Soil Engineers Ltd.
CONSULTING ENGINEERS
GEOTECHNICAL • ENVIRONMENTAL • HYDROGEOLOGICAL • BUILDING SCIENCE
100 NUGGET AVENUE, TORONTO, ONTARIO M1S 3A7 • TEL: (416) 754-8515 • FAX: (416) 754-8516

BARRIE	MISSISSAUGA	OSHAWA	NEWMARKET	GRAVENHURST	PETERBOROUGH	HAMILTON
TEL: (705) 721-7863	TEL: (905) 542-7605	TEL: (905) 440-2040	TEL: (905) 853-0647	TEL: (705) 684-4242	TEL: (705) 748-0576	TEL: (905) 777-7956
FAX: (705) 721-7864	FAX: (905) 542-2769	FAX: (905) 725-1315	FAX: (416) 754-8516	FAX: (705) 684-8522	FAX: (905) 725-1315	FAX: (905) 542-2769

A REPORT TO
THE TOWN OF UXBBRIDGE

A SOIL INVESTIGATION FOR PROPOSED CULVERT REPLACEMENT

CENTENNIAL DRIVE TO NORTH OF BROCK STREET

TOWN OF UXBRIDGE

Reference No. 1204-S048

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1.0 **INTRODUCTION**

In accordance with written authorization dated April 11, 2012, from Mr. Dale Dionne, General Manager of SRM Associates, a soil investigation was carried out along a proposed culvert alignment from Centennial Drive to north of Brock Street in the Town of Uxbridge, for a proposed Culvert Replacement.

The purpose of the investigation was to reveal the subsurface conditions and to determine the engineering properties of the disclosed soils for the design and construction of the proposed project.

The findings and resulting geotechnical recommendations are presented in this Report.

2.0 SITE AND PROJECT DESCRIPTION

The Township of Uxbridge is situated on Peterborough Drumlin Field, where the lacustrine sand, silt, clay and water-laid till (reworked) in Lake Schomberg (glacial lake) has, in places, modified the drumlinized soil stratigraphy.

The investigation area is located between Toronto Street and Bascom Street, from Centennial Drive to north of Brock Street where an existing culvert is to be replaced with a new culvert to facilitate the discharge of flooding of an existing watercourse. The alignment of the culvert replacement passes through a built-up area of existing buildings, roadways and a parking lot.

The invert of the proposed culvert replacement is to be founded at El. 259.8± m at the south end, lowering to El. 259.4± m at the north end.

3.0 FIELD WORK

The field work, consisting of 5 boreholes to depths of 12.6 to 20.0 m, was performed on May 7, 8, 14, and 15, 2012, at the locations shown on the Borehole Location Plan and Subsurface Profile, Drawing No. 1. In addition, monitoring wells were installed to a depth of 6.1 m in 4 of the 5 boreholes, at Boreholes 2, 3, 4 and 5, for groundwater sampling and monitoring.

The boreholes were advanced at intervals to the sampling depths by a truck-mounted, continuous-flight and hollow-stem power-auger machine equipped for soil sampling. Standard Penetration Tests, using the procedures described on the enclosed “List of Abbreviations and Terms”, were performed at the sampling depths. The test results are recorded as the Standard Penetration Resistance (or ‘N’ values) of the subsoil. The relative density of the granular strata and the consistency of the cohesive strata are inferred from the ‘N’ values. Split-spoon samples were recovered for soil classification and laboratory testing.

The field work was supervised and the findings recorded by a Geotechnical Technician.

The sampling depths and the depths of the soil strata changes were determined based on the data collected from Trimble Geoexplorer 6000 Series Global Navigation Satellite System (GNSS) at each of the borehole locations. The x, y and z coordinates for each borehole, with a maximum of 10 cm differential, are listed in Table 1.

Table 1 - GNSS Coordinates

Borehole No.	**X Coordinate**	**Y Coordinate**	**Z Coordinate**
1	650315.084 m E	4885630.733 m N	263.054 m
2	650313.131 m E	4885655.627 m N	262.894 m
3	650297.761 m E	4885713.626 m N	265.746 m
4	650278.627 m E	4885755.665 m N	265.449 m
5	650299.054 m E	4885791.165 m N	264.438m

4.0 **SUBSURFACE CONDITIONS**

Detailed descriptions of the encountered subsurface conditions are presented on the Borehole Logs, comprising Figures 1 to 5, inclusive. The revealed stratigraphy is plotted on the subsurface profile on Drawing No. 1, and the engineering properties of the disclosed soils are discussed herein.

The investigation has revealed that beneath a pavement structure consisting of 50 mm and 100 mm of asphaltic concrete and 200 to 650± mm of granular fill, a layer of earth fill to depths ranging from 1.5± to 6.6± m below pavement surface and, in places, layers of peat and topsoil, the site is underlain by a complex stratigraphy of silty sand till and sandy silt till, silty clay till, silt, and gravelly sand encountered at various locations and depths throughout the site. A localized deposit of silty fine sand was found in Borehole 4 beneath the earth fill and topsoil. Occasional wet sand and silt seams and layers, cobbles and boulders were encountered in the tills.

The upper layers of native soils have generally been weathered to a depth of 1.0 to 2.0± m beneath the surface of the native soils.

4.1 **Existing Pavement Structure** (All Boreholes)

The revealed pavement structure disclosed by the boreholes is presented in Table 2.

Table 2 - Revealed Pavement Structure

Borehole No.	Asphalt Thickness (mm)	Granular Fill Thickness (mm)
1	50	610
2	50	300
3	100	200
4	100	650
5	50	650

The asphaltic concrete ranges in thickness from 50 to 100 mm, with an average of 70 mm. The granular fill ranges from 200 to 650 mm in thickness, with an average of 482 mm.

The granular base consists of crushed gravel and pit-run material with a trace to some silt. The water content varies from 3% to 11%, with a median of 4%, indicating that the granular fill is in a moist to very moist condition.

Grain size analyses were performed on 2 representative samples; the results are plotted on Figure 6. While both samples failed to meet the requirements for Granular ‘A’, one sample met the requirements for Granular ‘B’ with a silt content of approximately 10% (the other sample had a silt content of 17%). The granular fill is only considered suitable for subgrade stabilization and structural backfill.

Frequent sampling and laboratory testing of the granular material should be conducted to assess its suitability for reuse as a road subgrade stabilization material or as a granular sub-base for road construction.

4.2 **Topsoil** (Boreholes 2, 4, 5)

The original topsoil, approximately 20 to 250 cm thick, was encountered underlying the earth fill. The topsoil is dark brown in colour, indicating that it contains appreciable amounts of roots and humus. These materials are unstable and compressible under loads; therefore, the topsoil is considered to be void of engineering value. Due to its humus content, it will generate an offensive odour and may produce volatile gases under anaerobic conditions. Therefore, the topsoil must not be buried deeper than 1.2 m below the finished grade so it will not have an adverse impact on the environmental well-being of the developed areas.

Since the topsoil is considered void of engineering value, it can only be used for general landscaping and landscape contouring purposes. A fertility analysis can determine the suitability of the topsoil as a planting material.

4.3 **Peat** (Borehole 1)

The peat, 0.8 m in thickness, was encountered immediately beneath the earth fill, overlying the upper gravelly sand stratum. The revealed peat deposit extends from 2.9 to 3.7 m from the prevailing ground surface.

The peat is amorphous-granular in texture and contains fine fibrous decaying vegetation. It was formed by the progressive accumulation of incompletely decomposed plants in a wet environment. The peat is black in colour and emits a musty odour of decaying vegetation.

The obtained ‘N’ value of 5 blows per 30 cm of penetration shows the deposit is very weak in shear strength and the amount of consolidation will correspond to the load applied.

The natural water content value was determined to be 205%. The very high water content value shows that the peat is highly compressible and would be unstable under loads. Since the peat is derived from vegetation, it will generate volatile gases under anaerobic conditions.

The peat is void of engineering value and cannot support structural loads.

4.4 **Earth Fill** (All Boreholes)

The earth fill consists of silty clay and silty sand materials and extends to depths ranging from 1.5 to 6.6 m below the prevailing ground surface. Sample examinations show that the silty clay fill contains a trace to some sand and a trace of gravel. Brick pieces were encountered in the silty sand fill in Borehole 3 and occasional wood debris was found in Boreholes 3 and 5.

The original topsoil was encountered in 3 of 5 boreholes, showing the site likely had not been stripped prior to filling the areas.

Sample examinations reveal that the composition of the silty clay fill and silty sand fill are similar to the underlying silty clay till and silty sand till, showing that the material is the spoil from vicinal construction.

The water content values of the samples were found to range from 2% to 61%, with a median of 19%, showing the fill is in a damp to wet, generally wet or saturated condition. The high moisture content indicates that the earth fill contains original topsoil inclusions.

The obtained ‘N’ values range from 2 blows per 30 cm to 28 blows per 30 cm, with a median of 5 blows per 30 cm of penetration. This shows that the fill was loosely placed with minimal compaction and has since partially self-consolidated. The fill is considered to be unsuitable to support structures.

Grain size analyses were performed on 2 representative samples; the results are plotted on Figure 7.

As noted, the relative density of the fill is generally loose and non-uniform. In using the fill for structural backfill or for pavement construction, it should be subexcavated, inspected, sorted free of serious topsoil inclusions, proof-rolled and properly recompacted.

The fill is amorphous in structure; it will ravel and is susceptible to collapse in steep cuts.

One must be aware that in cuts in the till, the sides are prone to sudden collapse, particularly if the fill is in a wet condition.

One must also be aware that the samples retrieved from boreholes 10 cm in diameter may not be truly representative of the geotechnical and environmental quality of the fill, and do not indicate whether the topsoil beneath the earth fill was completely stripped. This should be further assessed by laboratory testing and/or test pits.

4.5 **Silty Clay Till** (Boreholes 1, 3 and 5)

The silty clay till was encountered beneath the original topsoil or the stratum of silt. It consists of a random mixture of soils; the particle sizes range from clay to gravel, with the clay fraction exerting the dominant influence on its soil properties. The structure of the till is heterogeneous and amorphous, showing it is a glacial deposit and has been reworked by the past glaciations. It contains a trace of sand and has a trace of gravel.

The samples were found to contain occasional wet sand and silt seams and layers. Hard resistance was occasionally encountered during augering, showing the till might be embedded with occasional cobbles and boulders.

The obtained 'N' values range from 9 to 16, with a median of 10 blows per 30 cm of penetration, indicating that the consistency of the silty clay till is stiff to very stiff.

A grain size analysis was performed on 1 representative sample; the gradation is plotted on Figure 8.

The Atterberg Limits of 1 representative sample and the water content values of all of the samples were determined. The results are plotted on the Borehole Logs and summarized below:

Liquid Limit	22%
Plastic Limit	15%
Natural Water Content	8% to 17% (median 13%)

The above results show that the silty clay till is a cohesive material with low plasticity. The natural water content values generally lie from below its plastic limit to close to its liquid limit, confirming the generally stiff consistency of the clay determined from the ‘N’ values.

Based on the above findings, the following engineering properties are deduced:

- High frost susceptibility and high soil-adfreezing potential.
- Low water erodibility.
- Low permeability, with an estimated coefficient of permeability of 10^{-6} cm/sec and runoff coefficients of:

Slope	
0% - 2%	0.15
2% - 6%	0.20
6% +	0.28

- A cohesive soil, its shear strength is primarily derived from consistency which is inversely related to its moisture content. It contains sand; therefore, its shear strength is augmented by internal friction.
- It will generally be stable in a relatively steep cut; however, prolonged exposure will allow the wet sand and silt seams and layers to become saturated, which may lead to localized sloughing.
- A very poor pavement-supportive material, with an estimated California Bearing Ratio (CBR) value of 3% or less.
- Moderate corrosivity to buried metal, with an estimated electrical resistivity of 4000 ohm·cm.

4.6 **Sandy Silt Till** and **Silty Sand Till** (Boreholes 2, 3, 4, 5)

These deposits are found underlying the original topsoil or silt, silty clay till or silty fine sand strata. They consist of a random mixture of particle sizes ranging from clay to gravel, with either sand or silt being the dominant fraction. They are amorphous in structure showing the deposits are glacial tills, parts of which have been reworked by the glacial lake.

Tactile examinations of the soil samples indicated that the tills are dense, displaying some cohesion. The samples were found to contain occasional sand layers which are often wet.

The obtained ‘N’ values range from 3 per 30 cm to 92 per 23 cm, with a median of 50 blows per 15 cm. This shows that the relative density of the tills is very loose to very dense, being generally very dense. The loose condition occurs in the upper layers, showing the zone has been weathered.

Intermittent hard resistance to augering was encountered, indicating the presence of cobbles and boulders in the strata.

The natural water content values of the samples were determined; the results are plotted on the Borehole Logs. The values range from 7% to 20%, with a median of 10%, confirming the generally very dense condition disclosed by the sample examinations.

Grain size analyses were performed on 4 representative samples; the results are plotted on Figure 9.

According to the above findings, the engineering properties are listed below:

- Highly frost susceptible and moderately water erodible.
- Low permeability, with an estimated coefficient of permeability of 10^{-4} to 10^{-6} cm/sec and runoff coefficients of:

Slope	
0% - 2%	0.07 to 0.15
2% - 6%	0.12 to 0.20
6% +	0.18 to 0.28

- Frictional soils, their shear strength is primarily derived from internal friction, and is augmented by cementation. Therefore, their strength is density dependent.
- They will be stable in steep cuts; however, under prolonged exposure, localized sheet collapse will likely occur.
- Fair pavement-supportive materials, with a CBR value of 8%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 5000 ohm/cm.

4.7 **Silt** (Boreholes 1, 2, 3, 5)

Silt deposits were found at depths of 4.4 to 7.1 m. These deposits were encountered beneath the earth fill and topsoil layers or gravelly sand, overlying and underlying the silty clay till. In Borehole 2, the silt lies between layers of silty sand till and sandy silt till.

Sample examinations show that the silt is loose and in a wet condition. It contains a trace to some clay and occasional fine sand.

The natural moisture content values of the samples were found to range from 16% to 23%, with a median of 20%, confirming the wet condition.

The obtained ‘N’ values range from 5 to 26 with a median of 12, indicating that the relative density of the silt is loose to compact, being generally compact.

Grain size analyses were performed on 3 representative samples, and the gradations are plotted on Figure 10.

According to the above findings, the engineering properties relating to the project are given below:

- Highly frost susceptible, with high soil-adfreezing potential.
- Highly water erodible; it is susceptible to migration through small openings under seepage pressure.
- Relatively pervious, with an estimated coefficient of permeability of 10^{-4} to 10^{-6} cm/sec and runoff coefficients of:

Slope	
0% - 2%	0.07 to 0.15
2% - 6%	0.12 to 0.20
6% +	0.18 to 0.28

- The soil has a high capillarity and water retention capacity.
- A frictional soil, its shear strength is density dependent. Due to its dilatancy, the strength of the wet silt is susceptible to impact disturbance; i.e., the disturbance will induce a build-up of pore pressure within the soil mantle, resulting in soil dilation and a reduction in shear strength.

- In excavation, the moist silt will be stable in relatively steep cuts, while the wet silt will slough and run slowly with seepage bleeding from the cut face. It will boil with a piezometric head of 0.4 m.
- A poor pavement-supportive material, with an estimated CBR value of 4%.
- Moderately corrosive to buried metal, with an estimated electrical resistivity of 4500 ohm·cm.

4.8 **Silty Fine Sand** (Borehole 4)

The silty fine sand was found underlying the original topsoil at a depth of 5.5 m.

Sample examinations show that the sand is non-cohesive. It is generally in a wet condition and becomes highly dilatant when shaken by hand. Occasional sand seams and layers were found in the deposit; the laminated structure shows the sand is a lacustrine deposit.

The obtained ‘N’ value in the fine sand was 4. The relative density of the silt is thus inferred as very loose.

The natural water content value of the sample was determined to be 27%, indicating the soil is in a wet to water-bearing condition; the value is plotted on the Borehole Logs.

A grain size analysis was performed on 1 representative sample and the result is plotted on Figure 11.

According to the above findings, the engineering properties relating to the project are given below:

- Highly frost susceptible, with high soil-adfreezing potential.
- Highly water erodible; susceptible to migration through small openings under seepage pressure.
- Medium permeability, with an estimated coefficient of permeability of 10^{-6} cm/sec, and runoff coefficients of:

Slope	
0% - 2%	0.15
2% - 6%	0.20
6% +	0.28

- A frictional soil, its shear strength is density dependent. Due to its dilatancy, the strength of the wet silt is susceptible to impact disturbance; i.e., the disturbance will induce a build-up of pore pressure within the soil mantle, resulting in soil dilation and a reduction in shear strength.
- In relatively steep cuts, the sand will be stable in a damp to moist condition, but will slough if it is wet and run with water seepage.
- A fair pavement-supportive material, with an estimated CBR value of 10%.
- Moderately low corrosivity to buried metal, with an estimated electrical resistivity of 5000 ohm/cm.

4.9 **Gravelly Sand** (Boreholes 1, 3, 4, 5)

The gravelly sand was encountered below the layer of peat and, at a deeper depth, below the stratum of silt in Borehole 1. It contains a trace to some silt, with occasional boulders.

The gravelly sand extends beyond the maximum investigated depth in Boreholes 3, 4 and 5.

The obtained ‘N’ values range from 46 blows per 30 cm to 50 blows per 8 cm, with a median of 50 blows per 15 cm. This indicates that its relative density is dense to very dense, being generally very dense. The gravelly sand underlying the peat in Borehole 1 has an ‘N’ value of 4 and is in a very loose condition.

The natural water content values determined by laboratory testing were found to be 6% to 11%, with a median of 8%. Due to the pervious nature of the gravelly sand, a portion of the water in the gravelly sand likely was lost during sampling. The laboratory determined value is expected to not represent the in situ condition of the sand. The gravelly sand underlying the peat in Borehole 1 has a water content value of 21% and is in a wet condition.

Grain size analyses were performed on 2 representative samples; the results are plotted on Figure 12.

Based on sample examination, the following engineering properties are deduced:

- Low frost susceptibility and high water erodibility.
- Pervious, with an estimated coefficient of permeability of 10^{-3} cm/sec and runoff coefficients of:

Slope	
0% - 2%	0.04
2% - 6%	0.09
6% +	0.13

- A frictional soil, its shear strength is derived from internal friction and is therefore directly dependent on soil density.

- In cuts, the moist sand will be stable in a relatively steep slope and the dry sand will slough readily. It will run with water seepage and boil under a piezometric head of 0.4 m.
- A fair to good material to support flexible pavement, with an estimated CBR value of 15% to 25%.
- Low corrosivity to buried metal, with an estimated electrical resistivity of 6500 ohm·cm.

4.10 Compaction Characteristics of the Revealed Soils

The obtainable degree of compaction is primarily dependent on the soil moisture and, to a lesser extent, on the type of compactor used and the effort applied. As a general guide, the typical water content values of the revealed soils for Standard Proctor compaction are presented in Table 3.

Table 3 - Estimated Water Content for Compaction

Soil Type	Determined Natural Water Content (%)	Water Content (%) for Standard Proctor Compaction	
		100% (optimum)	Range for 95% or +
Granular Fill	3 to 11 (median 4)	6	3 to 11
Earth Fill	2 to 61 (median 19)	12	6 to 20
Silt	16 to 23 (median 20)	13	8 to 17
Silty Fine Sand	27	11	6 to 16
Silty Clay Till	8 to 17 (median 13)	15	11 to 20

Table 3 - Estimated Water Content for Compaction (cont'd)

Soil Type	**Determined Natural Water Content (%)**	**Water Content (%) for Standard Proctor Compaction**	
		100% (optimum)	**Range for 95% or +**
Silty Sand and Sandy Silt Tills	7 to 20 (median 10)	9	5 to 14
Drained Gravelly Sand	6 to 11 (median 8)	6	3 to 12

Based on the above findings, the in situ granular fill, silty clay till, and gravelly sand are generally suitable for a 95% or + Standard Proctor compaction. The silty fine sand and a portion of the earth fill are too wet and will require aeration or mixing with drier soils prior to Standard Proctor compaction. The soils can be aerated by spreading them thinly on the ground in the dry, warm weather. A portion of the earth fill is on the dry side of the optimum and will require wetting prior to structural compaction, particularly in the dry, warm weather and in areas where compaction is best performed on the wet side of the optimum.

The tills should be compacted using a heavy-weight, kneading-type roller. The earth fill and sands can be compacted by a smooth roller with or without vibration, depending on the water content of the soils being compacted. The lifts for compaction should be limited to 20 cm, or to a suitable thickness as assessed by test strips performed by the equipment which will be used at the time of construction.

The presence of boulders will prevent transmission of the compactive energy into the underlying material to be compacted. If an appreciable amount of boulders over 15 cm in size is mixed with the material, it must either be sorted or must not be used for structural backfill.

5.0 GROUNDWATER CONDITIONS

The boreholes were checked for groundwater upon their completion. The data are plotted on the borehole logs and summarized in Table 4.

Table 4 - Groundwater Levels

		Soil Colour Changes Brown to Grey	Seepage Encountered During Augering		Groundwater Level On Completion	
BH No.	**Depth (m)**	**Depth (m)**	**Depth (m)**	**Comment**	**Depth (m)**	**El. (m)**
1	12.7	3.7	4.0	Appreciable	0*	263.1
2	12.6	2.9	4.2	Moderate	4.9	258.0
3	20.0	3.6	4.1	Moderate	3.7	262.1
4	20.0	1.4	2.0	Some	2.4	263.1
5	20.0	0.7	2.7	Some	5.5	258.9

*Artesian condition, groundwater flowing out of the borehole.

Groundwater was encountered at depths ranging from 2.4± to 5.5± m from the prevailing ground surface, or El. 258.0± to El. 263.1± m. A subterranean artesian condition and artesian groundwater were encountered in the stratum of gravelly sand at a depth of over 12.0 m upon completion of Borehole 1. Groundwater was seen spouting out at the surface, showing the water in the gravelly sand stratum, in places, is under artesian condition. Some to moderate seepage was encountered in the earth fill, silty clay till and silty sand till strata in Boreholes 2 to 5, inclusive.

The colour of the revealed soils changed from brown to grey at depths ranging from 0.7 to 3.6 m. This indicates that the upper zone of the stratigraphy has oxidized and the groundwater regime is inferred to lie in the grey soils in the lower zone.

The groundwater yield from the silty clay and sandy silt tills, due to their low to relatively low permeabilities, is expected to be small and limited in quantity. The yield from the silty sand till, silt and gravelly sand will be moderate to appreciable and persistent. Groundwater will fluctuate with the seasons.

6.0 DISCUSSION AND RECOMMENDATIONS

The investigation has revealed that beneath a pavement structure consisting of 50 mm and 100 mm of asphaltic concrete and 200 to 650± mm of granular fill, a layer of earth fill to depths ranging from 1.5± to 6.6± m below the pavement surface and, in places, layers of peat and topsoil, the site is underlain by a complex stratigraphy of very loose to very dense, generally very dense silty sand till and sandy silt till; stiff to very stiff, generally stiff silty clay till; loose to compact, generally compact silt; and very loose to very dense, generally very dense gravelly sand encountered at various locations and depths throughout the site. A localized deposit of very loose silty fine sand was found in Borehole 4 beneath the earth fill and topsoil. Occasional wet sand and silt seams and layers, cobbles and boulders were encountered in the tills.

The upper layers of native soils have generally been weathered to a depth of 1.0 to 2.0± m beneath the surface of the native soils.

Groundwater was encountered at depths ranging from 2.4± to 5.5± m from the prevailing ground surface, or El. 258.0± to El. 263.1± m. An artesian condition was present at Borehole 1, resulting in the groundwater flowing spontaneously to the surface. Slight to moderate seepage was encountered in the earth fill, silty clay till and silty sand till strata in Boreholes 2 to 5, inclusive.

The colour of the revealed soils changed from brown to grey at depths of 0.7 to 3.6 m. This indicates that the upper zone of the stratigraphy has oxidized and the groundwater regime is inferred to lie in the grey soils in the lower zone.

The groundwater yield from the silty clay and sandy silt tills, due to their low to relatively low permeability, is expected to be small and limited in quantity. The yield from the silty sand till, silt and gravelly sand will be moderate to appreciable and persistent. Groundwater will fluctuate with the seasons.

The geotechnical findings which warrant special consideration are presented below:

1. The existing granular fill fails to meet the OPS Gradation Specification Requirements for Granular 'A' and a portion of the granular fill fails to meet the specification for Granular 'B'. Nevertheless, the granular fill can be used for road base material, if salvaged, for structural backfill and as a road subgrade stabilization material.
2. The original topsoil, 20 to 250 cm thick, will generate volatile gases under anaerobic conditions. It is unsuitable for engineering applications and must be stripped. For the environmental and geotechnical well-being of future development, it should not be buried over 1.2 m below the proposed finished grade or below any structures.
3. The earth fill, in its present state, is only suitable for supporting lightly loaded foundations or it can be subexcavated, inspected, sorted free of serious topsoil inclusions or any deleterious materials, if encountered, aerated and properly compacted.
4. Due to the occurrence of earth fill, topsoil and peat deposits, the footing subgrade must be inspected by a geotechnical engineer or a geotechnical technician under the supervision of a geotechnical engineer, to assess its suitability for bearing the designed foundations.
5. Excavation into the very stiff to hard and dense to very dense tills containing boulders may require extra effort and the use of a heavy-duty backhoe. Boulders larger than 15 cm in size are not suitable for structural backfill.

6. Earth fill extends to depths of up to 6.6 m, which indicates that the suitable founding level for the culvert is at least 1.1 m below the groundwater level. In order to limit water seepage that may impact the stability of the footing subgrade, the spread and/or strip foundations are to be constructed within sheeting enclosures.
7. As noted, artesian and subterranean artesian conditions were encountered in the gravelly sand stratum at a depth of 12.0 m. In view of the founding level of the proposed culvert replacement, the impact on the stability of the subgrade may need special consideration. However, should the condition occur, precautionary measures must be carried out to prevent subgrade soils being washed out.
8. In order to ensure that the integrity of the subgrade for the foundations and the stability of existing underground services, their location must be determined properly and properly shored against disruption by the construction of the culvert replacement. The sides of the excavation into the earth fill and filled sewer trenches must be properly protected against sloughing.

The recommendations appropriate for the project described in Section 2.0 are presented herein. One must be aware that the subsurface conditions may vary between boreholes. Should this become apparent during construction, a geotechnical engineer must be consulted to determine whether the following recommendations require revision.

6.1 **Culvert Foundations and Construction**

As noted, the proposed founding subgrade at the south end is at El. 259.8+ m lowering to El. 259.4+ m at the north end. The founding soils, based on the borehole results, are peat and loose gravelly sand (Borehole 1), topsoil (Borehole 2), silty sand fill and sandy silt fill (Borehole 3), very loose silty fine sand (Borehole 4) and stiff silty clay till (Borehole 5).

This shows the sands at this level (excluding peat) are only suitable to bear foundation designed with net Allowable Soil Pressure (SLS) of 30 kPa with Factored Ultimate Soil Bearing Pressure of 50 kPa.

Higher Maximum Allowable Pressures (SLS) with Factored Ultimate Soil Bearing Pressures (ULS) on natural soil, and corresponding suitable founding levels are presented in Table 5.

Table 5 - Founding Levels

	Recommended Maximum Allowable Soil Pressure (SLS)/ Factored Ultimate Soil Bearing Pressure (ULS) and Suitable Founding Levels			
	100 kPa (SLS) 180 kPa (ULS)		**250 kPa (SLS) 400 kPa (ULS)**	
BH No.	**Depth (m)**	**El. (m)**	**Depth (m)**	**El. (m)**
1	6.2 or +	256.9 or -	12.2 or +	250.9 or -
2	6.2[A]	256.7[A]	9.1[B]	253.8[B]
3	7.0 or +	258.8 or -	10.0 or +	255.8 or -
4	7.5 or +	258.0 or -	8.5 or +	257.0 or -
5	5.5[C]	258.9[C]	8.5 or +	255.9 or -

[A] Due to loose silt found in the middle of the layer, the Maximum Allowable Soil Pressure (SLS) should be linearly reduced from 100 kPa to 75 kPa at depth of 8.0 m.

[B] Due to compact sand till found beneath the silt, the the Maximum Allowable Soil Pressure (SLS) should be linearly reduced from 250 kPa to 150 kPa at a depth of 10.7 m.

[C] Due to loose silt found beneath the till, the Maximum Allowable Soil Pressure (SLS) should be linearly reduced from 100 kPa to 75 kPa at depth of 7.1 m.

As shown above, the suitable founding level lies below the water table. The foundation must be constructed in sheeting enclosures driven into the stiff to hard or dense to very dense tills to facilitate suitable conditions for the footing construction.

In this case the loose fill, peat and weathered soil must be excavated and the subgrade must be inspected and proof-rolled. A test pit programme must be carried out prior to or during construction to verify the suitability of the in situ soils. Where unsuitable subgrade is detected, it must be replaced with properly compacted engineered fill to correspond to the designed foundations.

Founding the culvert on piles driven below the firm silty clay till and/or the silt is not recommended. This may allow artesian and subterranean artesian groundwater from the gravelly sand stratum to unstabilize the subgrade.

For foundations designed with a Maximum Allowable Soil Pressure (SLS) of 100 kPa or over, the loose fill, peat and weathered soil extending below the proposed founding level of the culvert must be excavated and the excavation must be backfilled with 20-mm Crusher-Run Limestone (or equivalent), compacted to 100% of its maximum Standard Proctor dry density up to the proposed founding level.

The proposed upstream and downstream ends have been designed to be protected by 300 mm in diameter riverstone. A minimum thickness of 600 mm is considered to be appropriate. Cut-off wall foundations must be constructed upstream from the culvert to prevent runoff from eroding the founding subgrade during flooding.

In order to ensure that the integrity of the subgrade for the foundations and underground services is not compromised during excavation, drawings must be reviewed and the depths and locations of the foundations and underground services must be identified. Otherwise, such foundations and services must be exposed for inspection prior to excavation for the culvert replacement.

To ensure that the condition of the subgrade is compatible with the design requirements, the subgrade must be inspected by a geotechnical engineer, or a geotechnical technician under the supervision of a geotechnical engineer, to assess its suitability for bearing the designed foundations.

6.2 Wing Wall Construction

The backfill against the wing walls must consist of free-draining material and subdrains must be provided. This measure is to prevent a build-up of ice pressure behind the wall which would impact its structural integrity. Rip-rap should be placed along the wet perimeter to prevent further wave erosion, and the side slopes of the embankment should be sodded to protect against rainwash erosion.

6.3 Engineered Fill

Engineered fill can replace the loose soils for foundation construction where earth fill is required to raise the site or when extended footings are required. The engineering requirements for a certifiable fill for pavement construction, municipal services, slab-on-grade, and footings designed with a Maximum Allowable Soil Pressure (SLS) of 150 kPa and a Factored Ultimate Soil Bearing Pressure (ULS) of 225 kPa are presented below:

1. All of the topsoil and peat must be removed. Any badly weathered soils must be subexcavated, sorted free of topsoil inclusions and deleterious materials, aerated and properly compacted to 98% of their maximum Standard Proctor dry density. The subgrade surface must be inspected and proof-rolled prior to any fill placement.

2. Inorganic soils must be used, and they must be uniformly compacted in lifts 20 cm thick to 98% or + of their maximum Standard Proctor dry density up to the proposed finished grade and/or slab-on-grade subgrade. The soil moisture must be properly controlled on the wet side of the optimum.

   If the structure foundations are to be built soon after the fill placement, the densification process for the engineered fill must be increased to 100% of the maximum Standard Proctor compaction.
3. If imported fill is to be used, the hauler is responsible for its environmental quality and must provide a document to certify that it is free of hazardous contaminants.
4. If the engineered fill is to be left over the winter months, adequate earth cover, or equivalent, must be provided for protection against frost action.
5. The engineered fill must extend over the entire graded area; the fill envelope and finished elevations must be clearly and accurately defined in the field and be precisely documented by qualified surveyors. Foundations partially on engineered fill must be reinforced and designed by a structural engineer to properly distribute the stress induced by the abrupt differential settlement (estimated to be 15± mm) between the natural soils and engineered fill.
6. The engineered fill must not be placed during the period from late November to early April, when freezing ambient temperatures occur either persistently or intermittently. This is to ensure that the fill is free of frozen soils, ice and snow.
7. Where the ground is wet due to subsurface water seepage, an appropriate subdrain scheme must be implemented prior to the fill placement, particularly if it is to be carried out on sloping ground.
8. Where the fill is to be placed on sloping ground steeper than 1 vertical: 3 horizontal, the face of the sloping ground must be flattened to 3+ so that it is suitable for safe operation of the compactor and the required compaction can be obtained.

9. The fill operation must be inspected on a full-time basis by a technician under the direction of a geotechnical engineer.
10. The footing and underground services subgrade must be inspected by the geotechnical consulting firm that inspected the engineered fill placement. This is to ensure that the foundations are placed within the engineered fill envelope, and the integrity of the fill has not been compromised by interim construction, environmental degradation and/or disturbance by the footing excavation.
11. Any excavation carried out in the certified engineered fill must be reported to the geotechnical consultant who inspected the fill placement in order to document the locations of the excavation and/or to inspect reinstatement of the excavated areas to engineered fill status. If construction on the engineered fill does not commence within a period of 2 years from the date of certification, the condition of the engineered fill must be assessed for re-certification.
12. Despite stringent control in the placement of the engineered fill, variations in soil type and density may occur in the engineered fill. Therefore, the foundation must be properly reinforced and designed by the structural engineer for the project. The total and differential settlements of 25 mm and 15 mm, respectively, should be considered in the design of the foundations founded on engineered fill. In sewer construction, the engineered fill is considered to have the same structural proficiency as a natural inorganic soil.

6.4 **Backfill in Trenches and Excavated Areas**

The on-site organic-free native soils are suitable for trench backfill. In the zone within 1.0 m below the pavement subgrade and below the slab-on-grade, the backfill should be compacted to at least 98% of its maximum Standard Proctor dry density with the moisture content 2% to 3% drier than the optimum. In the lower zone, a 95% or + Standard Proctor compaction is considered to be adequate; however, the material must be compacted on the wet side of the optimum. Backfill below the slab-on-grade which is sensitive to settlement must be compacted to at least 98% of its maximum Standard Proctor dry density.

The natural water content of the soils, as determined, indicates that the in situ granular fill, silty clay till, and gravelly sand are generally suitable for a 95% or + Standard Proctor compaction. The silty fine sand and a portion of the earth fill are too wet and will require aeration or mixing with drier soils prior to Standard Proctor compaction. The soils can be aerated by spreading them thinly on the ground in the dry, warm weather. A portion of the earth fill is on the dry side of the optimum and will require wetting prior to structural compaction, particularly in the dry, warm weather and in areas where compaction is best performed on the wet side of the optimum.

In normal underground services and slab-on-grade construction practice, the problem areas of road settlement largely occur adjacent to manholes, catch basins, services crossings, foundation walls and columns. In areas which are inaccessible to a heavy compactor, sand backfill should be used. The interface of the native soils and the sand backfill will have to be flooded for a period of several days.

The narrow trenches should be cut at 1 vertical:2 or + horizontal so that the backfill can be effectively compacted. Otherwise, soil arching will prevent the achievement of proper compaction. The lift of each backfill layer should either be limited to a thickness of 20 cm, or the thickness should be determined by test strips.

One must be aware of the possible consequences during trench backfilling and exercise caution as described below:

- When construction is carried out in freezing winter weather, allowance should be made for these following conditions. Despite stringent backfill monitoring, frozen soil layers may inadvertently be mixed with the structural trench backfill. Should the in situ soil have a water content on the dry side of the optimum, it would be impossible to wet the soil due to the freezing condition, rendering difficulties in obtaining uniform and proper compaction. Furthermore, the freezing condition will prevent flooding of the backfill when it is required, such as in a narrow vertical trench section, or when the trench box is removed. The above will invariably cause backfill settlement that may become evident within 1 to several years, depending on the depth of the trench which has been backfilled.
- In areas where the underground services construction is carried out during winter months, prolonged exposure of the trench walls will result in frost heave within the soil mantle of the walls. This may result in some settlement as the frost recedes, and repair costs will be incurred prior to final surfacing of the new pavement and the slab-on-grade construction.
- To backfill a deep trench, one must be aware that future settlement is to be expected, unless the side of the cut is flattened to at least 1 vertical: 1.5 + horizontal, and the lifts of the fill and its moisture content are stringently controlled; i.e., lifts should be no more than 20 cm (or less if the backfilling conditions dictate) and uniformly compacted to achieve at least 95% of the maximum Standard Proctor dry density, with the moisture content on the wet side of the optimum.
- It is often difficult to achieve uniform compaction of the backfill in the lower vertical section of a trench which is an open cut or is stabilized by a trench box, particularly in the sector close to the trench walls or the sides of the box. These sectors must be backfilled with sand. In a trench stabilized by a trench box, the void left after the removal of the box will be filled by the backfill. It

is necessary to backfill this sector with sand, and the compacted backfill must be flooded for 1 day, prior to the placement of the backfill above this sector, i.e., in the upper sloped trench section. This measure is necessary in order to prevent consolidation of inadvertent voids and loose backfill which will compromise the compaction of the backfill in the upper section. In areas where groundwater movement is expected in the sand fill mantle, seepage collars should be provided.

6.5 Sidewalks and Landscaping

The sidewalks in areas which are sensitive to frost-induced ground movement, such as entrances, must be constructed on a free-draining, non-frost-susceptible granular material such as Granular 'B'. It must extend to 1.2 m below the slab or pavement surface and be provided with positive drainage such as weeper subdrains connected to manholes or catch basins. Alternatively, the sidewalk should be properly insulated with 50-mm Styrofoam, or equivalent.

6.6 Pavement Design

Based on the borehole findings, the recommended pavement design for roadway construction is presented in Table 6.

Table 6 - Pavement Design (Roadway)

Course	Thickness (mm)	OPS Specifications
Asphalt Surface	40	HL-3
Asphalt Binder	50	HL-8
Granular Base	150	Granular 'A' or equivalent
Granular Sub-Base	300	Granular 'B' or equivalent

The pavement design for parking area construction is given in Table 7.

Table 7 - Pavement Design (Parking Area)

Course	**Thickness (mm)**	**OPS Specifications**
Asphalt Surface	25	HL-3
Asphalt Binder	35	HL-8
Granular Base	150	Granular ‘A’
Granular Sub-Base	200	Granular ‘B’

The existing granular fill, due to its high silt content, can only be used as road subgrade stabilization material; in using the granular fill as pavement sub-base material, its structural proficiency is considered to be half that of Granular ‘B’. The existing asphalt surface can be pulverized and mixed with new Granular ‘A’ for the granular base construction.

The subgrade within a depth of 1.0 m from the underside of the granular sub-base must be properly surface compacted to 95% of its maximum Standard Proctor dry density, with the water content on the dry side of the optimum.

The granular base and sub-base should be compacted to 100% of their maximum Standard Proctor dry density.

Roadside drainage ditches should be provided, and the bottom of the ditch should be at or below the depth of the underside of the granular sub-base of the reconstructed roadway.

The subgrade will suffer a strength regression if water is allowed to saturate the mantle. The following measures should, therefore, be incorporated in the construction procedures and road design:

- The subgrade should be properly crowned and smooth-rolled to allow interim precipitation to be properly drained.
- Areas adjacent to the roads should be properly graded to prevent ponding of large amounts of water. Otherwise, the water will seep into the subgrade mantle and induce a regression of the subgrade strength, with costly consequences for the pavement construction.
- Prior to placement of the granular bases, the subgrade should be proof-rolled, and any soft spots and weathered soil should be rectified.
- In extreme cases during the wet seasons, the top 0.8 m of the subgrade should be replaced by compacted granular material with the silt content less than 8% to compensate for the inadequate strength of the soft subgrade.

6.7 Soil Parameters for the Design of the Culvert

The recommended soil parameters for the project design are given in Table 8.

Table 8 - Soil Parameters

Soil Unit Weight (kN/m³)	**Bulk**	**Immersed**
Earth Fill	20.5	11.5
Silty Sand Till and Sandy Silt Till	22.5	12.5
Silty Clay Till	22.0	12.5
Silt	21.0	10.5
Sands	20.0	10.8

Table 8 - Soil Parameters (cont'd)

Soil Strength Parameters	**Apparent Cohesion c (kPa)**	**Effective Friction Angle ϕ (°)**
Earth Fill	0	26
Silty Sand Till and Sandy Silt Till	2	31
Silty Clay Till	5	30
Silt	0	30
Sands	0	33
Coefficients of Friction		
Between Concrete and Granular Base		0.60
Between Concrete and Sound Natural Soil		0.40

6.8 Excavation

Excavation should be carried out in accordance with Ontario Regulation 213/91.

Excavation above groundwater should be sloped at 1 vertical:1 horizontal for stability. The sides of excavation into earth fill must be cut at 1 vertical: 1.5 horizontal for stability. The silty clay till contains occasional boulders. Therefore, extra effort will be required in excavation.

For excavation purposes, the types of soils are classified in Table 9.

Table 9 - Classification of Soils for Excavation

Material	**Type**
Sound Tills	2
Earth Fill, Weathered Soils and Gravelly Sand	3
Water-Bearing Silt	4

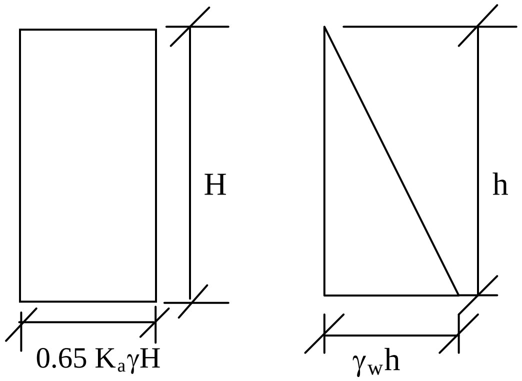
The groundwater yield from the silty clay and sandy silt tills, due to their low to relatively low permeability, is expected to be small and limited in quantity. The yield from the silty sand till, silt and gravelly sand will be moderate to appreciable and persistent. Groundwater will fluctuate with the seasons.

Where excavation is to be carried out in the water-bearing sands and silt, the possibility of flowing sides and bottom boiling dictates that the ground be predrained. However, due to the close proximity of the building envelopes, it may be very difficult to create enough drawdown required for excavation.

The sides of the bank or excavation can be sheeted. The sheeting structure should be driven to a depth below the bottom of the excavation equal to at least the height of water above the bed of the excavation.

The sheeting structure should be properly embedded into the tills deposits to prevent hydrostatic uplift and should be properly designed to support the earth pressure, hydrostatic pressure and applicable surcharge. The sheeting must not be driven to depths which may induce the artesian effect of the subterranean artesian condition from the gravelly sand stratum which will have an impact on the stability of the founding subgrade of the culvert replacement. It should be designed using the lateral earth pressure diagram shown in Diagram 1.

Diagram 1 - Lateral Earth Pressure



h - Height of Water
H - Height of Excavation
K_a = Coefficient of Lateral Earth Pressure
γ_w - Weight of Water
γ - Bulk Unit Weight of Soil

If tiebacks are to be used for the shoring structure, the anchors should be embedded into the hard or very dense tills. An average undrained shear strength of 100 kPa can be used for the design of the anchorage embedded in the silty clay till, sandy silt till and silty sand till. All the tieback anchors should be proof-loaded to at least 133% of the design load, and at least 1 full scale test should be carried out on 1 anchor.

Prospective contractors must be asked to assess the in situ subsurface conditions for soil cuts by digging test pits to at least 0.5 m below the intended bottom of excavation. These test pits should be allowed to remain open for a period of at least 4 hours to assess the trenching conditions.

7.0 LIMITATIONS OF REPORT

It should be noted that Phase One and Phase Two Environmental Site Assessments have been completed and the assessment and recommendations will be presented under separate cover, Reference No. 1204-S048E. Therefore, this report deals only with a study of the geotechnical aspects of the proposed project for the new alignment.

This report was prepared by Soil Engineers Ltd. for the account of The Town of Uxbridge and for review by its designated consultants and government agencies. The material in it reflects the judgement of Benjamin Shindman, M.A.Sc., Kelvin Lee, B.Eng., EIT., and Victor Chan, P.Eng., in light of the information available to it at the time of preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be made based on it, are the responsibility of such Third Parties. Soil Engineers Ltd. accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

SOIL ENGINEERS LTD.

BShindman
Benjamin Shindman, M.A.Sc.

Kelvin Lee, B.Eng., EIT

Victor S. Chan, P.Eng.
BS/KL/VSC:dd

LICENSED PROFESSIONAL ENGINEER
V.S. CHAN
7/9/2012
PROVINCE OF ONTARIO

LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

The abbreviations and terms commonly employed on the borehole logs and figures, and in the text of the report are as follows:

1. SAMPLE TYPES

AS	Auger sample
CS	Chunk sample
DO	Drive open
DS	Denison type sample
FS	Foil sample
RC	Rock core with size and percentage of recovery
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash Sample

2. PENETRATION RESISTANCE/'N'

Dynamic Cone Penetration Resistance:

A continuous profile showing the number of blows for each foot of penetration of a 2-inch diameter 90° point cone driven by a 140-pound hammer falling 30 inches.
Plotted as ______

Standard Penetration Resistance or 'N' value:

The number of blows of a 140-pound hammer falling 30 inches required to advance a 2-inch O.D. drive open sampler one foot into undisturbed soil.
Plotted as 'O'

WH	Sampler advanced by static weight
PH	Sampler advanced by hydraulic pressure
PM	Sampler advanced by manual pressure
NP	No penetration

3. SOIL DESCRIPTION

a) Cohesionless Soils:

'N' (Blows/ft)	Relative Density
0 to 4	very loose
4 to 10	loose
10 to 30	compact
30 to 50	dense
over 50	very dense

b) Cohesive Soils:

Undrained Shear Strength (ksf)	'N' (Blows/ft)	Consistency
Less than 0.25	0 to 2	very soft
0.25 to 0.50	2 to 4	soft
0.50 to 1.0	4 to 8	firm
1.0 to 2.0	8 to 16	stiff
2.0 to 4.0	16 to 32	very stiff
over 4.0	over 32	hard

c) Method of Determination of Undrained Shear Strength of Cohesive Soils:

x 0.0 - Field vane test in borehole
The number denotes the sensitivity to remoulding.

△ - Laboratory vane test

☐ - Compression test in laboratory

For a saturated cohesive soil, the undrained shear strength is taken as one half of the undrained compressive strength.

METRIC CONVERSION FACTORS

1 ft. = 0.3048 metres
1 lb. = 0.453 kg
1 inch = 25.4 mm
1 ksf = 47.88 kN/m^2

JOB NO: 1204-S048

LOG OF BOREHOLE NO: 1

FIGURE NO: 1

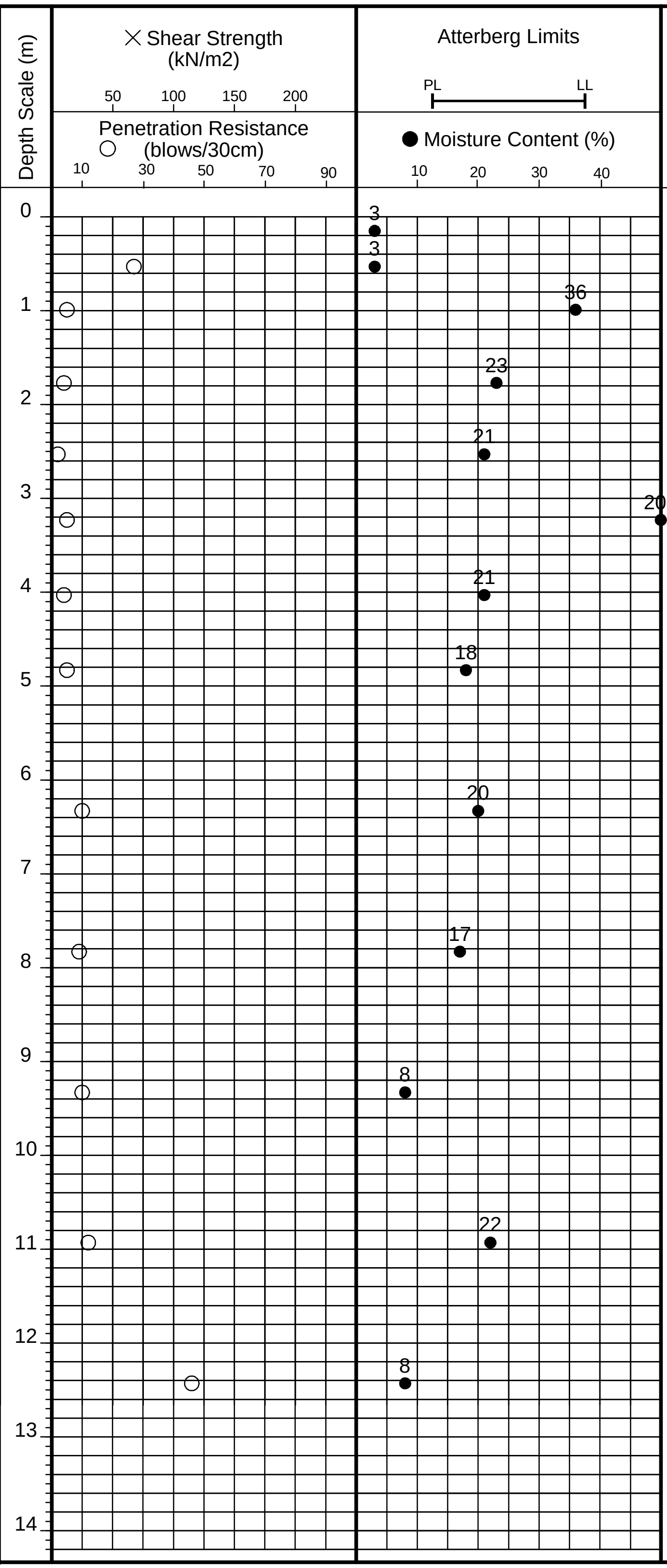
JOB DESCRIPTION: Proposed Culvert Replacement

JOB LOCATION: Centennial Drive to north of Brock Street
Town of Uxbridge

METHOD OF BORING: Flight-Auger

DATE: May 14, 2012

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
0.0	Pavement Surface			
263.1	**50 mm ASPHALTIC CONCRETE** **610 mm GRANULAR, Fill**	1A	AS	
		1B	DO	27
	Brown **SILTY CLAY, Fill and** **SILTY SAND, Fill** a trace of gravel occ. cobbles and boulders with organic material	2	DO	5
		3	DO	4
		4	DO	2
2.9 260.2	Black **PEAT**	5	DO	5
3.7 259.4	Grey, very loose **GRAVELLY SAND**	6	DO	4
4.4 258.7	Grey, very loose **SILT** a trace to some clay a trace of fine sand occ. wet sand seams and layers	7	DO	5
		8	DO	10
7.0 256.1	Grey, stiff **SILTY CLAY, Till** traces of sand and gravel occ. wet sand and silt seams and layers, cobbles and boulders	9	DO	9
		10	DO	10
10.1 253.0	Grey, compact **SILT** traces of clay and fine sand occ. wet sand seams and layers	11	DO	12
12.0 251.1	Grey, dense **GRAVELLY SAND** some silt	12	DO	46
12.7 250.4	**END OF BOREHOLE**			



WATER LEVEL

W.L. @ surface
Cave-in @ El. 257.6 m on completion

Soil Engineers Ltd.

JOB NO: 1204-S048

LOG OF BOREHOLE NO: 2

FIGURE NO: 2

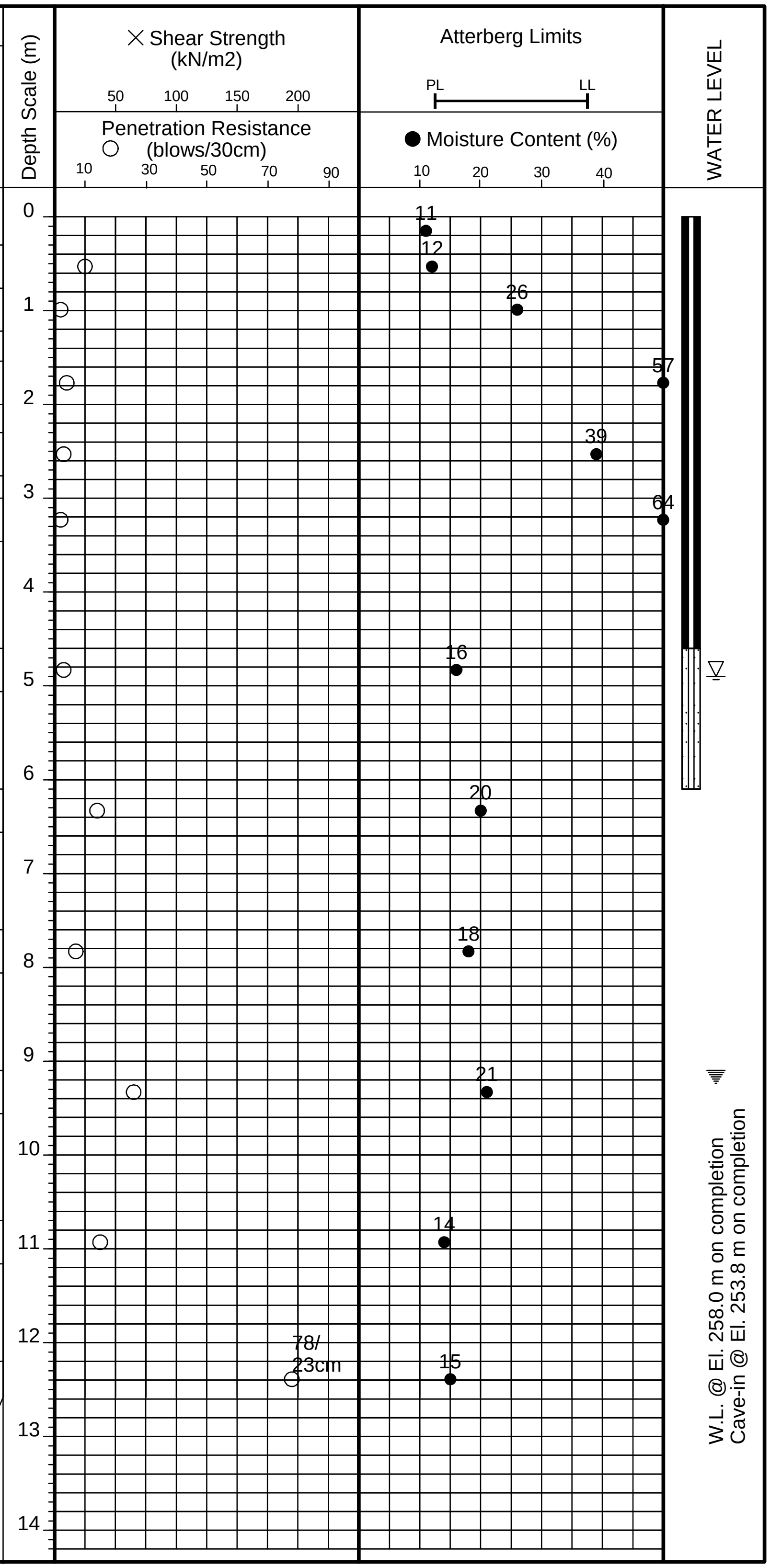
JOB DESCRIPTION: Proposed Culvert Replacement

JOB LOCATION: Centennial Drive to north of Brock Street
Town of Uxbridge

METHOD OF BORING: Flight-Auger

DATE: May 14, 2012

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
0.0 262.9	Pavement Surface **50 mm ASPHALTIC CONCRETE** **300 mm GRANULAR, Fill**	1A	AS	
	Brown **SILTY SAND, Fill** a trace of gravel occ. cobbles and boulders with organic material	1B	DO	10
		2	DO	2
1.5 261.4	**TOPSOIL** dark brown grey	3	DO	4
		4	DO	3
		5	DO	2
4.0 258.9	Grey, very loose **SANDY SILT, Till** a trace to some clay a trace of gravel occ. wet sand and silt seams and layers, cobbles and boulders	6	DO	3
5.5 257.4	Grey, loose to compact **SILT** some clay occ. wet sand seams and layers	7	DO	14
		8	DO	7
		9	DO	26
10.1 252.8	Grey, compact to very dense **SILTY SAND, Till** a trace of clay a trace to some gravel occ. wet sand and silt seams and layers, cobbles and boulders	10	DO	15
		11	DO	78/ 23
12.6 250.3	**END OF BOREHOLE** Installed 50 mm Ø monitoring well to 6.1 m (1.5 m screen) Sand backfill from 4.6 m to 6.1 m Bentonite holeplug from 0.0 m to 4.0 m Provided with top and bottom caps			



Soil Engineers Ltd.

JOB NO: 1204-S048

LOG OF BOREHOLE NO: 3

FIGURE NO: 3A

JOB DESCRIPTION: Proposed Culvert Replacement

JOB LOCATION: Centennial Drive to north of Brock Street
Town of Uxbridge

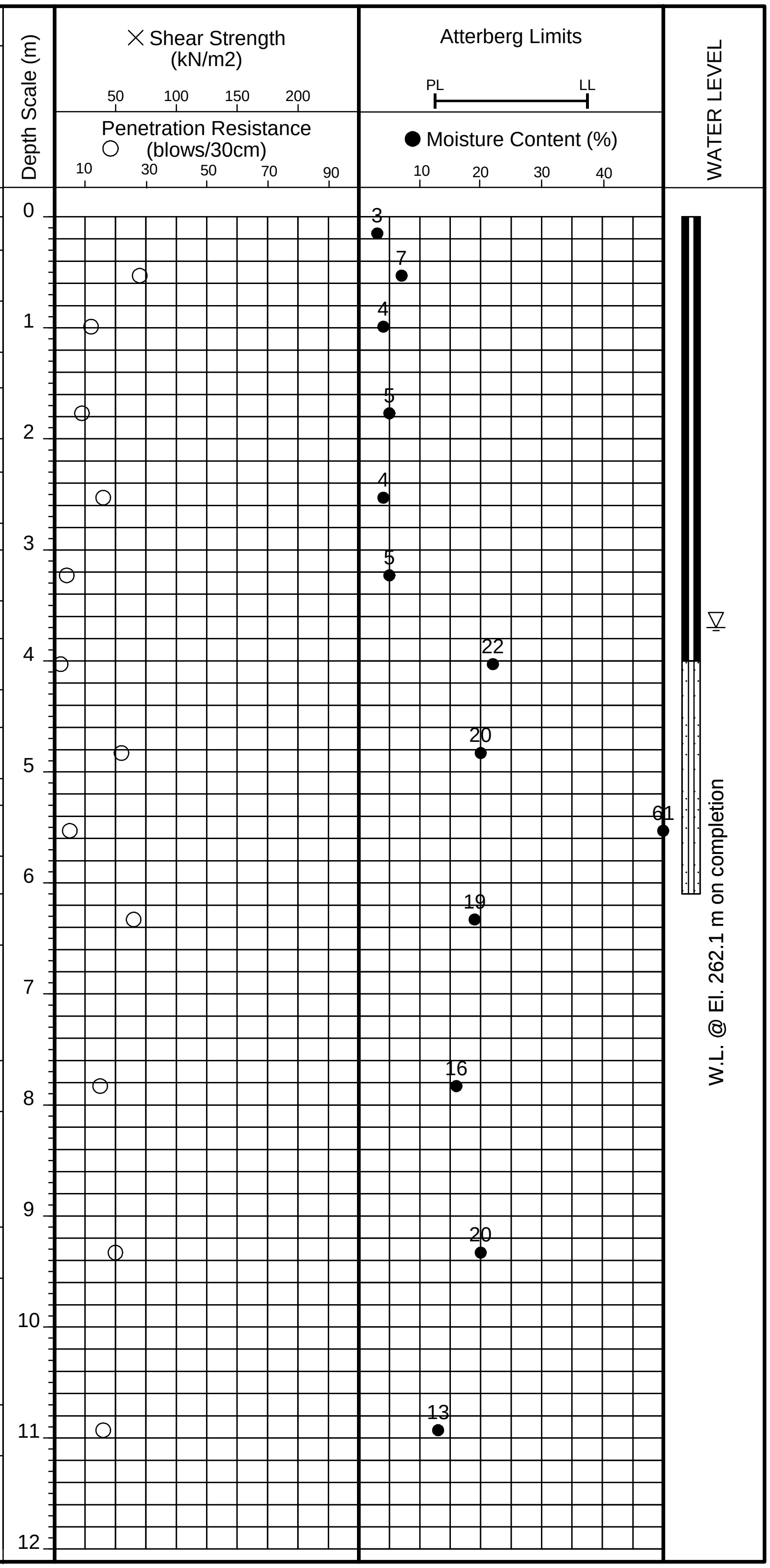
METHOD OF BORING: Flight-Auger

DATE: May 7, 2012

Depth Elev. (m)	SOIL DESCRIPTION
0.0	Pavement Surface
265.8	**100 mm ASPHALTIC CONCRETE** **200 mm GRANULAR, Fill**
	Brown **SILTY SAND, Fill and SAND, Fill** a trace of gravel occ. cobbles and boulders with organic material, wood and rock inclusions pieces of rock
3.6 262.2	Grey **FINE TO COARSE SAND, Fill** a trace to some sand a trace of gravel occ. cobbles and boulders
4.4 261.4	Grey **SILTY SAND, Fill and SANDY SILT, Fill** a trace of gravel occ. cobbles and boulders with wood inclusions and brick fragments wood pieces brick fragments
6.6 259.2	Grey, compact **SILT** a trace to some fine sand occ. gravel, clay seams and layers and cobbles clay layers
10.1 255.7	Grey, stiff **SILTY CLAY, Till** some sand, a trace of gravel occ. wet sand and silt seams and layers, cobbles and boulders silt layers
12.0	

SAMPLES

Number	Type	N-Value
1	AS	-
2	DO	28
3	DO	12
4	DO	9
5	DO	16
6	DO	4
7	DO	2
8	DO	22
9	DO	5
10	DO	26
11	DO	15
12	DO	20
13	DO	16



Soil Engineers Ltd.

LOG OF BOREHOLE NO: 3

JOB NO: 1204-S048

FIGURE NO: 3B

JOB DESCRIPTION: Proposed Culvert Replacement

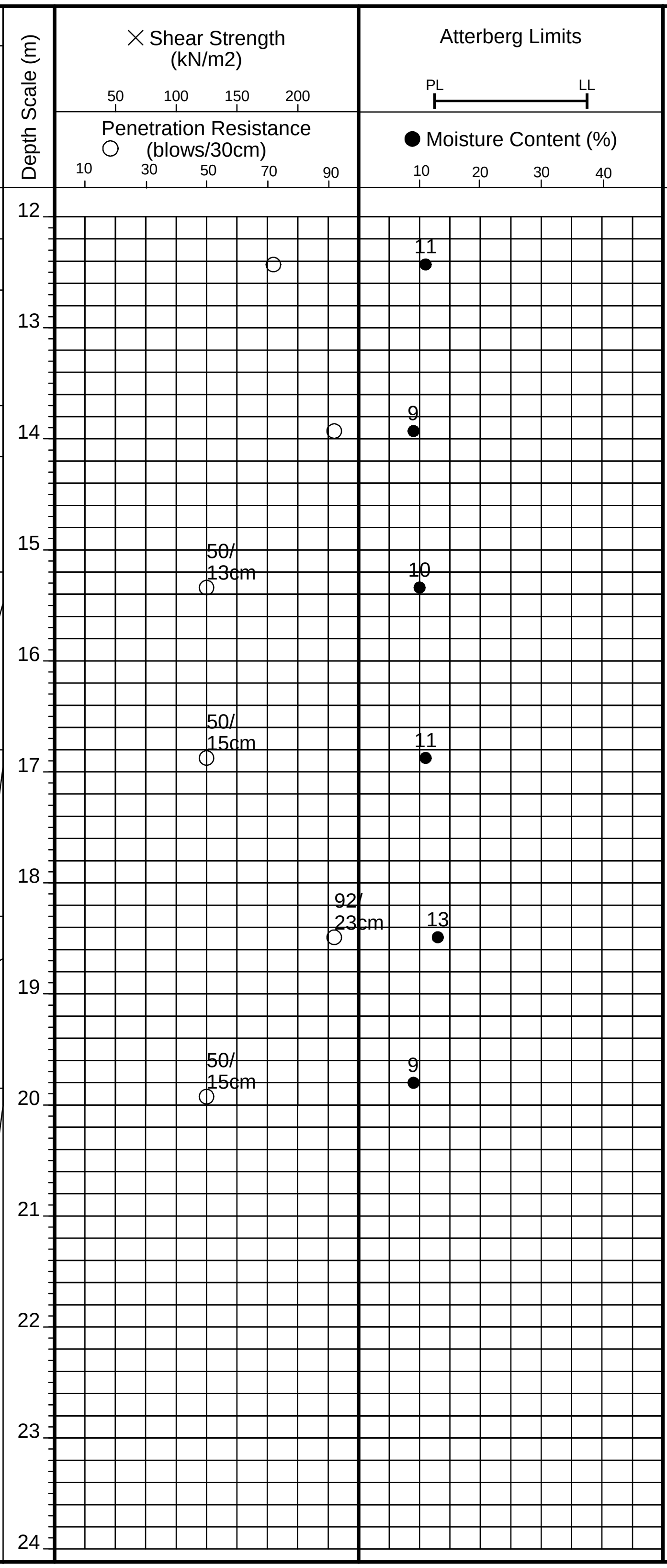
JOB LOCATION: Centennial Drive to north of Brock Street
Town of Uxbridge

METHOD OF BORING: Flight-Auger

DATE: May 7, 2012

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
12.0				
253.8	Grey, very dense **SILTY SAND, Till and SANDY SILT, Till** a trace of gravel occ. wet sand and silt seams and layers, cobbles and boulders	14 15	DO DO	72 92
14.6 251.2	Grey, very dense **SILTY SAND, Till** some gravel to gravelly a trace of clay occ. wet sand and silt seams and layers, cobbles and boulders	16 17	DO DO	50/13 50/15
17.7 248.1	Grey, very dense **SANDY SILT, Till** a trace of gravel occ. wet sand and silt seams and layers, cobbles and boulders	18	DO	92/23
19.4 246.4	Grey, very dense **GRAVELLY SAND** a trace to some silt occ. cobbles and boulders	19	DO	50/15
20.0 245.8	**END OF BOREHOLE**			

Installed 50 mm Ø monitoring well to 6.1 m (1.5 m screen)
Sand backfill from 4.0 m to 6.1 m
Bentonite holeplug from 0.0 m to 4.0 m
Provided with top and bottom caps



WATER LEVEL

W.L. @ El. 262.1 m on completion

Soil Engineers Ltd.

JOB NO: 1204-S048

LOG OF BOREHOLE NO: 4

FIGURE NO: 4A

JOB DESCRIPTION: Proposed Culvert Replacement

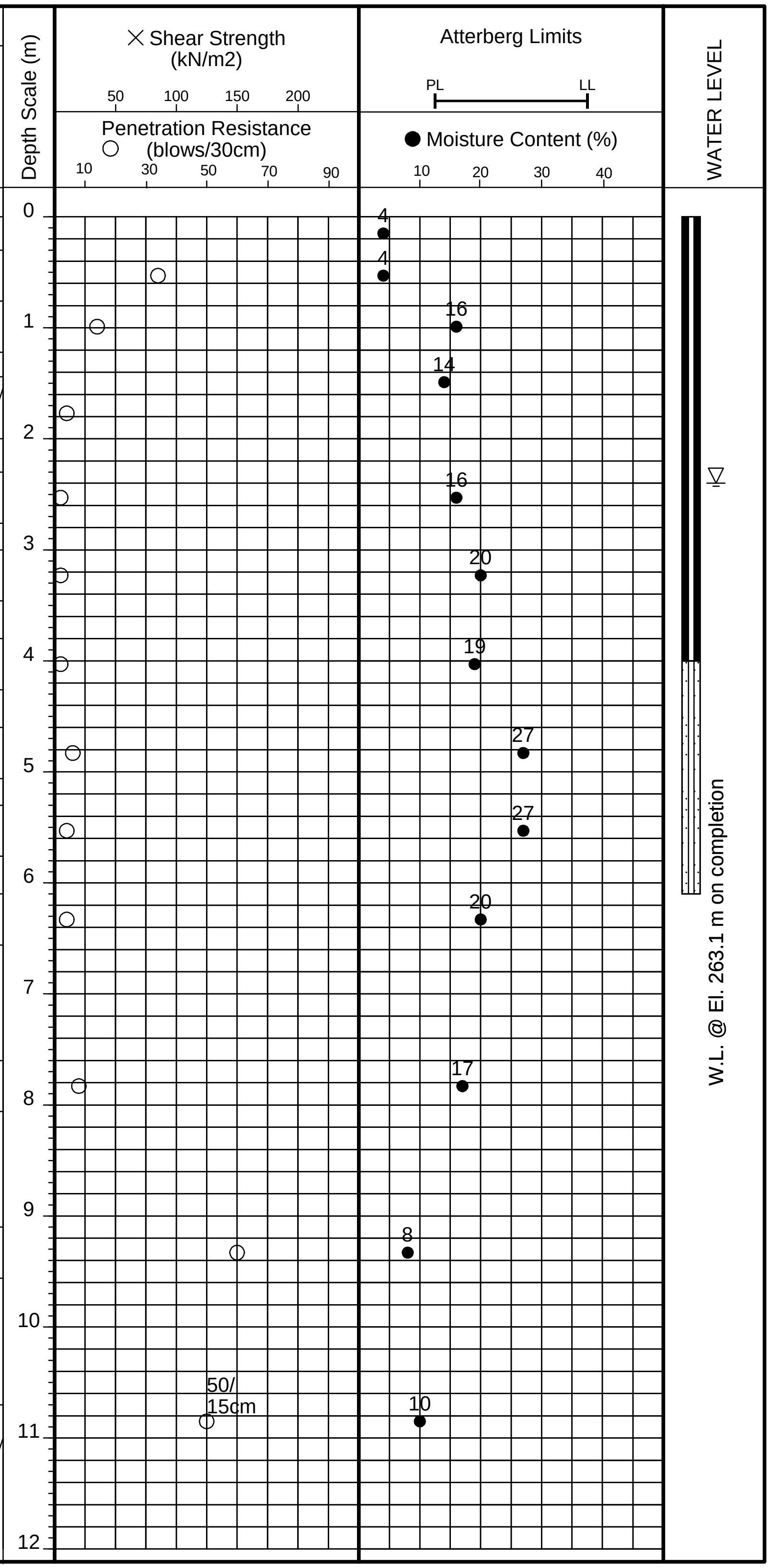
JOB LOCATION: Centennial Drive to north of Brock Street
Town of Uxbridge

METHOD OF BORING: Flight-Auger

DATE: May 8, 2012

Depth Elev. (m)	SOIL DESCRIPTION
0.0	Pavement Surface
265.5	**100 mm ASPHALTIC CONCRETE**
	650 mm GRANULAR, Fill
	SILTY CLAY, Fill brown / grey a trace to some sand a trace of gravel occ. sand seams with organic material and root inclusions
3.2 262.3	organic materials Grey **SILTY SAND, Fill and** **SANDY SILT, Fill** traces of clay and gravel with organic material and root inclusions
4.4 261.1	Grey **SILTY CLAY, Fill** some sand to sandy a trace of gravel
5.3 260.2	**TOPSOIL** Grey, very loose, weathered **SILTY FINE SAND** a trace to some clay occ. sand seams and layers
6.0 259.5	Grey, loose to very dense **SILTY SAND, Till and** **SANDY SILT, Till** weathered a trace to some gravel a trace of clay occ. wet sand and silt seams and layers, cobbles and boulders
12.0	

SAMPLES Number	Type	N-Value	Moisture Content (%)
1	DO	-	4
2	DO	34	4
3	DO	14	16
4	AS DO	- 4	14
5	DO	2	16
6	DO	2	20
7	DO	2	19
8	DO	6	27
9	DO	4	27
10	DO	4	20
11	DO	8	17
12	DO	60	8
13	DO	50/ 15	10



JOB NO: 1204-S048

LOG OF BOREHOLE NO: 4

FIGURE NO: 4B

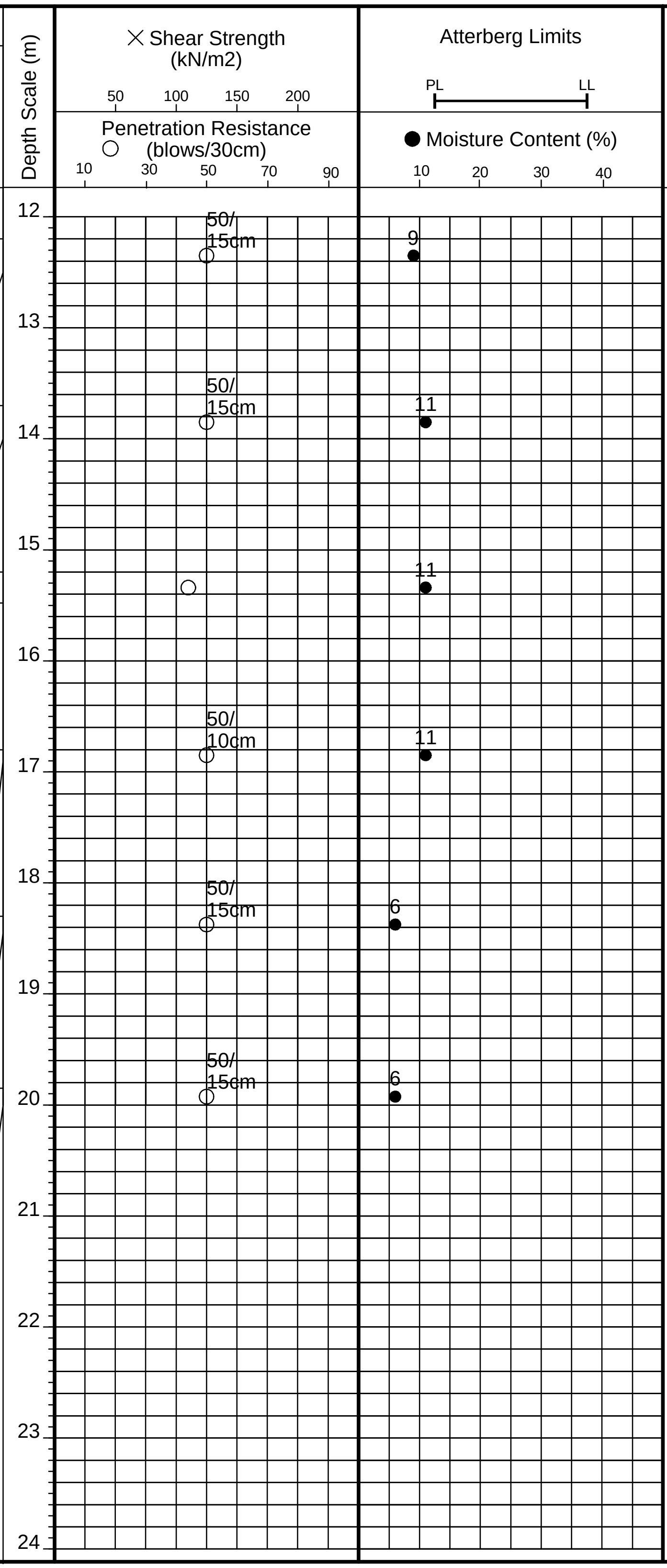
JOB DESCRIPTION: Proposed Culvert Replacement

JOB LOCATION: Centennial Drive to north of Brock Street
Town of Uxbridge

METHOD OF BORING: Flight-Auger

DATE: May 8, 2012

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
12.0 253.5	Grey, loose to very dense **SILTY SAND, Till and SANDY SILT, Till** a trace to some gravel a trace of clay occ. wet sand and silt seams and layers, cobbles and boulders	14	DO	50/15
13.0 252.5	Grey, dense to very dense **SILTY SAND, Till** some gravel occ. wet sand and silt seams and layers, cobbles and boulders	15	DO	50/15
		16	DO	44
16.2 249.3	Grey, very dense **GRAVELLY SAND** a trace to some silt occ. cobbles and boulders	17	DO	50/10
		18	DO	50/15
		19	DO	50/15
20.0 245.5	**END OF BOREHOLE** Installed 50 mm Ø monitoring well to 6.1 m (1.5 m screen) Sand backfill from 4.0 m to 6.1 m Bentonite holeplug from 0.0 m to 4.0 m Provided with top and bottom caps			



WATER LEVEL

W.L. @ El. 263.1 m on completion

Soil Engineers Ltd.

JOB NO: 1204-S048

LOG OF BOREHOLE NO: 5

FIGURE NO: 5A

JOB DESCRIPTION: Proposed Culvert Replacement

JOB LOCATION: Centennial Drive to north of Brock Street
Town of Uxbridge

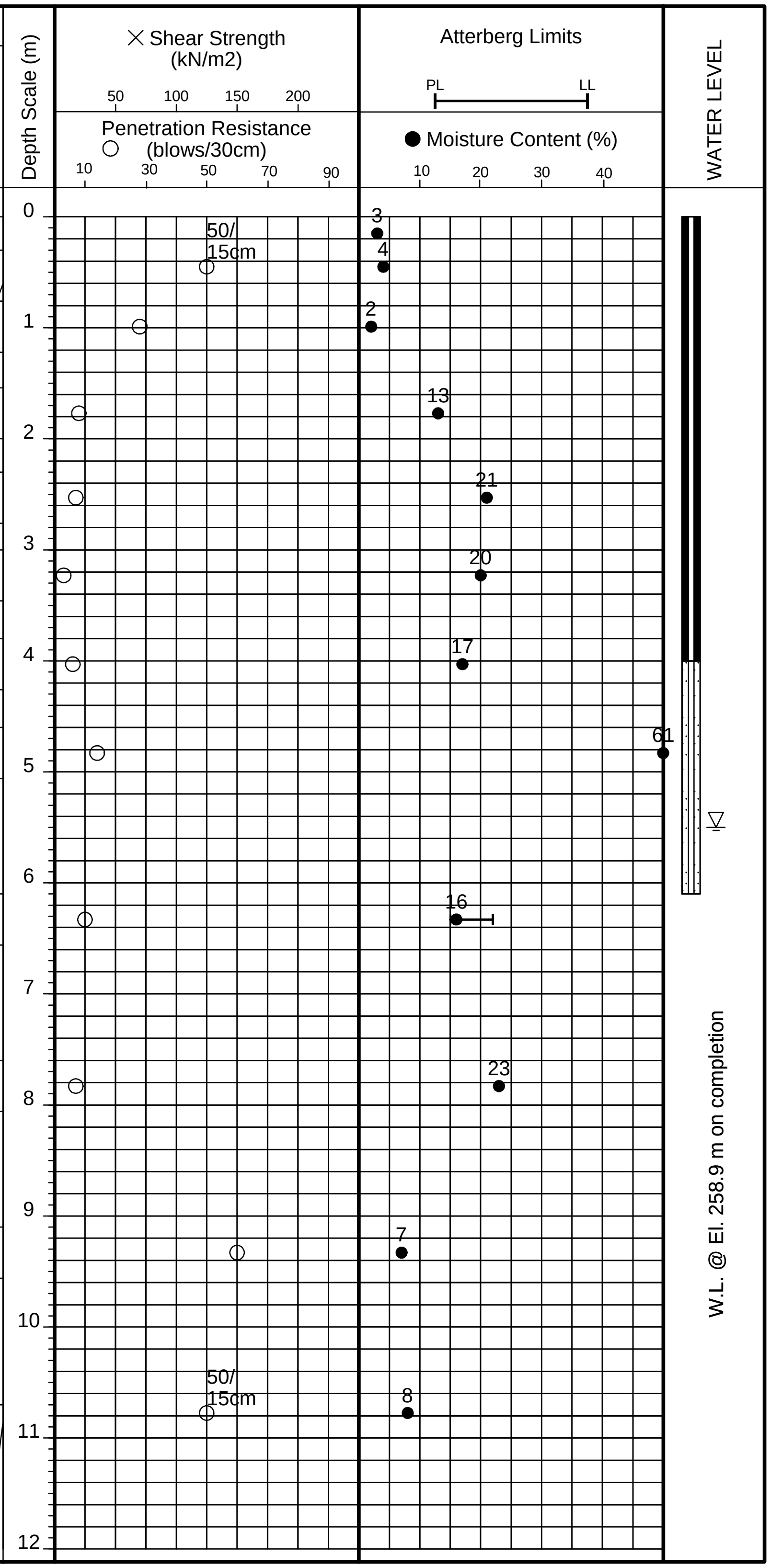
METHOD OF BORING: Flight-Auger

DATE: May 7 and 8, 2012

Depth Elev. (m)	SOIL DESCRIPTION
0.0	Pavement Surface
264.4	**50 mm ASPHALTIC CONCRETE**
	650 mm GRANULAR, Fill
	Grey **SAND, Fill** a trace of gravel with rock inclusions rock pieces
1.4 263.0	Grey **SILTY CLAY, Fill** wood pieces a trace to some sand a trace of gravel with wood, root and rock inclusions
4.6 259.8	**TOPSOIL**
	Grey, stiff **SILTY CLAY, Till** weathered silt layers traces of sand and gravel occ. wet sand and silt seams and layers, cobbles and boulders
7.1 257.3	Grey, loose **SILT** some clay, a trace of fine sand occ. clay seams and layers
8.5 255.9	Grey, very dense **SILTY SAND, Till and SANDY SILT, Till** rock/boulder pieces a trace of gravel occ. wet sand and silt seams and layers, cobbles and boulders with rock inclusions
12.0	

SAMPLES

Number	Type	N-Value
1	AS	-
2	DO	50/ 15
3	DO	28
4	DO	8
5	DO	7
6	DO	3
7	DO	6
8	DO	14
9	DO	10
10	DO	7
11	DO	60
12	DO	50/ 15



Soil Engineers Ltd.

JOB NO: 1204-S048

LOG OF BOREHOLE NO: 5

FIGURE NO: 5B

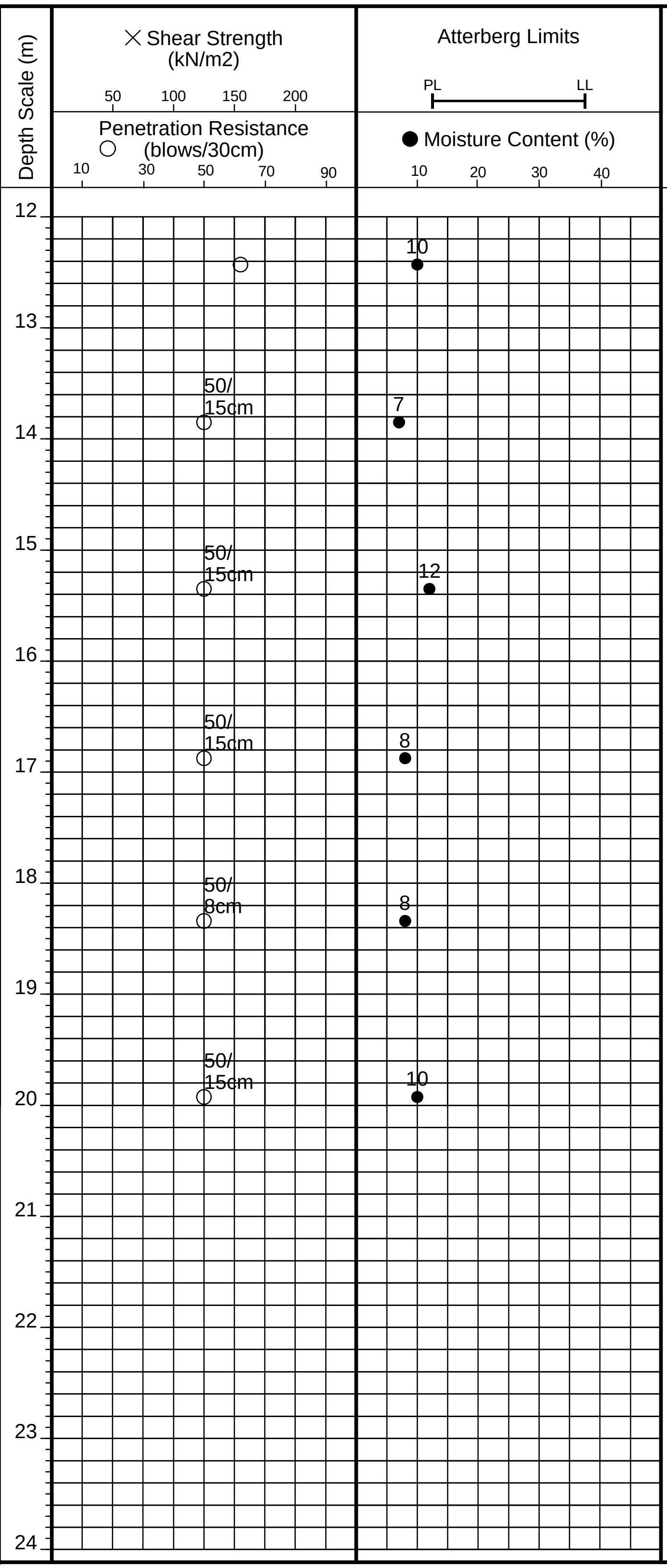
JOB DESCRIPTION: Proposed Culvert Replacement

JOB LOCATION: Centennial Drive to north of Brock Street
Town of Uxbridge

METHOD OF BORING: Flight-Auger

DATE: May 7 and 8, 2012

Depth Elev. (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
12.0 252.4	Grey, very dense **SILTY SAND, Till and SANDY SILT, Till** a trace of gravel occ. wet sand and silt seams and layers, cobbles and boulders	13	DO	62
		14	DO	50/ 15
14.6 249.8	Grey, very dense **GRAVELLY SAND** a trace of silt to silty occ. cobbles and boulders	15	DO	50/ 15
		16	DO	50/ 15
		17	DO	50/ 8
		18	DO	50/ 15
20.0 244.4	**END OF BOREHOLE** Installed 50 mm Ø monitoring well to 6.1 m (1.5 m screen) Sand backfill from 4.0 m to 6.1 m Bentonite holeplug from 0.0 m to 4.0 m Provided with top and bottom caps			



WATER LEVEL

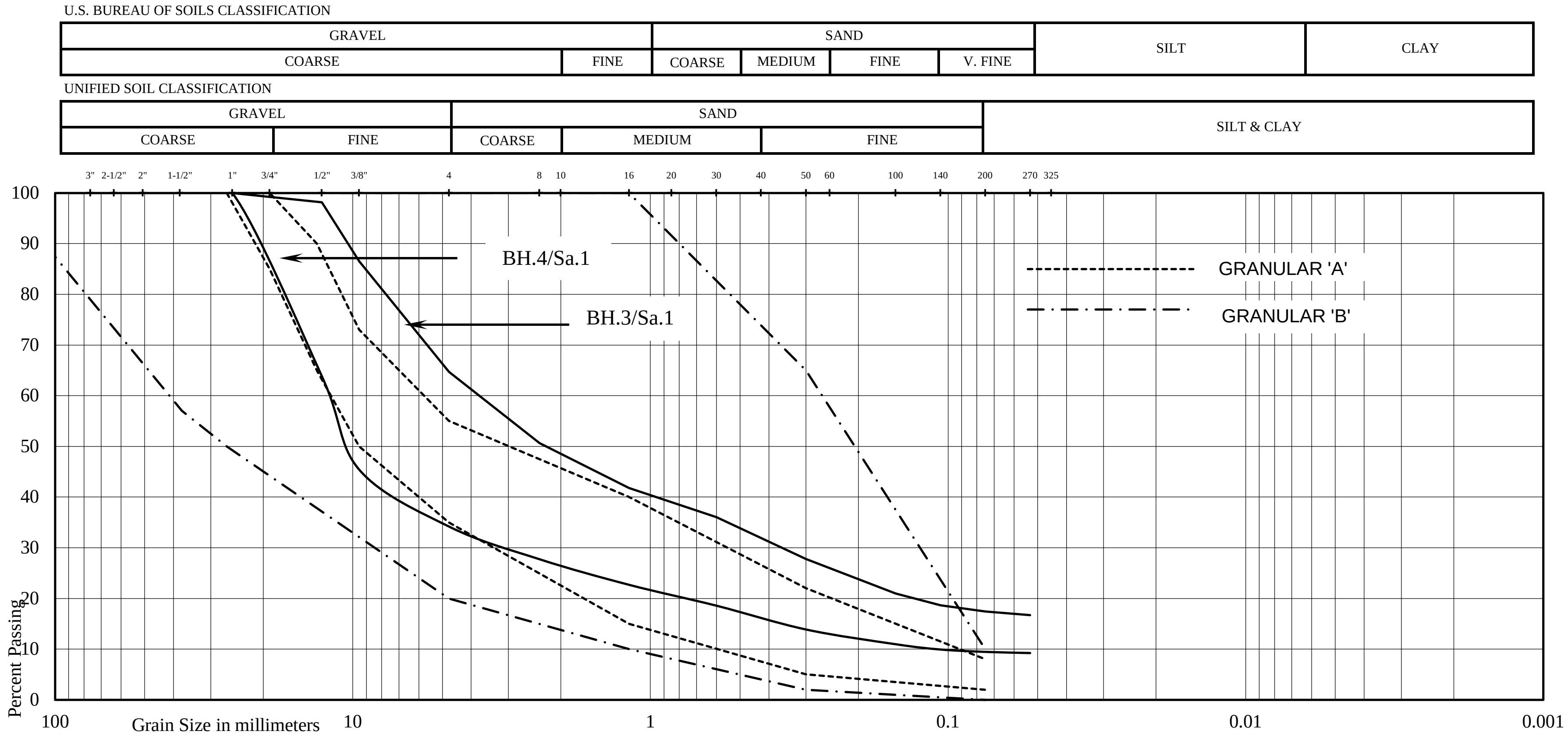
W.L. @ El. 258.9 m on completion

Soil Engineers Ltd.

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1204-S048



Project: Proposed Culvert Replacement

Location: Centennial Drive to north of Brock Street, Town of Uxbridge

Borehole No:	3	4
Sample No:	1	1
Depth (m):	0.2	0.2
Elevation (m):	265.6	265.3

BH./Sa.	3/1	4/1
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	3	4
Estimated Permeability (cm./sec.) =	10^{-4}	10^{-2}

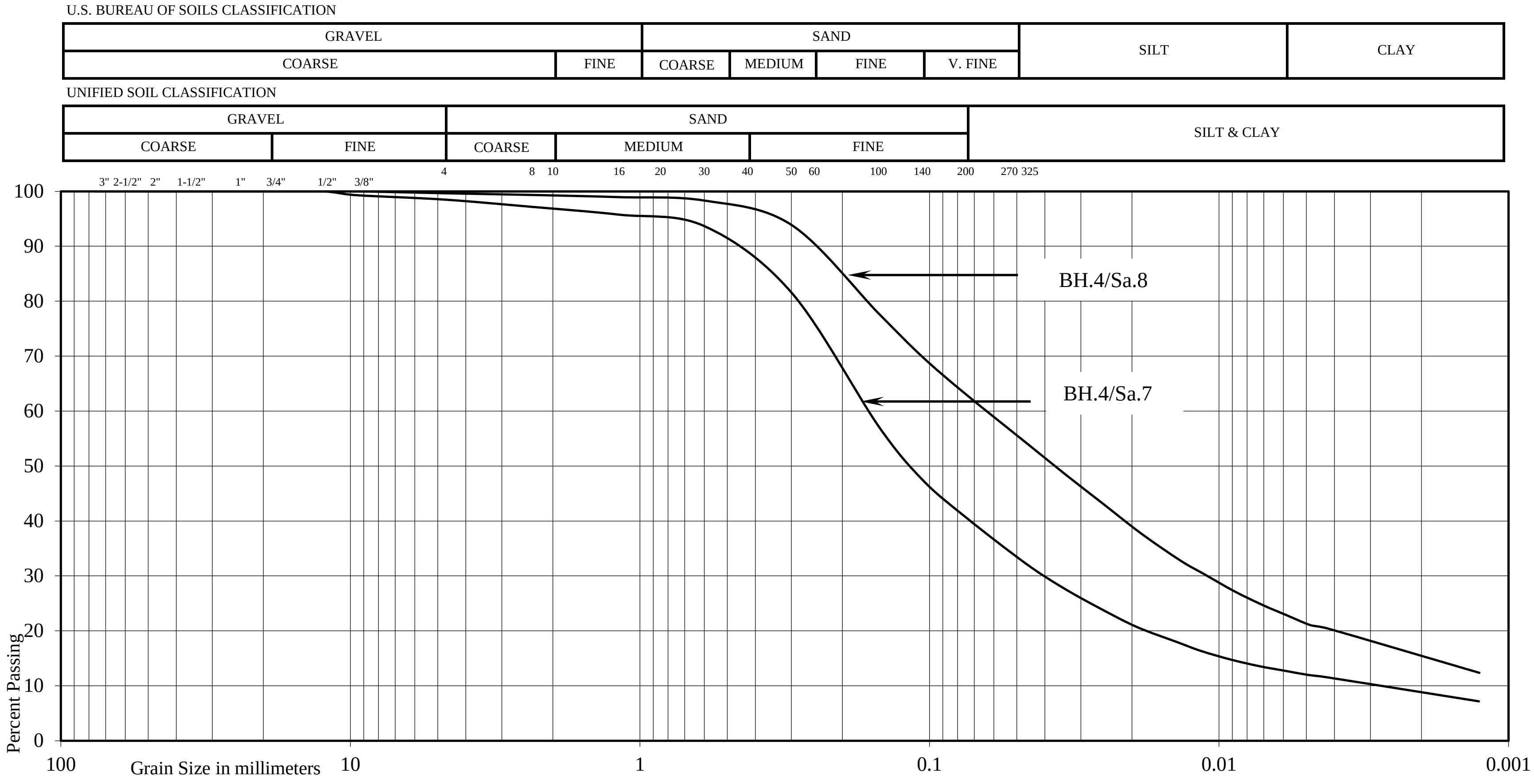
Classification of Sample [& Group Symbol]: GRANULAR, Fill
a trace to some silt

Figure: 6

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1204-S048



Project: Proposed Culvert Replacement

Location: Centennial Drive to north of Brock Street, Town of Uxbridge

Borehole No:	4	4
Sample No:	7	8
Depth (m):	4.0	4.8
Elevation (m):	261.5	260.7

BH./Sa.	4/7	4/8
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	19	27
Estimated Permeability (cm./sec.) =	10^{-6}	10^{-6}

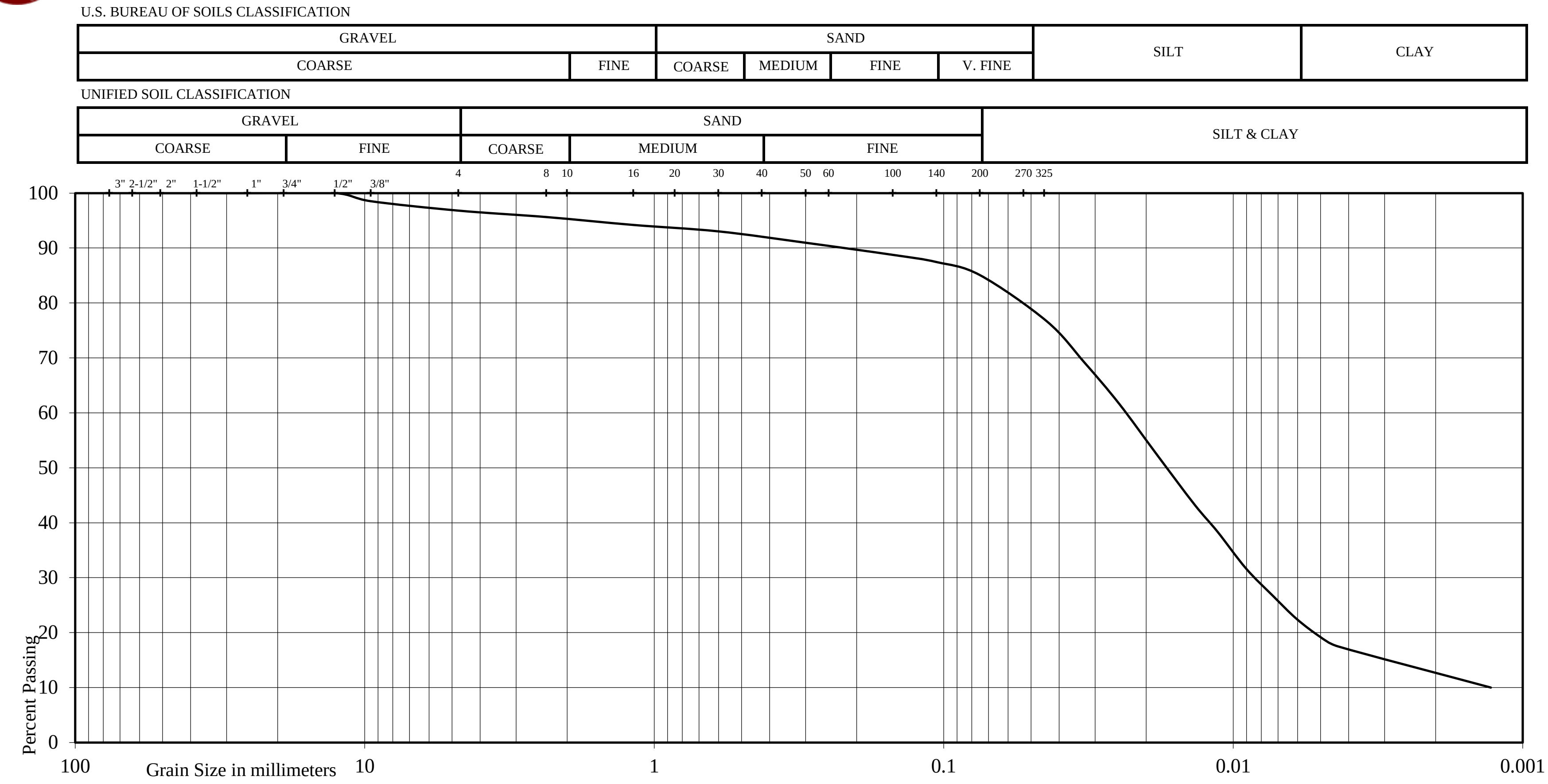
Classification of Sample [& Group Symbol]: BH.4/Sa.7 - SILTY SAND, Fill, some clay, a trace of gravel
BH.4/Sa.8 - SILTY CLAY, Fill, sandy

Figure: 7

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1204-S048



Project: Proposed Culvert Replacement

Location: Centennial Drive to north of Brock Street, Town of Uxbridge

Liquid Limit (%) = 22

Plastic Limit (%) = 15

Borehole No: 5

Plasticity Index (%) = 7

Sample No: 9

Moisture Content (%) = 16

Depth (m): 6.4

Estimated Permeability (cm./sec.) = 10^{-6}

Elevation (m): 258.0

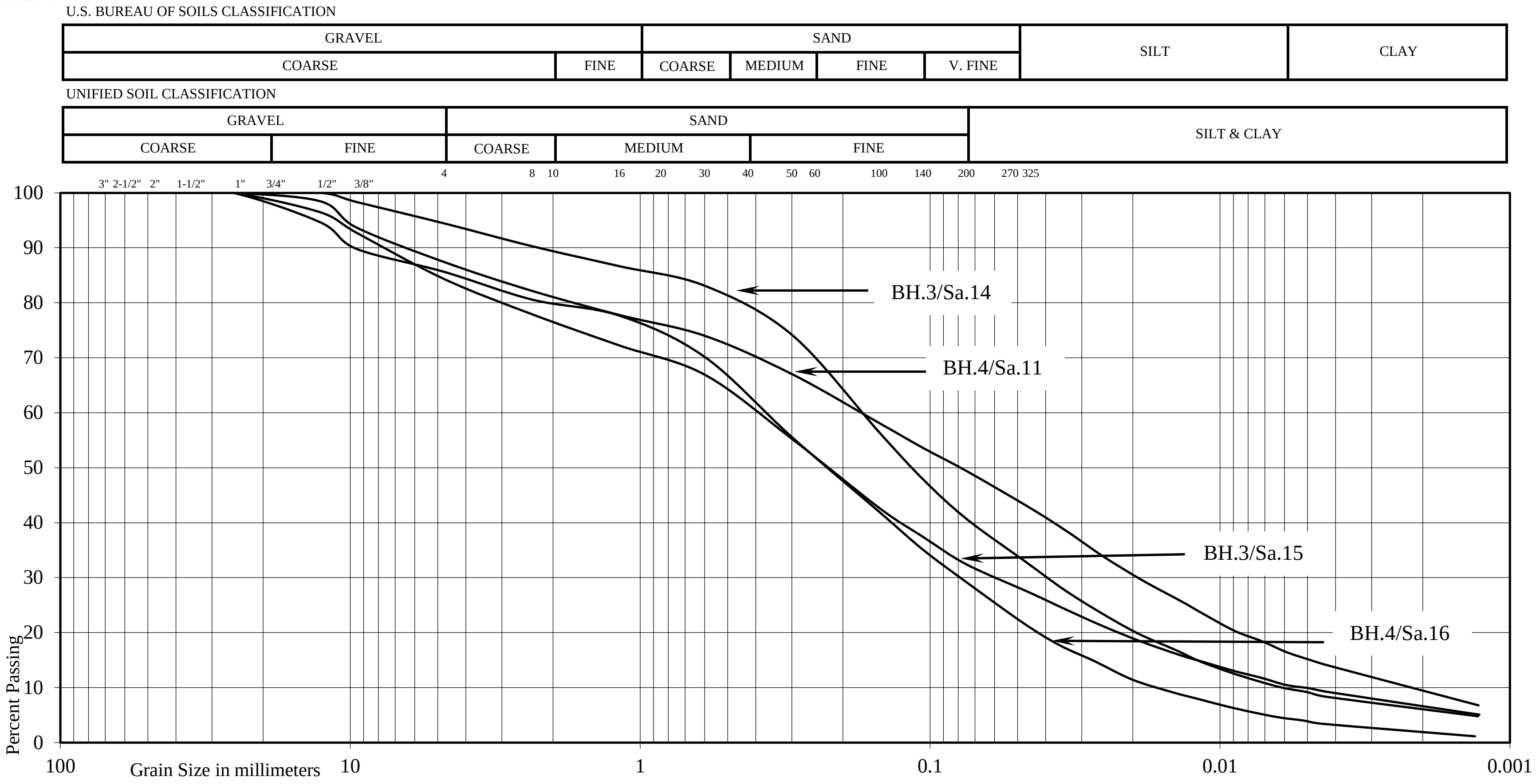
Classification of Sample [& Group Symbol]: SILTY CLAY, Till
traces of sand and gravel

Figure: 8

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1204-S048



Project:	Proposed Culvert Replacement			
Location:	Centennial Drive to north of Brock Street, Town of Uxbridge			
Borehole No:	3	3	4	4
Sample No:	14	15	11	16
Depth (m):	12.5	14.0	7.8	15.3
Elevation (m):	253.3	251.8	257.7	250.2

BH./Sa.	3/14	3/15	4/11	4/16
Liquid Limit (%) =	-	-	-	-
Plastic Limit (%) =	-	-	-	-
Plasticity Index (%) =	-	-	-	-
Moisture Content (%) =	11	9	17	11
Estimated Permeability (cm./sec.) =	10^{-5}	10^{-5}	10^{-6}	10^{-4}

Classification of Sample [& Group Symbol]: SILTY SAND, Till

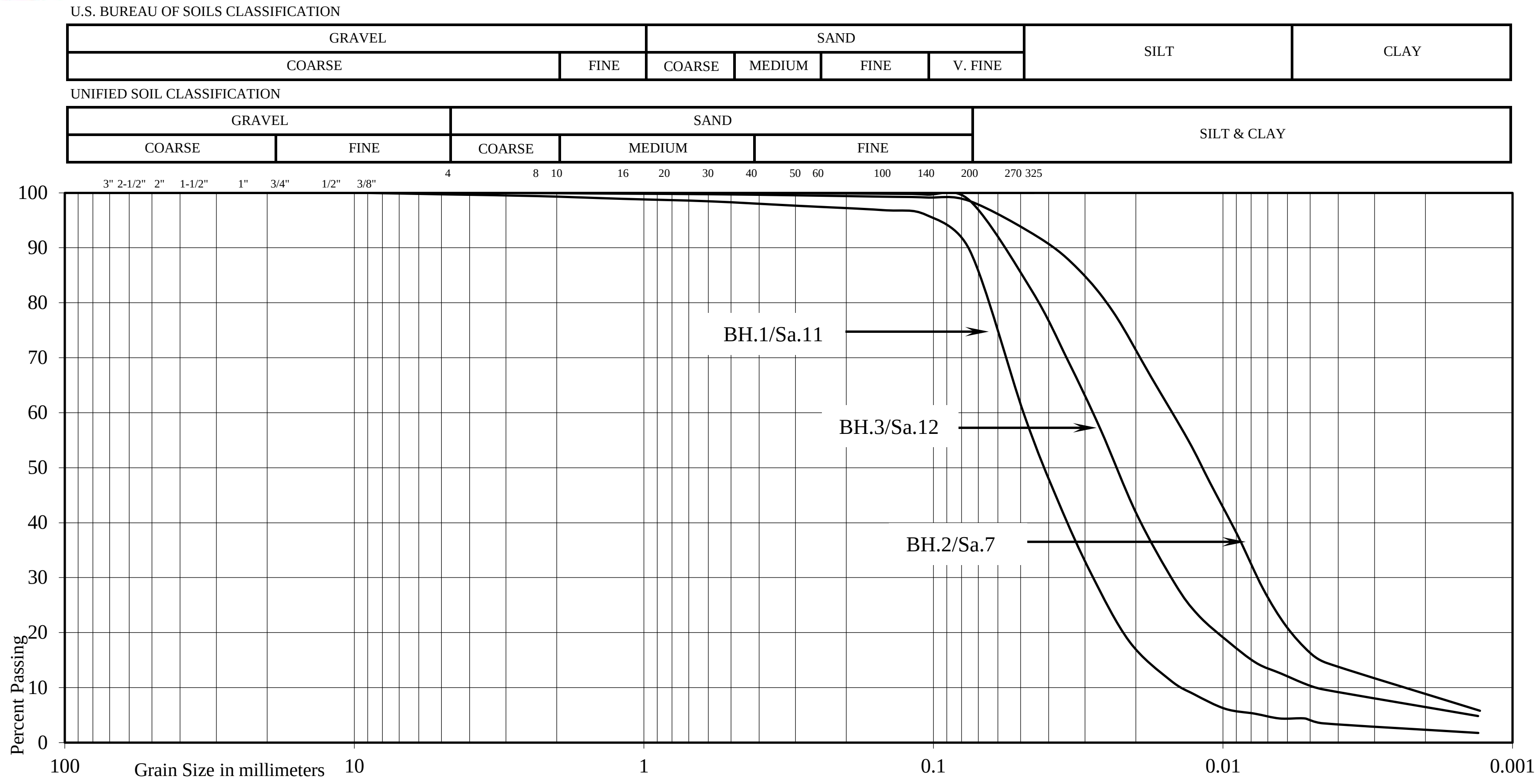
traces to some clay and gravel

Figure: 9

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1204-S048



Project: Proposed Culvert Replacement

Location: Centennial Drive to north of Brock Street, Town of Uxbridge

Borehole No:	1	2	3
Sample No:	11	7	12
Depth (m):	10.9	6.3	9.3
Elevation (m):	252.2	256.6	256.5

BH./Sa.	1/11	2/7	3/12
Liquid Limit (%) =	-	-	-
Plastic Limit (%) =	-	-	-
Plasticity Index (%) =	-	-	-
Moisture Content (%) =	22	20	20
Estimated Permeability (cm./sec.) =	10^{-4}	10^{-6}	10^{-5}

Classification of Sample [& Group Symbol]: SILT

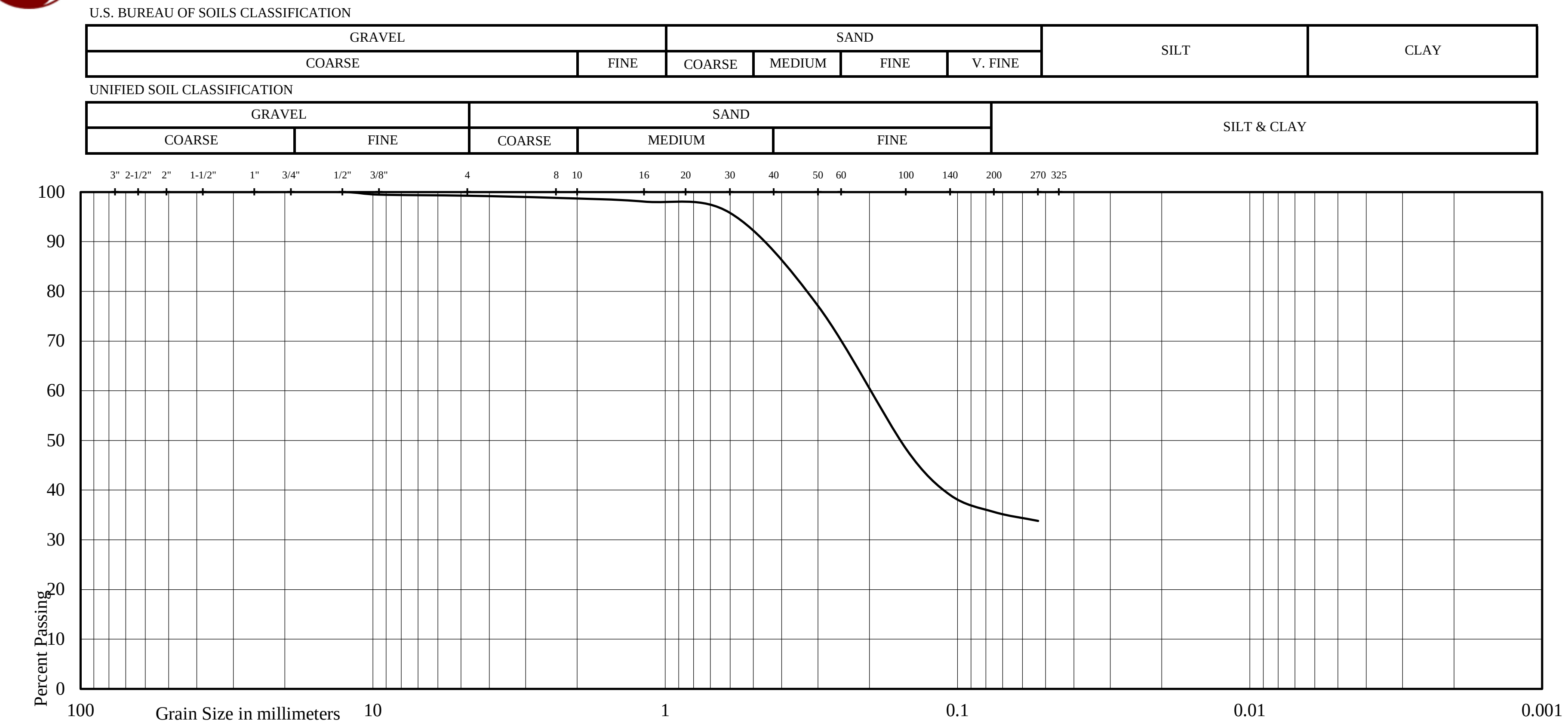
a trace to some clay, a trace of fine sand

Figure: 10

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1204-S048



Project: Proposed Culvert Replacement

Location: Centennial Drive to north of Brock Street, Town of Uxbridge

Borehole No: 4

Sample No: 9

Depth (m): 5.6

Elevation (m): 259.9

Liquid Limit (%) = -

Plastic Limit (%) = -

Plasticity Index (%) = -

Moisture Content (%) = 27

Estimated Permeability
(cm./sec.) = 10^{-6}

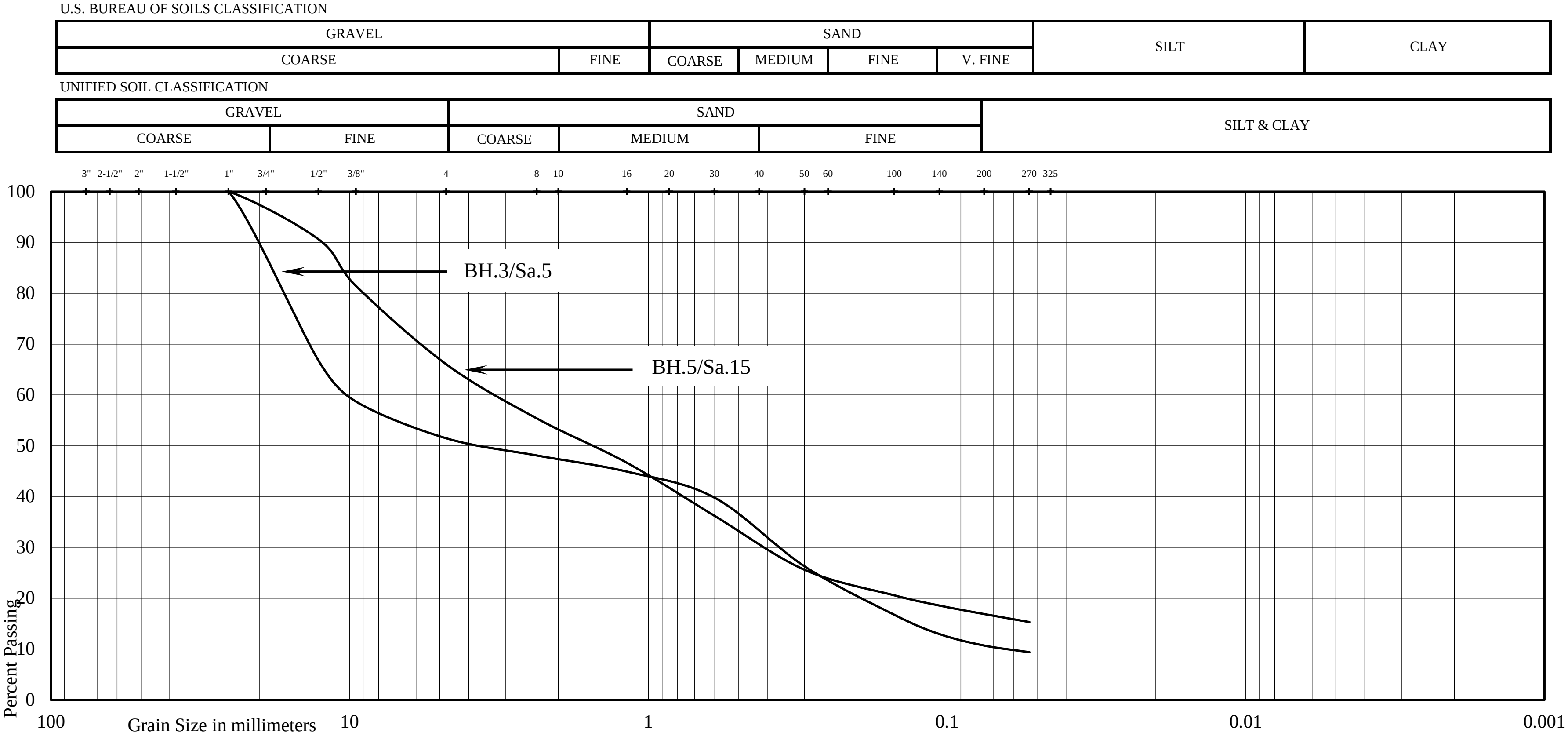
Classification of Sample [& Group Symbol]: SILTY FINE SAND

Figure: 11

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1204-S048



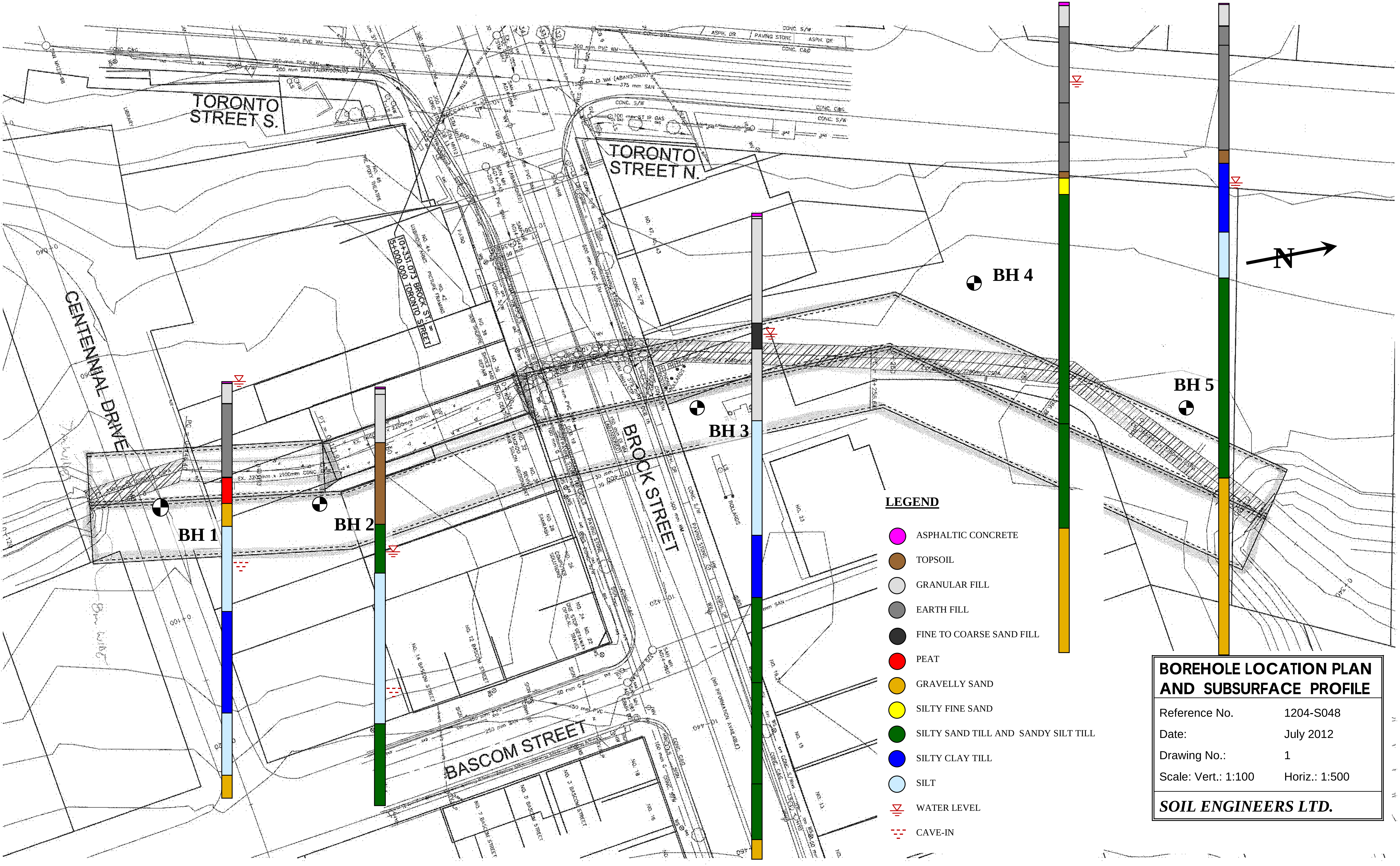
Project:	Proposed Culvert Replacement	
Location:	Centennial Drive to north of Brock Street, Town of Uxbridge	

Borehole No:	3	5
Sample No:	5	15
Depth (m):	2.5	15.3
Elevation (m):	263.3	249.1

BH./Sa.	3/5	5/15
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	4	12
Estimated Permeability (cm./sec.) =	10^{-3}	10^{-3}

Classification of Sample [& Group Symbol]: GRAVELLY SAND
some silt

Figure: 12



LEGEND

🟣 ASPHALTIC CONCRETE
🟤 TOPSOIL
⚪ GRANULAR FILL
⚫ EARTH FILL
⚫ FINE TO COARSE SAND FILL
🔴 PEAT
🟠 GRAVELLY SAND
🟡 SILTY FINE SAND
🟢 SILTY SAND TILL AND SANDY SILT TILL
🔵 SILTY CLAY TILL
⚪ SILT
▽ WATER LEVEL
▽ CAVE-IN

BOREHOLE LOCATION PLAN AND SUBSURFACE PROFILE

Reference No.	1204-S048
Date:	July 2012
Drawing No.:	1
Scale: Vert.: 1:100	Horiz.: 1:500

SOIL ENGINEERS LTD.