Government of Nunavut

Geotechnical Investigation

Type of Document
Final

Project Name
Sewage Lagoon Upgrades
Repulse Bay, Nunavut

Project Number
OTT-00207086-A0

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Date Submitted
April 2, 2013

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Executive Summary

A geotechnical investigation was undertaken at the site of the proposed sewage lagoon to be located in the Hamlet of Repulse Bay, Nunavut. This work was authorized by the Government of Nunavut on April 3rd, 2012

It is proposed to construct a sewage lagoon measuring approximately 210 m by 60 m. The east embankment of the lagoon will be formed by a bedrock ridge whereas berms up to 4.5 m in height would be constructed along the other three sides with locally available sandy silt/silty sand and gravel material. It is proposed to render the berms impervious by installation of a synthetic liner that will be sealed in the permafrost. The base of the lagoon will not be lined.

The investigation consisted of drilling seven boreholes to 1.2 m to 6.1 m depth using an electrical drill (Hilti drill). Standard penetration tests were performed in the unfrozen overburden and soil samples obtained by split barrel samples. The frozen overburden and the underlying bedrock was core drilled using Nx-size core barrel. Thermisters were installed in Borehole Nos. 1 and 3 to monitor the ground temperature.

The investigation revealed that the overburden soils at the site comprise of sandy silt to silty sand, which extends to bedrock in some of the boreholes, while some of the boreholes were terminated in this stratum. The bedrock at the site is granite. It slopes down towards the west and south.

The berms are to be constructed using locally available sand and gravel. The recommended gradation for the berm fill is given on Table No. III. The fill should be placed in 300 mm lift thickness and each lift compacted to 95 percent Standard Proctor maximum dry density. All the tundra should be stripped from the site prior to placement of fill. The berms may be rendered impervious by lining them with a synthetic liner that is anchored into the permafrost. Alternatively, the berms may be maintained in a constantly frozen state by installation of thermosyphons. If the entire lagoon were to be made impervious, a synthetic liner and underfloor drains and heat tracers would be required.

A stability of slope analysis was performed in order to determine the stable berm slopes. For the purpose of the analysis, it was assumed that the overburden at the site is not frozen and that locally available sandy silt/silty sand with gravel material will be used to construct the berms. The stability of the slope analysis was performed using the Geoslope computer program and Morgenstern-Price method. Three cross sections of the east berm were analysed since this berm will be the highest and is also located close to the bottom of the valley where a drainage ditch is located. It is considered that the design slope computed for the west berm will also be adequate for the north and south berms. The analysis was performed for static as well as seismic loading. It revealed that the required factors of safety of 1.5 in the case of static loading and 1.1 m the case of seismic loading will be satisfied with upstream slopes of 3.0H:1V and downstream slopes of 4H:1V for the reservoir. A slope stability analysis for the rapid drawdown condition was also undertaken using Seep W and Geoslope computer programs. The analysis revealed that the berm slopes will be stable (factor of safety of 1.1) provided that the lagoon is drained in 10 or more days.

The depth to bedrock under the west berm could not be established due to equipment and time limitation. However, based on the information obtained during the investigation, it was estimated to be present at a depth of 5 m to 8 m approximately below the proposed inward of the lagoon, which will be Elevation 22.0 m.

The settlements of the lagoon and the berms will result due to degradation of the permafrost under the lagoon and the berms. The depth to which the permafrost will degrade would be determined from the geothermal analysis, which is issued under a separate cover. However, thaw settlements are not expected to have an adverse affect on the synthetic liner, which is to be used to seal the berms since this liner will be anchored into permafrost and will settle with the berms.

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

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1 Introduction

Exp Services Inc. (**exp**) completed a geotechnical investigation at the site of the proposed sewage lagoon in the Hamlet of Resolute Bay, Nunavut (Figure 1). This work was authorized by the Government of Nunavut on April 3, 2012.

It is proposed to construct a new sewage lagoon approximately 600 m east of the Community of Repulse Bay (Figure 2). The lagoon is to be located in an existing valley. A bedrock ridge located at the site will form the east berm of the lagoon. Berms would be constructed along the south, west and north sides to form the lagoon. The toe of the west berm will be located close to the bottom of the valley. It is understood that seepage of the effluent through the berms is to be prevented. However, it is not required to seal the bottom of the lagoon to make it impervious.

Exp terms of reference for the geotechnical investigation were as follows:

1) Establish geotechnical profile at the site of the proposed lagoon; and
2) Make recommendations regarding the design and construction of the new lagoon from a geotechnical perspective.

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 Procedure

2.1 Drilling and Soil Sampling

The fieldwork for the geotechnical investigation was undertaken between October 3 and October 11, 2012 with a Hilti drill rig. The fieldwork was supervised by a representative of **exp** on a full-time basis.

The fieldwork consisted of drilling seven boreholes to depths varying between 1.2 m and 6.1 m. The locations of the boreholes are shown on the Borehole Location Plan, Figure 3.

The boreholes were initially advanced in the active layer by performing continuous standard penetration tests and retrieving the soil samples. However, the boreholes could only be advanced by this method in unfrozen soil. The boreholes were then cased and advanced by core drilling techniques with the Hilti drill rig. Most of the boreholes were drilled using water as a flushing medium. 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 1 and 3 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 containers and identified. The boreholes were logged. Similarly, the rock core was placed in core boxes, identified and logged. On completion of drilling, all the soil samples and rock core were transported to the **exp** laboratory in the City of Ottawa.

The locations and elevations of the boreholes were established by representative of **exp**. The elevations of the boreholes were established from a contour plan available for the site, and therefore are considered to be approximate. These elevations refer to the geodetic datum.

All the soil samples and rock cores 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, on selected soil samples.

3 Site and Soil Description

The site of the proposed lagoon is located approximately 600 m east of the community of Repulse Bay, Nunavut. It is located in a valley. The valley floor is at Elevation 22.0 m approximately. The bedrock ridge on the east side of the valley is approximately 20 m high (Elevation 42 m) whereas on the west side, it is 17 m high (Elevation 37 m). The bottom of the valley is a wet swampy area with a drainage ditch running through it. The drainage ditch is understood to carry a substantial quantity of water during the spring melt.

Detailed descriptions of the geotechnical conditions encountered in the seven boreholes drilled at the site are given on the borehole logs, Figures 4 to 10 inclusive. The borehole logs and related information depict subsurface conditions only at the specific locations and times 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.

A review of the borehole logs indicates the following soil stratography.

3.1 Tundra

The site is covered with a thin veneer of tundra.

3.2 Silty Sand / Sandy Silt

The tundra is underlain by sandy silt/silty sand to 1.2 m to 4.4 m depth (Elevation 16.8 m to 23.9 m). The exception to this is Borehole No. 5 where bedrock was encountered from the existing groundsurface. Borehole Nos. 2 and 4 were terminated in this stratum. This stratum contains trace to some gravel and occasional cobbles and boulders.

The results of the six grain-size analyses performed on this stratum are given in Figures 11 to 16 inclusive. These figures indicate that this stratum comprises of 14 to 43 percent clay and silt, 24 to 54 percent sand and 10 to 62 percent gravel. Based on the grain-size analyses, the permeability of this stratum was estimated to vary from 4 x 10^{-8} to 6.4 x 10^{-7} m/sec (Table No. I).

Table No. I: Estimated Permeability of Overburden Soils

Borehole No.	Depth (m)	Soil Description	Estimated Permeability (m/sec)
1	0.6 – 1.2	Silt and sand, some gravel	3×10^{-7}
1	1.5 – 1.8	Sandy gravel, some silt	1.6×10^{-5}
3	0.6 – 1.3	Gravelly sandy silt	4×10^{-8}
4	3.1 – 3.3	Silt and Sand, trace gravel	9×10^{-8}
6	0 – 0.6	Silty gravelly sand	4.9×10^{-7}
6	0.6 – 1.2	Silty sand, some gravel	6.4×10^{-7}
7	1.5 – 1.7	Gravelly silt and sand	3.6×10^{-7}

3.3 Sandy Gravel

The silty sand/sandy silt in Borehole No. 1 is underlain by sandy gravel, which extends to 2.3 m depth (Elevation 23.1 m). This stratum comprises of 14 percent silt and clay, 24 percent sand and 62 percent gravel (Figure 17).

The permeability of this stratum was estimated to be 1.6×10^{-5} m/sec (Table No. 1).

3.4 Granite Bedrock

The sandy gravel in Borehole No. 1 and the sandy silt/silty sand in the other boreholes are underlain by granite bedrock to the entire depth investigated, 3.7 m to 6.1 m depth (Elevation 15.1 m to 21.1 m). A Total Core Recovery and Rock Quality Designation of 73 to 100 percent and 9 to 100 percent respectively was retrieved when core drilling the bedrock. On this basis, the bedrock quality may be described as very poor to excellent.

4 Ground Temperature

Thermisters were installed in Borehole Nos. 1 and 3 to 4.5 m depth and 6 m depth respectively at 1 m depth intervals. Ground temperature readings taken during the fieldwork are given on Table No. II.

Table No. II: Ground Temperature Readings

Borehole #	Thermister Depth (m)	Ground Temperature °C Date & Elapsed Time Since Installation			
		Oct. 9, 2012 6:30 p.m.	Oct. 9, 2012 9:00 a.m.	Oct. 11, 2012 10:00 a.m.	
1	0.5	0	-0.2	-0.1	
	1.5	-0.1	-0.1	-0.1	
	2.5	-0.2	-0.3	-0.4	
	3.5	-1.4	-1.9	-1.9	
	4.5	-1.9	-2.8	-2.8	
		Oct. 8, 2012 9:45 a.m..	Oct. 9, 2012 10:30 a.m.	Oct. 10, 2012 10:40 a.m.	Oct. 11, 2012
3	0	-1.0	-1.0	-1.4	-1.8
	1	0	0	0	0
	2	-0.1	-0.3	-1.8	-1.8
	3	-4.6	-4.9	-4.9	-5.2
	4	-5.9	-6.0	-6.2	-6.2
	5	-6.7	-7.0	-6.9	-6.9
	6	-7.2	-7.4	-7.4	-7.4

5 Discussion

The investigation has revealed that the geotechnical conditions at the site are suitable for construction of the proposed lagoon. The silt and sand to sandy gravel overburden soils are underlain by granite bedrock. The overburden soils are permeable. Also, the material available for construction of the berms is silts, sand and gravel, which are also permeable. It is therefore considered that it would be necessary to render the lagoon impervious. This may be achieved by one of the following three methods:

1) Installing synthetic liner in the berms and keying it into permafrost;
2) Maintaining the central core of the berms and the underlying natural soil in a constantly frozen state; and,
3) Fully lining the lagoon using a synthetic liner.

5.1 Synthetic Liner in Berms

The berms of the lagoon to be constructed with granular materials may be made impervious by installing a liner in the berms and anchoring the liner into the permafrost. It is noted that the permafrost under the lagoon will be subject to degradation. Therefore, a geothermal analysis of the site should be performed to assess the degradation of the permafrost that may result over the life expectancy of the lagoon. The liner should be anchored at least 1 m into the permafrost below the depth computed to which the permafrost may degrade over the life of the structure, or into bedrock that is shown to be impermeable. The liner may consist of high-density polyethylene (HDPE) or equivalent. It should be installed in a narrow trench to the design depth and the trench backfilled with well compacted on site soils. The upper end of the liner (at the crest of the berm) should be buried in an approximately 0.6 m deep trench, which is also backfilled with well-compacted on site soils.

Depending on the results of the geothermal analysis, if it becomes evident that it would be difficult to install the liner to the required depth, the soil beneath the berm may be maintained in a permanently frozen state by installation of thermosyphons. This will enable the liner to be installed approximately 1 m below the base of the lagoon.

5.2 Frozen Berms

The alternative to lining the berms to render them impermeable will be to maintain the central core of the berms and the underlying soil in a permanently frozen state so as to impede migration of effluent. This would be accomplished by constructing a water (ice) saturated containment structure with local materials. The constantly frozen soil will act as an impervious barrier. A geothermal analysis would be required for this case to assess if the construction and operation of a lagoon holding wastewater through all or part of the year would induce a talik (unfrozen zone) under the lagoon and if long-term climate changes would cause thawing through the containment structures. If necessary, to mitigate the effects of climate warming and talik development, the geothermal modeling could also assess the utility of thermal mitigation schemes such as rigid (board) insulation or thermosyphons. The geothermal modeling could be used to determine the thermosyphon spacing, thermosyphon radiator area, etc.

The geothermal modeling could also be used to assess the value of thermal mitigation for post construction rehabilitation should it be found that an frozen core containment structure might experience undesirable thawing at some point in the future during operations, for example after 10 or 15 years of operation.

While the geothermal modeling is useful in assessing the technical suitability of thermosyphon use and for determining general thermosyphon configurations, it should be noted that thermosyphon design is a proprietary activity by the manufacturer. A qualified thermosphyon manufacturer should be retained to provide site-specific engineering design.

5.3 Fully Lined Lagoon

The proposed lagoon may be constructed as a fully lined lagoon to prevent seepage out of the lagoon. However, a fully lined lagoon will be subject to uplift hydrostatic pressure since the site is located in a valley and likely subject to artesian pressure. Groundwater may be confined in the seasonal talik between impermeable surface frost and impermeable permafrost so that down slope drainage creates artesian pressure. The thaw bulb below the lagoon intersects the talik, creating a natural relief point. As a result, the lining of a fully lined lagoon may be subject to uplift hydrostatic pressure. This could result in the liner lifting up when the lagoon is empty. It is therefore considered that installation of subsurface drains below the liner would be required, leading to a sump from which water is pumped out. The drains would have to be prevented from freezing by installation of heat tracers. For these reasons, this option is expected to be expensive.

6 Construction Materials

6.1 Sand & Gravel for Construction of Berms

It is understood that the berms are to be constructed with locally available sand and gravel. It is considered that it would be necessary to grade these materials to exclude any cobbles and boulders and to obtain a well-graded material that would be easy to compact.

The following gradation is recommended for the sand and gravel fill to be used for construction of the berms.

Table No. III: Gradation Requirements of Engineered Fill

Sieve Size	Percentage Passing
100 mm	100
25 mm	50 – 100
4.75 m	20 – 55
1.18 mm	10 – 40
300 µm	5 – 22
75 µm	0 - 10

Prior to placement of fill for construction of the berms, all the tundra / topsoil should be stripped from the site. The entire surface should be proof rolled. Sand and gravel fill meeting the gradation requirements of Table No. III should be placed in 300 mm lift thickness and each lift compacted to at least 95 percent of Standard Proctor maximum dry density. The placement and compaction of the fill should b supervised on a full-time basis by a representative of this office. In-place density tests should be performed on each lift to ensure that the specified degree of compaction is being achieved.

6.2 Synthetic Liners

Synthetic liners offer advantages to provide primary containment in cold regions. They are useful in locations where fine-grained soils are not available to construct a natural impermeable liner and containment structure. They are also insensitive to climate warming and will be effective in both frozen and unfrozen conditions. They have good performance where the ground is stable and not subject to subsidence due to thawing of permafrost. Most liner materials require burial for several reasons including ultraviolet light protection, traffic protection and ice run-up or gouging protection.

One important restriction on the use of synthetic liners is that they have limited strain capacity and if the lagoon construction and operation induces thaw settlement of the ground to melting of ice-rich permafrost at depth, then the liners may strain to the point of rupture; loss of containment could then occur.

It is noted that a number of liners have been used in the past in permafrost regions to make sewage lagoons constructed with granular materials impervious. These materials include polyvinylchloride (PVC), reinforced polyethylene (RPE), polypropylene (PP) and synthetic clay liners.

RPE liners are normally preferred for lining sewage lagoons as they can withstand very low temperatures, have high tear strength and are highly resistant to chemicals.

7 Slope Stability Analysis

It has been recommended that the berms should be made impervious either by installation of a synthetic liner, which is anchored into permafrost, or by maintaining the central core of the berms and the underlying soil in a permanently frozen state. In either case, the inside and outside slopes of the berms would be subject to seasonal freezing and thawing. Also, although the permeability of the frozen soil is very low, it is feasible that a steady-state seepage condition may develop in the berms over a long period of time. Steady-state seepage condition may also develop in the berms if the liner is damaged. Therefore, the slope stability analysis to determine the berm slope was based on unfrozen soils.

The stability of slopes was analyzed using Slope W, Geoslope Office, version 7.2 computer program using Morgenstern-Price Method. Three cross-sections of the west berm (Sections AA, BB and CC) were analyzed. The stability of this berm is more critical compared to the other berms since this berm is the highest as the groundsurface slopes down to the west. Also, its toe will be located close to a drainage ditch in which water flows year-round. North and south berms were not analysed as the heights of these berms are less than that of the west berms, and it was considered that the design slopes computed for the west berm would also be satisfactory for the north and south berms. The berms were analysed using effective stress analysis with static loading and total stress analysis with seismic loading. Total stress analysis for static loading conditions was not undertaken since the factors of safety would be the same as for effective stress analysis.

The following assumptions were made for slope stability analysis:

1.) The crest of the berms will be at Elevation 26.5 m whereas the base of the lagoon will be at Elevation 22.0 m. The crest width of the berms will be 4 m. The upstream and downstream slopes of the berms were analysed for slopes of 3H:1V and 4H:1V respectively.

2.) The berms will be constructed with material which is similar to the one encountered in the boreholes, i.e. sandy silt to silt-sand with varying gravel content.

3.) The soils below the berms are unfrozen to the bedrock surface.

4.) The engineering properties of the various soil strata were assumed as given on Table No. IV based on previous experience in the region and literature research.

Table No. IV: Engineering Properties of Soils Used in Slope Stability Analysis

Soil Type	Unit Weight (kN/m3)	Effective Cohesion c' (kPa)	Effective Angle of Internal Friction ϕ (degrees)
Sandy silt/silty sand with gravel fill	20	0	34
Sandy Silt//silty sand with gravel	21	0	33
Bedrock	26		--

5.) The water level in the lagoon will be maintained at Elevation 25.5 m or lower and that the berms will not be overtopped at any time.

The results of the slope stability analysis are given on Table V.

Table No. V: Computed Factors of Safety for Outside and Inside Berm Slopes

Slope Section	Slope Inclination	Slope Identification	Loading Condition	Computed Factor of Safety	Figure No.
AA	4H:1V	Downstream slope	Effective stress analysis	1.54	18
			Total stress analysis + seismic loading	1.26	19
	3H:1V	Upstream slope	Effective stress analysis	2.18	20
			Total stress analysis + seismic loading	1.83	21
BB	4H:1V	Downstream slope	Effective stress analysis	1.72	22
			Total stress analysis + seismic loading	1.38	23
	3H:1V	Upstream slope	Effective stress analysis	2.16	24
			Total stress analysis + seismic loading	1.83	25
CC	4H:1V	Downstream slope	Effective stress analysis	1.52	26
			Total stress analysis + seismic loading	1.23	27
	3H:1V	Upstream slope	Effective stress analysis	2.13	28
			Total stress analysis + seismic loading	1.82	29

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 is required for seismic loading conditions. A review of Table No. V indicates that a 3H:IV upstream slope and 4H:IV downstream slope would satisfy the requisite factors of safety. Therefore, those slopes may be used in the design of the berms.

It is noted that the computed slopes would be stable provided that they are not overtopped, and that the lagoon is drained in a minimum of 10 days (see subsequent section).

8 Rapid Drawdown Condition

The upstream slope of the west berm was also analysed for rapid drawdown condition. The analysis was based on Morgenstern-Price Method coupled with the Seep W computer program to simulate the rapid drawdown condition. The following permeability values were assumed for the analysis:

Silty sand and gravel fill............	1×10^{-7} m/sec
Silty sand and gravel	3×10^{-7} m/sec
Bedrock....................................	5×10^{-8} m/sec

The factor of safety of the slopes was computed assuming that the lagoon will be emptied in 10 days. The results (Table No. VI) indicate that the factor of safety of the slopes will temporarily decrease to 1.13 to 1.31. The typical acceptable factor of safety for rapid drawdown condition is 1.1. This factor of safety will be the minimum on emptying of the lagoon and is expected to increase thereafter as the excess pore pressure in the berms dissipates with time. Therefore, this factor of safety is considered acceptable for the temporary condition. The alternative to this would be to flatten the upstream lagoon slopes, which would result in a higher factor of safety against slope failure.

Table No. VI: Slope Stability Analysis of West Berm for Rapid Drawdown Condition

Slope Section	Slope Inclination	Loading Condition	Computed Factor of Safety	Figure No.
A-A	3H:1V	Rapid drawdown	1.31	30
B-B	3H:1V	Rapid drawdown	1.28	31
C-C	3H:1V	Rapid drawdown	1.13	32

9 Thaw Settlements

The construction of the sewage lagoon at the site will result in degradation of the permafrost under the lagoon and the berms. Degradation of the permafrost will result in settlements of the lagoon and the berms. The magnitude of thaw settlement is a function of the type of soil, its density and ice content, and the depth of thaw. A geothermal analysis is currently being undertaken by others and would establish the thaw depth underneath the berms and the reservoir subsequent to which thaw settlements would be computed. However, if the reservoir is not fully lined and the liner is to be installed in the berms and anchored into the permafrost, it is expected to settle with the berms and tensile forces will not develop in the liner. Consequently, rupture of the liner due to thaw settlements is not a concern in this case. Some settlements of the berms would result and would require occasional topping up to maintain the crest elevation of the berms.

If the lagoon is fully lined, provision should be made for settlement of the berms and the lagoon. This may be achieved by providing folds in the liner.

10 Erosion Protection

It is noted that the computed upstream and downstream slopes will be stable provided that the berms are not overtopped. 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 holding the overflow.

11 Additional Investigation

It is noted that the geotechnical conditions in the vicinity of the west berm were not established since the berm was relocated subsequent to completion of the fieldwork. It is recommended that an additional geotechnical investigation should be undertaken at the site in order to establish the soil and bedrock profile at the location of the west berm to confirm assumptions made in the slope stability analysis.

12 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.

Figures

0 150 km 300 km 600 km

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scale 1:15,000,000	CLIENT:	GOVERNMENT OF NUNAVUT	project no. OTT-00207086-A0
date JAN. 2012	TITLE:	SITE LOCATION PLAN REPULSE BAY, NUNAVUT	FIG 1
drawn by M.N.			

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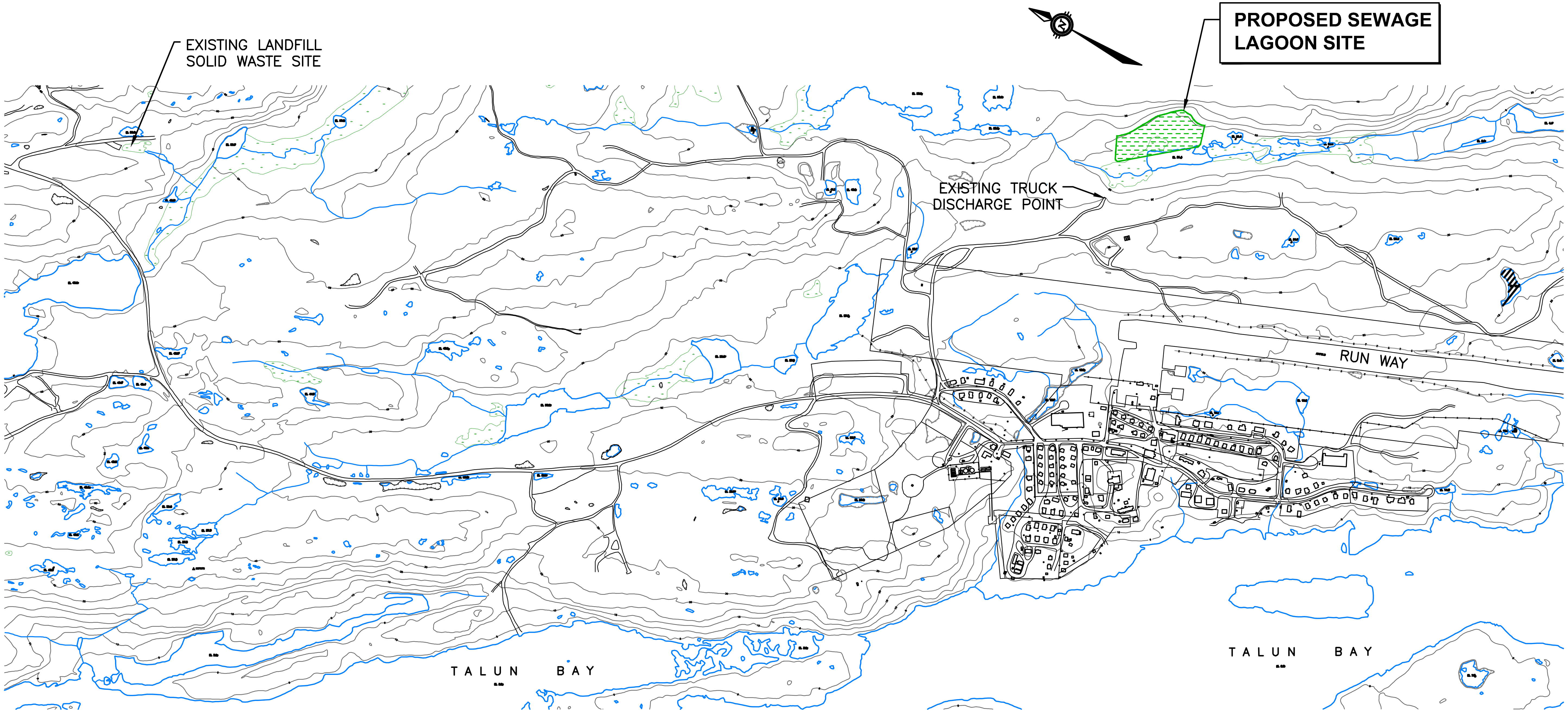

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scale 1:10,000	CLIENT: GOVERNMENT OF NUNAVUT	project no. OTT–00207086A
date JAN. 2013	TITLE: PROPOSED SEWAGE LAGOON SITE REPULSE BAY, NUNAVUT	FIGURE 2
drawn by S.B./M.N.		

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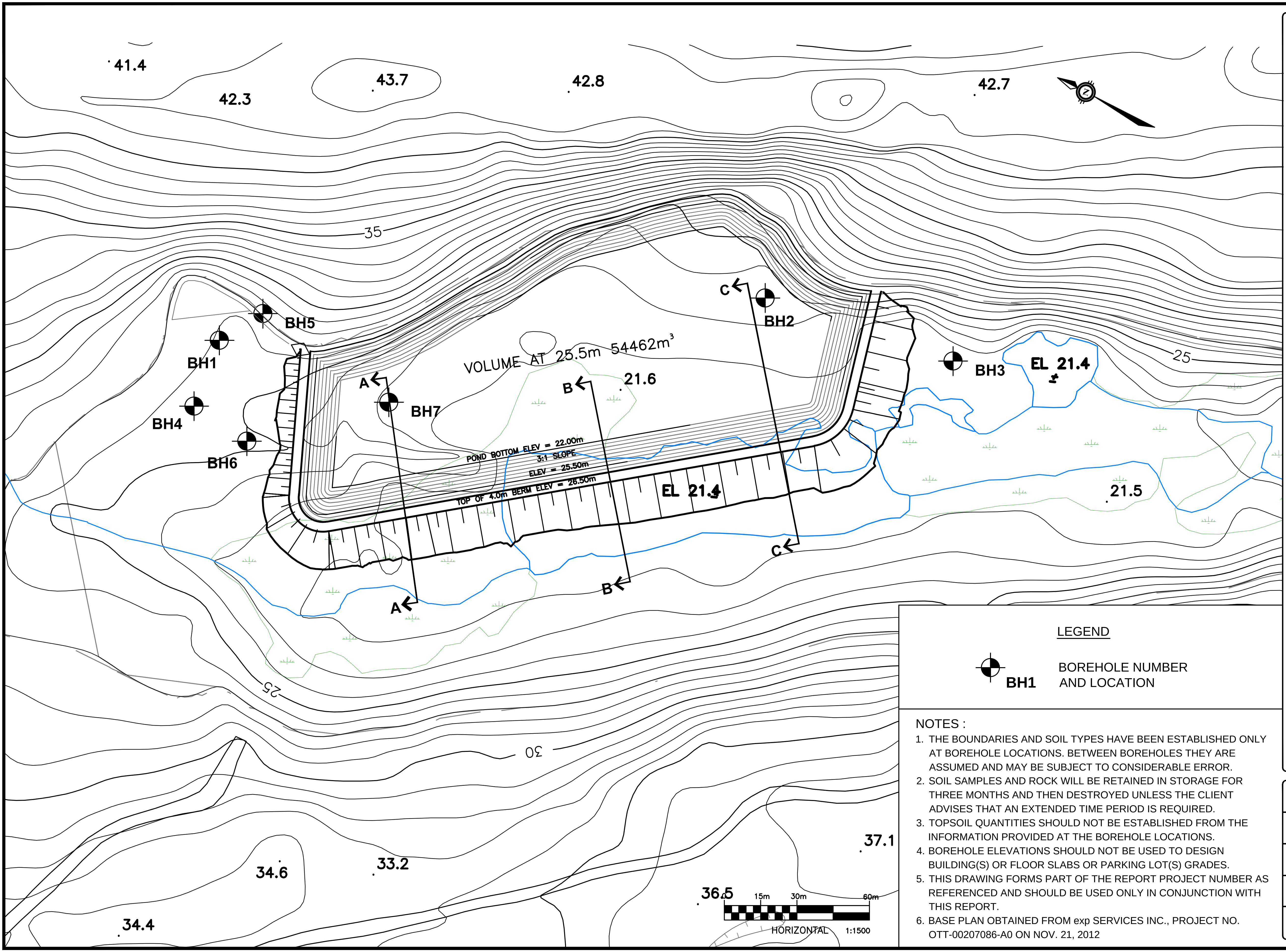
References:



LEGEND

● BH1 BOREHOLE NUMBER AND LOCATION

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 DESIGN BUILDING(S) OR FLOOR SLABS OR PARKING LOT(S) 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 exp SERVICES INC., PROJECT NO. OTT-00207086-A0 ON NOV. 21, 2012

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www.exp.com

• BUILDINGS • EARTH & ENVIRONMENT • ENERGY •
• INDUSTRIAL • INFRASTRUCTURE • SUSTAINABILITY •

CLIENT: GOVERNMENT OF NUNAVUT

TITLE: BOREHOLE LOCATION PLAN & CROSS SECTIONS FOR SLOPE STABILITY ANALYSIS
PROPOSED SEWAGE LAGOON, REPULSE BAY, NUNAVUT

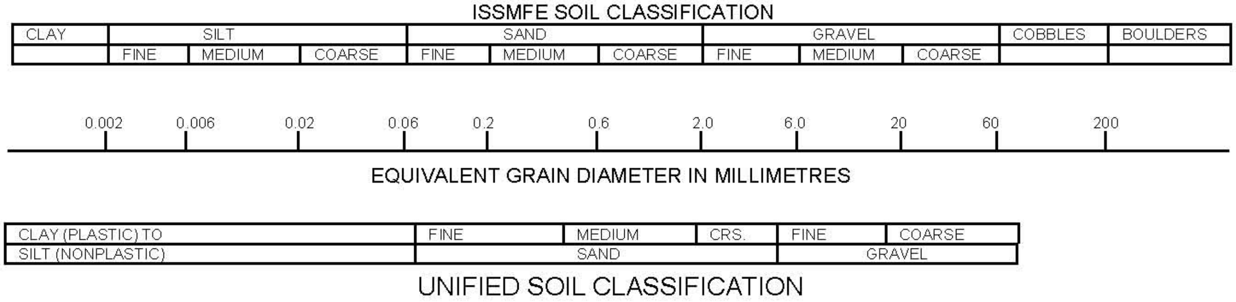
scale 1:1500
date JAN. 2013
drawn by M. NUGENT
project no. OTT-00207086-A0

Figure 3

Filename: r:\200000\207000\207086-a0 repulse bay\207086-a0 fig 1 and 3 rev 2013-01.dwg
Last Saved: 2/5/2013 12:32:03 PM
Last Plotted: 2/5/2013 12:33:43 PM   Plotted by: nugentm   Pen Table:: exp-64.ctb

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 Societv for Soil Mechanics and Foundation Engineering. Laboratory grain size analyses provided by **exp** Services 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.



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 1

Project No: OTT-00207086-A0

Project: Geotechnical Investigation. Proposed Sewage Lagoon

Location: Hamlet of Repulse Bay, Nunavut

Figure No. 4

Page. 1 of 1

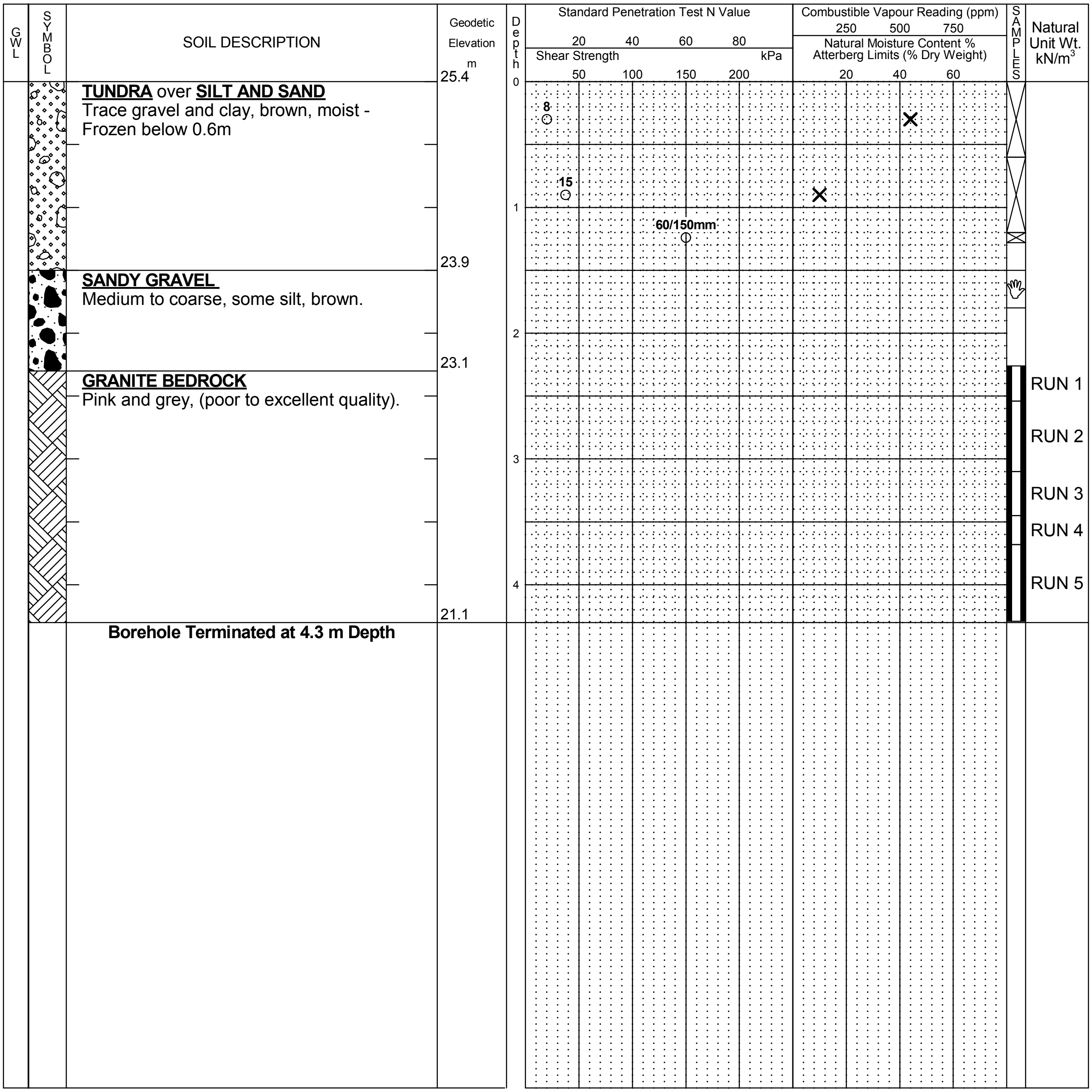
Date Drilled: 'October 3, 2012

Drill Type: Hilti Drill

Datum: Geodetic Elevation

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	▲



TUNDRA over **SILT AND SAND**
Trace gravel and clay, brown, moist - Frozen below 0.6m

SANDY GRAVEL
Medium to coarse, some silt, brown.

GRANITE BEDROCK
Pink and grey, (poor to excellent quality).

Borehole Terminated at 4.3 m Depth

NOTES:
1. Borehole data requires interpretation by exp. before use by others
2. Thermistors installed in the borehole upon completion
3. Field work supervised by an exp representative.
4. See Notes on Sample Descriptions
5. This Figure is to read with exp. Services Inc. report OTT-00207086-A0

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)
Completion	No Water	No Cave

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	2.3 - 2.5	100	91
2	2.5 - 3.1	93	73
3	3.1 - 3.5	79	45
4	3.5 - 3.7	100	44
5	3.7 - 4.3	100	100

Log of Borehole 2

Project No: OTT-00207086-A0

Project: Geotechnical Investigation. Proposed Sewage Lagoon

Location: Hamlet of Repulse Bay, Nunavut

Figure No. 5

Page. 1 of 1

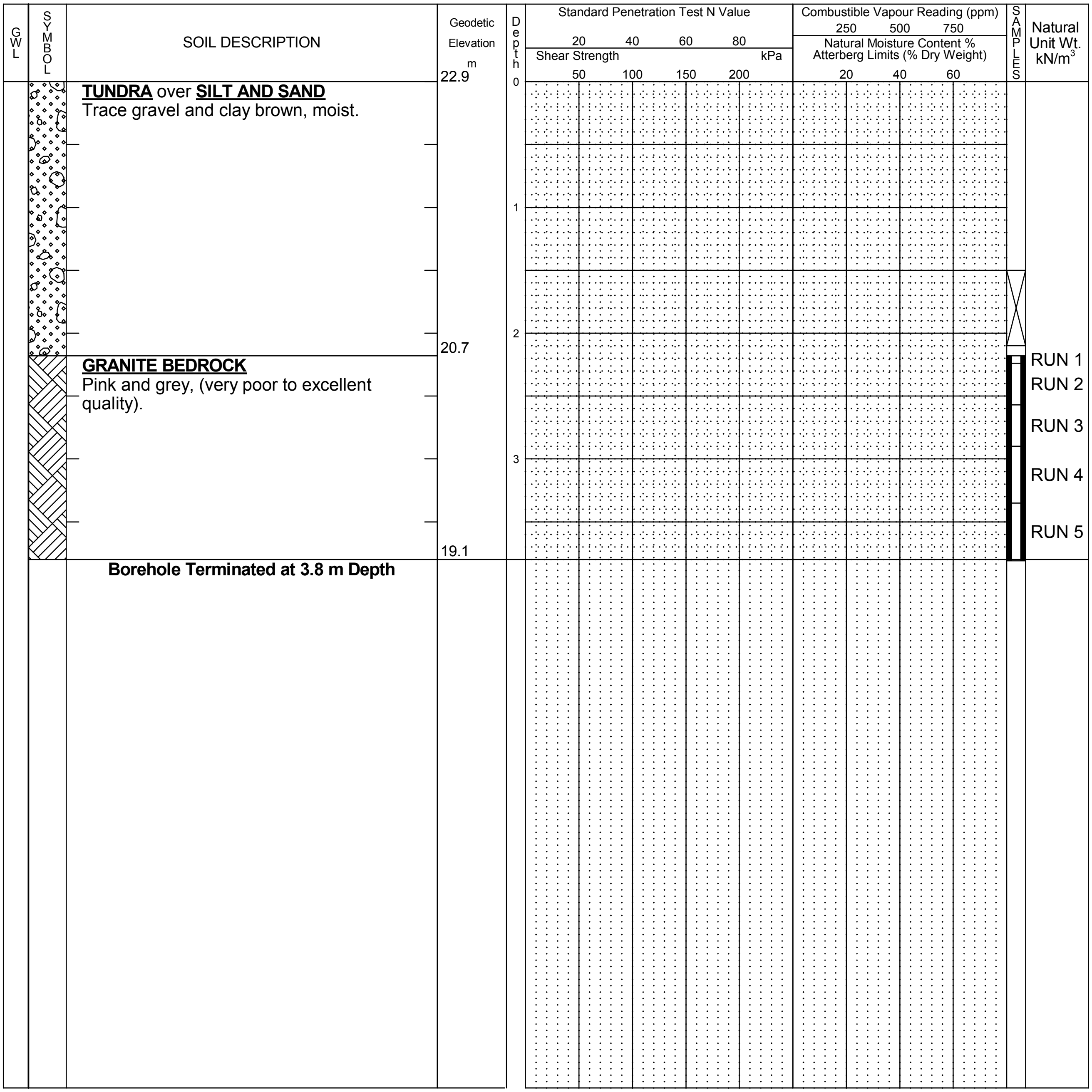
Date Drilled: 'October 10, 2012

Drill Type: Hilti Drill

Datum: Geodetic Elevation

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	▲



TUNDRA over **SILT AND SAND**
Trace gravel and clay brown, moist.

GRANITE BEDROCK
Pink and grey, (very poor to excellent quality).

Borehole Terminated at 3.8 m Depth

NOTES:
1. Borehole data requires interpretation by exp. before use by others
2. Borehole backfilled on completion of drilling.
3. Field work supervised by an exp representative.
4. See Notes on Sample Descriptions
5. This Figure is to read with exp. Services Inc. report OTT-00207086-A0

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)
Completion	No Water	No Cave

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	2.1 - 2.2	100	55
2	2.2 - 2.6	75	0
3	2.6 - 2.9	100	92
4	2.9 - 3.4	100	50
5	3.4 - 3.8	100	83

Log of Borehole 3

Project No: OTT-00207086-A0

Project: Geotechnical Investigation. Proposed Sewage Lagoon

Location: Hamlet of Repulse Bay, Nunavut

Figure No. 6

Page. 1 of 1

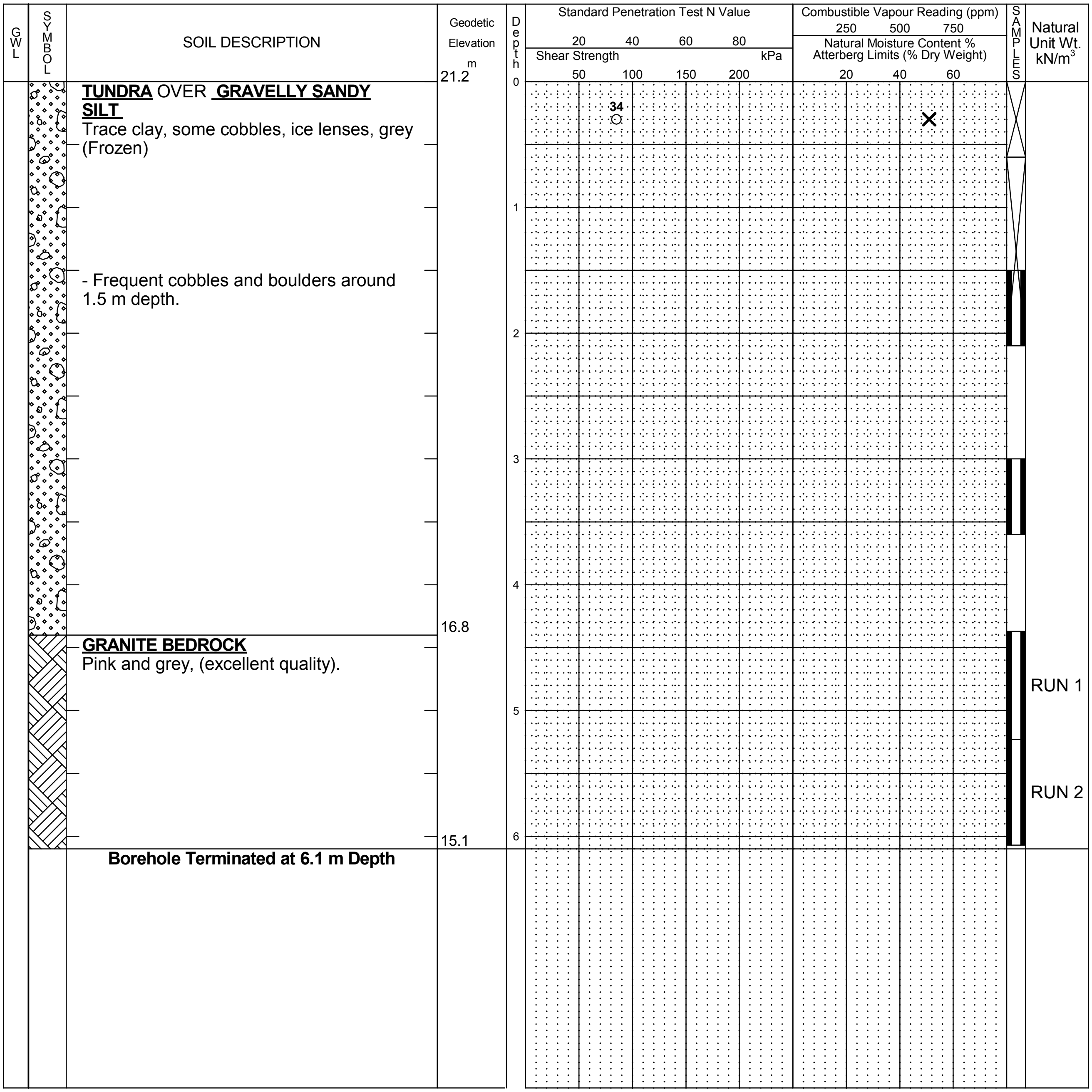
Date Drilled: 'October 3, 2012

Drill Type: Hilti Drill

Datum: Geodetic Elevation

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	▲



21.2

TUNDRA OVER **GRAVELLY SANDY SILT**

Trace clay, some cobbles, ice lenses, grey (Frozen)

- Frequent cobbles and boulders around 1.5 m depth.

16.8

GRANITE BEDROCK

Pink and grey, (excellent quality).

15.1

Borehole Terminated at 6.1 m Depth

NOTES:

1. Borehole data requires interpretation by exp. before use by others
2. Thermistors installed in the borehole upon completion
3. Field work supervised by an exp representative.
4. See Notes on Sample Descriptions
5. This Figure is to read with exp. Services Inc. report OTT-00207086-A0

WATER LEVEL RECORDS

Elapsed Time	Water Level (m)	Hole Open To (m)
Completion	No Water	No Cave

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	4.4 - 5.2	100	100
2	5.2 - 6.1	100	94

Log of Borehole 4

Project No: OTT-00207086-A0

Project: Geotechnical Investigation. Proposed Sewage Lagoon

Location: Hamlet of Repulse Bay, Nunavut

Figure No. 7

Page. 1 of 1

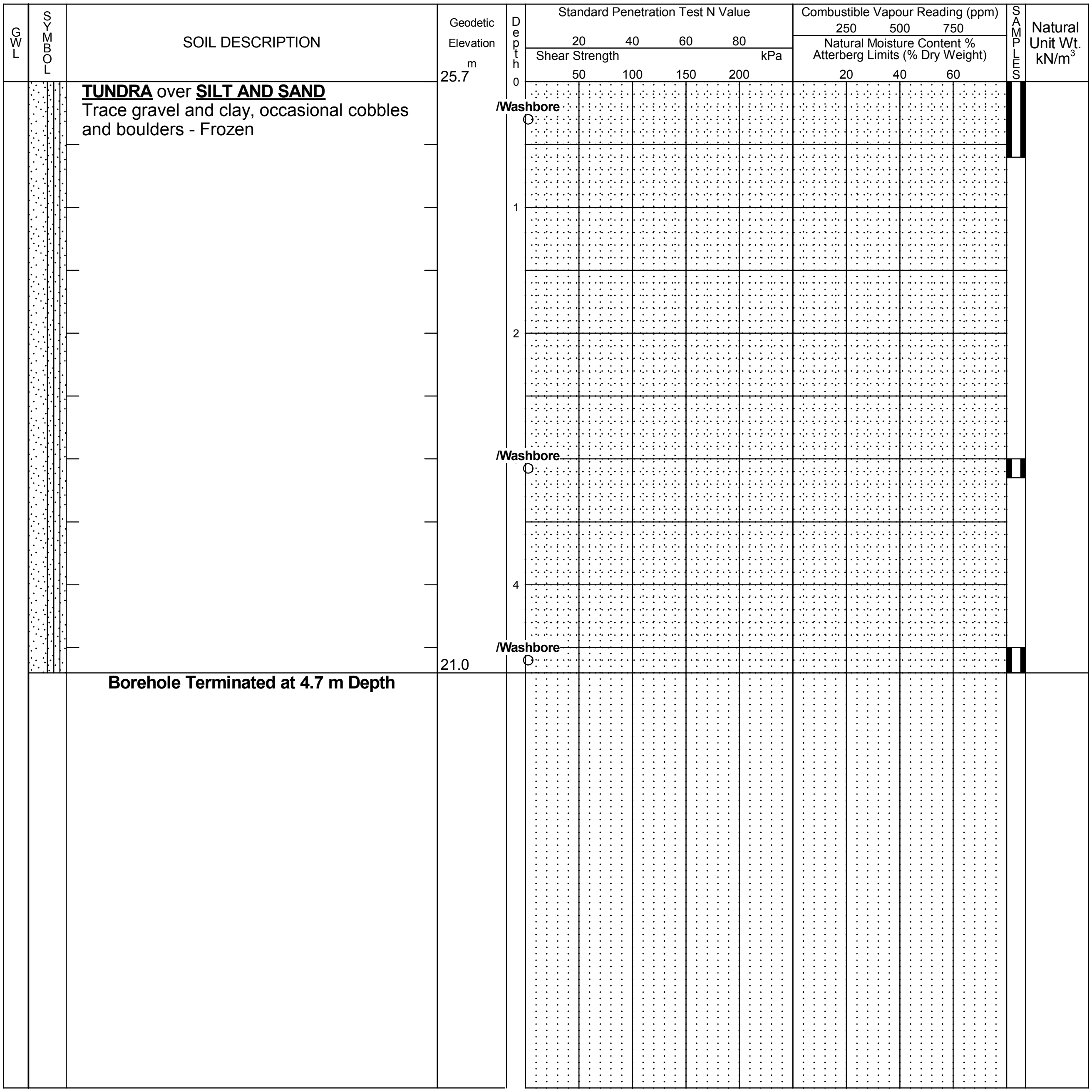
Date Drilled: 'October 11, 2012

Drill Type: Hilti Drill

Datum: Geodetic Elevation

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	▲



TUNDRA over **SILT AND SAND**
Trace gravel and clay, occasional cobbles and boulders - Frozen

Borehole Terminated at 4.7 m Depth

NOTES:
1. Borehole data requires interpretation by exp. before use by others
2. Borehole backfilled on completion of drilling and coring.
3. Field work supervised by an exp representative.
4. See Notes on Sample Descriptions
5. This Figure is to read with exp. Services Inc. report OTT-00207086-A0

WATER LEVEL RECORDS

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

CORE DRILLING RECORD

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

Log of Borehole 5

Project No: OTT-00207086-A0

Project: Geotechnical Investigation. Proposed Sewage Lagoon

Location: Hamlet of Repulse Bay, Nunavut

Figure No. 8

Page. 1 of 1

Date Drilled: 'October 9, 2012

Drill Type: Hilti Drill

Datum: Geodetic Elevation

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	Standard Penetration Test N Value 20 40 60 80 Shear Strength kPa 50 100 150 200	Combustible Vapour Reading (ppm) 250 500 750 Natural Moisture Content % Atterberg Limits (% Dry Weight) 20 40 60	SAMPLES	Natural Unit Wt. kN/m^3
	▨	**GRANITE BEDROCK** Pink and grey (good quality)	26.6	0				RUN 1
	▨			1				RUN 2
	▨		24.8					RUN 3
		Borehole Terminated at 1.8 m Depth						

NOTES:
1. Borehole data requires interpretation by exp. before use by others
2. Borehole backfilled on completion of drilling and coring.
3. Field work supervised by an exp representative.
4. See Notes on Sample Descriptions
5. This Figure is to read with exp. Services Inc. report OTT-00207086-A0

WATER LEVEL RECORDS

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

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	0 - 0.7	92	88
2	0.7 - 1	90	90
3	1 - 1.8	100	75

Log of Borehole 6

Project No: OTT-00207086-A0

Project: Geotechnical Investigation. Proposed Sewage Lagoon

Location: Hamlet of Repulse Bay, Nunavut

Figure No. 9

Page. 1 of 1

Date Drilled: 'October 3, 2012

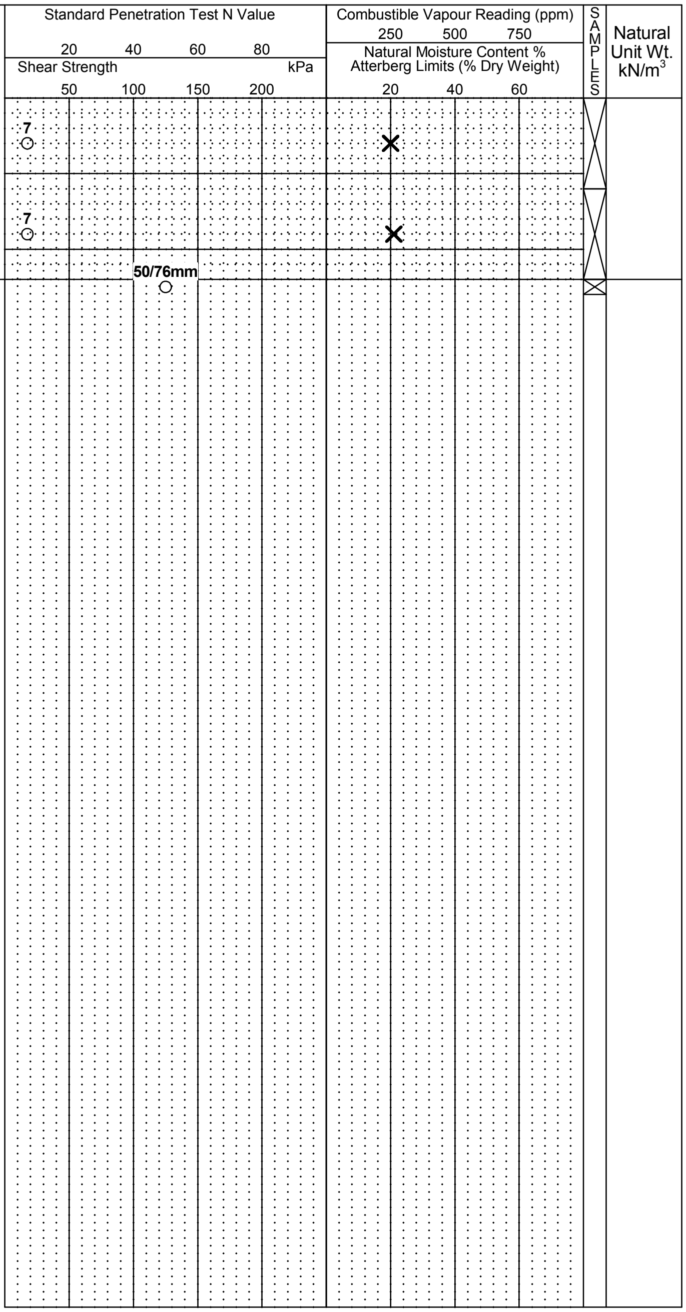
Drill Type: Hilti Drill

Datum: Geodetic Elevation

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
			24.1	0
		TUNDRA over **SILTY GRAVELLY SAND** Trace clay, gret to brown - Frozen		
			23.5	
		SILTY SAND Trace to some gravel, trace clay, grey		
				1
		Borehole Terminated at 1.2 m Depth		



NOTES:
1. Borehole data requires interpretation by exp. before use by others
2. Borehole backfilled on completion of drilling and coring.
3. Field work supervised by an exp representative.
4. See Notes on Sample Descriptions
5. This Figure is to read with exp. Services Inc. report OTT-00207086-A0

WATER LEVEL RECORDS

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

CORE DRILLING RECORD

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

Log of Borehole 7

Project No: OTT-00207086-A0

Project: Geotechnical Investigation. Proposed Sewage Lagoon

Location: Hamlet of Repulse Bay, Nunavut

Figure No. 10

Page. 1 of 1

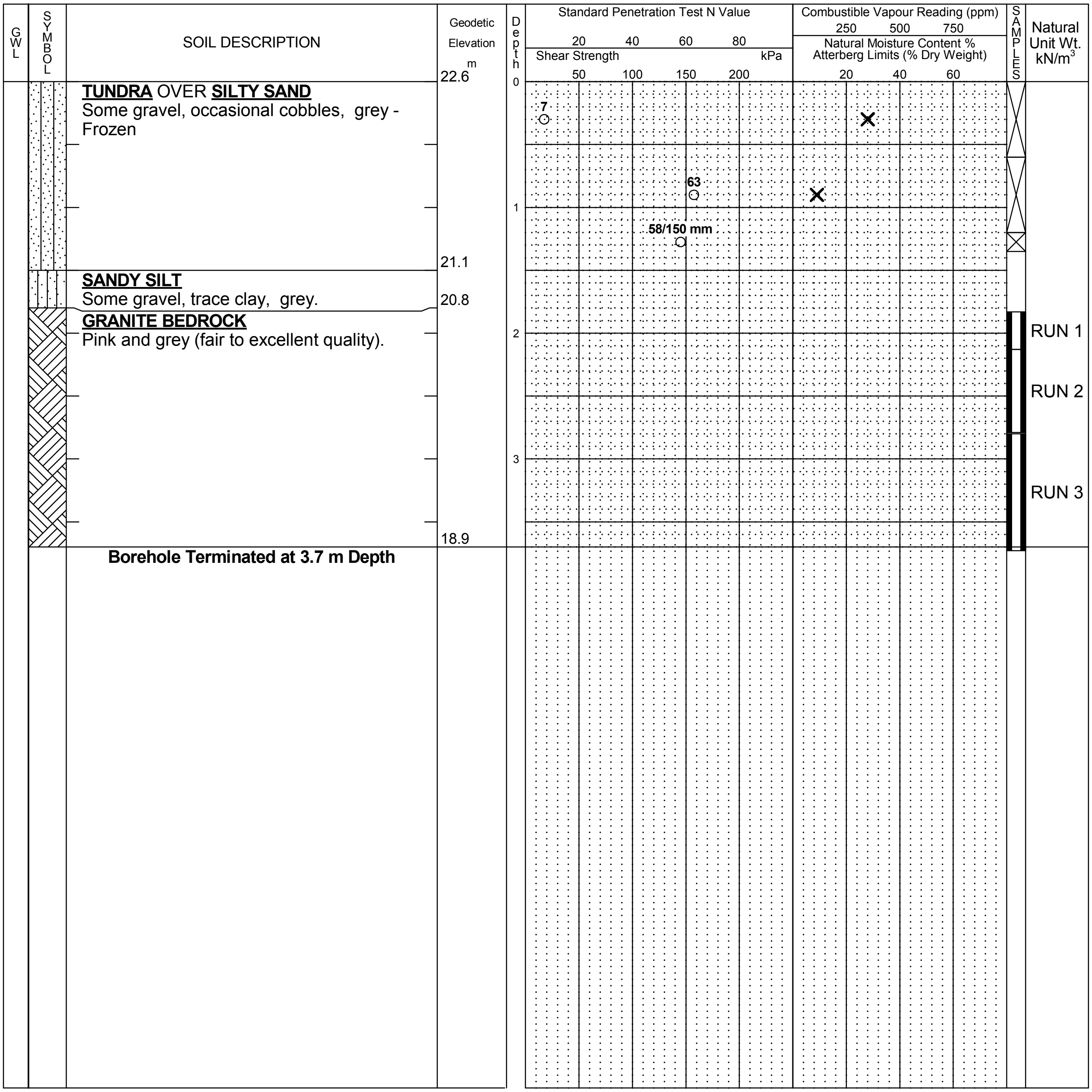
Date Drilled: 'October 3, 2012

Drill Type: Hilti Drill

Datum: Geodetic Elevation

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		



TUNDRA OVER **SILTY SAND**
Some gravel, occasional cobbles, grey - Frozen

SANDY SILT
Some gravel, trace clay, grey.

GRANITE BEDROCK
Pink and grey (fair to excellent quality).

Borehole Terminated at 3.7 m Depth

NOTES:
1. Borehole data requires interpretation by exp. before use by others
2. Borehole backfilled on completion of drilling and coring.
3. Field work supervised by an exp representative.
4. See Notes on Sample Descriptions
5. This Figure is to read with exp. Services Inc. report OTT-00207086-A0

WATER LEVEL RECORDS

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

CORE DRILLING RECORD

Run No.	Depth (m)	% Rec.	RQD %
1	1.8 - 2.1	100	96
2	2.1 - 2.8	73	73
3	2.8 - 3.7	97	95

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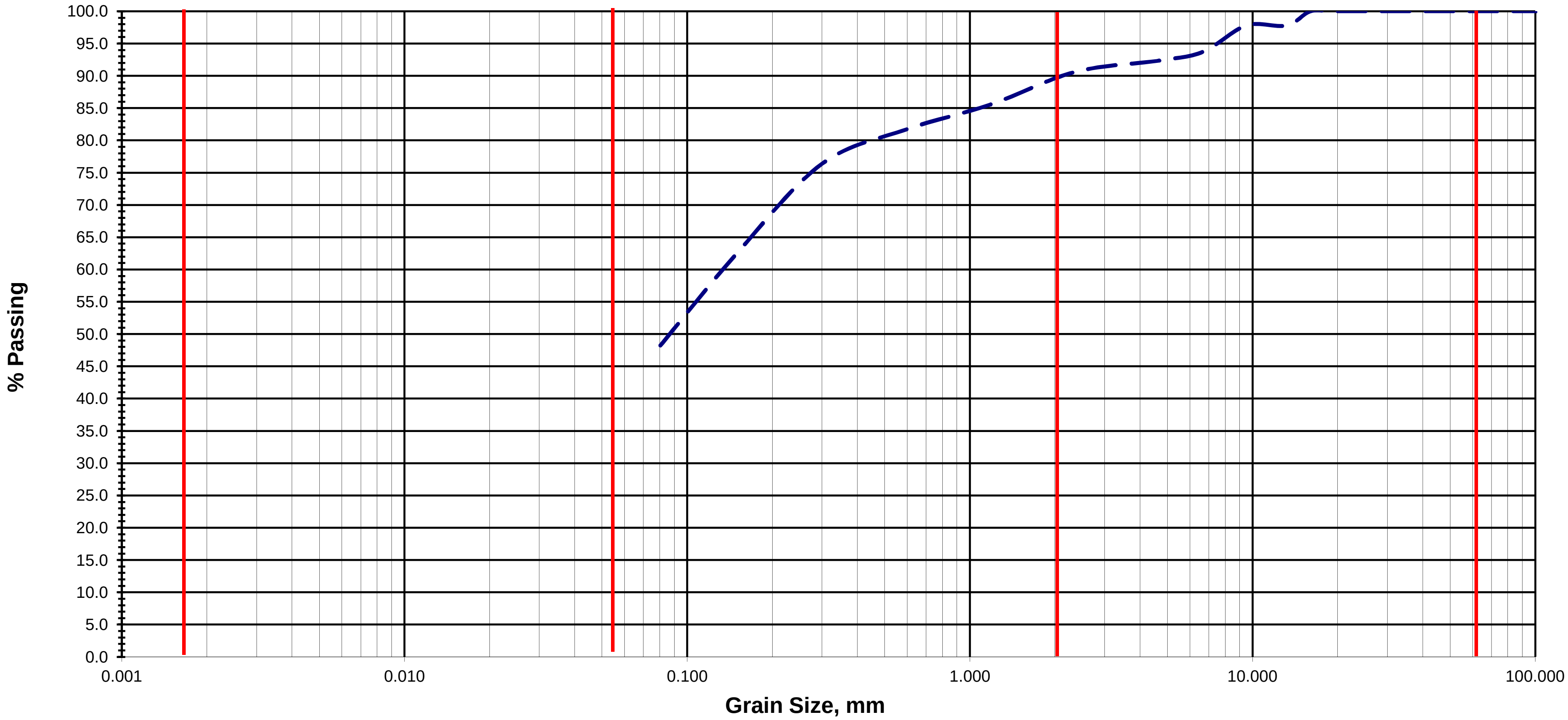
Method of Test for Sieve Analysis of Aggregate

ASTM C 136

Grain Size Distribution Curve



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

Exp Project No.:	**OTT-000207086-AO**	**Project Name :**	**Sewage Lagoon Upgrades**		
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet of Repulse Bay, Nunavut**		
Date Sampled	**October 3, 2012**	**Borehole** **1**	**Sample No.:** **SS2**	**Depth (m) :**	**0.6 to 1.2**
Sample Description :	**Silty Sand, some Gravel**			**Figure :**	**11**

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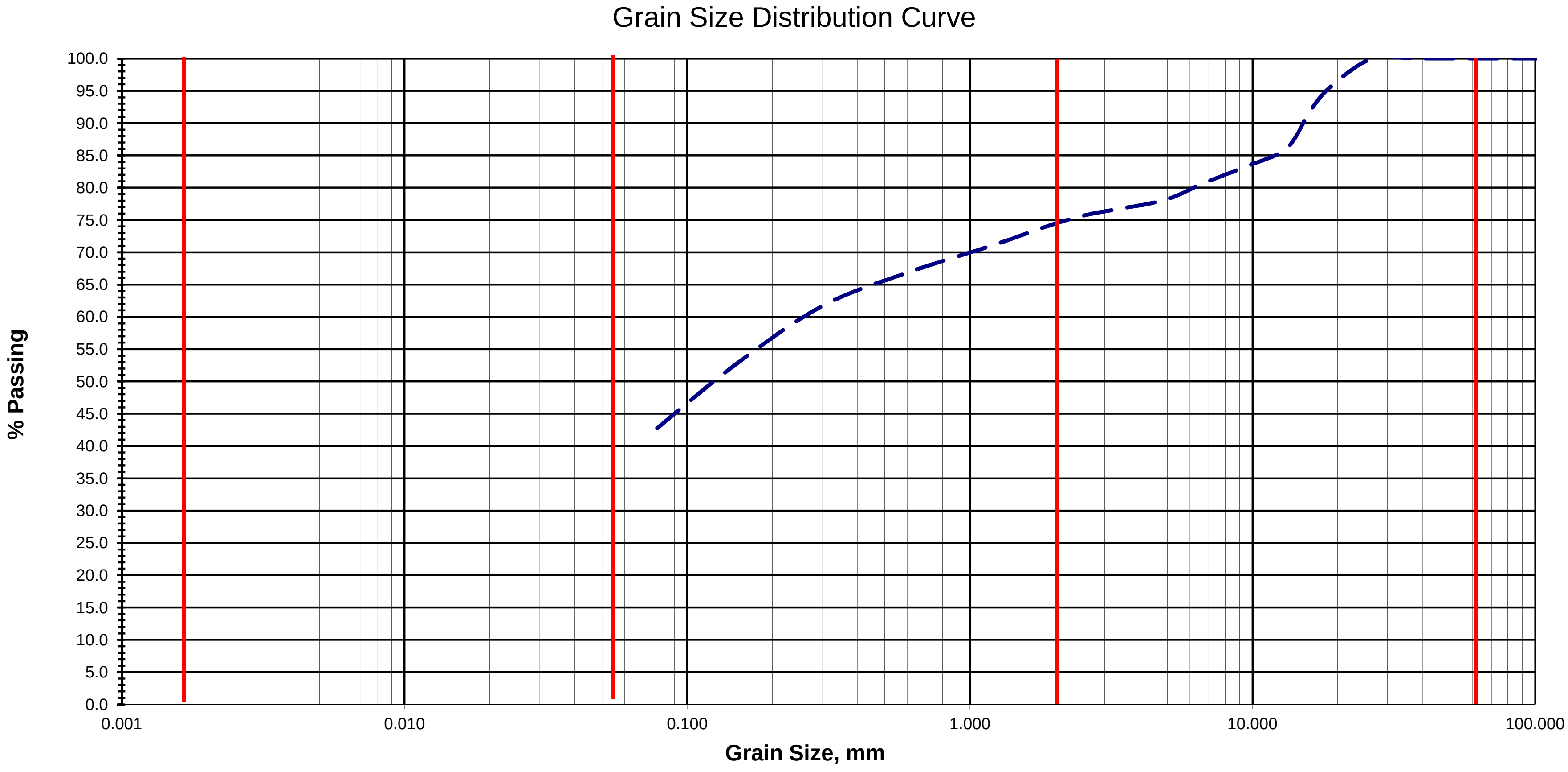
Method of Test for Sieve Analysis of Aggregate

ASTM C 136



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

Exp Project No.:	**OTT-000207086-AO**	**Project Name :**	**Sewage Lagoon Upgrades**		
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet of Repulse Bay, Nunavut**		
Date Sampled	**October 3, 2012**	**Borehole**	**3**	**Sample No.: SS2**	**Depth (m) : 0.6 to 1.35**
Sample Description :	**Gravelly Sandy Silt**				**Figure : 12**

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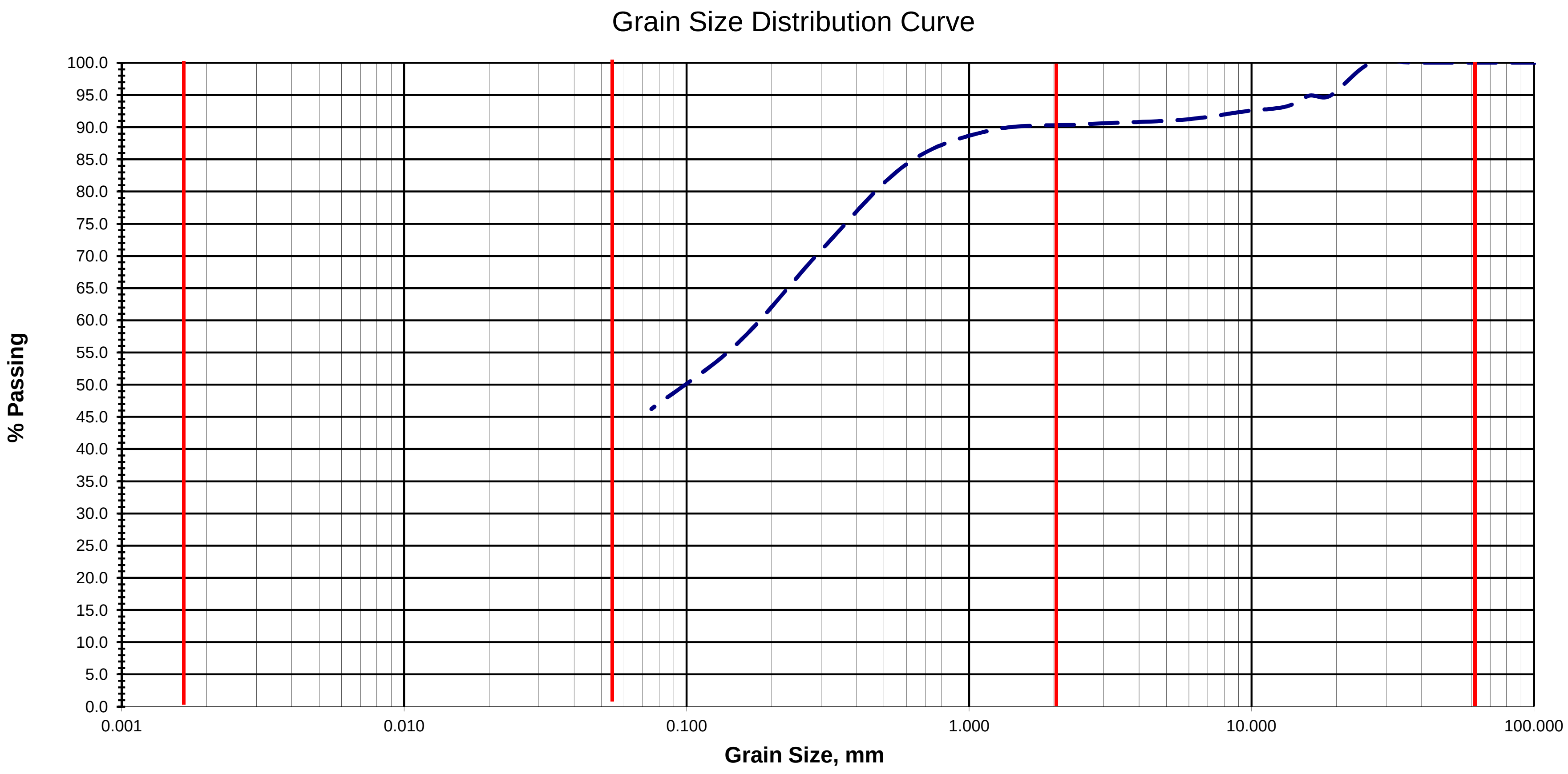
Method of Test for Sieve Analysis of Aggregate

ASTM C 136



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

Exp Project No.:	**OTT-000207086-AO**	**Project Name :**	**Sewage Lagoon Upgrades**				
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet of Repulse Bay, Nunavut**				
Date Sampled	**October 11, 2012**	**Borehole**	**4**	**Sample No.:**	**SS2**	**Depth (m) :**	**3.0 m**
Sample Description :	**Silt and Sand, Some Gravel, Trace Clay**					**Figure :**	**13**

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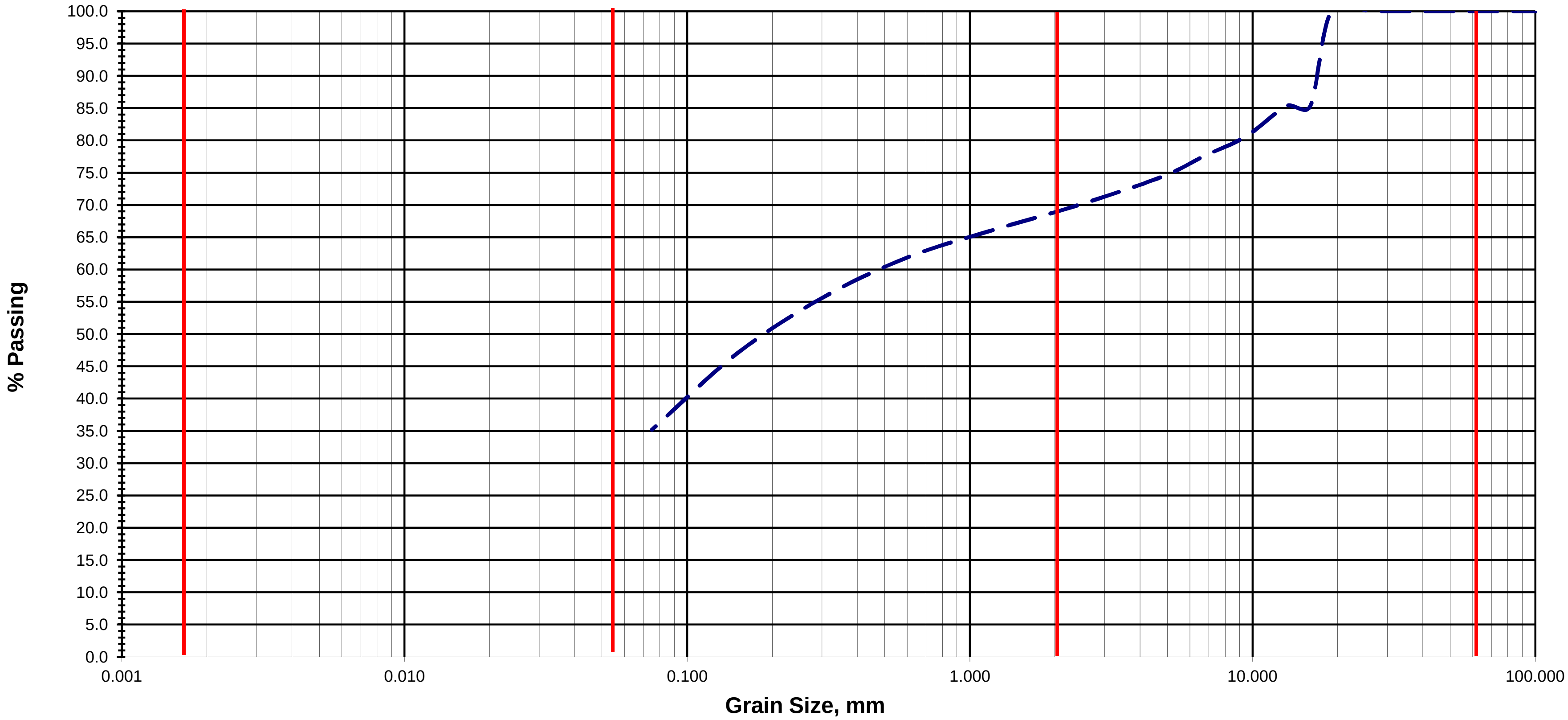
Method of Test for Sieve Analysis of Aggregate

ASTM C 136

Grain Size Distribution Curve



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<tr><td colspan="11">Modified M.I.T. Classification</td></tr>
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Exp Project No.:	**OTT-000207086-AO**	**Project Name :**	**Sewage Lagoon Upgrades**		
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet of Repulse Bay, Nunavut**		
Date Sampled	**October 3, 2012**	**Borehole** 6	**Sample No.:** SS1	**Depth (m) :**	**0 to 0.6 m**
Sample Description :	**Silty Gravelly Sand**			**Figure :**	**14**

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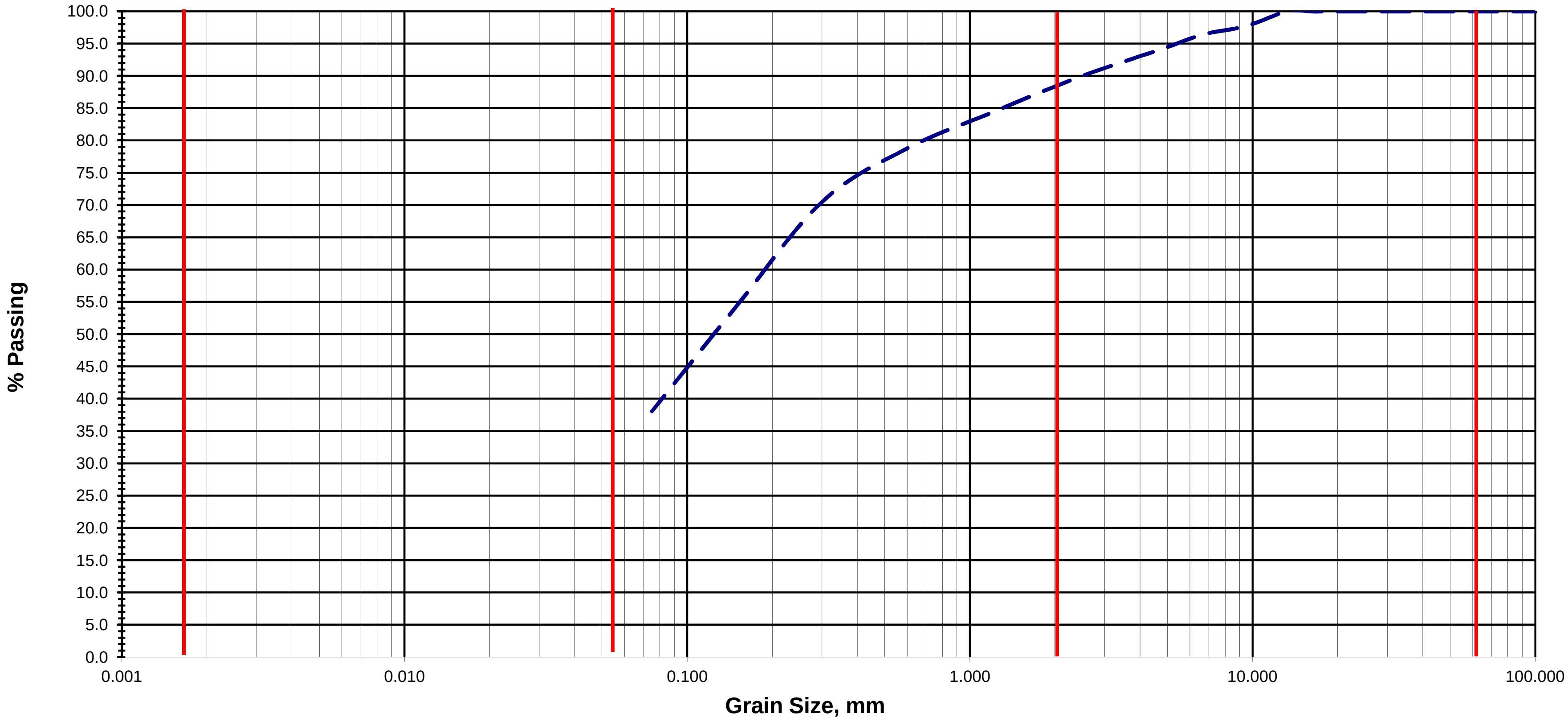
Method of Test for Sieve Analysis of Aggregate

ASTM C 136

Grain Size Distribution Curve



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

Exp Project No.:	**OTT-000207086-AO**	**Project Name :**	**Sewage Lagoon Upgrades**		
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet of Repulse Bay, Nunavut**		
Date Sampled	**October 3, 2012**	**Borehole** 6	**Sample No.:** SS2	**Depth (m) :**	**0.6 to 1.2**
Sample Description :		**Silty Sand, Some Gravel**		**Figure :**	**15**

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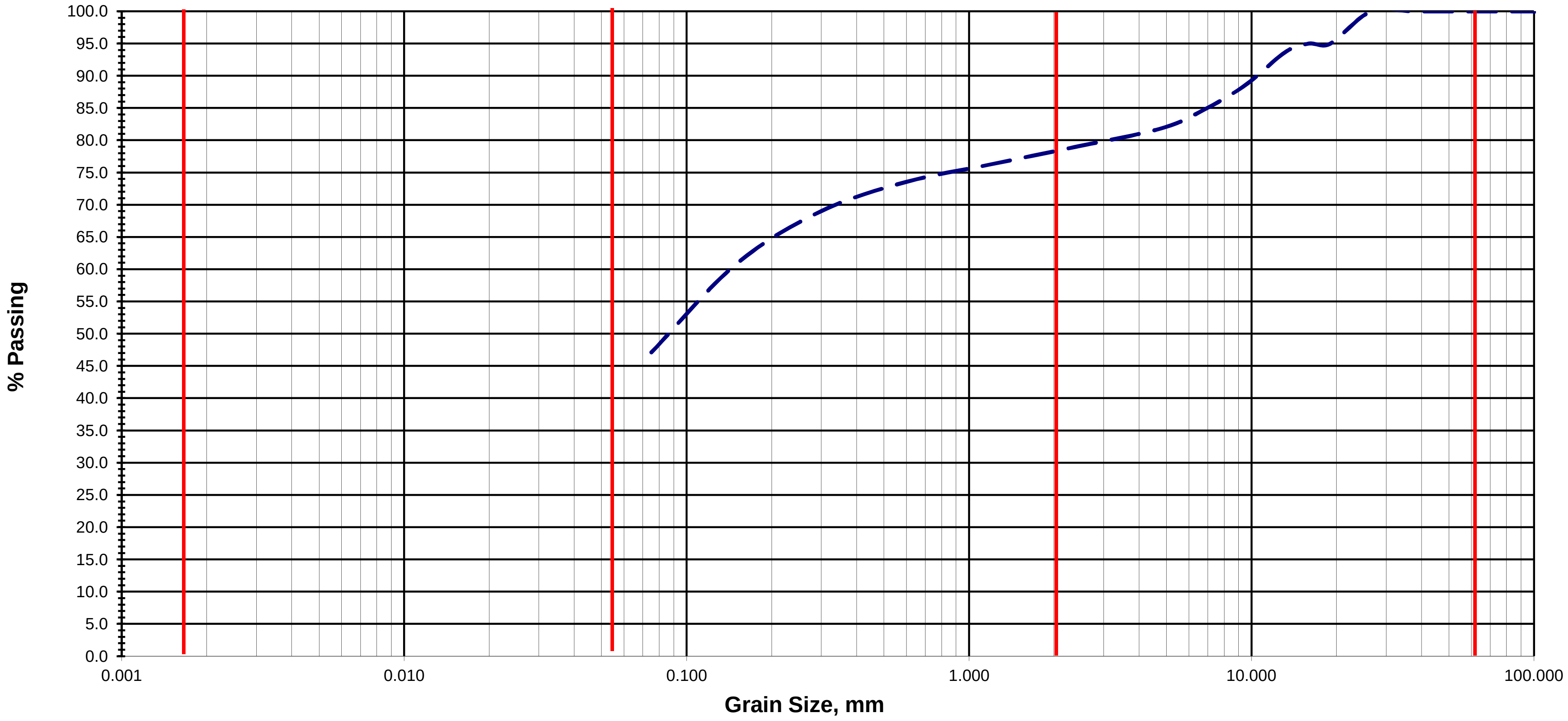
Method of Test for Sieve Analysis of Aggregate

ASTM C 136

Grain Size Distribution Curve



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

Exp Project No.:	**OTT-000207086-AO**	**Project Name :**	**Sewage Lagoon Upgrades**		
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet of Repulse Bay, Nunavut**		
Date Sampled	**October 3, 2012**	**Borehole** **7**	**Sample No.:** **SS2**	**Depth (m) :**	**1.5 to 2.1**
Sample Description :	**Gravelly Silt and Sand**			**Figure :**	**16**

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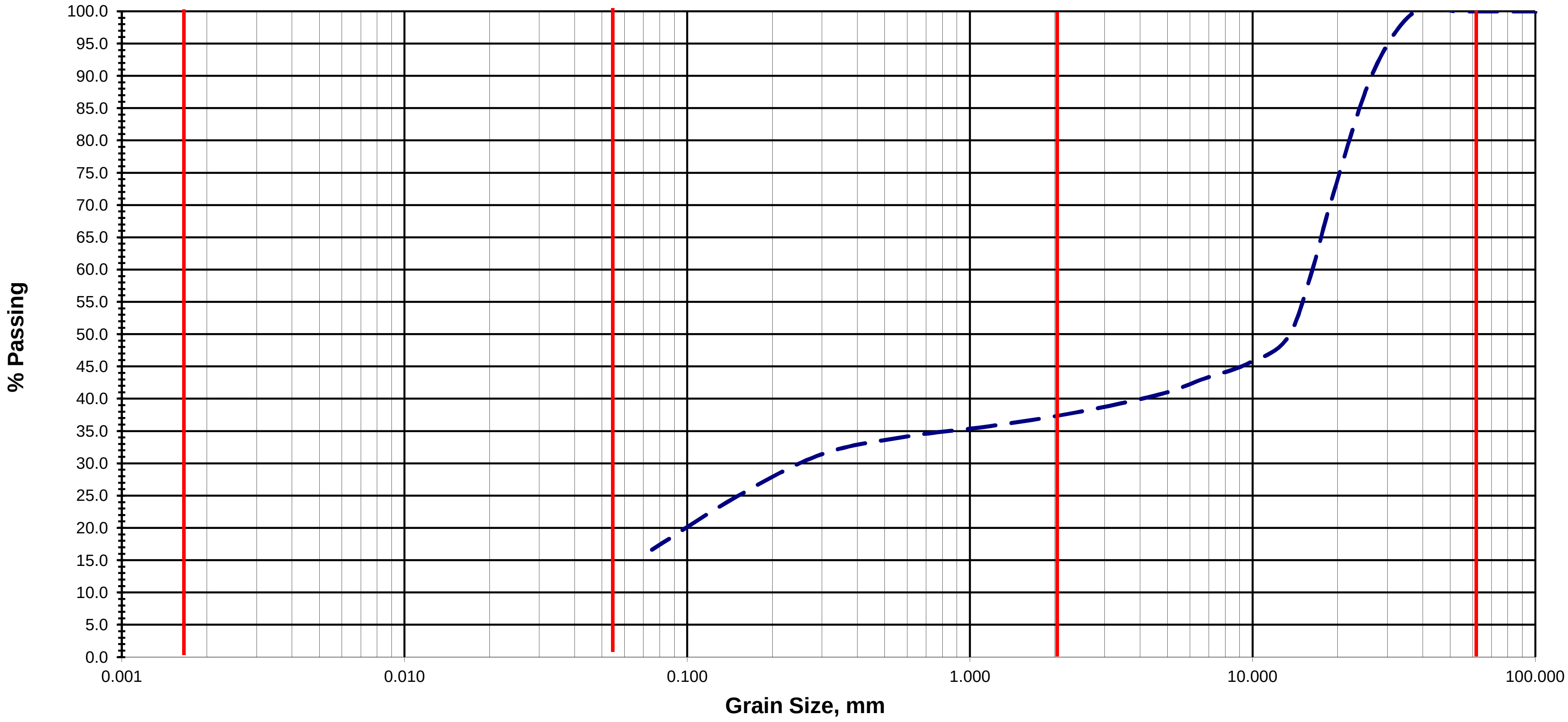
Method of Test for Sieve Analysis of Aggregate

ASTM C 136

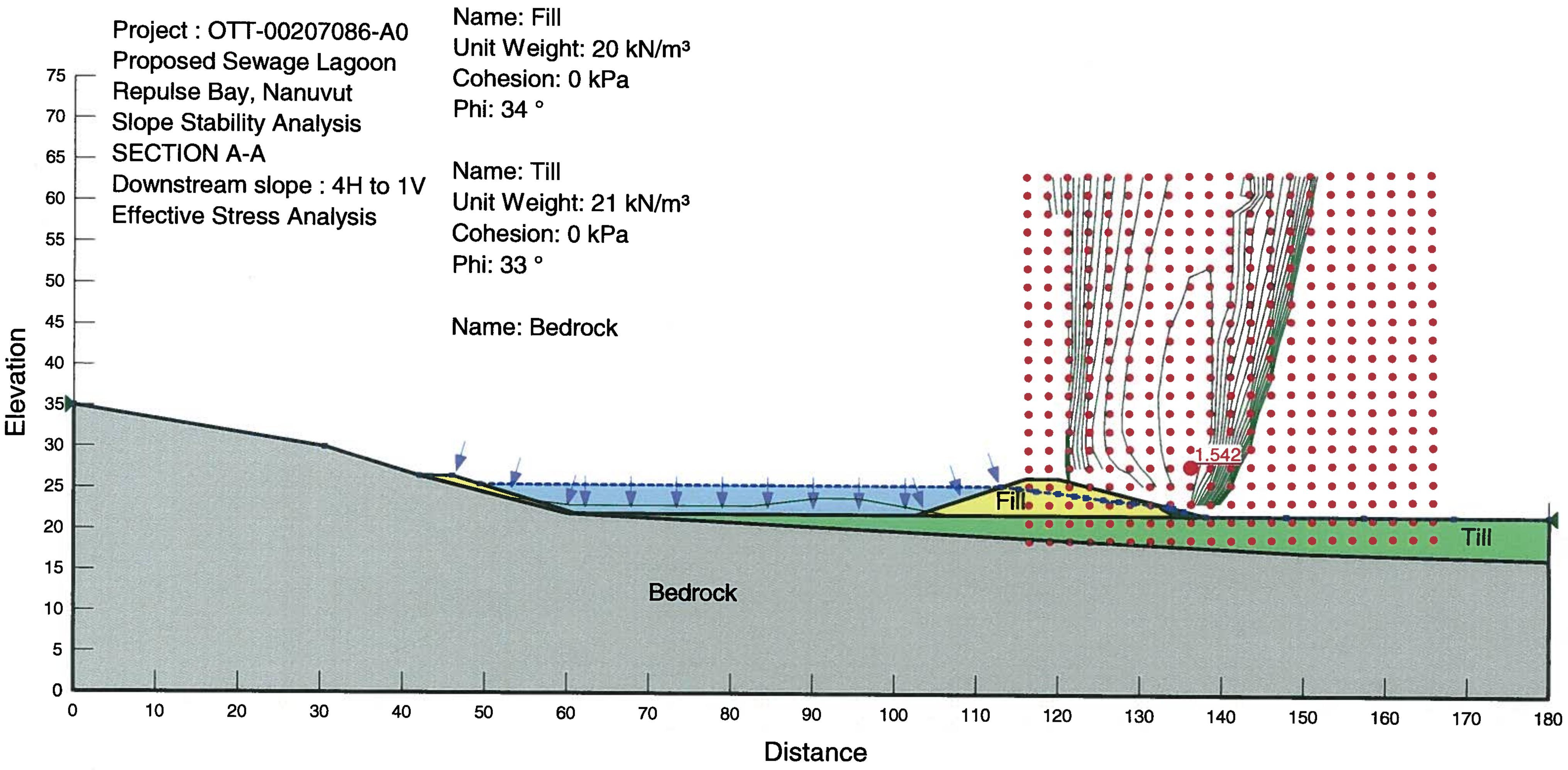
Grain Size Distribution Curve



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

Exp Project No.:	**OTT-000207086-AO**	**Project Name :**	**Sewage Lagoon Upgrades**				
Client :	**Government of Nunavut**	**Project Location :**	**Hamlet of Repulse Bay, Nunavut**				
Date Sampled	**October 3, 2012**	**Borehole**	**1**	**Sample No.:**	**SS3**	**Depth (m) :**	**1.5**
Sample Description :	**Sandy Gravel, Some Silt**					**Figure :**	**17**

Figure 18



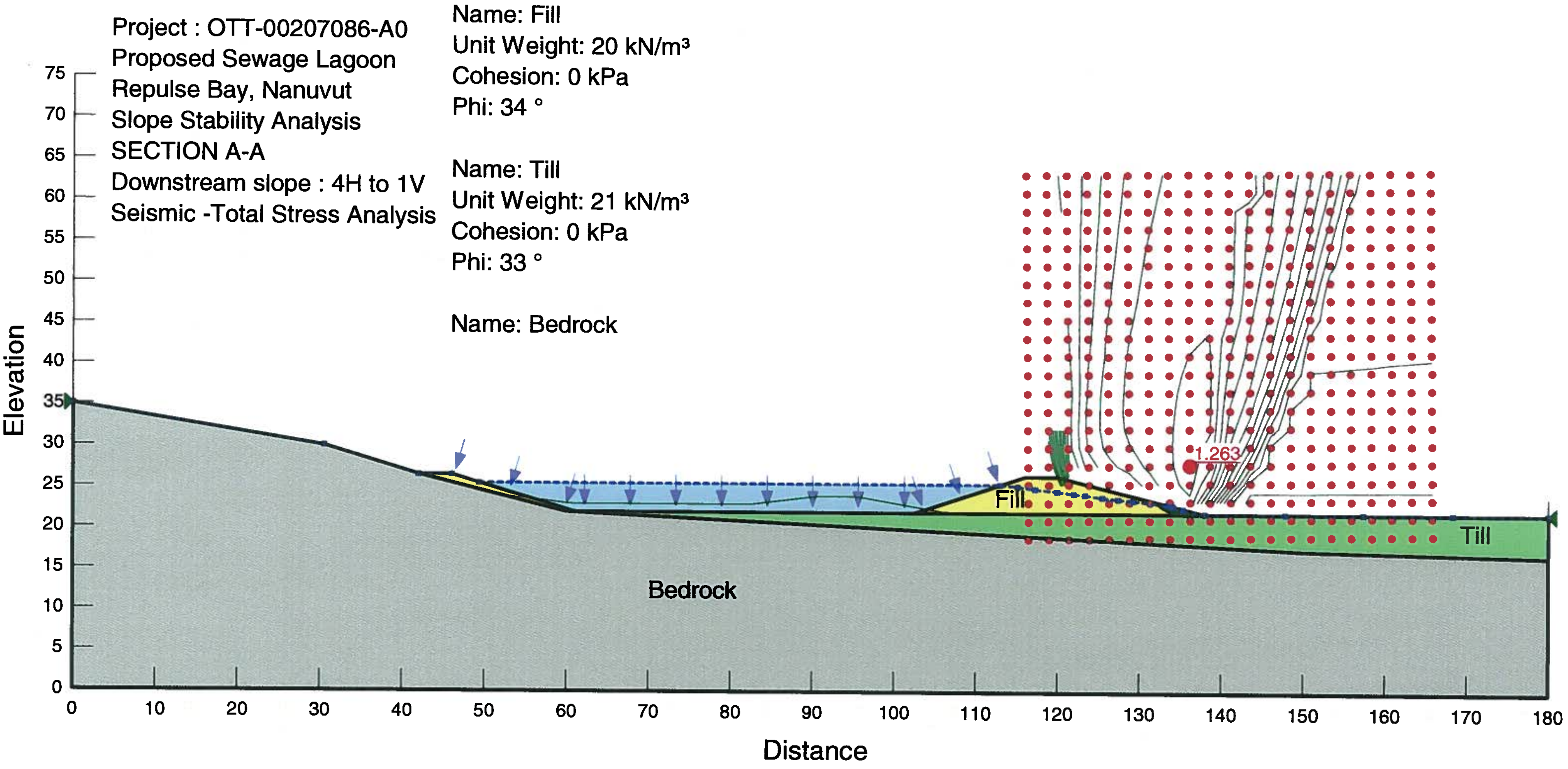
Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION A-A
Downstream slope : 4H to 1V
Effective Stress Analysis

Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °

Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °

Name: Bedrock

Figure 19



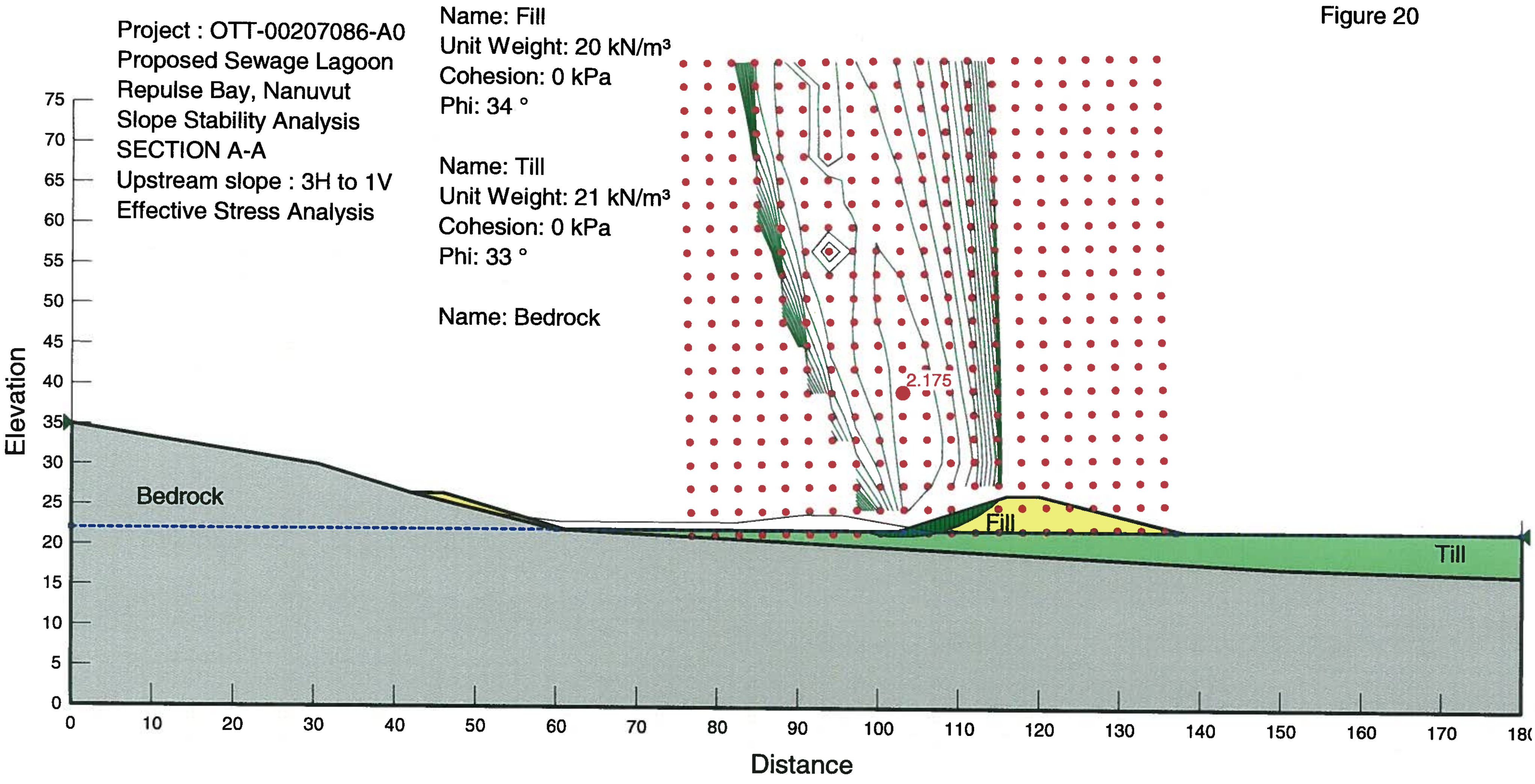
Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION A-A
Downstream slope : 4H to 1V
Seismic -Total Stress Analysis

Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °

Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °

Name: Bedrock

Figure 20



Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION A-A
Upstream slope : 3H to 1V
Effective Stress Analysis

Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °

Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °

Name: Bedrock

Figure 21

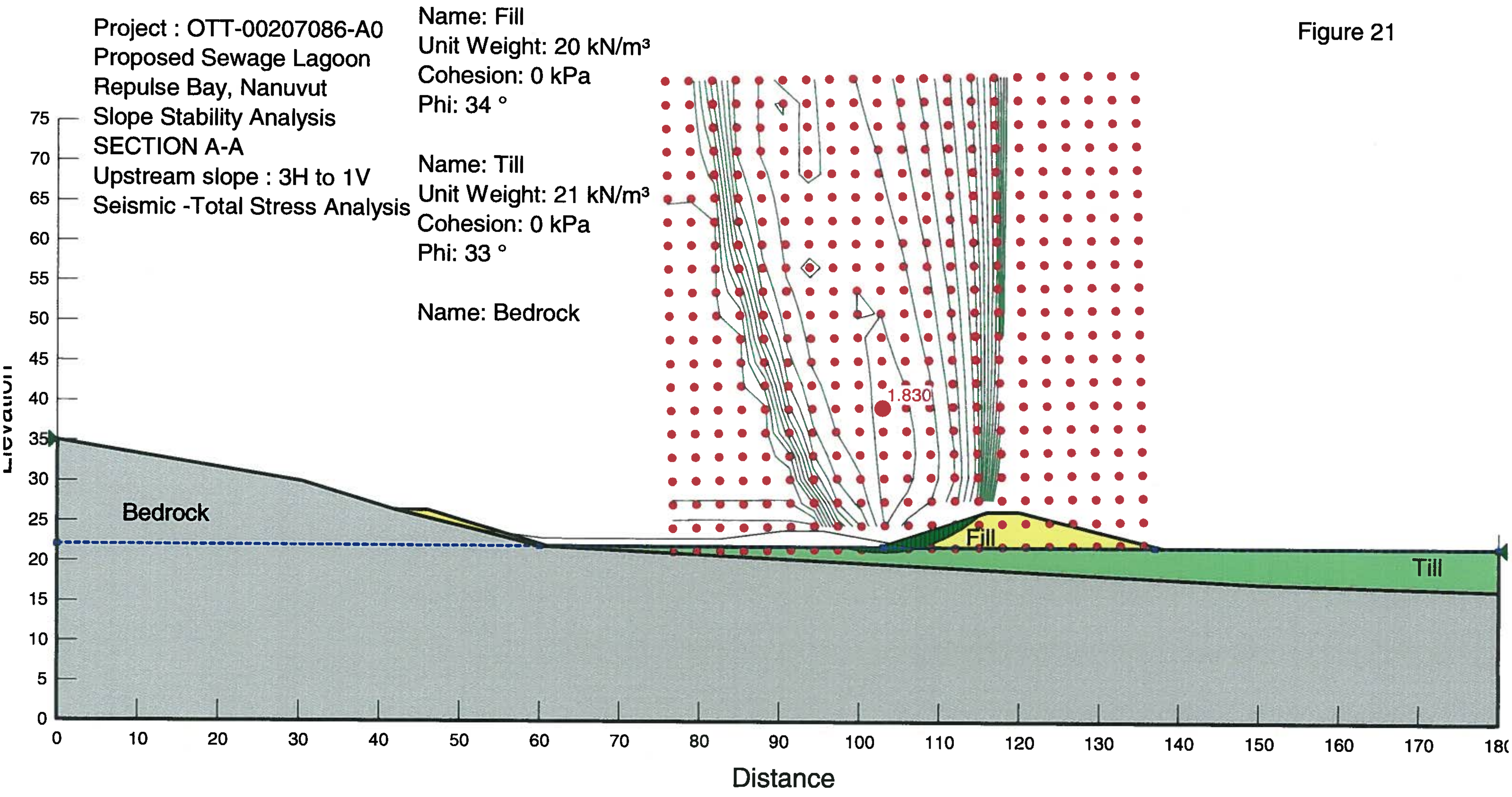

Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION A-A
Upstream slope : 3H to 1V
Seismic -Total Stress Analysis
Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °
Name: Bedrock
1.830
Bedrock
Fill
Till
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Distance

Figure 22

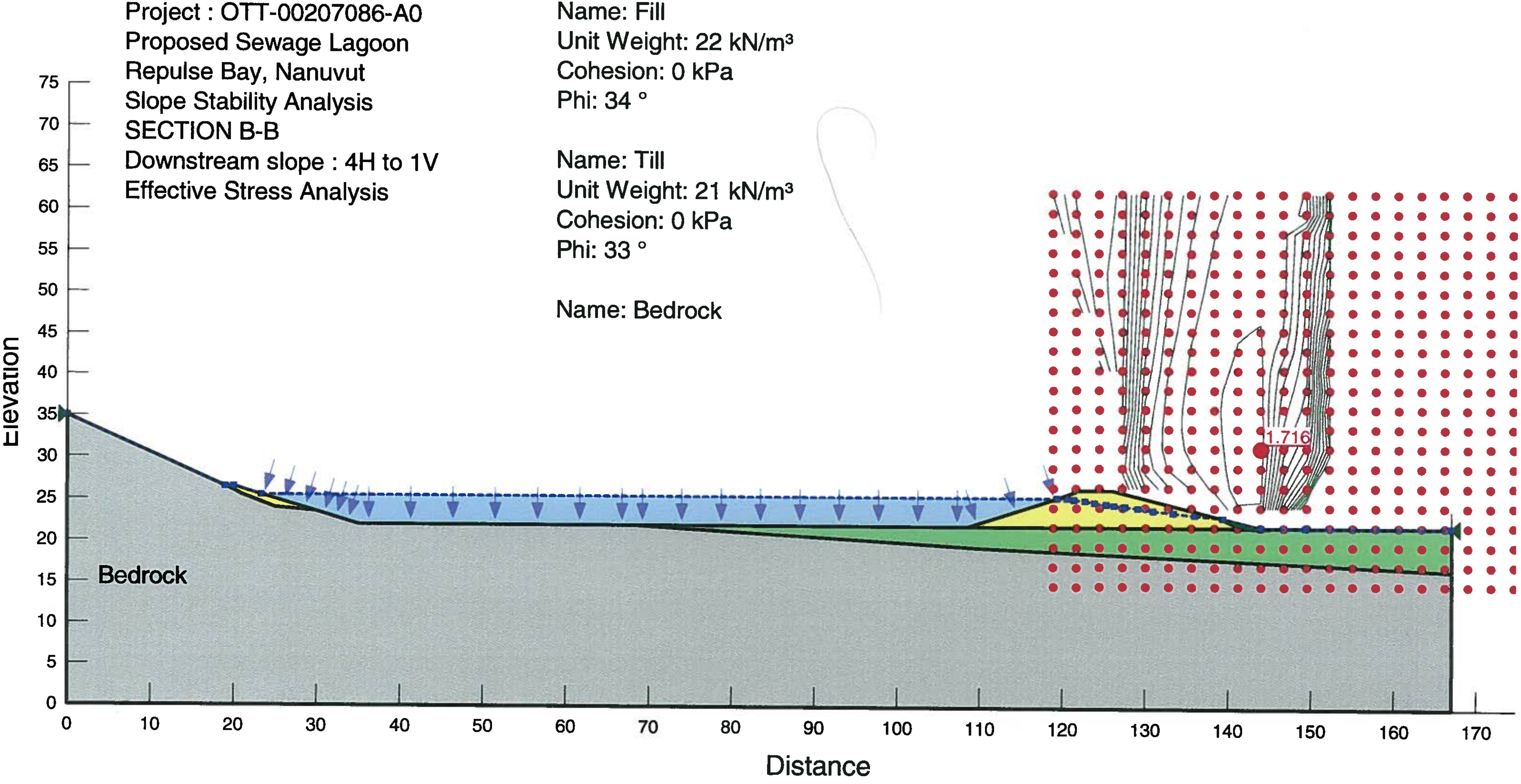
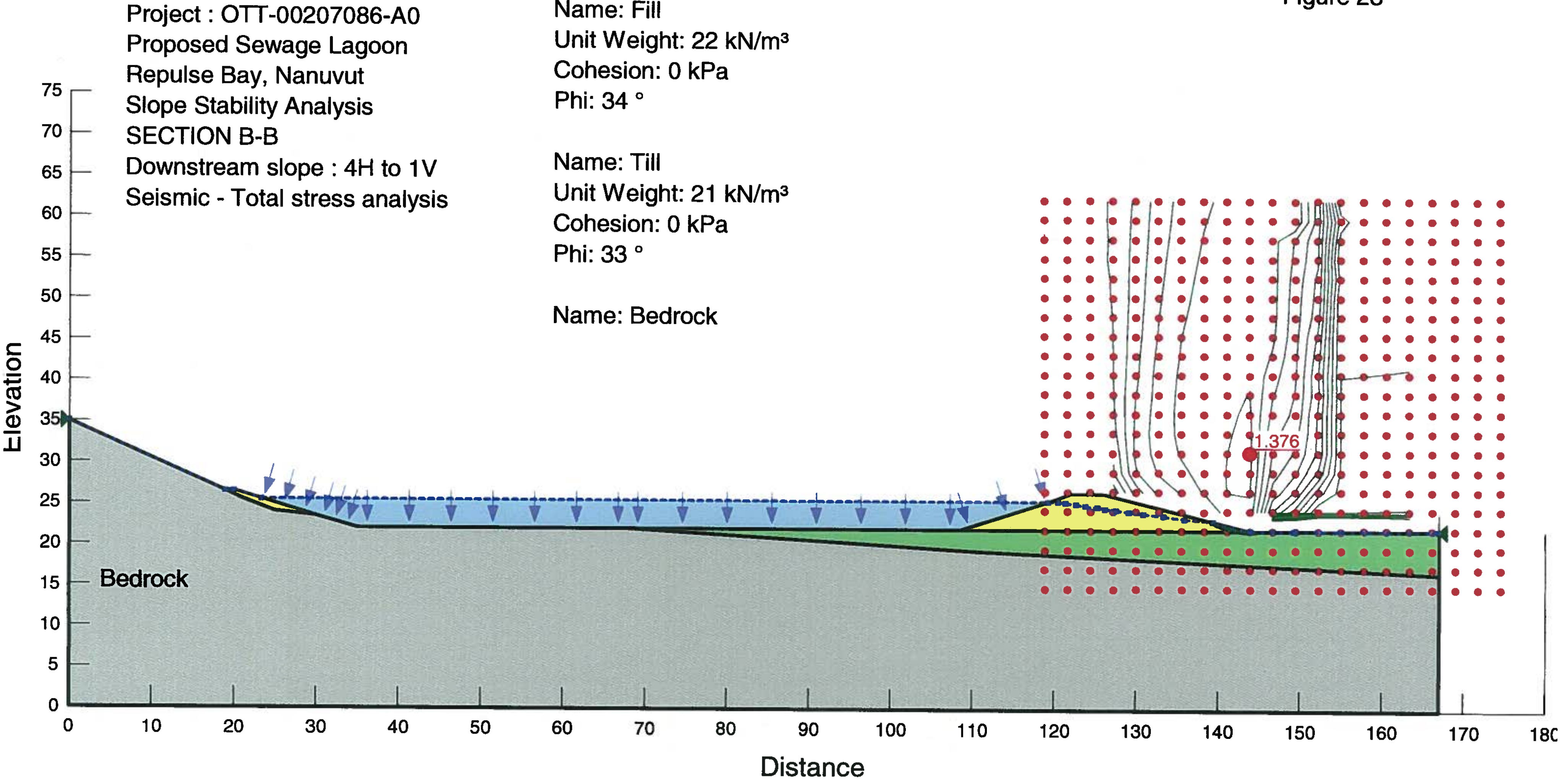

Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION B-B
Downstream slope : 4H to 1V
Effective Stress Analysis
Name: Fill
Unit Weight: 22 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °
Name: Bedrock
1.716
Bedrock
Elevation
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170

Figure 23



Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION B-B
Downstream slope : 4H to 1V
Seismic - Total stress analysis

Name: Fill
Unit Weight: 22 kN/m³
Cohesion: 0 kPa
Phi: 34 °

Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °

Name: Bedrock

Figure 24

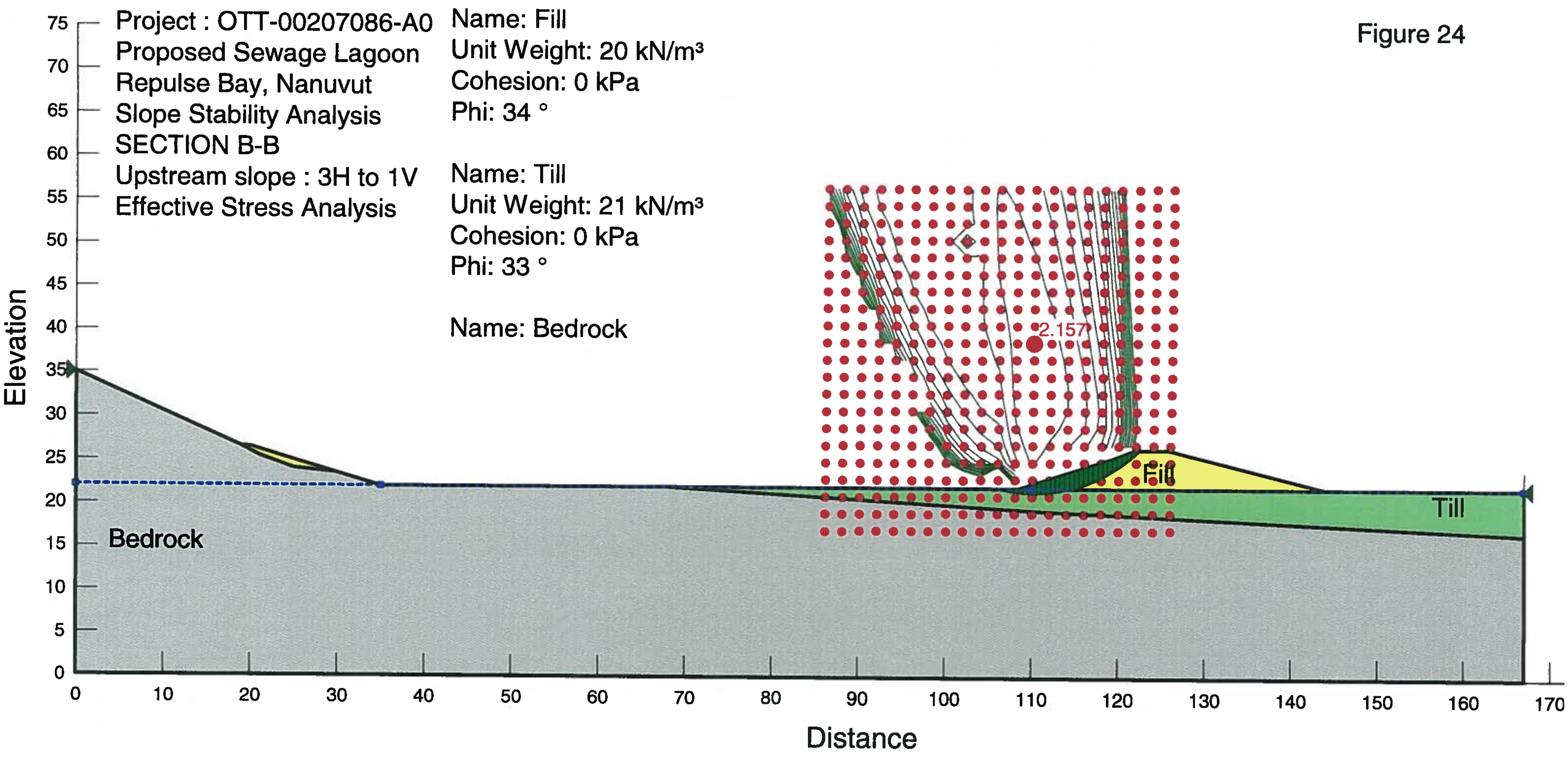
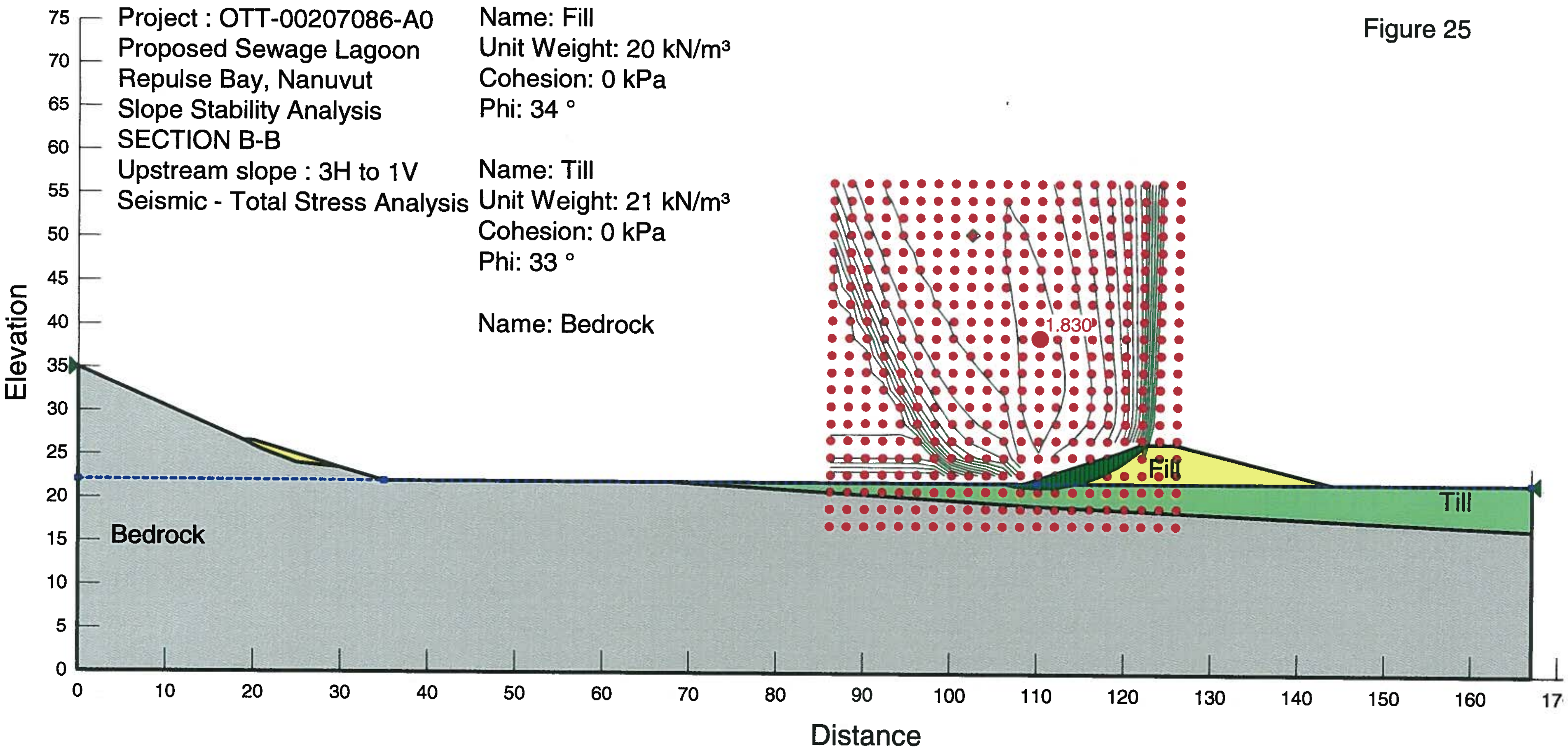
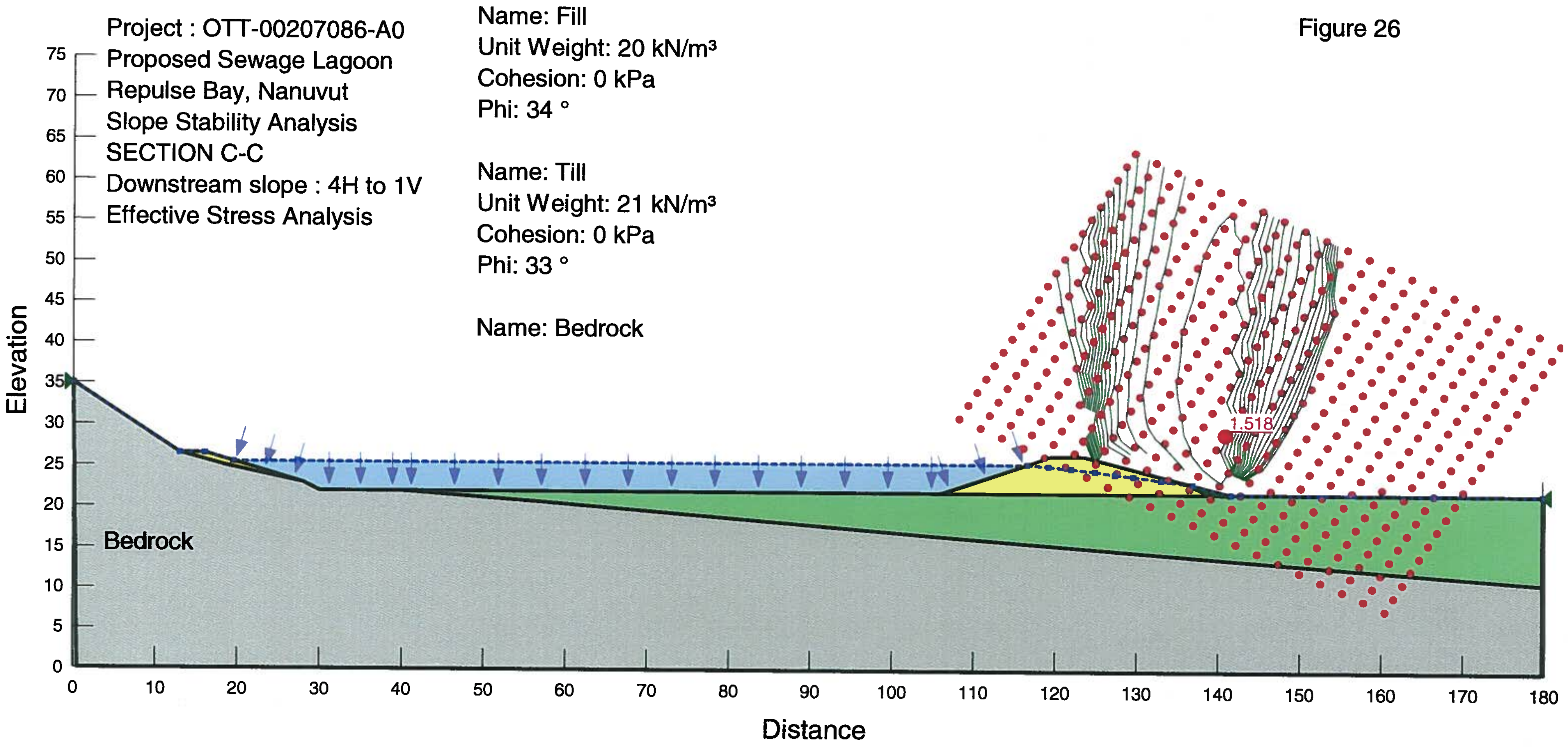

Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION B-B
Upstream slope : 3H to 1V
Effective Stress Analysis
Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °
Name: Bedrock
2.157
Fill
Till
Bedrock
Elevation
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170

Figure 25



Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION B-B
Upstream slope : 3H to 1V
Seismic - Total Stress Analysis
Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °
Name: Bedrock
1.830
Fill
Till
Bedrock
Elevation
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
17

Figure 26



Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION C-C
Downstream slope : 4H to 1V
Effective Stress Analysis

Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °

Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °

Name: Bedrock

Figure 27

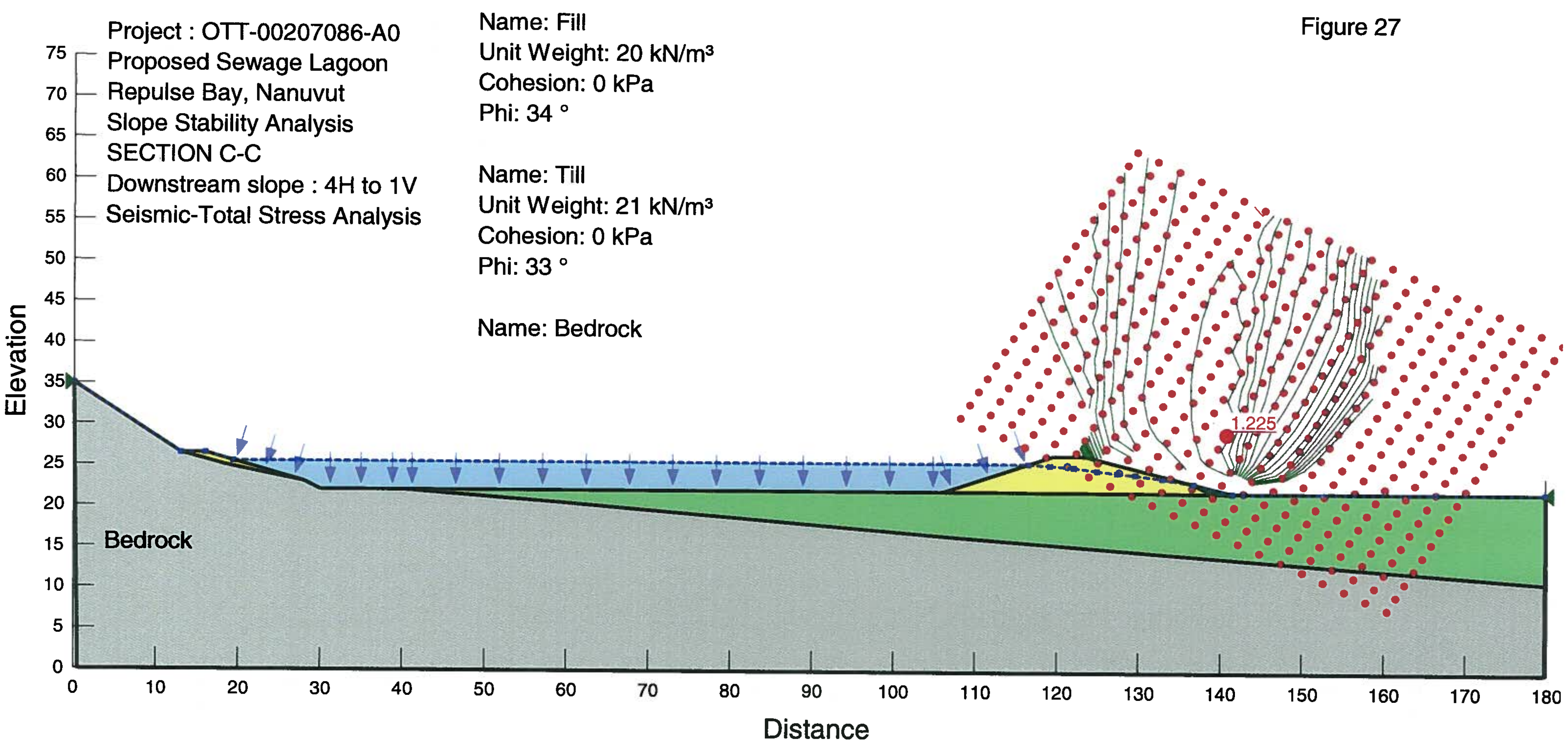
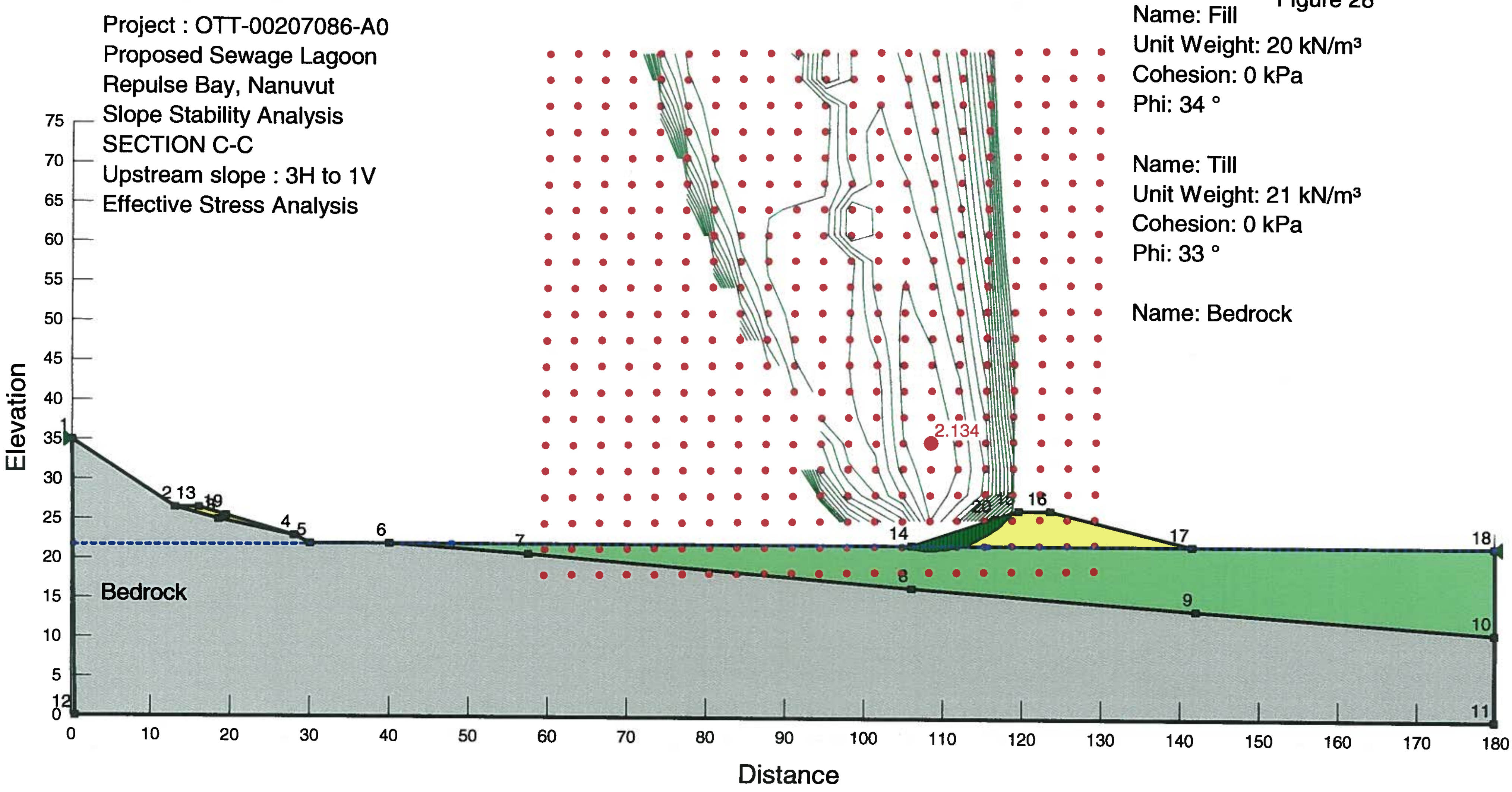

Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION C-C
Downstream slope : 4H to 1V
Seismic-Total Stress Analysis
Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °
Name: Bedrock
Bedrock
1.225
Elevation
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180

Figure 28



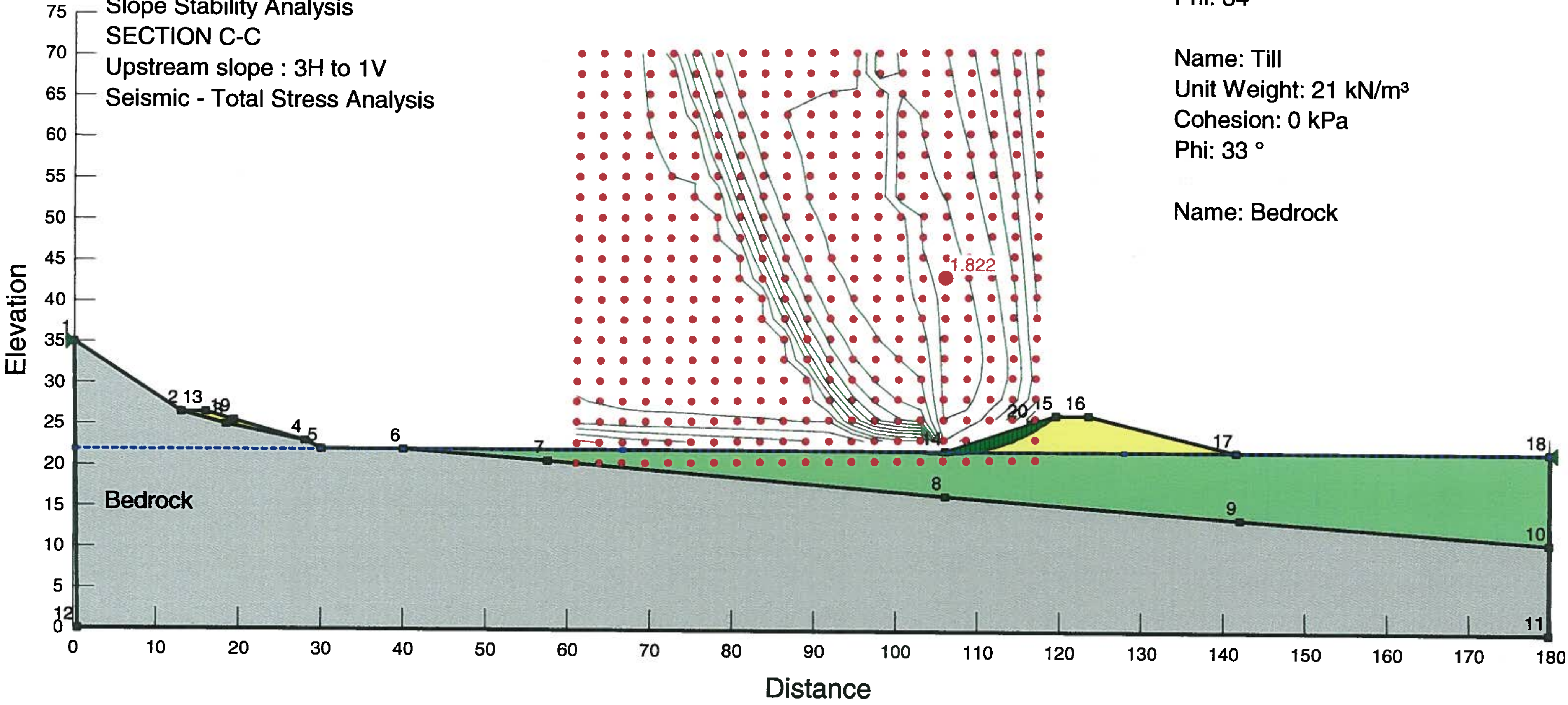
Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION C-C
Upstream slope : 3H to 1V
Effective Stress Analysis

Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °

Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °

Name: Bedrock

Figure 29



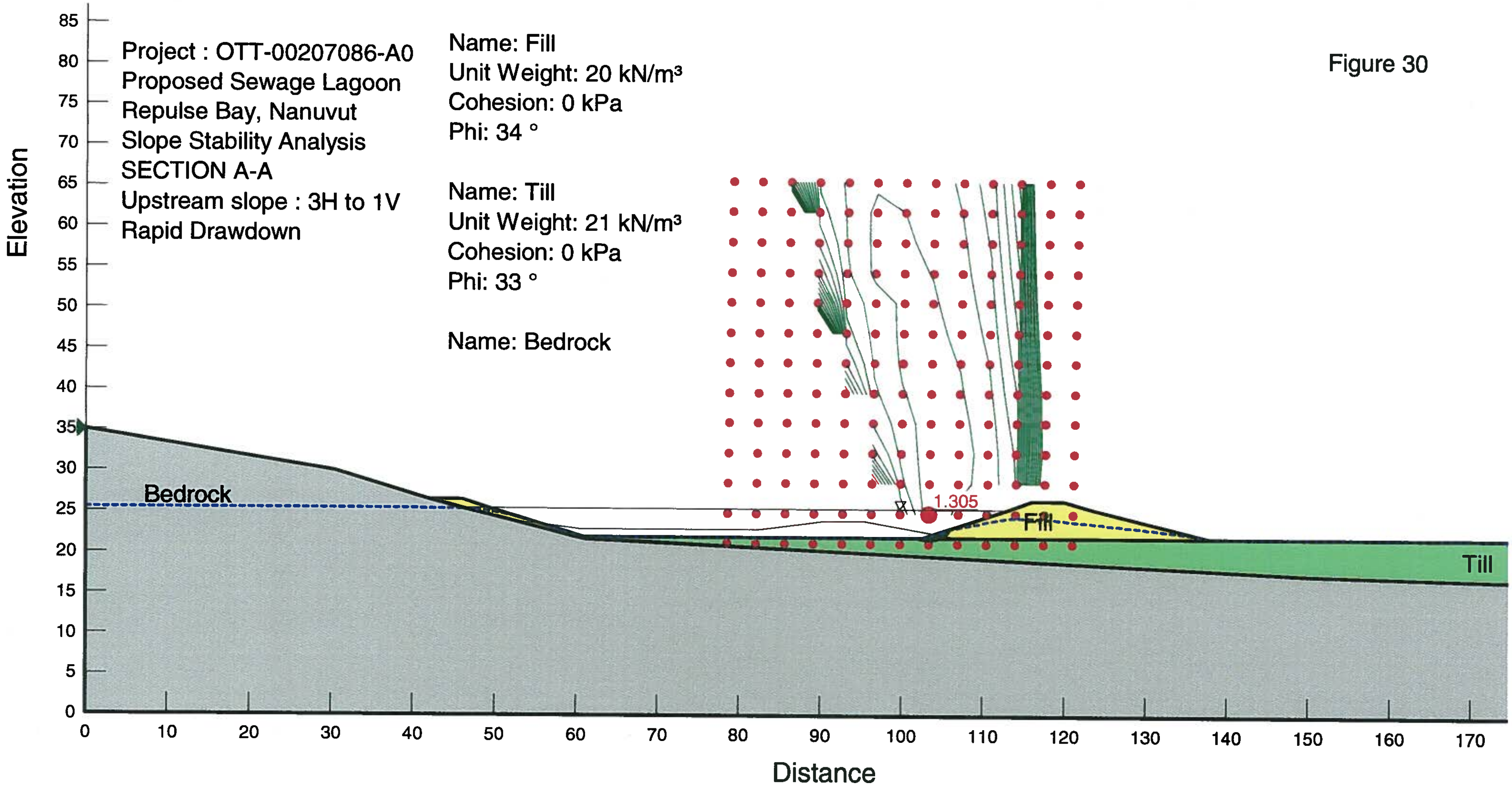
Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION C-C
Upstream slope : 3H to 1V
Seismic - Total Stress Analysis

Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °

Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °

Name: Bedrock

Figure 30



Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION A-A
Upstream slope : 3H to 1V
Rapid Drawdown
Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °
Name: Bedrock
1.305
Bedrock
Fill
Till
Elevation
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170

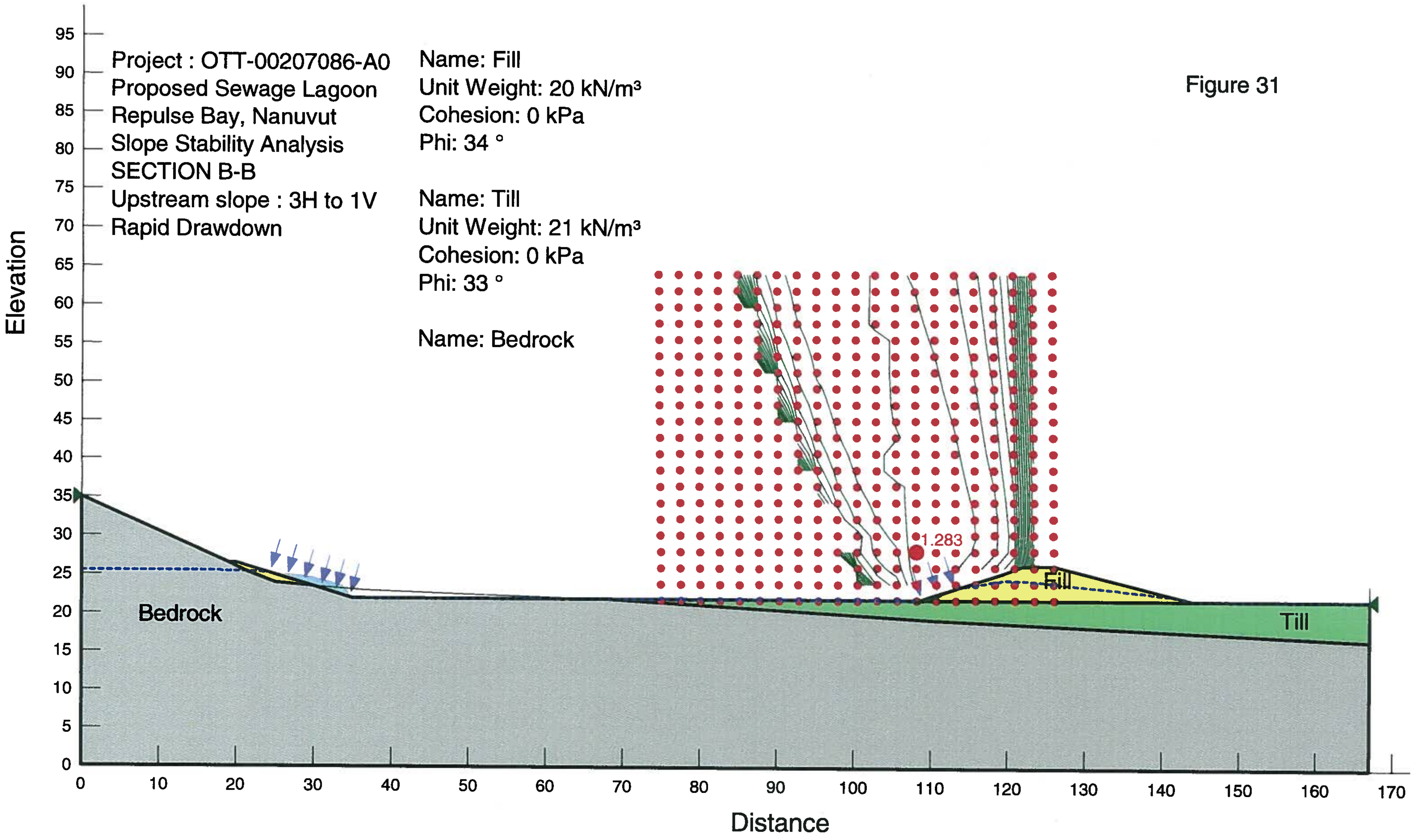
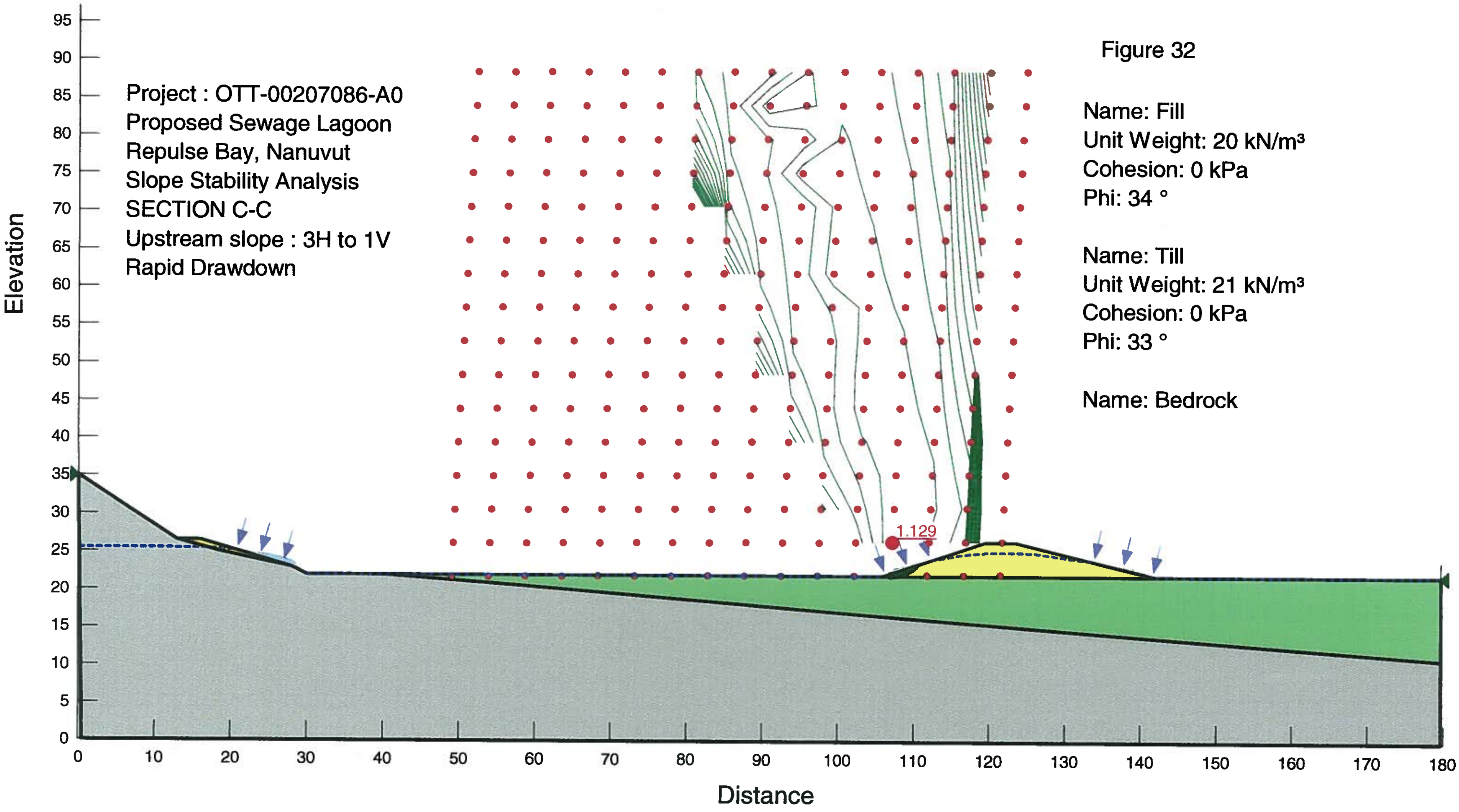


Figure 31

Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION B-B
Upstream slope : 3H to 1V
Rapid Drawdown
Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °
Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °
Name: Bedrock
1.283
Fill
Till
Bedrock
Elevation
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Distance
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170

Figure 32


Project : OTT-00207086-A0
Proposed Sewage Lagoon
Repulse Bay, Nanuvut
Slope Stability Analysis
SECTION C-C
Upstream slope : 3H to 1V
Rapid Drawdown

Name: Fill
Unit Weight: 20 kN/m³
Cohesion: 0 kPa
Phi: 34 °

Name: Till
Unit Weight: 21 kN/m³
Cohesion: 0 kPa
Phi: 33 °

Name: Bedrock

List of Distribution

Report Distributed To:

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