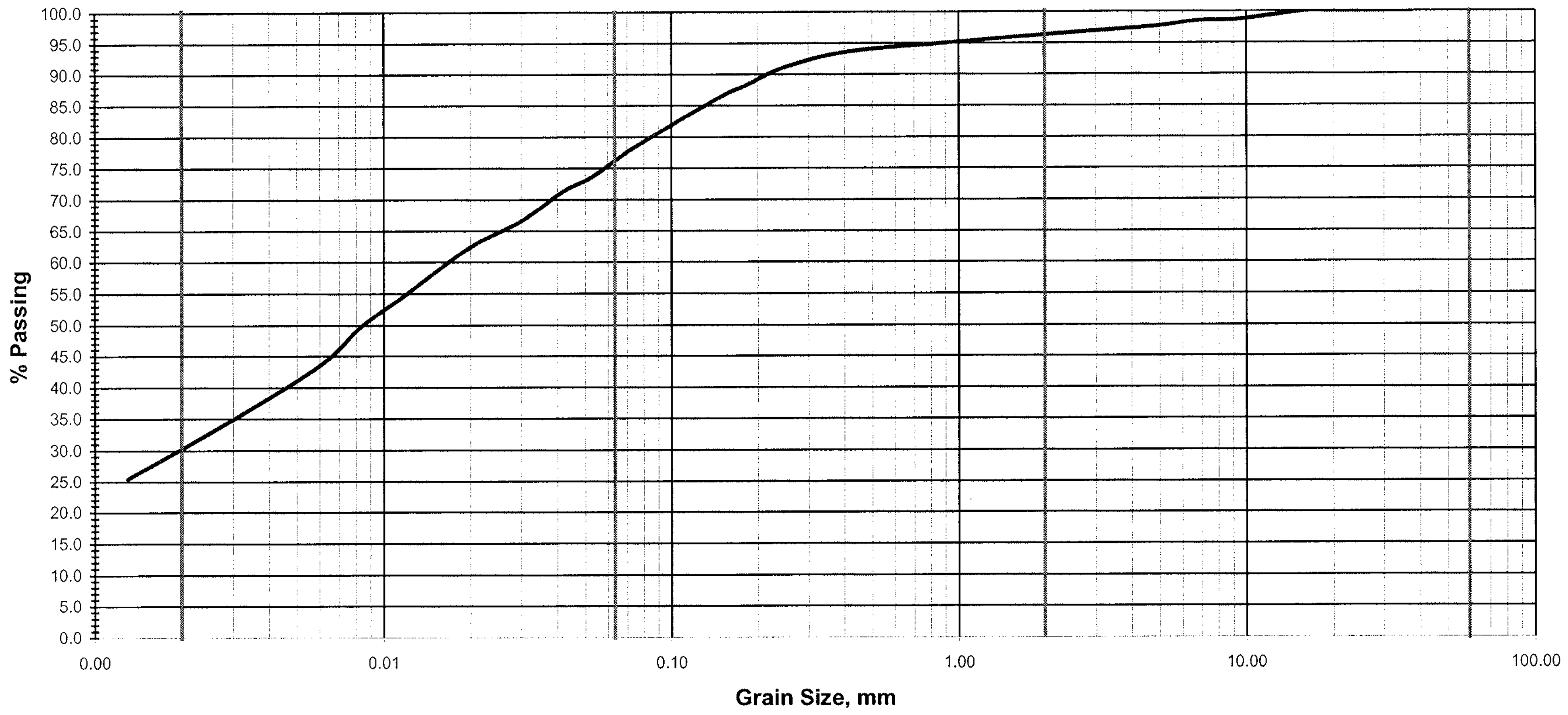
Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse
	SILT			SAND			GRAVEL		
Modified M.I.T. Classification									

Trow Project No.:	OTGEO0019838B	Project Name :	Geotechnical Investigation, Liquid and Solid Waste Management				
Client :	Government of Nunavut	Project Location :	Hamlet, Igloolik, Nunavut				
Date Sampled :	November 3, 2009	Borehole No.:	BH L9	Sample No.:	SS 6	Depth (m) :	2.1 to 2.6
Sample Description :	Clayey Silt, some Sand, trace Gravel					Figure :	21

Trow Associates Inc.
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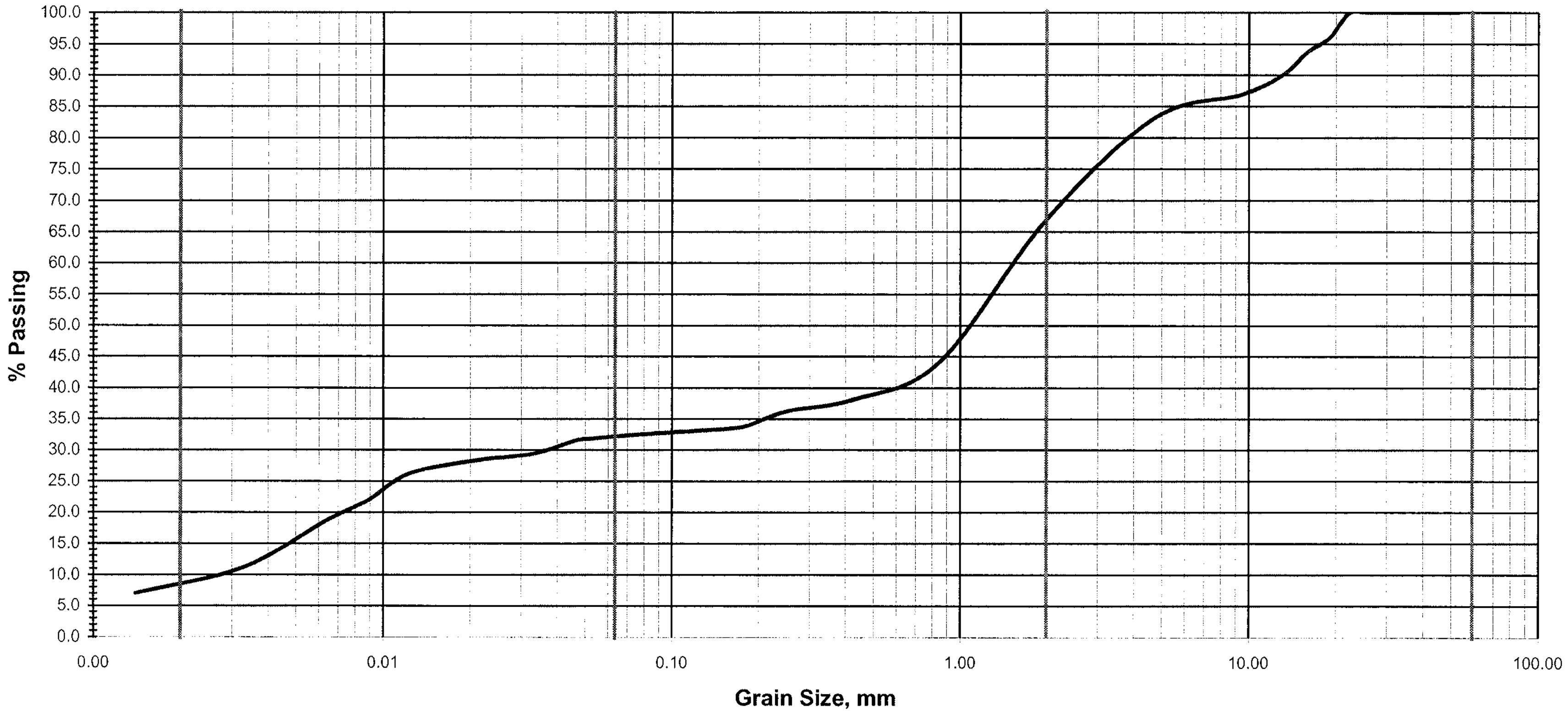
Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
		SILT			SAND			GRAVEL		
Modified M.I.T. Classification										

Trow Project No.: OTGEO0019838B	**Project Name :** Geotechnical Investigation, Liquid and Solid Waste Management				
Client : Government of Nunavut	**Project Location :** Hamlet, Igloolik, Nunavut				
Date Sampled : December 23, 2009	**Borehole No.:**	BH 1	**Sample No.:** SS 2	**Depth (m) :**	0.6 to 1.2
Sample Description :	Silty Sand some Gravel, trace Clay			**Figure :**	22

Trow

Trow Associates Inc.
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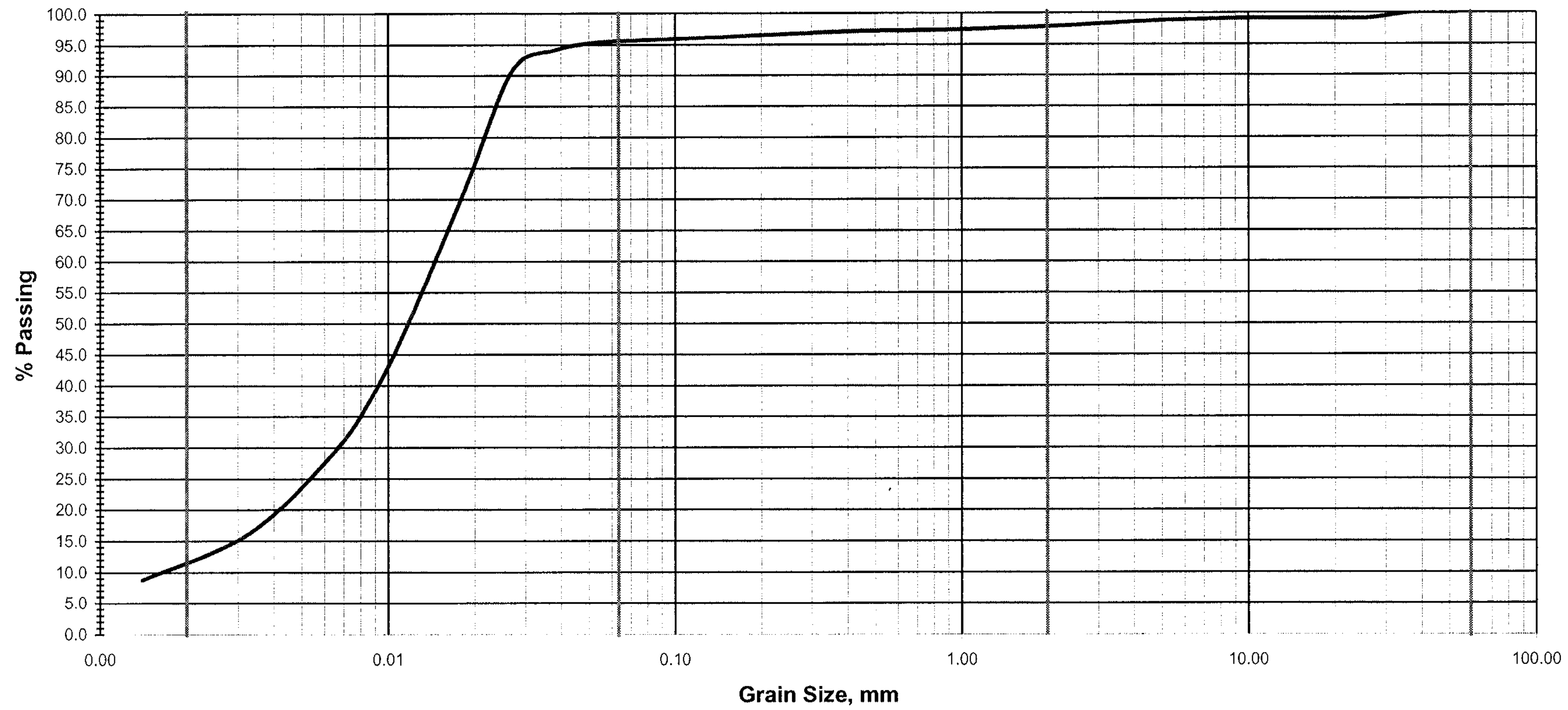
Method of Test for Particle Size Analysis of Soil

MTO Test Method LS - 702, Rev. No. 19

Grain Size Distribution Curve



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	
	SILT			SAND			GRAVEL			
Modified M.I.T. Classification										

Trow Project No.:	**OTGEO0019838B**	**Project Name :**	**Geotechnical Investigation, Liquid and Solid Waste Management**				
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet, Igloolik, Nunavut**				
Date Sampled :	**November 3, 2009**	**Borehole No.:**	**BH 2**	**Sample No.:**	**SS 4**	**Depth (m) :**	**1.6 to 2.0**
Sample Description :	**Silt, some Clay traceSand & Gravel**					**Figure :**	**23**

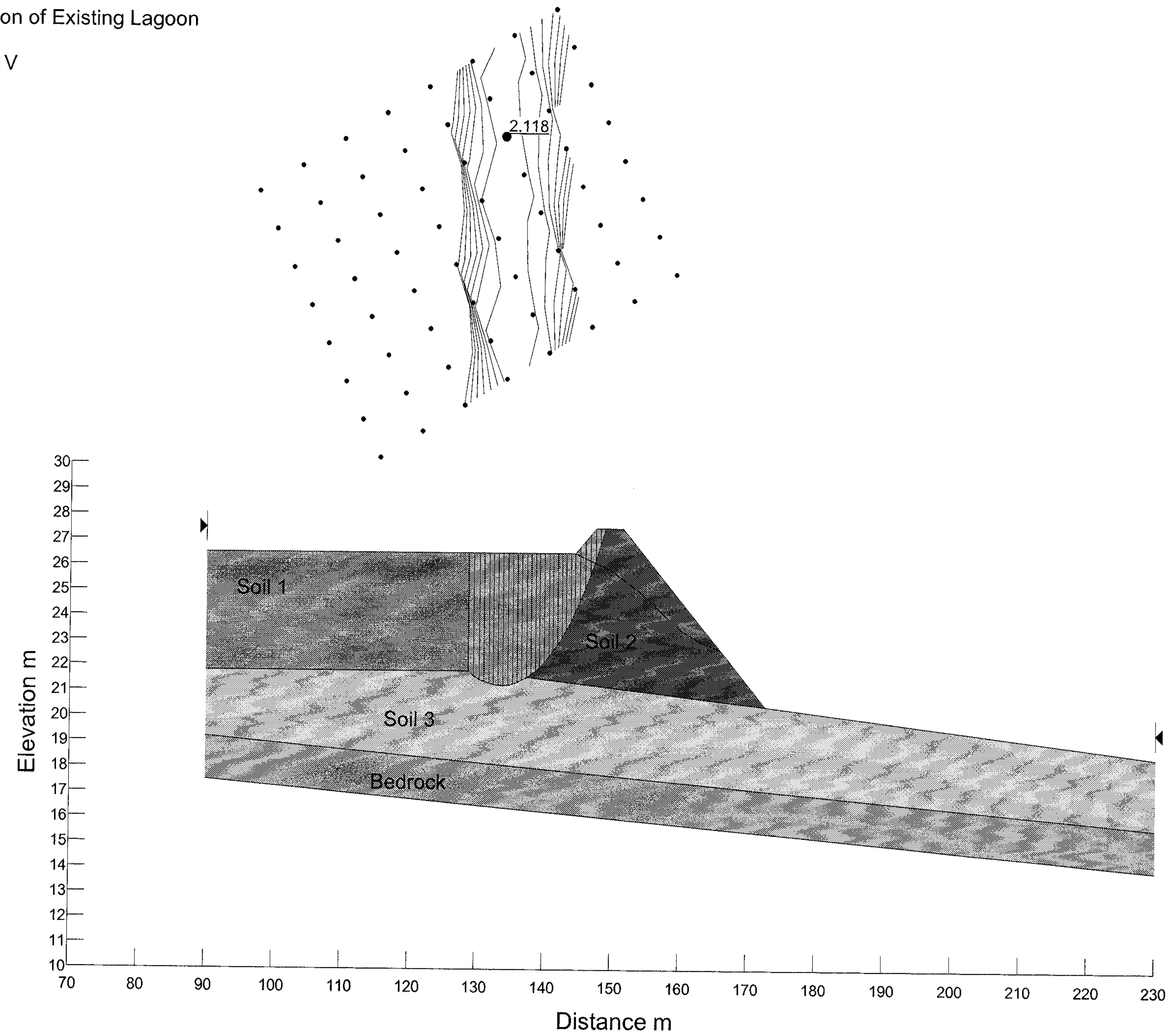
OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section A-A Inside Slope @ 3.0 H to 1V
Fully Submerged Condition

Figure 24

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30



OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section A-A Inside Slope @ 3.0 H to 1V
Fully Submerged Condition
Seismic = 0.03

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

Figure 25

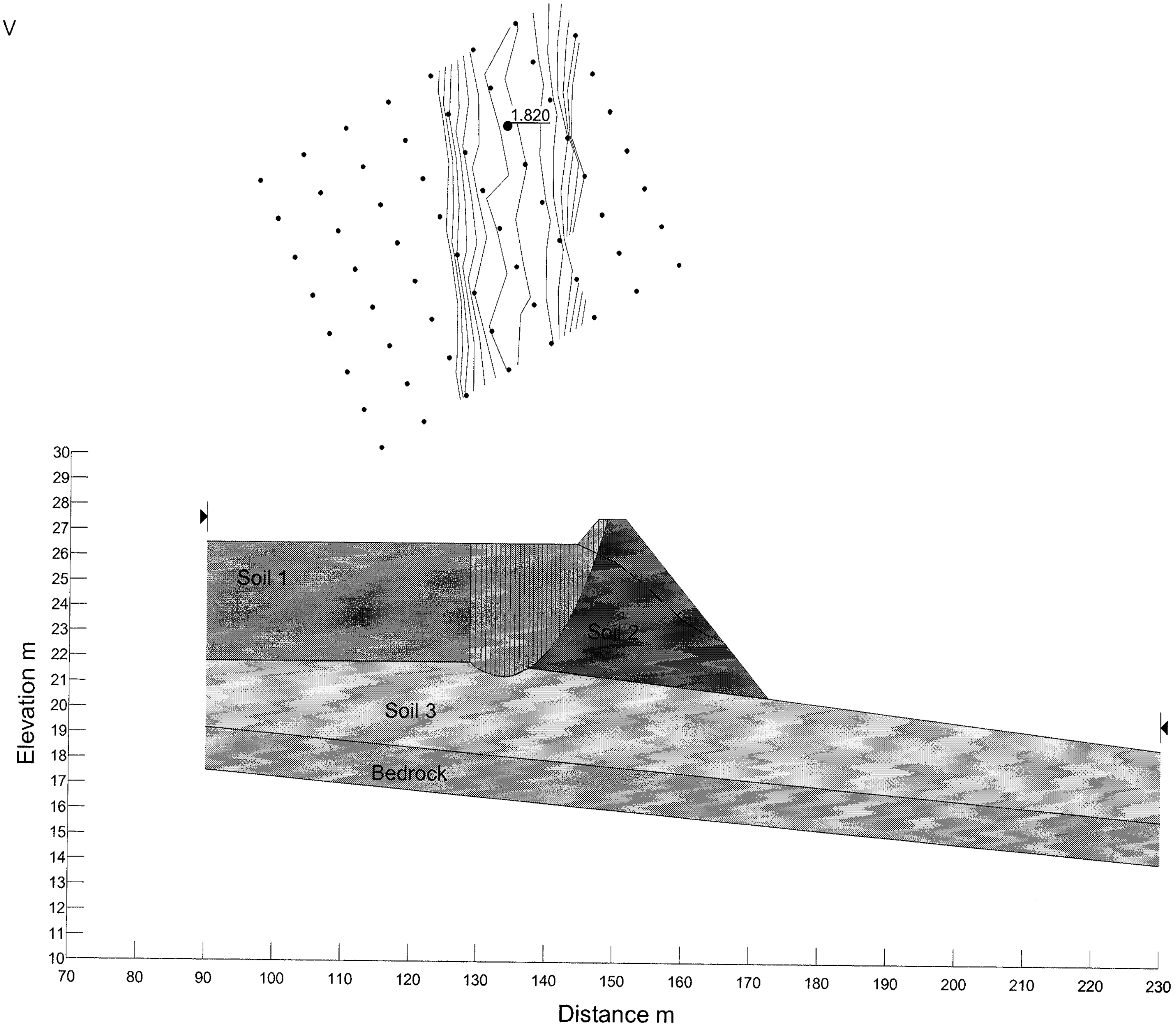


Figure 26

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section A-A Outer Slope @ 3.0 H to 1V
Steady State Condition

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

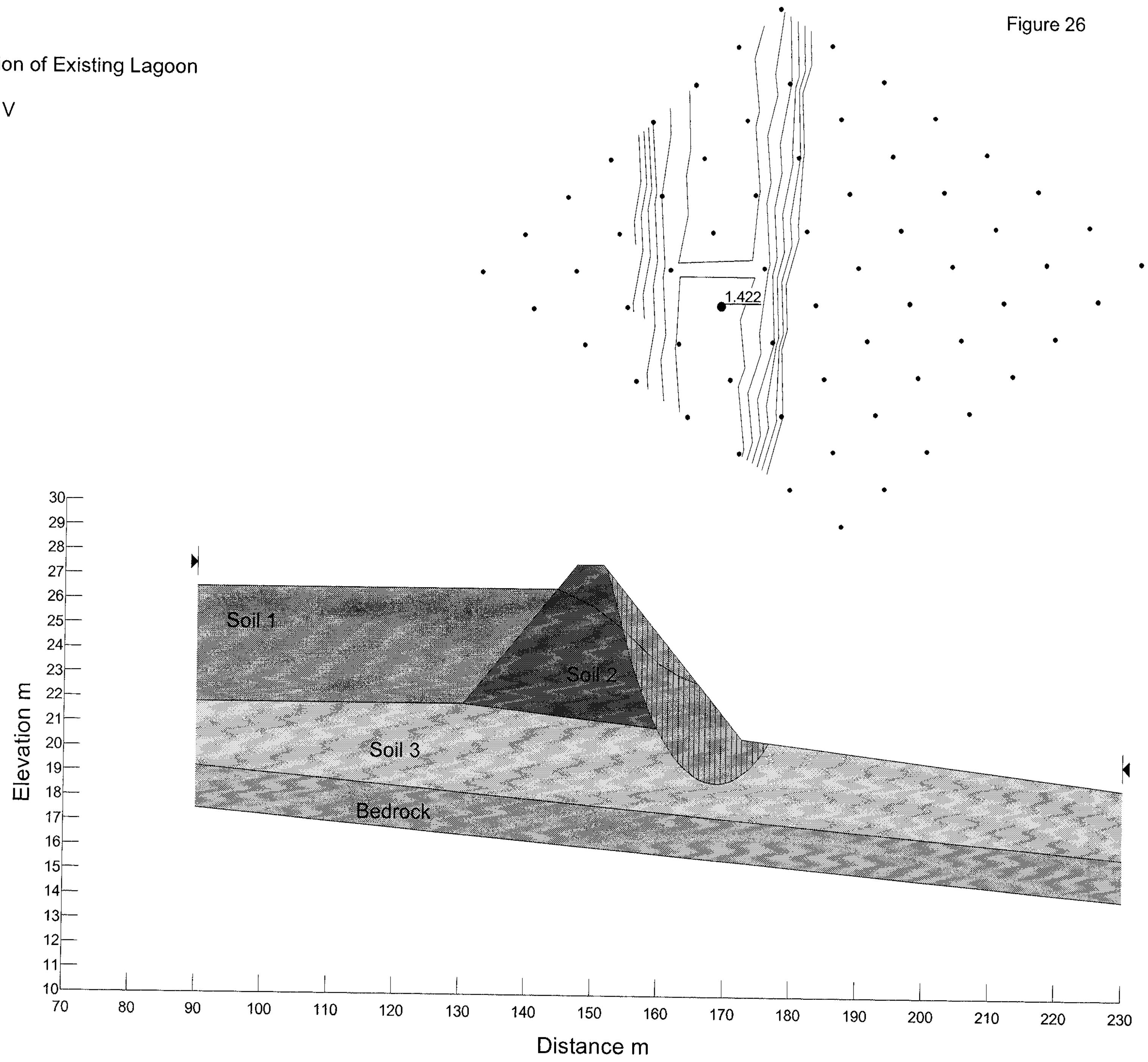


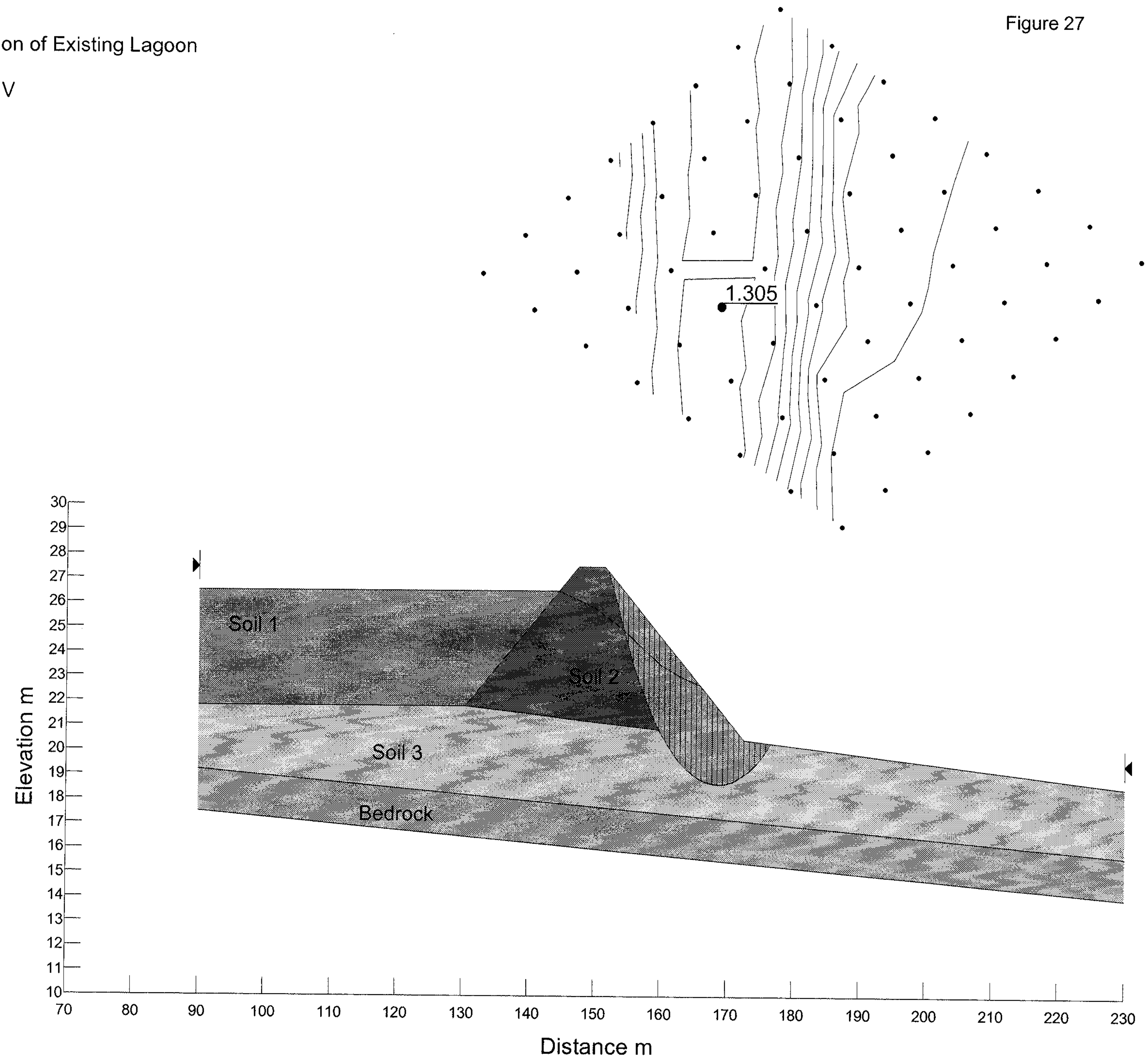
Figure 27

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section A-A Outer Slope @ 3.0 H to 1V
Steady State Seepage Condition
Seismic = 0.03

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30



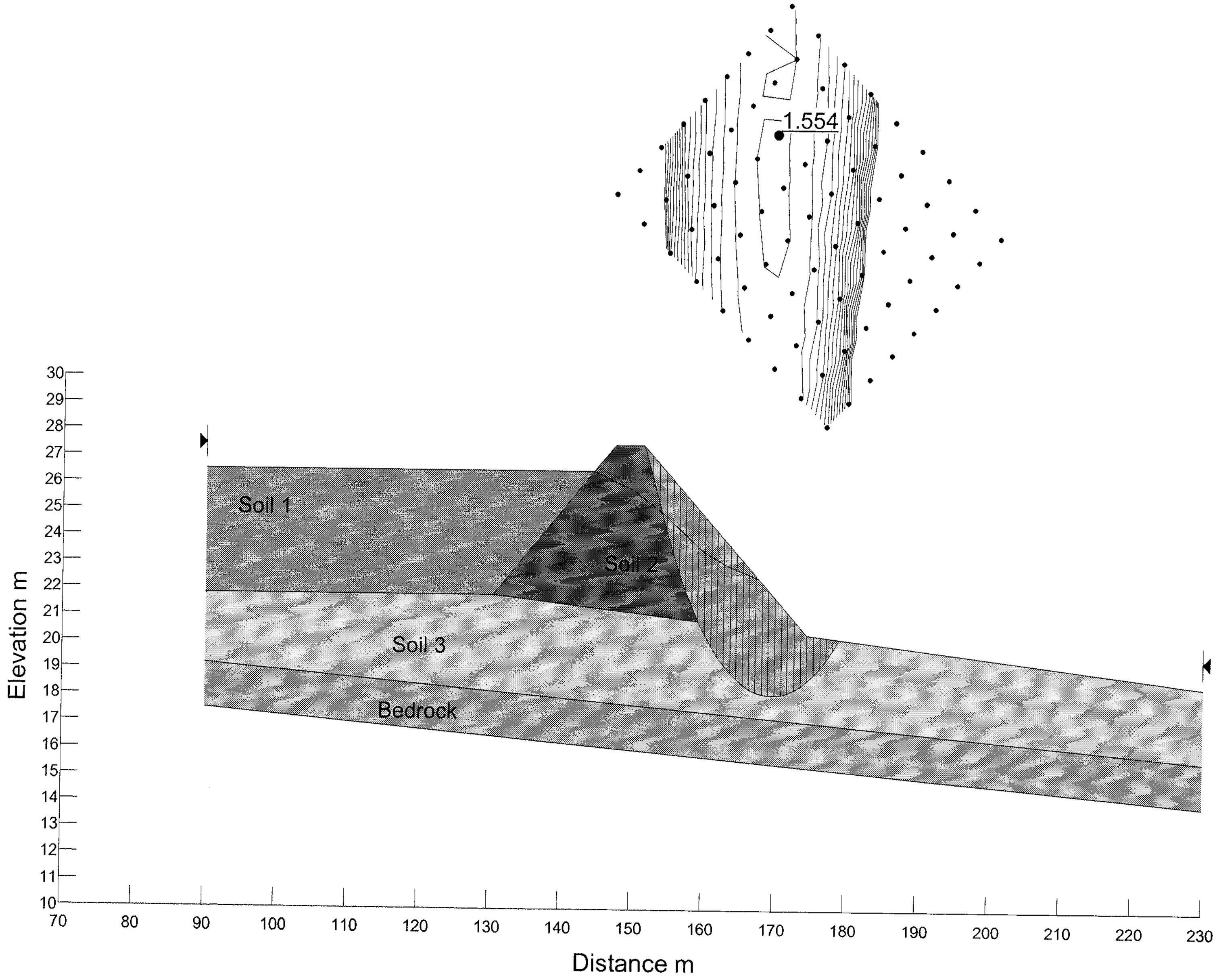
OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section A-A Outer Slope @ 3.25 H to 1V
Steady State Seepage Condition

Figure 28

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30



OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section A-A Outer Slope @ 3.25 H to 1V
Steady State Seepage Condition
Seismic = 0.03

Figure 29

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

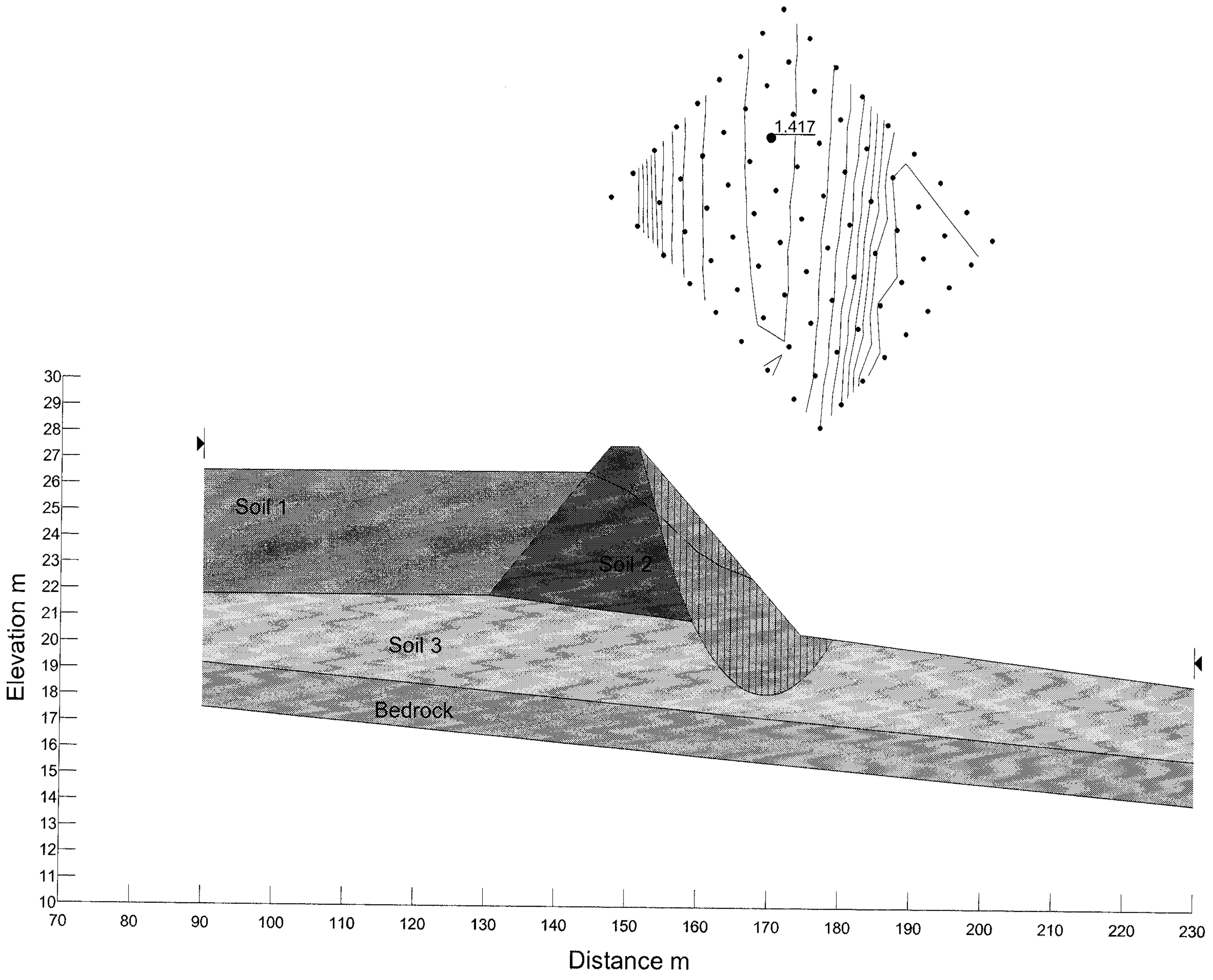
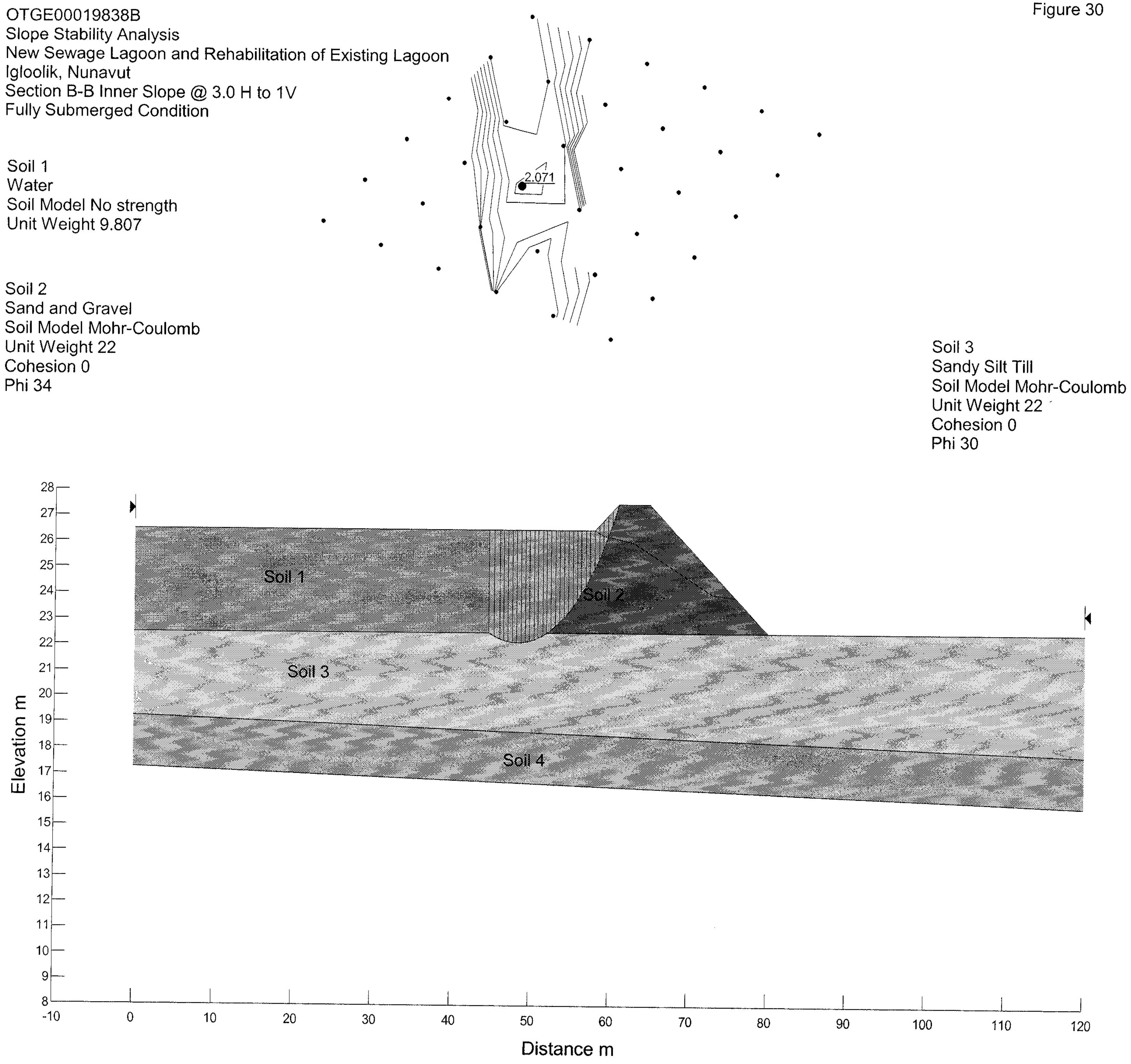


Figure 30

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section B-B Inner Slope @ 3.0 H to 1V
Fully Submerged Condition



Soil 1
Water
Soil Model No strength
Unit Weight 9.807

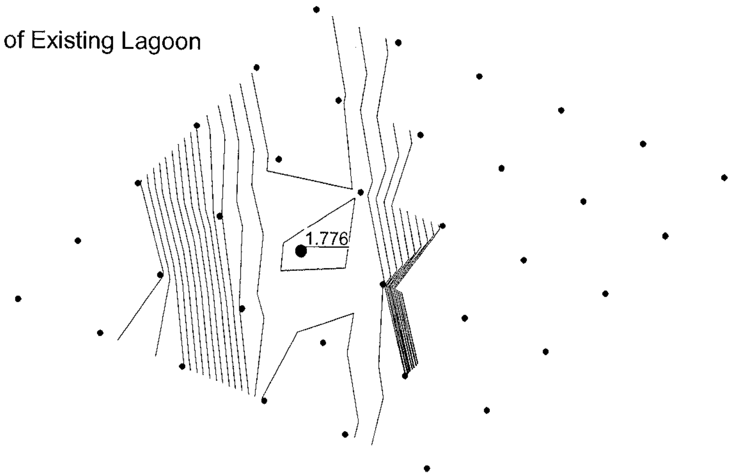
Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section B-B Inside Slope @ 3.0 H to 1V
Fully Submerged Condition
Seismic=0.03

Figure 31

Soil 1
Water
Soil Model No strength
Unit Weight 9.807



Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

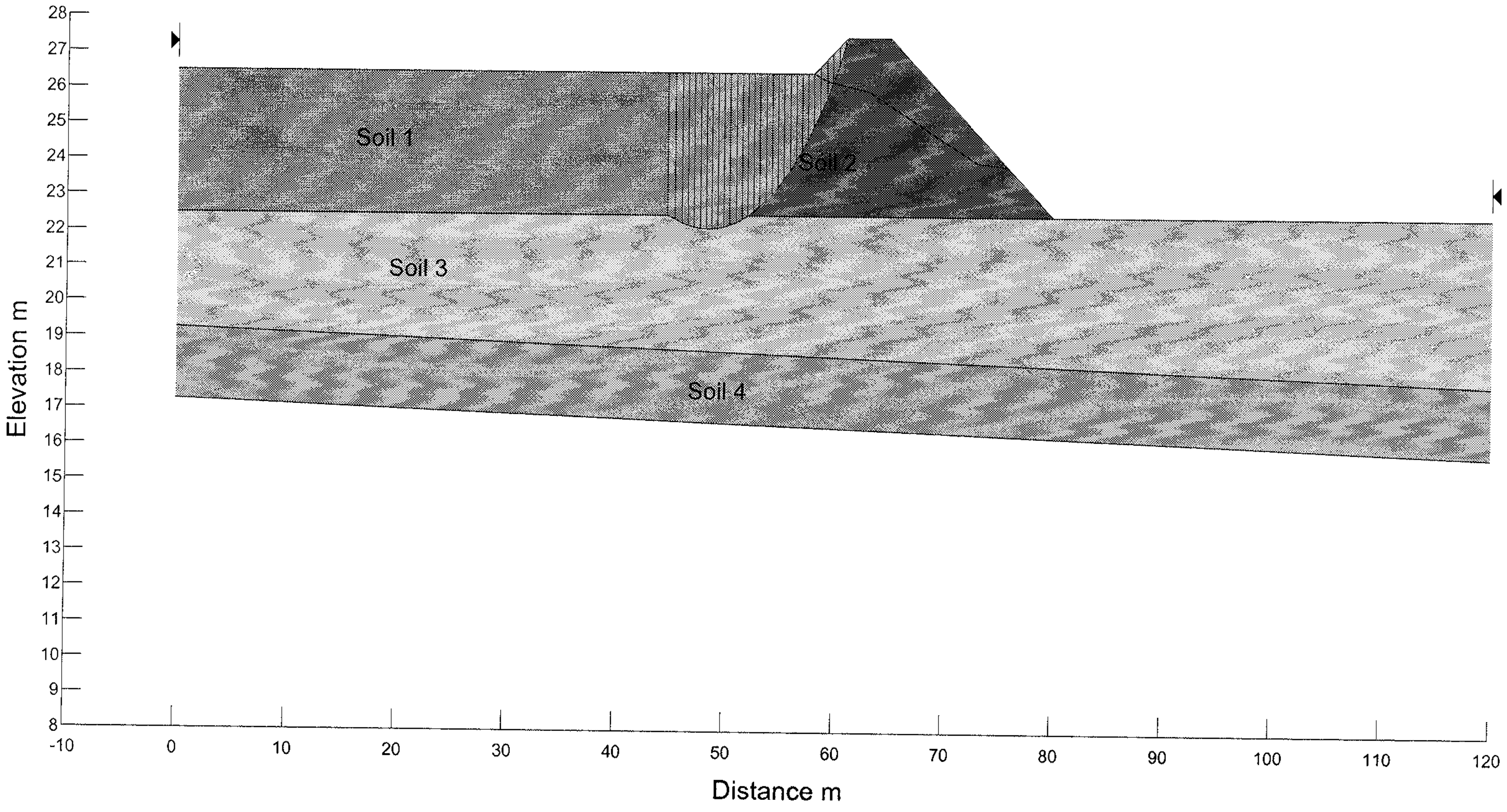
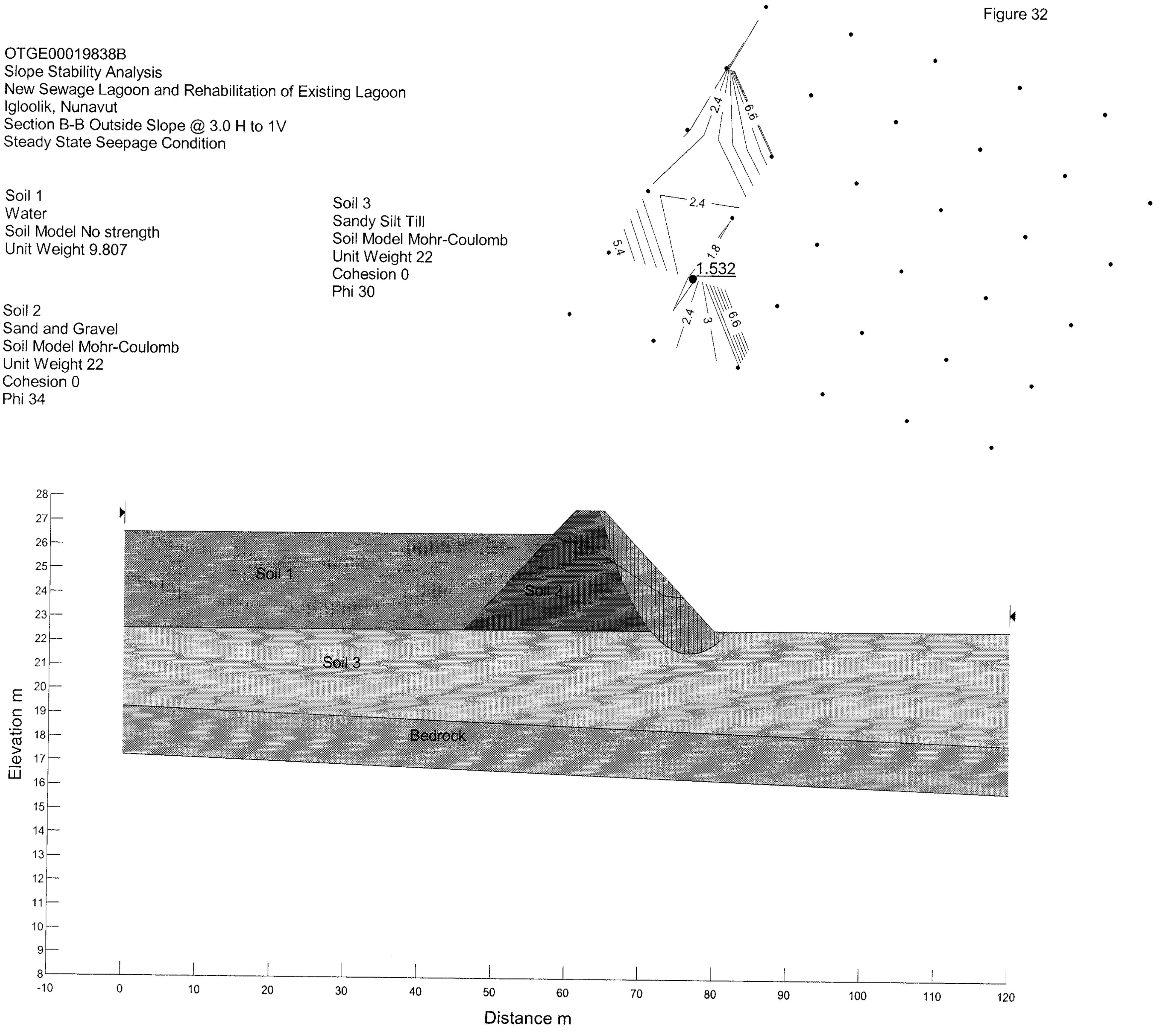


Figure 32



OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section B-B Outside Slope @ 3.0 H to 1V
Steady State Seepage Condition

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section B-B Outside Slope @ 3.0 H to 1V
Steady State Seepage Condition
Seismic=0.03

Figure 33

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

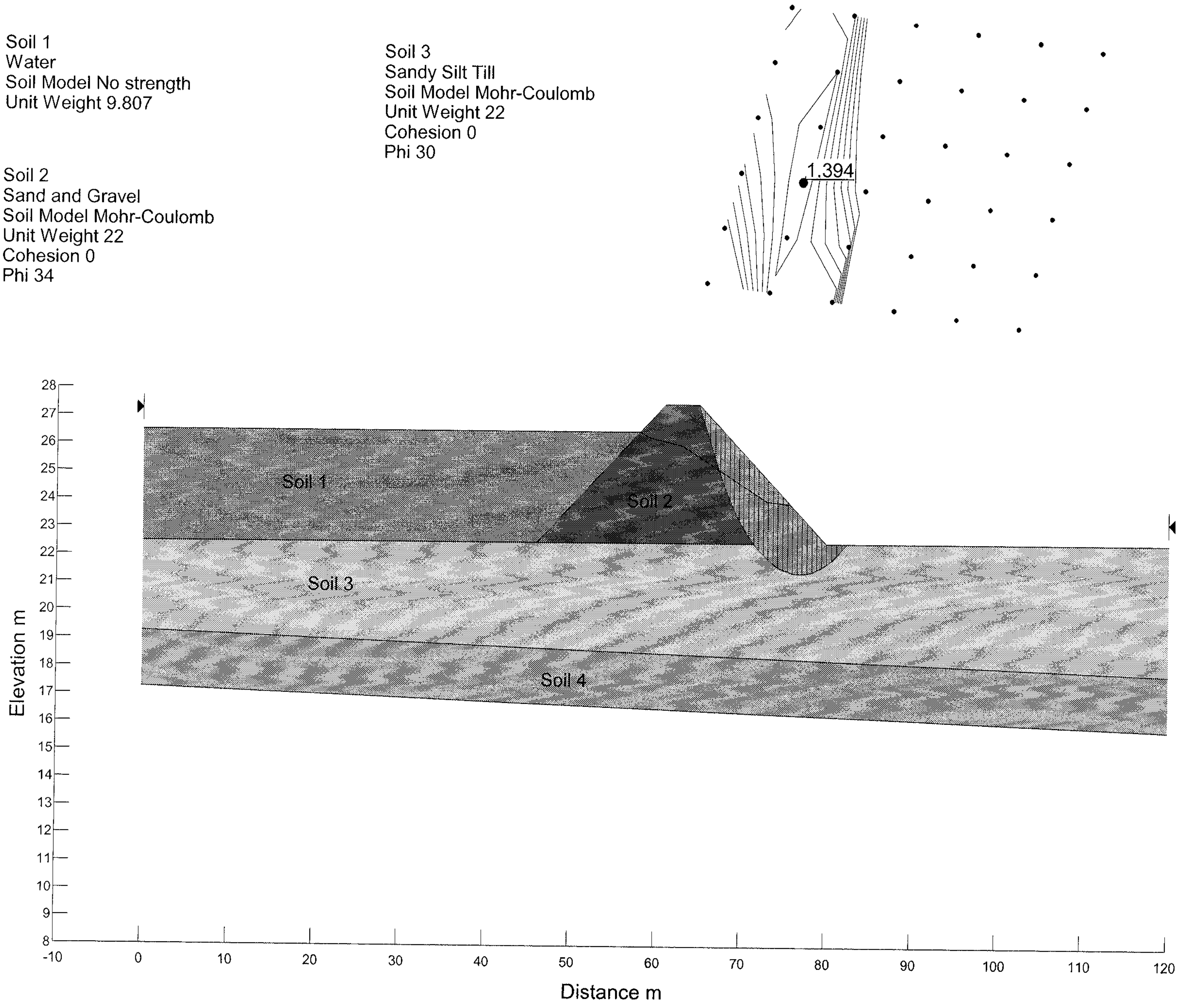


Figure 34

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section C-C Existing Inside Slope @1.7H:1V
Fully Submerged Condition

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Silty Sand
Soil Model Mohr-Coulomb
Unit Weight 20
Cohesion 0
Phi 27

Soil 4
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

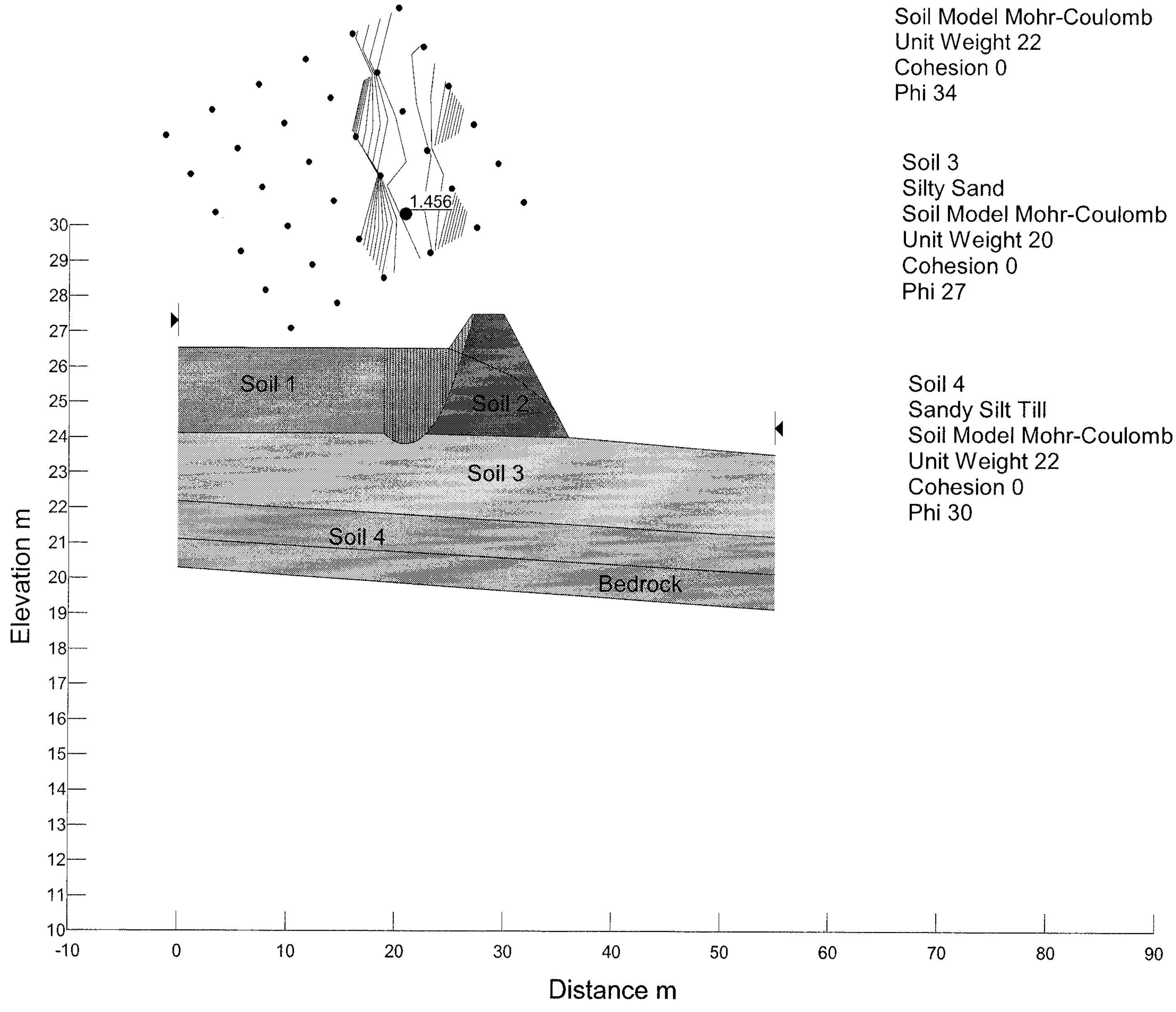
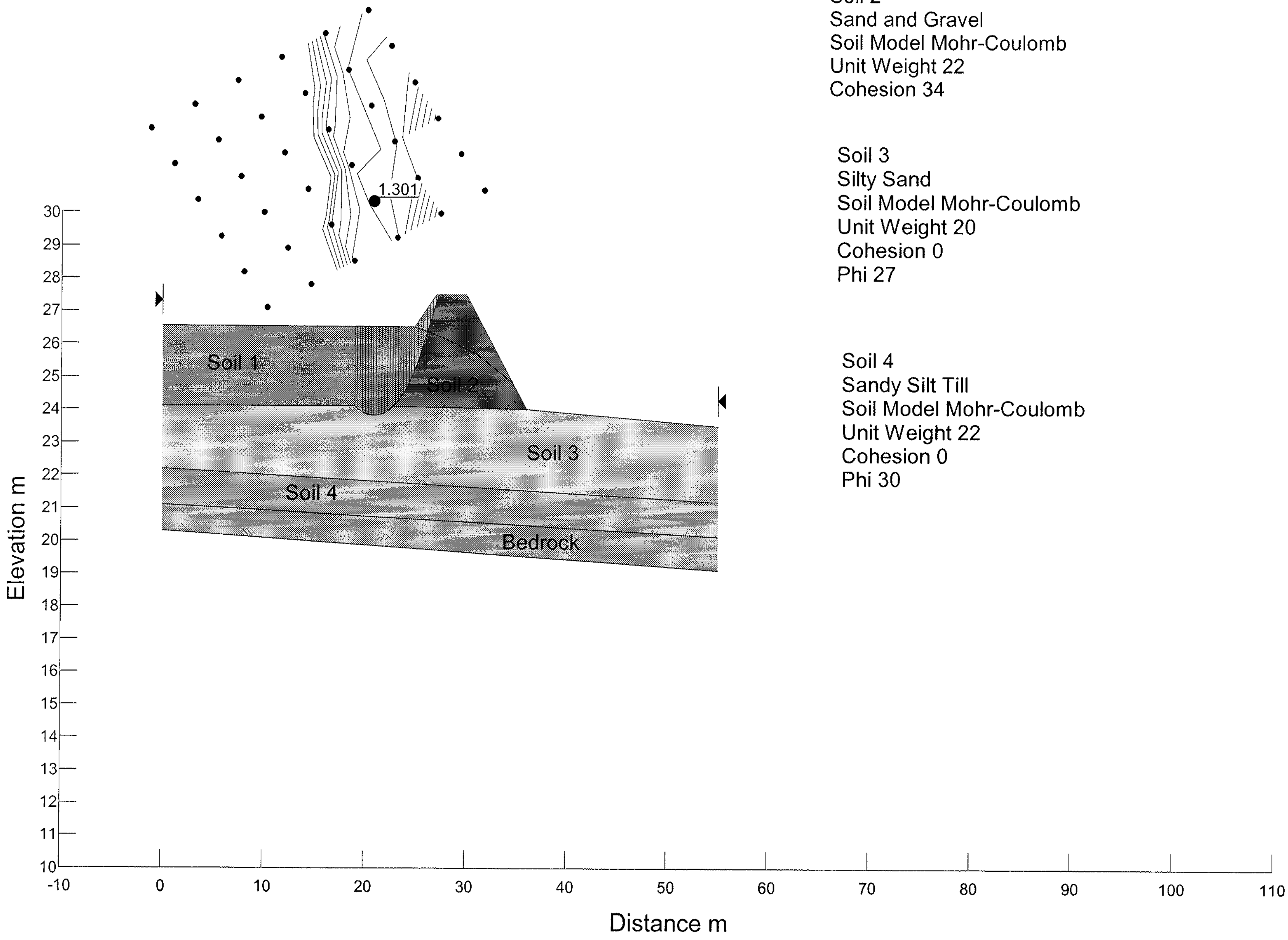


Figure 35

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section C-C Existing Inside Slope @1.7H:1V
Fully Submerged Condition
Seismic = 0.03



Soil 1
Water
Soil Model No strength
Unit Weight 9.807

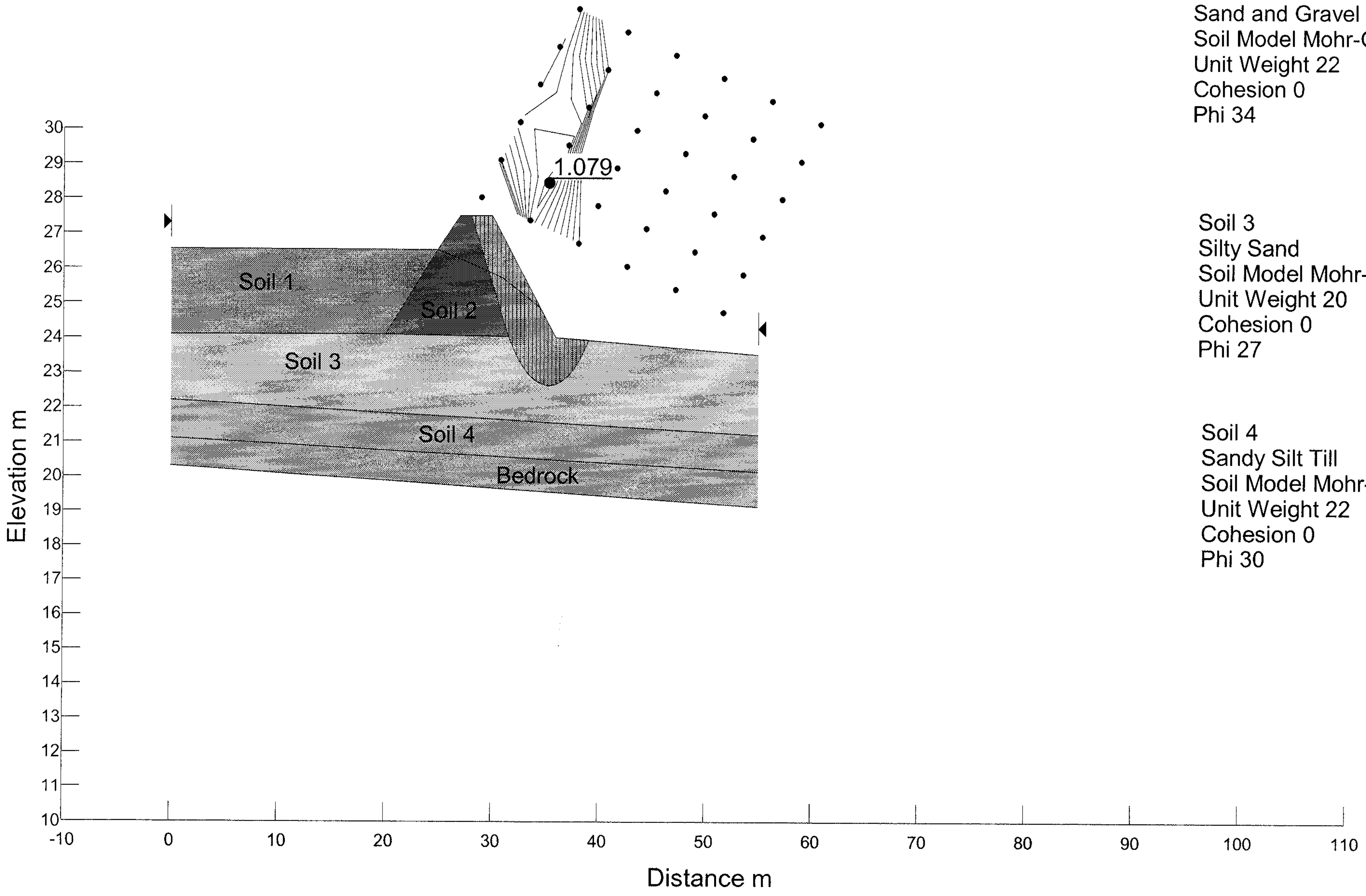
Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 34

Soil 3
Silty Sand
Soil Model Mohr-Coulomb
Unit Weight 20
Cohesion 0
Phi 27

Soil 4
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

Figure 36

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section C-C Existing Outside Slope @ 2H:1V
Steady State Seepage



Soil 1
Water
Soil Model No strength
Unit Weight 9.807

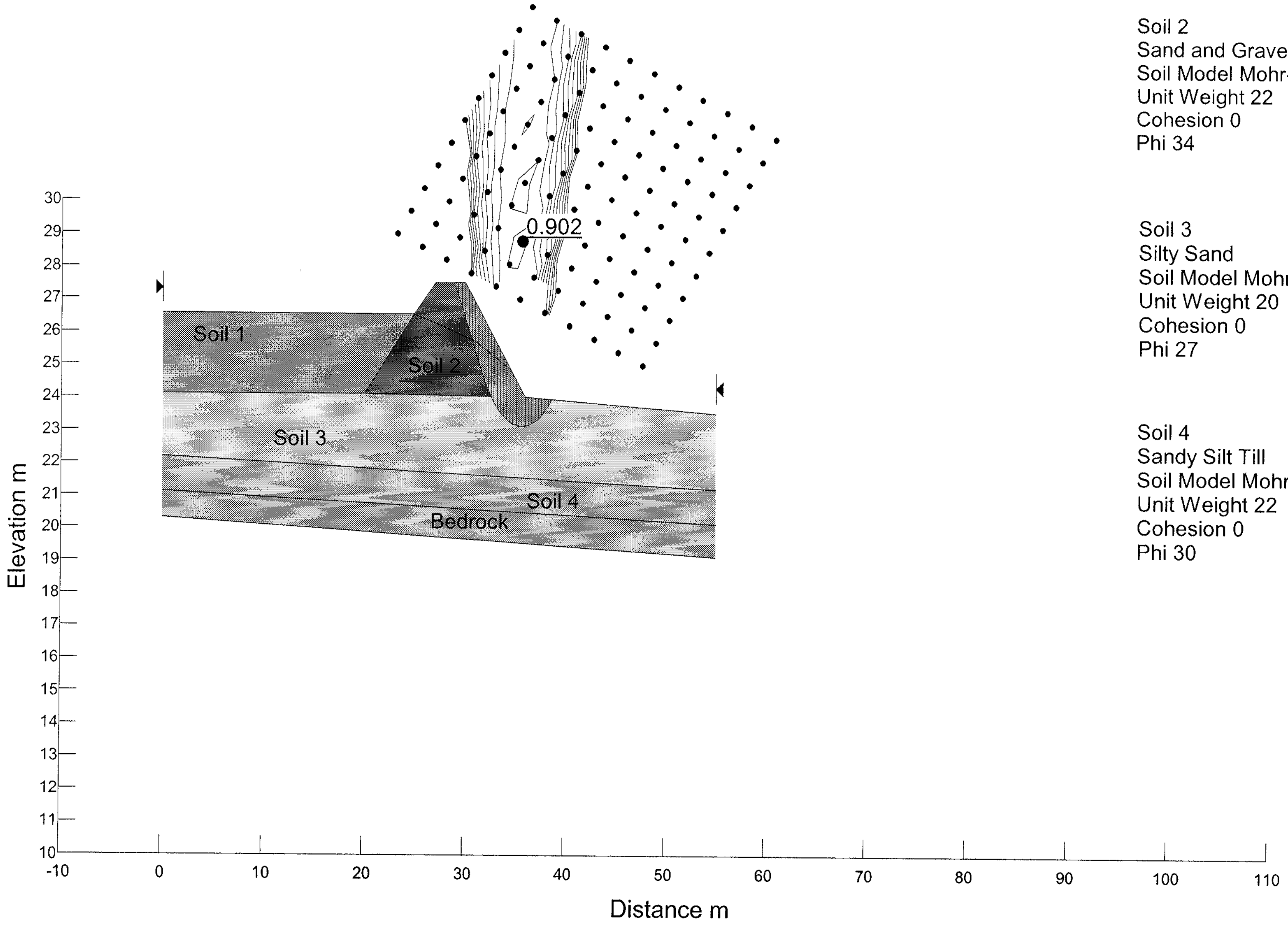
Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Silty Sand
Soil Model Mohr-Coulomb
Unit Weight 20
Cohesion 0
Phi 27

Soil 4
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section C-C Existing Outside Slope @ 2H:1V
Steady State Seepage
Seismic = 0.03

Figure 37



Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 3
Silty Sand
Soil Model Mohr-Coulomb
Unit Weight 20
Cohesion 0
Phi 27

Soil 4
Sandy Silt Till
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 30

Figure 38

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section D-D Existing Inside Slope @ 1.16H:1V
Fully Submerged Condition

Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Top Soil
Soil Model Mohr-Coulomb
Unit Weight 20
Cohesion 0
Phi 27

Soil 3
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 4
Sandy Silt
Soil Model Mohr-Coulomb
Unit Weight 18
Cohesion 0
Phi 27

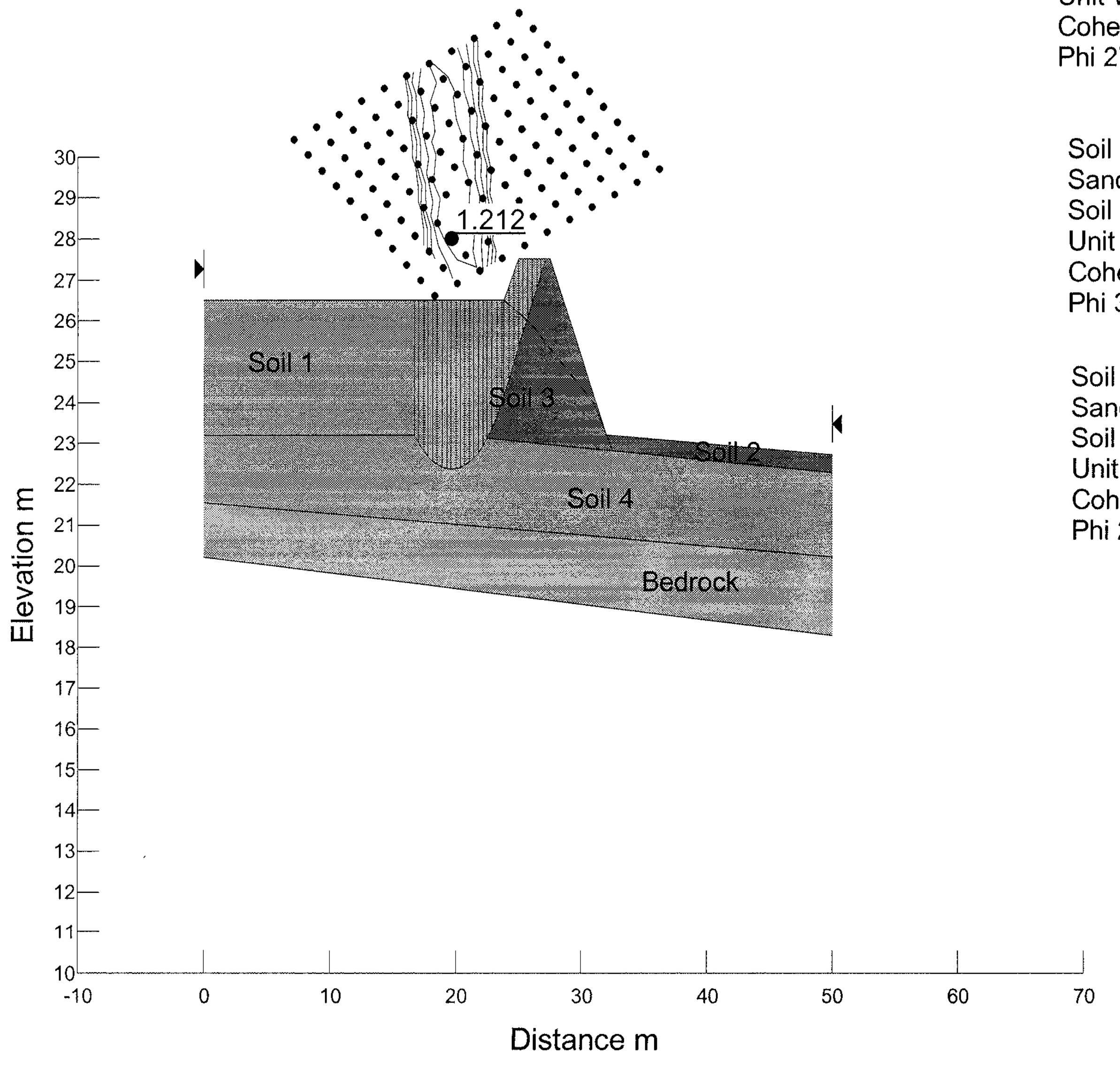
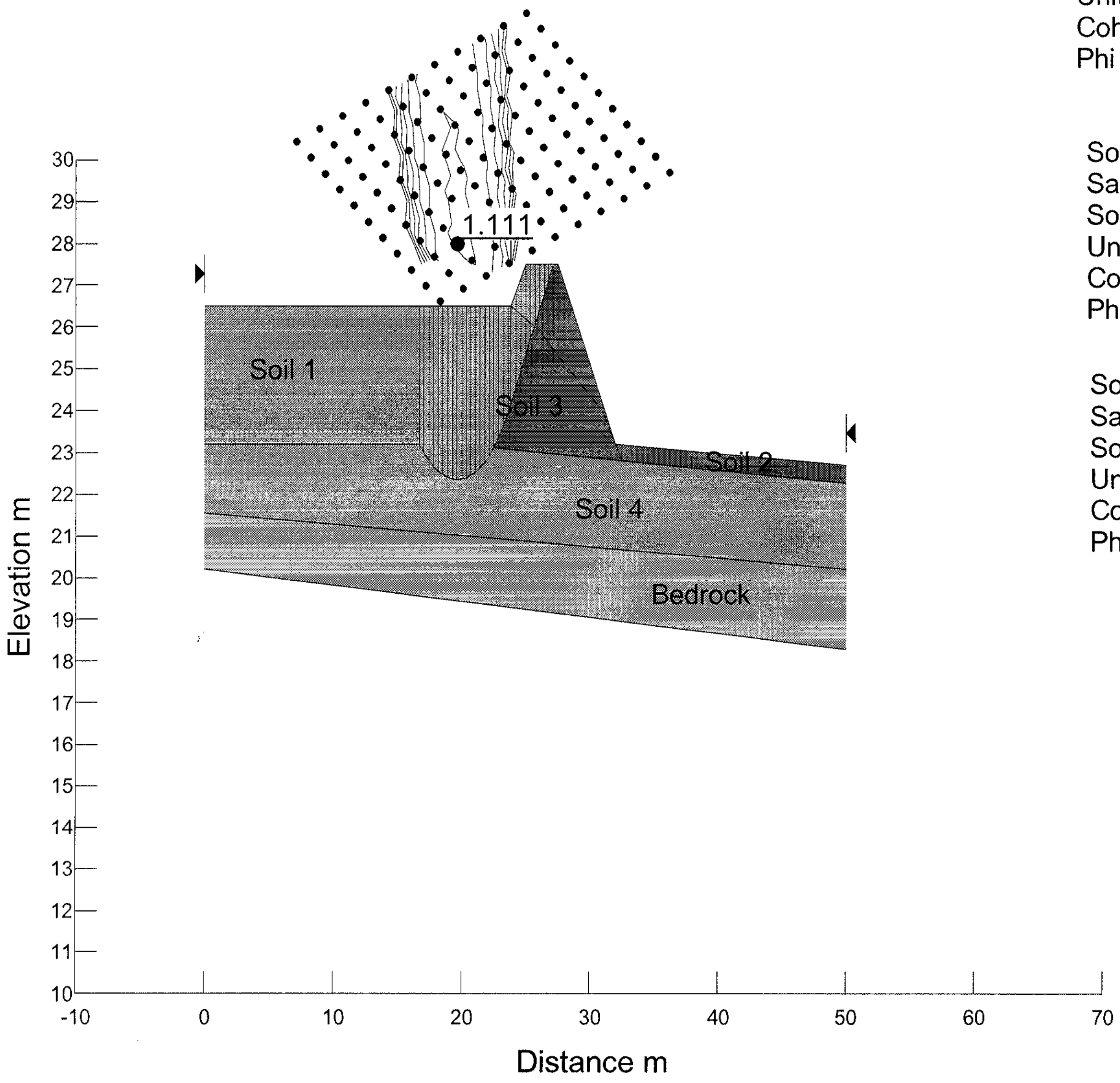


Figure 39

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section D-D Existing Inside Slope @ 1.16H:1V
Fully Submerged Condition
Seismic = 0.03



Soil 1
Water
Soil Model No strength
Unit Weight 9.807

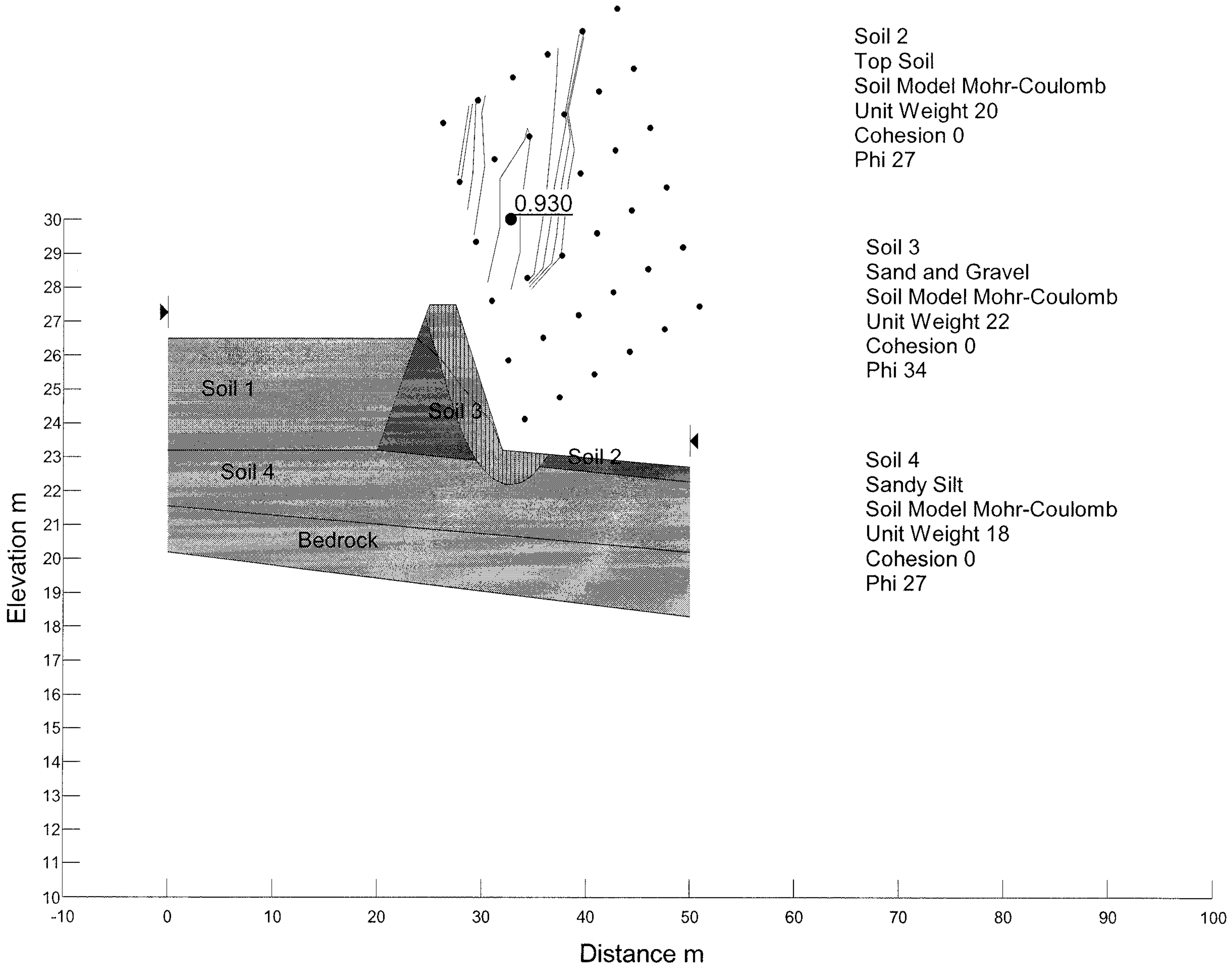
Soil 2
Top Soil
Soil Model Mohr-Coulomb
Unit Weight 20
Cohesion 0
Phi 27

Soil 3
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 4
Sandy Silt
Soil Model Mohr-Coulomb
Unit Weight 18
Cohesion 0
Phi 27

Figure 40

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section D-D Existing Outside Slope @ 1.06H:1V
Steady State Seepage Condition



Soil 1
Water
Soil Model No strength
Unit Weight 9.807

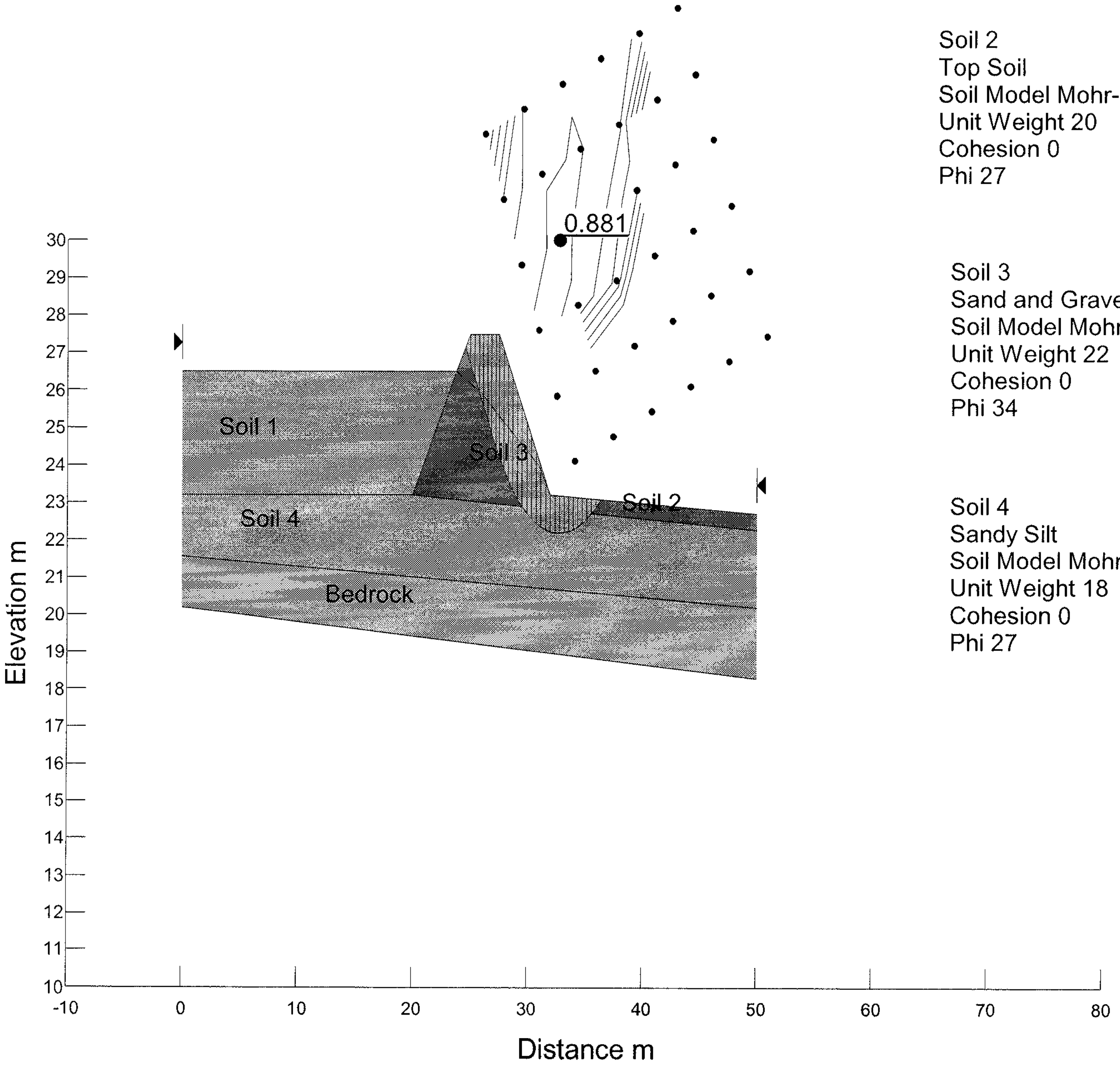
Soil 2
Top Soil
Soil Model Mohr-Coulomb
Unit Weight 20
Cohesion 0
Phi 27

Soil 3
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 4
Sandy Silt
Soil Model Mohr-Coulomb
Unit Weight 18
Cohesion 0
Phi 27

Figure 41

OTGE00019838B
Slope Stability Analysis
New Sewage Lagoon and Rehabilitation of Existing Lagoon
Igloolik, Nunavut
Section D-D Existing Outside Slope @ 1.06H:1V
Steady State Seepage Condition
Seismic = 0.03



Soil 1
Water
Soil Model No strength
Unit Weight 9.807

Soil 2
Top Soil
Soil Model Mohr-Coulomb
Unit Weight 20
Cohesion 0
Phi 27

Soil 3
Sand and Gravel
Soil Model Mohr-Coulomb
Unit Weight 22
Cohesion 0
Phi 34

Soil 4
Sandy Silt
Soil Model Mohr-Coulomb
Unit Weight 18
Cohesion 0
Phi 27