Foundation Investigation and Design Report

High Mast Lights
Highway 401 Eastbound Collector Lanes, Avenue Road to Warden Avenue, Toronto, Ontario
MTO G.W.P. 2130-01-00

Submitted to:

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PART A

FOUNDATION INVESTIGATION REPORT
HIGH MAST LIGHTS
HIGHWAY 401 EASTBOUND COLLECTOR LANES FROM AVENUE ROAD TO WARDEN AVENUE, TORONTO, ONTARIO
MTO GWP 2130-01-00

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by AECOM on behalf of the Ministry of Transportation, Ontario (MTO) to provide foundation engineering services for the rehabilitation of the Highway 401 Eastbound Collector lanes between Avenue Road and Warden Avenue (approximately 10 km) in Toronto, Ontario (Assignment No. 2016-E-0089).

This report presents the subsurface conditions at the site of two new high mast lights (HMLs) located south of the proposed Highway 401 Eastbound Collector widening and was developed based on the results from Golder's foundation investigation and an investigation and testing completed by others on MTO's GEOCRES System. The results of foundation investigations for other works associated with this assignment are presented in separate reports.

2.0 SITE DESCRIPTION

The two existing HMLs, one located to the east and the other to west of Leslie Street, south of the existing Highway 401 Eastbound Collector Lanes as shown on Drawing 1. The immediate area surrounding HMLs consists of vegetated with grass and low-lying shrubs with the MTO Right-of-Way. The ground surface at HML No. 60 and No. 62 is at approximate Elevation 145 m and Elevation 139 m.

3.0 INVESTIGATION PROCEDURES

3.1 2015 Investigation (GEOCRES No. 30M14-463)

From April 2 to 22, 2015, a foundation investigation was completed by Thurber Engineering Ltd. (Thurber) during which time a total of four boreholes were advanced; and one of which, designated as Boreholes M-03 is in the immediate vicinity of HML No. 60. The results of the investigation are contained in their report titled, "Foundation Investigation and Design Report, Highway 401 Overpass At GO Station Parking Lot and Leslie Street, Highway 401 and Leslie Street Interchange, City of Toronto, W.P. 2061-13-00, Site 37-206/1-4", dated September 11, 2017 (GEOCRES No. 30M14-463). It should be noted that the report does not reference the coordinate system of the borehole locations, it is inferred that they are referenced to the MTM NAD 83 (Zone 10) coordinate system based on the plotted position relative to that reference system. The location of Borehole M-03 is presented below, along with the geographic coordinates, ground surface elevations (in Geodetic Datum), and the depth of borehole prior to termination. This borehole is shown on plan on Drawing 1 and the borehole records and the summary of the relevant laboratory testing results from the investigation are presented in Appendix A.

Borehole No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Depth of Borehole (m)
	Northing (Latitude, °)	Easting (Longitude, °)		
M-03	4,847,317.6 (43.765745)	315,777.0 (-79.363665)	145.3	31.2

3.2 Current Investigation

The current foundations investigation for the proposed re-aligned N-E ramp was carried out between September 4 and 5, 2019 where one borehole, designated as Borehole N/E RS-10, was advanced in the vicinity of HML No. 62.

The borehole was advanced using a CME 55 track-mounted drill rig, supplied and operated by Geo-Environmental Drilling Inc. of Halton Hills, Ontario. Borehole N/E RS-10 was advanced using 150 mm outside diameter (O.D.) hollow-stem augers and 110 mm O.D. casing with drilling mud. Soil samples were generally obtained at 0.75 m, 1.5 m and 3.0 m intervals of depth, using a 50 mm O.D. split-spoon sampler driven by automatic hammer in accordance with Standard Penetration Test (SPT) procedures (ASTM D1586[1]). The split-spoon samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 35 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension would not be sampled or represented in the grain size distributions. Samples of the cohesive soils were obtained at selected locations using 76 mm O.D. thin-walled ‘Shelby’ tubes (ASTM D1587[2]) for relatively undisturbed samples. Field vane shear tests were carried out in cohesive soils for assessment of undrained shear strengths (ASTM D2573[3]) using MTO Standard ‘N’ size vanes.

Groundwater conditions and water levels in the open borehole was observed during and immediately following the drilling operations. The borehole was backfilled with bentonite upon completion in accordance with Ontario Regulation 903 Wells (as amended), and the ground surface was restored to near original condition as practical.

The field work was observed by members of Golder’s engineering and technical staff, who marked the location of the borehole, arranged for the clearance of underground services, observed the drilling, sampling and in-situ testing operations, logged the borehole, and examined and cared for the soil samples. The soil samples were identified in the field, placed in appropriate containers, labelled, and transported back to Golder’s Mississauga geotechnical laboratory where the samples and cores underwent further visual examination and laboratory testing. All the soil laboratory tests were carried out to MTO and/or ASTM Standards, as appropriate. Classification testing (water content, Atterberg limits and grain size distribution) was carried out on selected soil samples. The results of the laboratory testing for the current investigation are included in Appendix C.

The as-drilled borehole location and the ground surface elevation was obtained using a GPS Trimble GEO 7X, having an accuracy of approximately 0.1 m in the vertical and 0.1 m in the horizontal directions. The location given on the Record of Borehole, and as shown on Drawing 1 are positioned related to MTM NAD 83 (Zone 10) CSRS CGVD28 northing and easting coordinates and the ground surface elevations are referenced to Geodetic datum. The borehole location, geographic coordinates, ground surface elevation and drilled depth is presented below.

Borehole No.	Location (MTM NAD 83 Zone 10)		Ground Surface Elevation (m)	Depth of Borehole (m)
	Northing (Latitude, °)	Easting (Longitude, °)		
N/E RS-10	4,847,313.6 (43.765707)	315,912.3 (-79.361985)	137.3	35.1

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[1] ASTM D1586 – Standard Test Method for Standard Penetration Tests and Split Barrel Sampling of the Soils.

[2] ASTM D1587 – Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes.

[3] ASTM D2573 – Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The area surrounding the Highway 401 /Leslie Street interchange is within the physiographic region known as the South Slope, as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984) [4] and *Urban Geology of Canadian Cities* (Menzies and Taylor, 1998) [5].

The South Slope physiographic region is characterized by a smooth to drumlinized till plain that was formed as a result of glacial action and deposition of till material south of the Oak Ridges Moraine. The South Slope contains a variety of soil deposits that have developed over till and the overburden soils can typically be more than 50 m thick. The underlying bedrock consists of grey shale of the Georgian Bay Formation interbedded with limestone, siltstone and sandstone. Within and adjacent to the East Don River, interglacial and post-glacial flooding in the valley has produced deposits of glaciolacustrine sands, silts, and silty clay.

4.2 General Overview of Subsurface Conditions

The Record of Borehole and laboratory testing summary figures from the previous investigation are presented in Appendix A. The soil and groundwater conditions as encountered in the borehole advanced during the current investigation is presented on the Record of Borehole sheets in Appendix B. The geotechnical laboratory test results are presented in Appendix C.

The results of in-situ tests (i.e., SPT and field vanes) as presented in the borehole records and in Section 4.2 are uncorrected. The boundaries between the soil deposits on the borehole records have been inferred from non-continuous sampling, observations of drilling progress and the results of Standard Penetration Tests. These boundaries, therefore, represent transitions between soil types rather than exact planes of geological change. Variation in the stratigraphic boundaries between and beyond boreholes will exist and is to be expected.

In general, the subsurface soils encountered consist of surficial layers of topsoil, underlain by non-cohesive fill. The fill is then underlain by a deposit of silt to silty sand, which is in turn underlain by a deposit consisting of silty clay to clayey silt-silt. Underlying the silty clay to clayey silt-silt deposit is a glacial till deposit consisting of silty clay to sandy clayey silt, followed by a non-cohesive deposit of sand. The sand deposit is in turn underlain by residual soil. A more detailed description of the subsurface conditions encountered in the boreholes is provided in the following sections.

4.2.1 Topsoil

An approximately 100 mm and 230 mm thick layer of topsoil was encountered at ground surface in Boreholes M-03 and N/E RS-10, respectively.

These materials were classified solely based on visual and textural evidence. Testing of organic content or for other nutrients was not carried out. Therefore, the use of materials classified as topsoil cannot be relied upon for support and growth of landscaping vegetation.

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[4] Chapman, L.J. and Putnam, D,F. 1984. *The Physiography of Southern Ontario*, Ontario Geological Survey, Special Volume 2, Third Edition. Accompanied by Map P. 2715, Scale 1:600,000.

[5] Menzies, J., and Taylor, E.M., 1998. *Urban Geology of St. Catharines-Niagara Falls, Region Niagara*. In Urban Geology of Canadian Cities, Geological Association of Canada Special Paper 42, Ed. P.F. Karrow and O.L. White.

4.2.2 SILTY SAND (SM) to Gravelly SAND (SW) (FILL)

A 2.9 m and 6.8 m thick layer of non-cohesive fill consisting of silty sand to gravelly sand was encountered underlying the topsoil in Boreholes N/E RS-10 and M-03, respectively. In Borehole M-03, a 0.7 m thick layer of clayey silt fill, some sand, trace gravel, was encountered at a depth of 2.3 m below ground surface (Elevation 143.0 m) and extends to a depth of 3.0 m below ground surface (Elevation 142.3 m), and possible cobbles were noted at a depth of 6.2 m below ground surface (Elevation 139.1 m). In addition, the gravelly sand fill at Borehole N/E RS-10 contained rootlets, wood, and asphalt fragments. The top of the non-cohesive fill was encountered at depths of 0.1 m and 0.2 m below ground surface (at Elevations 145.2 m and 137.1 m) and extends to depths of 6.9 m and 3.1 m below ground surface (at Elevations 138.4 m and 134.3 m) at Boreholes M-03 and N/E RS-10 respectively.

The SPT “N”-values measured within the gravelly sand to silty sand fill ranges from 5 blows to 53 blows per 0.3 m of penetration, indicating a loose to very dense state of compactness.

Water content measured on samples of the non-cohesive fill range from about 4% to 17%.

Gain size distribution testing was carried out on a sample of the non-cohesive fill, and the result is shown on Figure A1 in Appendix A.

4.2.3 SILT to SILTY SAND (SM)

A 6.9 m thick deposit of silt, trace sand to silty sand, trace plastic fines, trace gravel was encountered underlying the non-cohesive fill in Borehole M-03. The silty sand deposit was encountered at a depth of 6.9 m below ground surface (Elevation 138.4 m) and extends to a depth of 13.8 m below ground surface (Elevation 131.5 m).

The SPT “N”-values measured within the silty sand deposit ranges from 7 blows to 25 blows per 0.3 m of penetration.

Water content measured on samples of the silty sand deposit ranges from about 4% to 23%.

Grain size distribution testing was carried out on a sample of the silt to sandy silt deposit, and the result is shown on Figure A2 in Appendix A.

4.2.4 CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML)

A 12.5 m and 17.0 m thick deposit of clayey silt to clayey silt-silt, trace sand to sandy, trace gravel, was encountered underlying the silt to silty sand deposit and the non-cohesive fill in Boreholes M-03 and N/E RS-10, respectively. The clayey silt to clayey silt-silt deposit was encountered at depths of 3.1 m and 13.8 m below ground surface (at Elevations 134.3 m and 131.5 m) and extended to depths of 20.1 m and 26.3 m below ground surface (at Elevations 117.2 m and 119.0 m) in Boreholes N/E RS-10 and M-03, respectively.

The SPT “N”-values measured within this cohesive deposit range from 0 blows (weight of hammer) to 11 blows per 0.3 m of penetration. In-situ field vane tests carried out within the deposit measured undrained shear strengths generally ranging from about 34 kPa to greater than 96 kPa, indicating that cohesive deposit has a firm to stiff consistency. The sensitivity of the cohesive deposit ranges from about 1.8 and 8.0. The field vane test results indicate that the silty clay to clayey silt-silt deposit has a firm to stiff consistency.

Grain size distribution testing was carried out on samples of the clayey silt to clayey silt-silt deposit, and the results are shown on Figures A3 and A4 in Appendix A, and on Figure C1 in Appendix C.

Atterberg limit testing was carried out on samples of the cohesive deposit and measured liquid limits ranging from about 18% to 29%, plastic limits ranging from about 11% to 16%, and plasticity index ranging from about 4% to 14%. The Atterberg limit test results are presented on Figure A5 in Appendix A, and on Figure C2 in Appendix C and indicates that the material is a clayey silt to clayey silt-silt of low plasticity. The water content measured on samples of this deposit ranges from about 8% to 38%.

4.2.5 SILTY CLAY (CI) to Sandy CLAYEY SILT (CL) TILL

A 1.7 m to 6.1 m thick deposit of glacial till was encountered underlying the silty clay to clayey silt-silt deposit, and it consists of silty clay, trace sand to sandy clayey silt, trace gravel. The till deposit was encountered at depths of 20.1 m and 26.3 m below ground surface (at Elevations 117.2 m and 119.0 m) and extends to depths of 26.2 m and 28.0 m below ground surface (at Elevations 111.1 m and 117.3 m) in Boreholes N/E RS-10 and M-03, respectively. Although not encountered, cobbles and boulders are commonly present within glacially derived soils and therefore should be expected within this deposit.

SPT “N”-values measured within the cohesive till deposit ranges from 15 blows per 0.3 m of penetration to 102 blows per 0.23 m of penetration, suggesting a very stiff to hard consistency.

Grain size distribution testing was carried out on samples of the till deposit and the results are presented in Figure A6 in Appendix A, and on Figure C3 in Appendix C.

Atterberg limit testing was carried out on a sample of the sandy clayey silt till deposit and measured a liquid limit of about 21% , a plastic limit of about 13% , corresponding to a plasticity index of about 8% . The Atterberg limit test result, as presented on Figure C4 in Appendix C, indicates that the material is a clayey silt of low plasticity. The water content measured on samples of this deposit range from about 13% to 19%.

4.2.6 SAND (SP-SM)

A 3.2 m to 5.9 m thick deposit of sand, trace silt, trace gravel was encountered underlying the cohesive till deposit in Boreholes M-03 and N/E RS-10, respectively. The sand deposit was encountered at depths of 26.2 m to 28.0 m below ground surface (at Elevations 111.1 m and 117.3 m) and extends to a depth of 32.1 m below ground surface (Elevation 105.2 m) in Borehole N/E RS-10, while Borehole M-03 was terminated within this deposit at a depth of 31.2 m below ground surface (Elevation 114.1 m).

The SPT “N”-values measured within the sand deposit ranges from 47 blows per 0.3 m of penetration to 100 blows per 0.2 m of penetration, suggesting a dense to very dense state of compactness.

The water content measured on samples of this deposit range from about 18% to 20%.

Grain size distribution testing was carried out on a sample of the sand deposit and the results are presented on Figure C5 in Appendix C.

4.2.7 Residual Soil

Residual soil was encountered underlying the sand deposit in Borehole N/E RS-10 and consists of sandy clayey silt, trace gravel. The residual soil was encountered at a depth of 32.1 m below ground surface (Elevation 105.2 m) and extends to a depth of 35.1 m below ground surface (Elevation 102.2 m) prior to borehole termination.

The SPT “N”-values measured within the residual soil deposit range from 100 blows per 0.3 m of penetration to 100 blows per 0.03 m of penetration, suggesting a hard consistency.

The water content measured on samples of the residual deposit are 13% and 16%.

4.2.8 Groundwater Conditions

Details of the water levels observed in the boreholes upon completion of drilling are summarized on the borehole records. A standpipe piezometer was installed as part of the previous investigation. It should be noted that the groundwater level is subject to seasonal fluctuations and precipitation events and should be expected to be higher during wet periods of the year.

Station / High Mast Light No.	Borehole	Screened Stratigraphy	Water Level		Date of Measurement
			Depth (m)	Elevation (m)	
25+630 / HML#60	M-03	Sand	7.0	138.3	April 22, 2015
			6.9	138.4	June 3, 2015
			6.9	138.4	June 17, 2015
			6.7	138.6	January 30, 2016
			8.2	137.1	February 25, 2016

5.0 CLOSURE

The Foundation Investigation Report was prepared by Ms. Katelyn Nero, E.I.T., and reviewed by Ms. Manisha Ahuja, P.Eng., P.E., a geotechnical engineer with Golder. Mr. Christopher Ng, P.Eng., a MTO Foundations Designated Contact and Associate with Golder conducted an independent technical and quality review of this report.

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PART B

FOUNDATION DESIGN REPORT
HIGH MAST LIGHTS
HIGHWAY 401 EASTBOUND COLLECTOR LANES FROM AVENUE ROAD TO WARDEN AVENUE, TORONTO, ONTARIO
MTO GWP 2130-01-00

6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

6.1 General

This section of the report provided geotechnical engineering parameters and foundation recommendations for the design of two high mast light (HML) foundations. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during previous and current subsurface investigations within the project limits. The design report with the interpretation and recommendations is intended for the use of the Ministry of Transportation to provide the designers with sufficient information to carry out detail design of the HML foundations and shall not be used or relied upon for any other purpose or by any other parties, including the constructor or design-build contractor. The contractor must make their own interpretation based on the factual data in the Foundation Investigation Report (i.e. Part A of the report). Where comments are made on construction, they are provided to highlight those aspects that could affect the design on the project, and for which special provisions or operation constraints may be required in the Contract Documents. Contractors must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

The following points are noted regarding the locations of pertinent boreholes for developing foundation design recommendations for the proposed HML pole locations:

- In general, the existing boreholes are located no further away than approximately 20 m of the proposed HML pole location; and,
- As multiple boreholes are located near the proposed HML pole locations, the more conservative (i.e. lower strength soil) data was assumed from the nearest boreholes in selecting the recommended parameter values for use in the HML pole foundation design.

6.2 Design of High Mast Light Foundations

It is understood that two new HMLs are required at the following location as part of the widening of the Highway 401 Eastbound Collector:

- HML No. 60: Located between Oriole GO Station and the N-E Ramp from Leslie Street to Highway 401 at Station 25+630; and,
- HML No. 62: Located between the Leslie Street and the S-E Ramp from Leslie Street to Highway 401 at Station 25+790.

The HML foundations should be designed in accordance with MTO's *Guidelines for the Design of High Mast Pole Foundations,* (MTO 2004), based on the interpreted stratigraphy and groundwater conditions and the recommended geotechnical design parameters given in Table 1 following the text of this report. Table 1 provides a summary of the selected relevant borehole at each HML location, and a summary of the subsurface conditions encountered in the boreholes. The parameters presented in Table 1 are based on field and laboratory test data as well as accepted correlations (NAVFAC, 1986, Bowles, 1984, and Kulhawy and Mayne, 1990) and the analysis was tempered by engineering judgement based on experience in similar soils.

While the General Arrangement drawing provided by AECOM seems to indicate that the HML will be located at relatively level grade, in the event that the poles are to be located on the embankment slope there would be unbalanced earth pressures around the HML due to its foundation begin located on sloping ground (assumed 2 horizontal to 1 vertical (2H:1V) embankment) or at a distance equal to one time the depth to the bottom of the footing from the toe of slope. For this case, the passive earth pressure coefficients ($K_{p2:1}$), to be used in the foundation design are also included in Table 1.

Where both undrained shear strength, s_u, and effective stress, φ', parameter values are provided in Table 1, for the cohesive deposits, the structural assessment should be completed for both the undrained and drained soil cases, and the more conservative approach (design) should be adopted.

In the design of the foundations, the passive resistance of the soil within the upper 1.2 m below ground surface should be neglected to account for frost action as interpreted from OPSD 3090.101 (Foundation, Frost Penetration Depth for Southern Ontario).

6.3 Resistance to Lateral Loads

The design of piles and drilled shafts subjected to lateral loads should take into account such factors as the batter of the pile (if any), the relative rigidity of the pile/drilled shaft to the surrounding soil, the fixity condition at the head of the pile/drilled shaft (i.e., at the pile cap level), the structural capacity of the pile/drilled shaft to withstand bending moments, the soil resistance that can be mobilized, the tolerable lateral deflections at the head of the pile/drilled shaft and group effects. For longer, more flexible elements, the maximum yield moment of the pile may be reached prior to mobilization of the lateral geotechnical resistance. For design purposes, both the structural and geotechnical resistances should be evaluated to establish the governing case. Lateral loading could be resisted fully or partially using battered piles, where possible.

The resistance to lateral loading in front of a single pile or drilled shaft may be calculated using subgrade reaction theory where the coefficient of horizontal subgrade reaction, k_h (kPa/m), is based on the equations below. However, the response of a pile or drilled shaft to lateral loads is highly non-linear and methods that assume linear behavior (such as subgrade reaction theory) are only appropriate where the maximum drilled shaft deflections are less than 1% of the pile or drilled shaft diameter, where the loading is static (no cycling) and where the pile material is linear (CFEM, 2006). If one or more of these conditions are not satisfied, lateral pile analysis should be carried out using p-y curves.

For non-cohesive soils:

$$k_h = \frac{n_h z}{B}$$

where:
n_h = coefficient related to soil density (kPa/m);
z = depth below the top of the pile cap for semi-integral abutments and bottom of CSP for integral abutments (m), and,
B = width of pile or diameter of drilled shaft (m)

For cohesive soils:

$$k_h = \frac{67 s_u}{B}$$

where:
s_u = undrained shear strength of the soil (kPa), and,
B = width of pile or diameter of drilled shaft (m).

The values of n_h (Terzaghi, 1955 and Reese, 1975) and s_u to be incorporated into the calculations of the coefficient of horizontal subgrade reaction (k_h) within the native overburden, to be used for the structural analysis of the piles or drilled shafts at this site are summarized in Table 1, following the text of this report.

6.4 Construction Considerations

Water-bearing non-cohesive soils at this site should be expected to run or flow into the drilled shaft (caisson) hole during or after drilling of the caisson foundations for the HML. Therefore, appropriate equipment and procedures will be required to minimize ground loss during drilling and concrete placement. This could include the use of temporary or permanent caisson liners, and/or the use of bentonite and/or polymer slurry.

Although not typically noted on the borehole records, cobbles and/or boulders may be present in glacially derived till and granular deposits encountered at the HML locations. Possible cobbles were also noted in the granular fill near HML No. 60. Appropriate equipment and procedures may be required to penetrate the cobbles and/or boulders as part of caisson installation for the HML.

It is recommended that the Non-Standard Special Provisions (NSSP) presented in Appendix D be included in the Contract Documents to warn the Contractor of the potential presence of wet non-cohesive soils and the potential presence of cobbles and boulders within the fill and glacial till, which may affect the installation of the caisson foundations at this site.

7.0 CLOSURE

The Foundation Design Report was prepared by Ms. Katelyn Nero, E.I.T., and reviewed by Ms. Manisha Ahuja, P.Eng., P.E., a geotechnical engineer with Golder. Mr. Christopher Ng, P.Eng. and MTO Foundations Designated Contact and Associate with Golder conducted an independent quality review of this report.

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ASTM International:

ATSM D1586	Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
ASTM D1587	Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes
ASTMD2573	Standard Test Method for Field Vane Shear Test in Saturated Fine-Grained Soils

Ontario Occupational Health and Safety Act:

Ontario Regulation 903	Wells (as amended)

Ontario Provincial Standard Drawings (OPSD)

OPSD 3090.101	Foundation, Frost Penetration Depths for Southern Ontario

Table 1: Geotechnical Design Parameters for High Mast Light Foundations

Borehole No.	Station / HMP No.	Ground Surface Elevation at Reference Borehole No. (m)	Estimated Ground Surface Elevation at HML (m)	Stratum	Depth[1] (m)	Elevation[1] (m)	Groundwater Elevation[2] (m)	Design Parameters[3]							
								S_u (kPa)	φ' (°)	γ (kN/m^3)	γ' (kN/m^3)	K_p[4]	$K_{p2:1}$	n_h (kPa/m)	
M-03	25+630 / HML No. 60	145.3	145	Compact to Very Dense Silty Sand (Fill)	0.1 – 6.9	145.2 – 138.4	139	--	36	21	11	3.9	1.5	Above Groundwater	25,000
														Below Groundwater	15,000
				Compact Silty Sand	6.9 – 13.8	138.4 – 131.5		--	33	20	10	3.4	1.3	Above Groundwater	16,000
														Below Groundwater	10,000
				Firm to Stiff Clayey Silt	13.8 - 26.3	131.5 – 119.0		40	29	21	11	2.9	1.1	--	--
				Hard Silty Clay (Till)	26.3 – 28.0	119.0 – 117.3		200	34	22	12	3.5	1.3	--	--
				Dense to Very Dense Sand	Below 28.0	Below 117.3		--	37	22	12	4.0	1.5	Below Groundwater	24,000
N/E RS-10	25+790 / HML No. 62	137.3	139	Loose to Compact Gravelly Sand to Silty Sand (Fill)	0.2 – 3.0	137.1 – 134.3	137	--	36	21	11	3.9	1.5	Above Groundwater	11,000
														Below Groundwater	8,000
				Stiff Clayey Silt-Silt	3.0 – 5.6	134.3 – 131.7		50	32	21	11	3.3	1.2	--	--
				Firm to Stiff Clayey Silt	5.6 – 20.1	131.7 – 117.2		35	32	21	11	3.3	1.2	--	--
				Hard Sandy Clayey Silt (Till)	20.1 – 26.2	117.2 – 111.1		200	34	22	12	3.5	1.3	--	--
				Very Dense Sand	26.2 – 32.1	111.1 – 105.2		--	37	22	12	4	1.5	Below Groundwater	24,000

Borehole No.	Station / HMP No.	Ground Surface Elevation at Reference Borehole No. (m)	Estimated Ground Surface Elevation at HML (m)	Stratum	Depth[1] (m)	Elevation[1] (m)	Groundwater Elevation[2] (m)	Design Parameters[3]							
								S_u (kPa)	φ' (°)	γ (kN/m³)	γ' (kN/m³)	K_p[4]	$K_{p2:1}$	n_h (kPa/m)	
				Hard Sandy Clayey Silt (Residual Soil)	Below 32.1	Below 105.2		200	36	22	12	3.9	1.5	--	--

NOTES:

1. Depths are given related to the borehole ground surface elevation; the ground surface elevation at the borehole location(s) should be compared to the ground surface elevation at the actual HML pole location, and the depths to various soil stratum adjusted accordingly.
2. Groundwater level inferred based on additional boreholes in the vicinity of the HML pole.
3. Design Parameters:
   S_u = undrained shear strength (kPa)
   φ' = effective friction angle (degrees)
   γ = bulk unit weight (kN/m^3)
   γ' = effective unit weight below the groundwater level (kN/m^3)
   K_p = passive earth pressure coefficient
   $K_{p2:1}$ = passive earth pressure coefficient for 2H:1V sloping ground surface
   n_h = coefficient related to soil density (kPa/m)
4. The total passive resistance may be calculated based on the K_p indicated above but reduced by an approximate factor that considers the allowable wall movement in accordance with Figure C6.27 of the *Canadian Highway Bridge Design Code* (CHBDC, 2019) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

DRAWINGS

MINISTRY OF TRANSPORTATION, ONTARIO

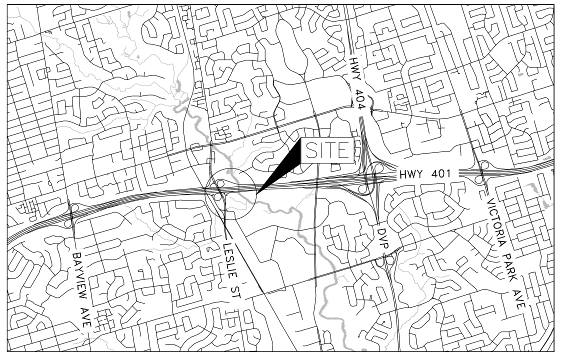
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No.
GWP No. 2130-01-00

SHEET

HIGHWAY 401
HIGH MAST LIGHT POLES
BOREHOLE LOCATIONS

GOLDER



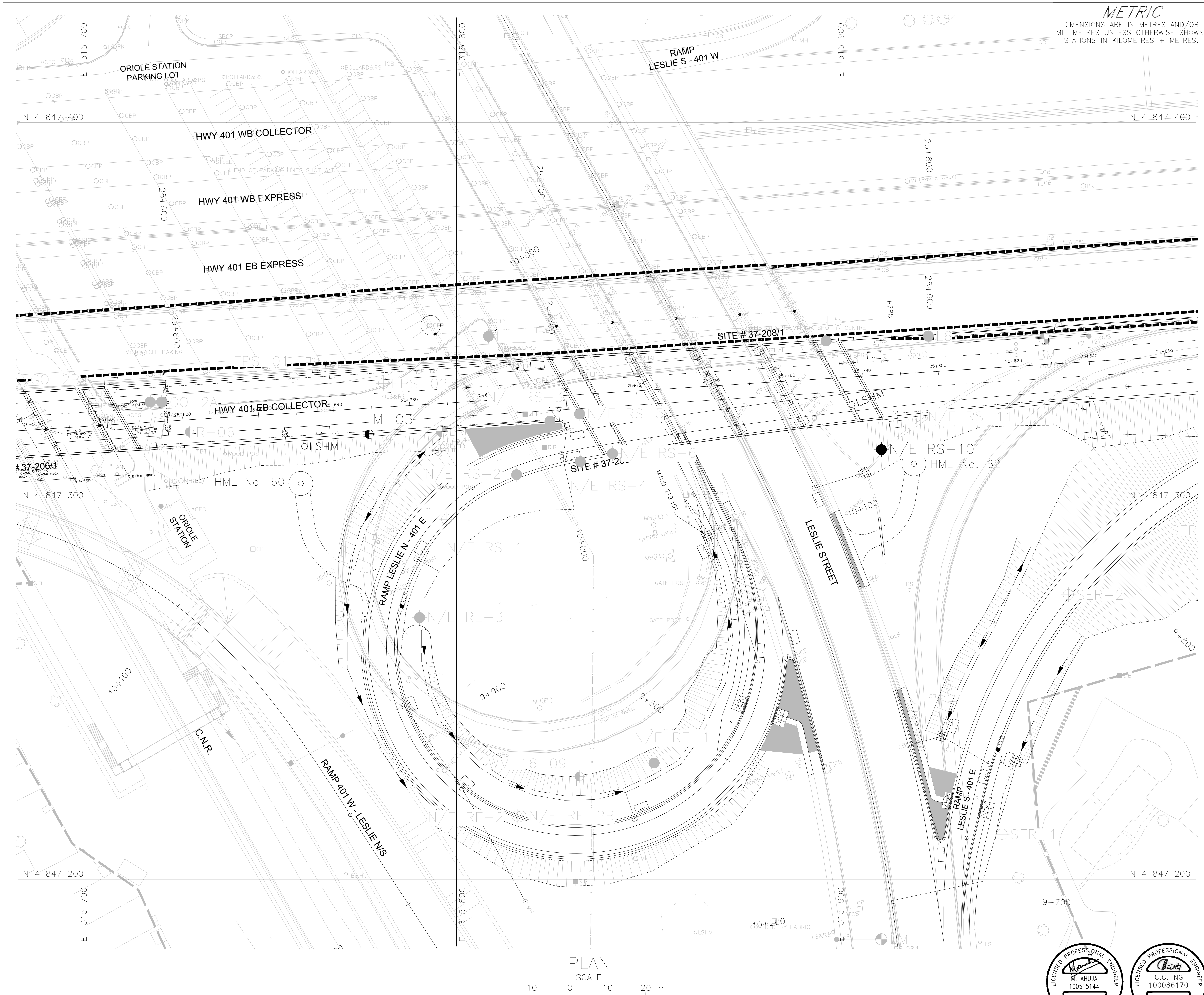
KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- ● Borehole – Current Investigation
- ◐ Borehole – Previous Investigation (MTO GEOCRES No. 30M14-463)
- ⊕ Cone Penetration Test (CPT) – Current Investigation
- ● Borehole – Golder Other Investigation
- ⊕ Cone Penetration Test (CPT) – Golder Other Investigation
- ◐ Borehole – Previous Investigation Other Report

BOREHOLE CO-ORDINATES (NAD 83 MTM ZONE 10)

No.	ELEVATION	NORTHING	EASTING
M-03	145.3	4847317.6	315777.0
N/E RS-10	137.3	4847313.6	315912.3



PLAN
SCALE

NOTES

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

The boundaries between soil strata have been established only at borehole locations. Between boreholes the boundaries are assumed from geological evidence.

REFERENCE

Base and design plans provided in digital format by AECOM, drawing file no. 401_EBC_Avenue-Warden_base.dwg, received MMM DD, YYYY and 401_EBC_Avenue-Warden_plan.dwg, received September 17, 2019. EB Collector general arrangement plan provided by AECOM, drawing file no. S13 GENERAL ARRANGEMENT.dwg, received March 24, 2020. Proposed and existing ground profiles provided in digital format by AECOM, drawing file no. xs_Leslie Ramp N-E.dwg, received March 6, 2019.

M. AHUJA
100515144
Oct. 22, 2020

C.C. NG
100086170
Oct. 22, 2020

NO.	DATE	BY	REVISION

Geocres No. 30M14-525

HWY. 401		PROJECT NO. 1786302	DIST.
SUBM'D. DH	CHKD. KN	DATE: 10/22/2020	SITE:
DRAWN: DD/MR	CHKD. MA	APPD. CN	DWG. 1

PLOT DATE: October 22, 2020
FILENAME: S:\Clients\MTO\Hwy_401_Leslie_Street\99_PROJ\1786302\40_PROD\0006_High_Mast_Light_Poles\1786302-0006-BG-0001.dwg

APPENDIX A

2015 INVESTIGATION (MTO GEOCRES NO. 30M14-463)

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT(1) 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

1) Laboratory Triaxial Testing
2) Field Insitu Vane Testing
3) Laboratory Vane Testing
4) SPT value
5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

SS Split Spoon Sample
WS Wash Sample
AS Auger (Grab) Sample
TW Thin Wall Shelby Tube Sample
TP Thin Wall Piston Sample
PH Sampler Advanced by Hydraulic Pressure
PM Sampler Advanced by Manual Pressure
WH Sampler Advanced by Self Static Weight
RC Rock Core
SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ($W_L < 30\%$).
		CI	Inorganic clays of medium plasticity, silty clays. ($30\% < W_L < 50\%$).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

Fresh (FR)	No visible signs of weathering.
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.

SYMBOLS

▨	CLAYSTONE
┅	SILTSTONE
░	SANDSTONE
■	COAL
▩	Bedrock (general)

DISCONTINUITY SPACING

Bedding	**Bedding Plane Spacing**
Very thickly bedded	Greater than 2m
Thickly bedded	0.6 to 2m
Medium bedded	0.2 to 0.6m
Thinly bedded	60mm to 0.2m
Very thinly bedded	20 to 60mm
Laminated	6 to 20mm
Thinly Laminated	Less than 6mm

TERMS

Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.

STRENGTH CLASSIFICATION

Rock Strength	**Approximate Uniaxial Compressive Strength**		**Field Estimation of Hardness***
	(MPa)	**(psi)**	
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

RECORD OF BOREHOLE No M-03

1 OF 4

METRIC

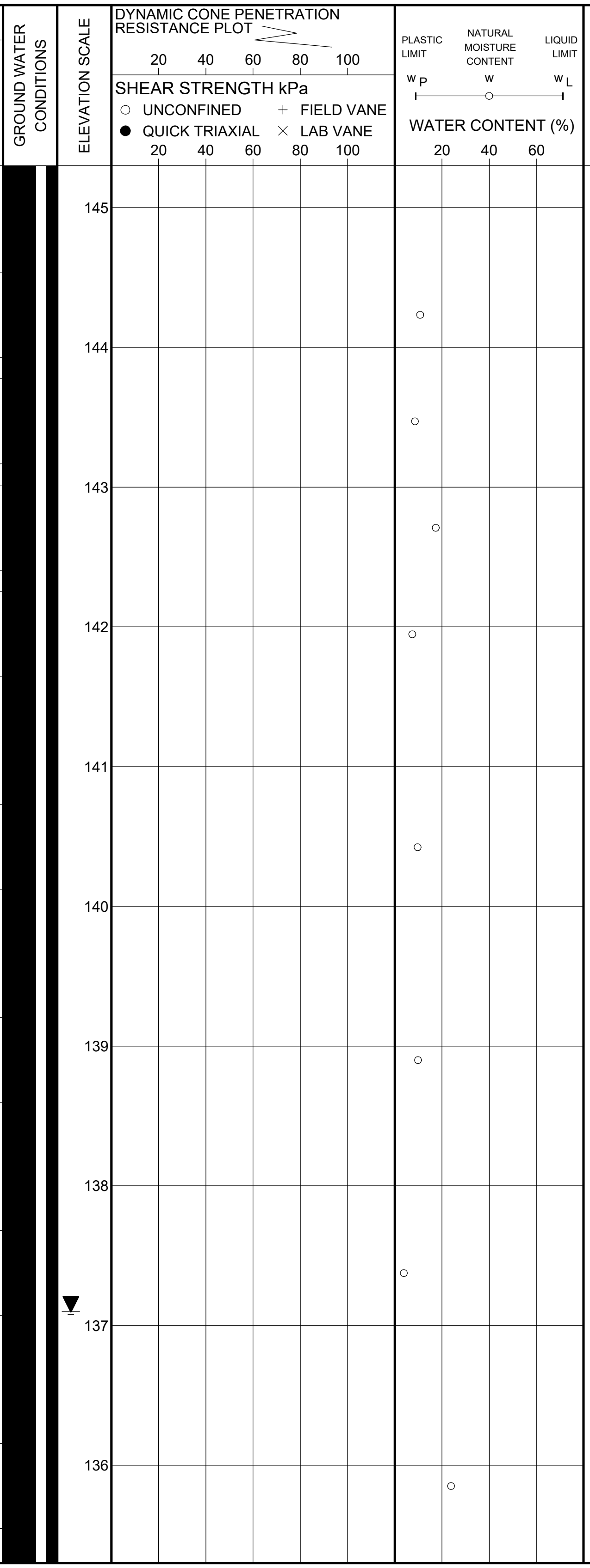
W.P.	2061-13-00	LOCATION	N 4 847 317.6 E 315 777.0	ORIGINATED BY	ES
HWY	401	BOREHOLE TYPE	Hollow Stem Augers/Dynamic Cone Penetration Test	COMPILED BY	AN
DATUM	Geodetic	DATE	2015.04.02 - 2015.04.07	CHECKED BY	MEF

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
145.3	GROUND SURFACE
0.0	**TOPSOIL:** (100mm)
0.1	**SAND** and **SILT**, trace gravel, trace clay Dense to Compact Brown Moist (FILL) Dark Brown
143.0 / 2.3	Clayey **SILT**, some sand, trace gravel Stiff Brown (FILL)
142.3 / 3.0	
141.2 / 4.1	Silty **SAND**, some clay, trace gravel, occasional cobbles
139.7 / 5.6	Very Dense Possible cobbles at 6.2m
138.4 / 6.9	**SAND** and **SILT**, trace clay, trace gravel Compact Brown Moist

SAMPLES

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
1	SS	33				
2	SS	23				
3	SS	14				
4	SS	21				
5	SS	31	9	53	26	12
6	SS	53				
7	SS	25				
8	SS	14				



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR SA SI CL

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No M-03

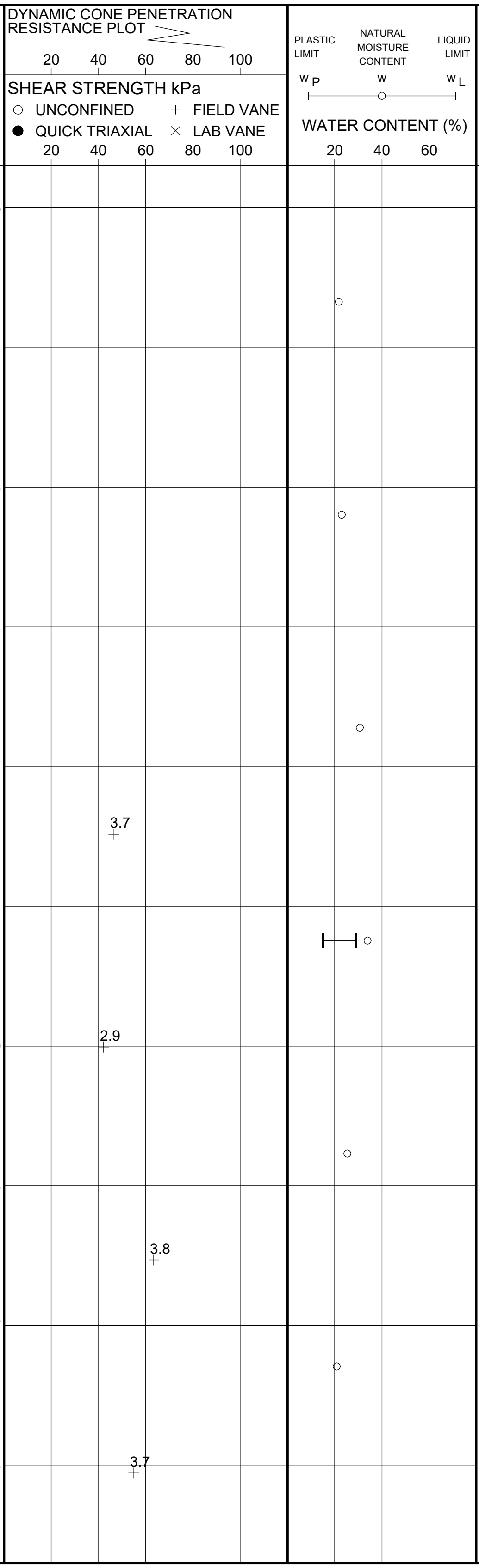
2 OF 4

METRIC

W.P. 2061-13-00
LOCATION N 4 847 317.6 E 315 777.0
ORIGINATED BY ES
HWY 401
BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test
COMPILED BY AN
DATUM Geodetic
DATE 2015.04.02 - 2015.04.07
CHECKED BY MEF

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
	SAND and **SILT**, trace clay, trace gravel Compact Brown Wet							
134.6 10.7	**SILT**, trace gravel, some clay	9	SS	7	0	6	84	10
133.6 11.7	Grey	10	SS	12				
131.5 13.8	CLAYEY SILT some to with sand Firm Grey Wet	11	SS	4				
		12	SS	1	0	17	37	46
		1	TW	PH				
	Firm to Stiff							
		13	SS	1				



Continued Next Page

+3, ×3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

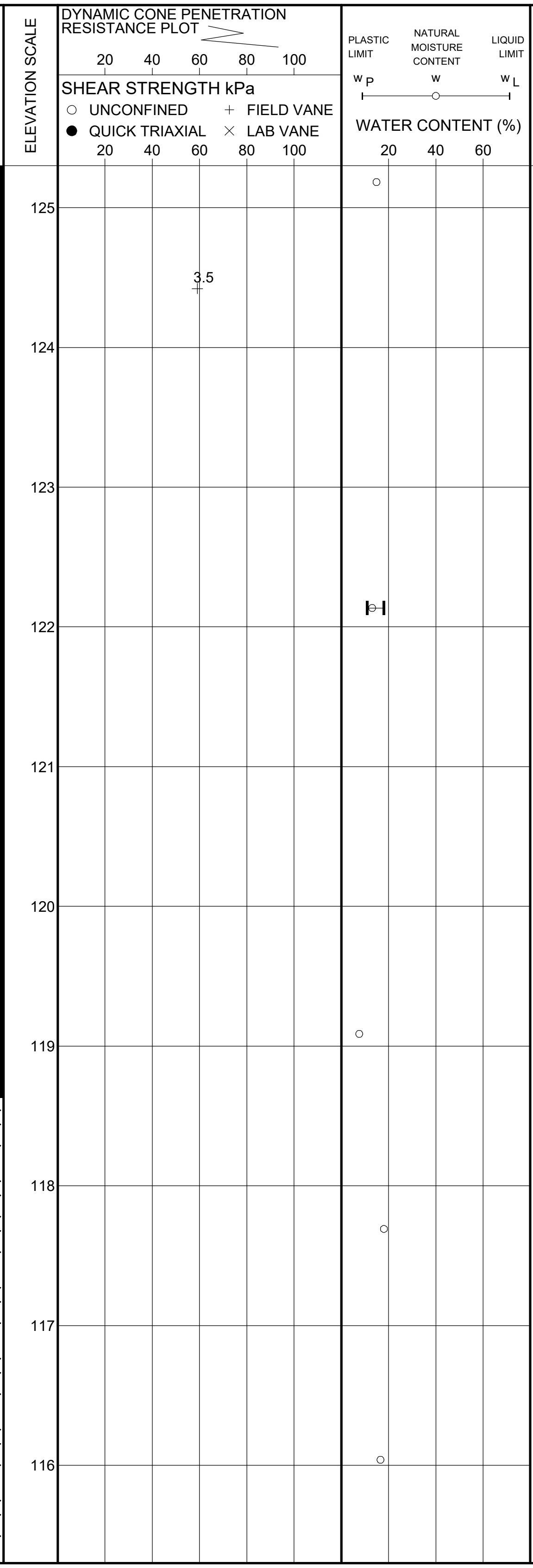
RECORD OF BOREHOLE No M-03

3 OF 4

METRIC

W.P. 2061-13-00
LOCATION N 4 847 317.6 E 315 777.0
ORIGINATED BY ES
HWY 401
BOREHOLE TYPE Hollow Stem Augers/Dynamic Cone Penetration Test
COMPILED BY AN
DATUM Geodetic
DATE 2015.04.02 - 2015.04.07
CHECKED BY MEF

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ kN/m 3	GR	SA	SI	CL
	Continued From Previous Page								
	CLAYEY SILT some to with sand Stiff Grey Wet	14	SS	0					
	Sand seams	15	SS	11		0	33	46	21
		16	SS	15					
119.0 26.3	Silty **CLAY**, trace sand Hard Grey Moist (TILL)	17	SS	102/ 0.225		0	9	43	48
117.3 28.0	**SAND**, trace gravel Dense Grey Wet	18	SS	47					



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+ 3, × 3: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

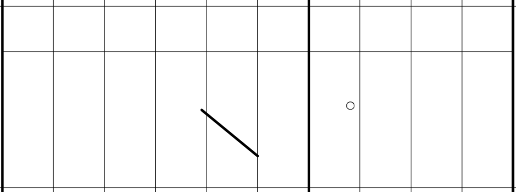
RECORD OF BOREHOLE No M-03

4 OF 4

METRIC

W.P.	2061-13-00	LOCATION	N 4 847 317.6 E 315 777.0	ORIGINATED BY	ES
HWY	401	BOREHOLE TYPE	Hollow Stem Augers/Dynamic Cone Penetration Test	COMPILED BY	AN
DATUM	Geodetic	DATE	2015.04.02 - 2015.04.07	CHECKED BY	MEF

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION Continued From Previous Page	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	SAND, trace gravel Dense Grey Wet		19	SS	100/ 0.200		115				
114.6 30.7	End of sampling at 30.7m and start of DCPT										
114.1 31.2	END OF BOREHOLE AT 31.2m UPON DCPT REFUSAL. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.04m slotted screen.										



WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
Apr 22/2015	7.0	138.3
Jun 03/2015	6.9	138.4
Jun 17/2015	6.9	138.4
Jan 30/2016	6.7	138.6
Feb 25/2016	8.2	137.1

$+^3, \times^3$: Numbers refer to Sensitivity

20
15 ◐ 5
10
(%) STRAIN AT FAILURE

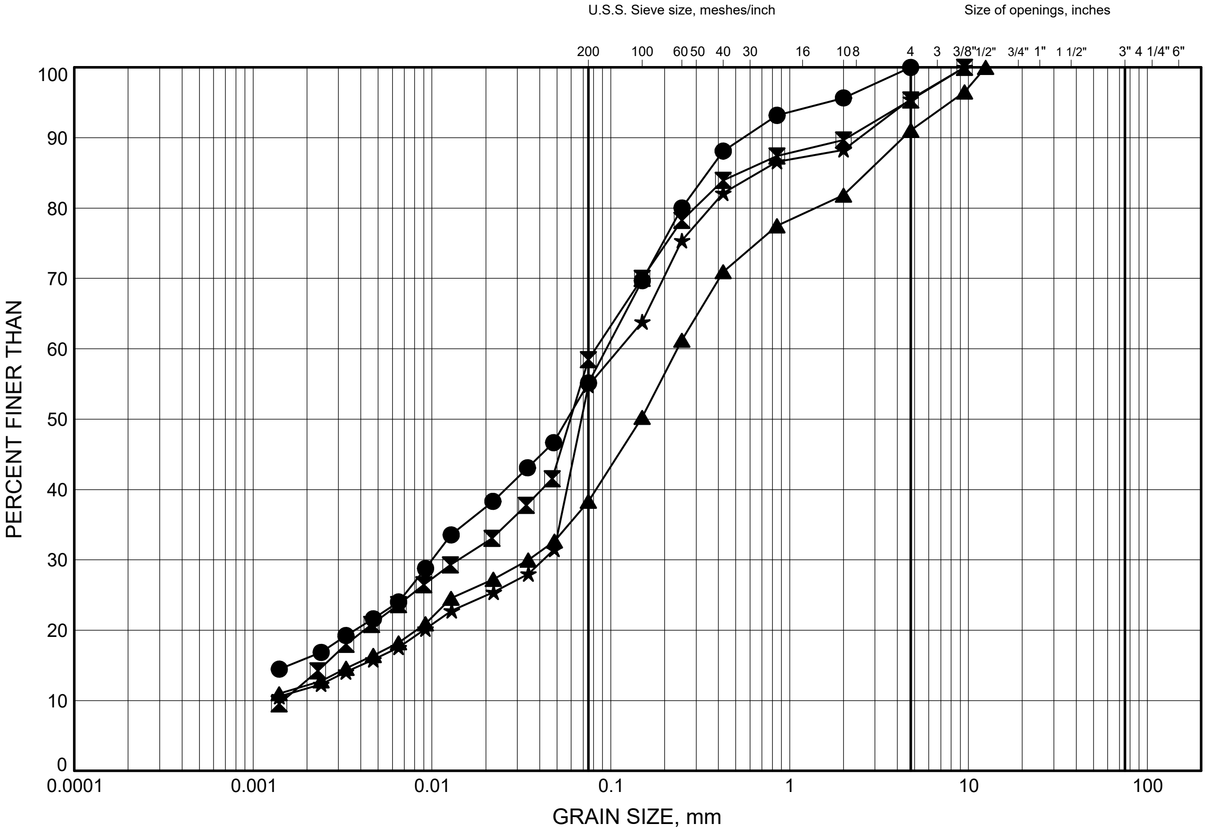
ONTMT4S 1205.GPJ 2015TEMPLATE(MTO).GDT 3/23/16

Hwy 401 Leslie Street 2013-E-0032

GRAIN SIZE DISTRIBUTION

FIGURE A1

SAND & SILT / Silty SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M-01	3.24	140.46
⧗	M-02	4.88	136.32
▲	M-03	4.88	140.42
★	M-04	1.83	138.37

Date March 2016

W.P. 2061-13-00

THURBER

Prep'd AN

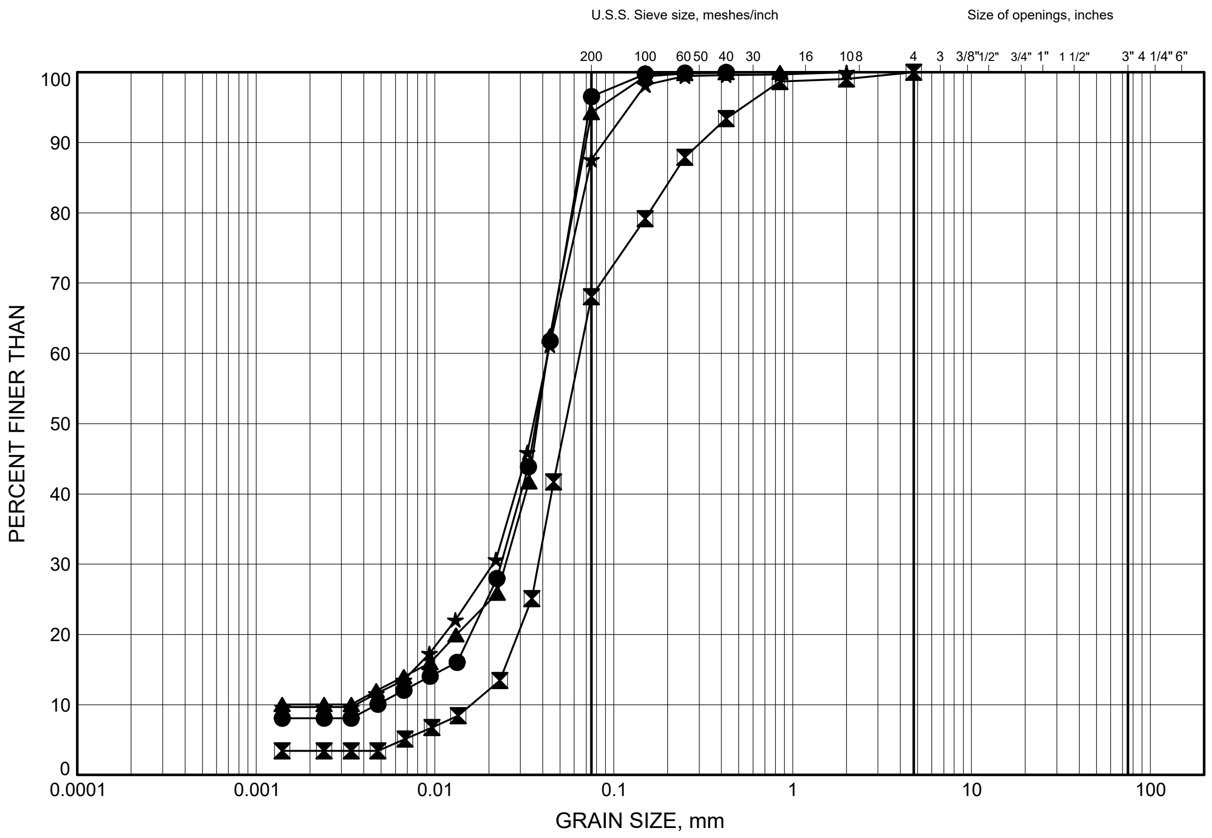
Chkd. SKP

Hwy 401 Leslie Street 2013-E-0032

GRAIN SIZE DISTRIBUTION

FIGURE A2

SANDS & SILTS



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M-01	7.92	135.78
⧗	M-02	7.92	133.28
▲	M-03	10.97	134.33
★	M-04	6.40	133.80

GRAIN SIZE DISTRIBUTION - THURBER 1205.GPJ 3/23/16

Date March 2016

W.P. 2061-13-00

THURBER

Prep'd AN

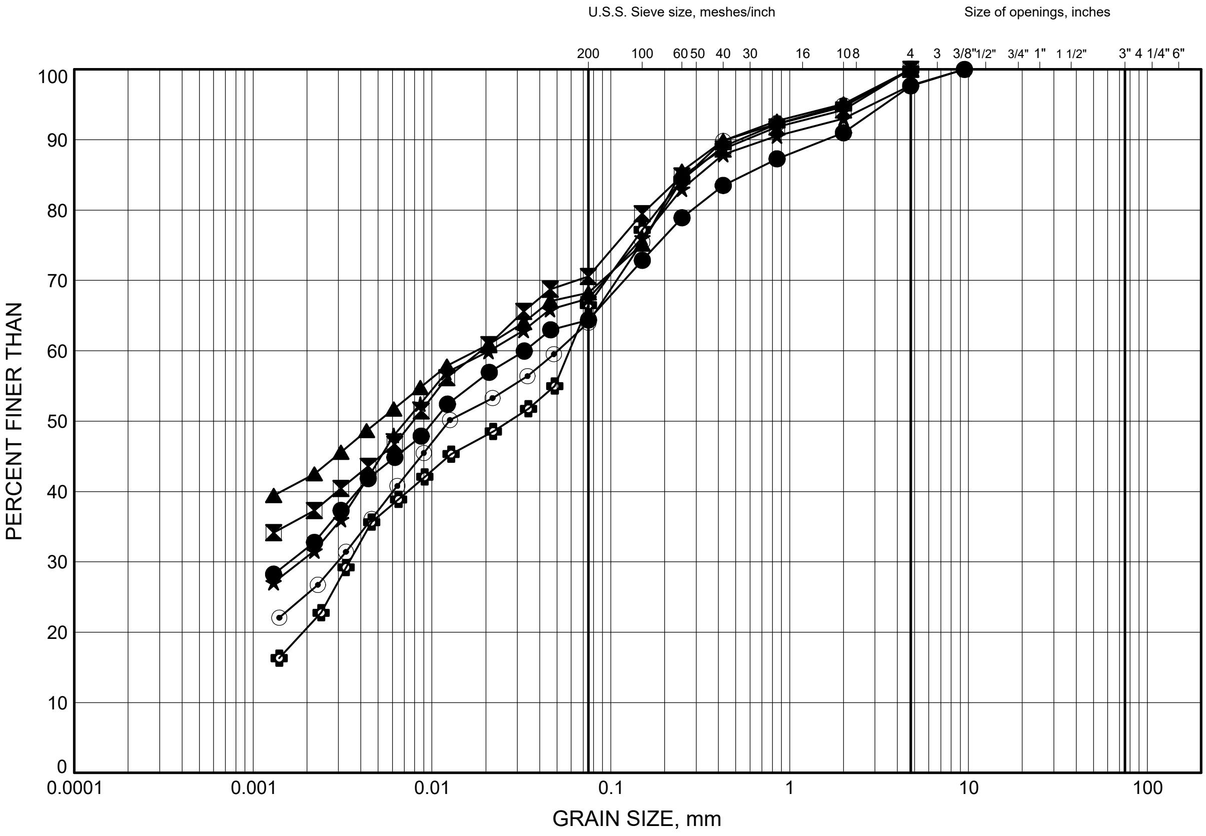
Chkd. SKP

Hwy 401 Leslie Street 2013-E-0032

GRAIN SIZE DISTRIBUTION

FIGURE A3

Silty CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M-01	14.02	129.68
⧗	M-01	20.12	123.58
▲	M-02	10.97	130.23
★	M-02	18.59	122.61
⊙	M-02	26.21	114.99
✜	M-03	23.16	122.14

Date March 2016

W.P. 2061-13-00

THURBER

Prep'd AN

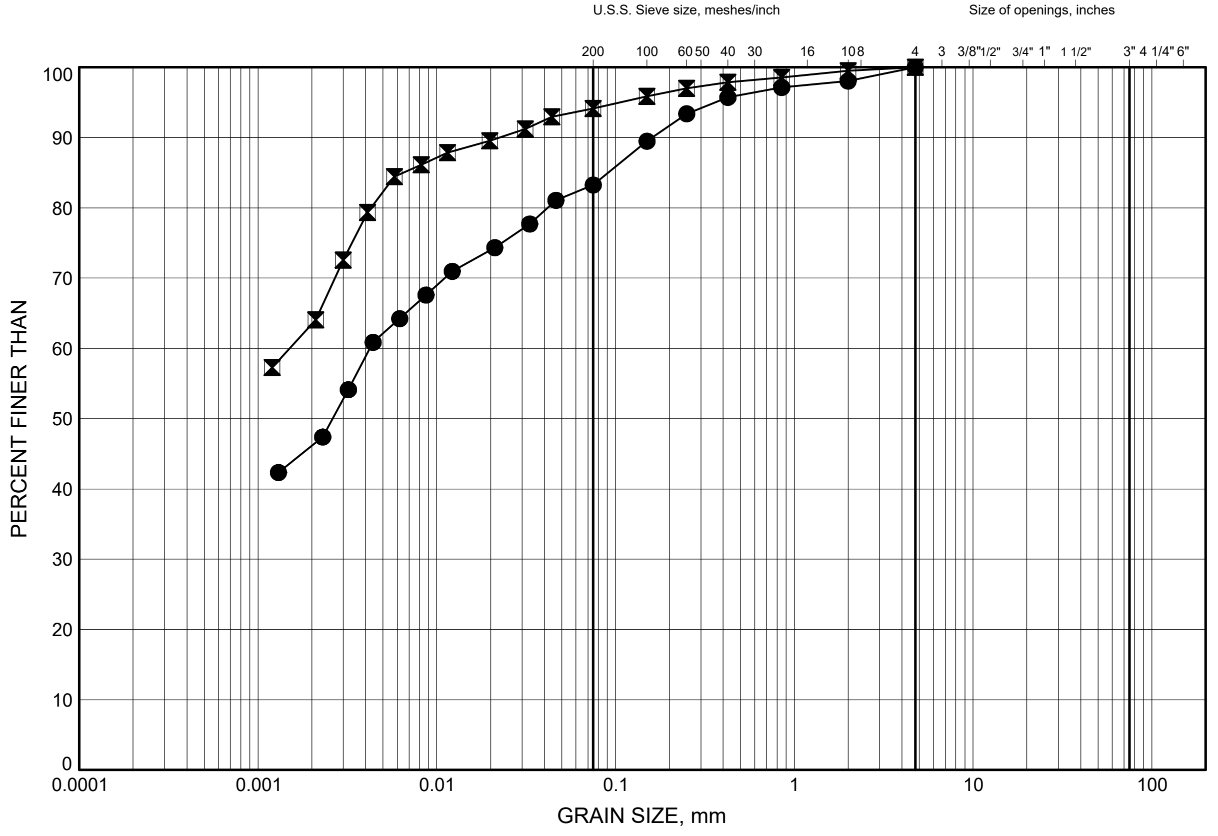
Chkd. SKP

Hwy 401 Leslie Street 2013-E-0032

GRAIN SIZE DISTRIBUTION

FIGURE A4

Silty CLAY



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M-03	15.54	129.76
⧗	M-04	14.02	126.18

Date March 2016

W.P. 2061-13-00

THURBER

Prep'd AN

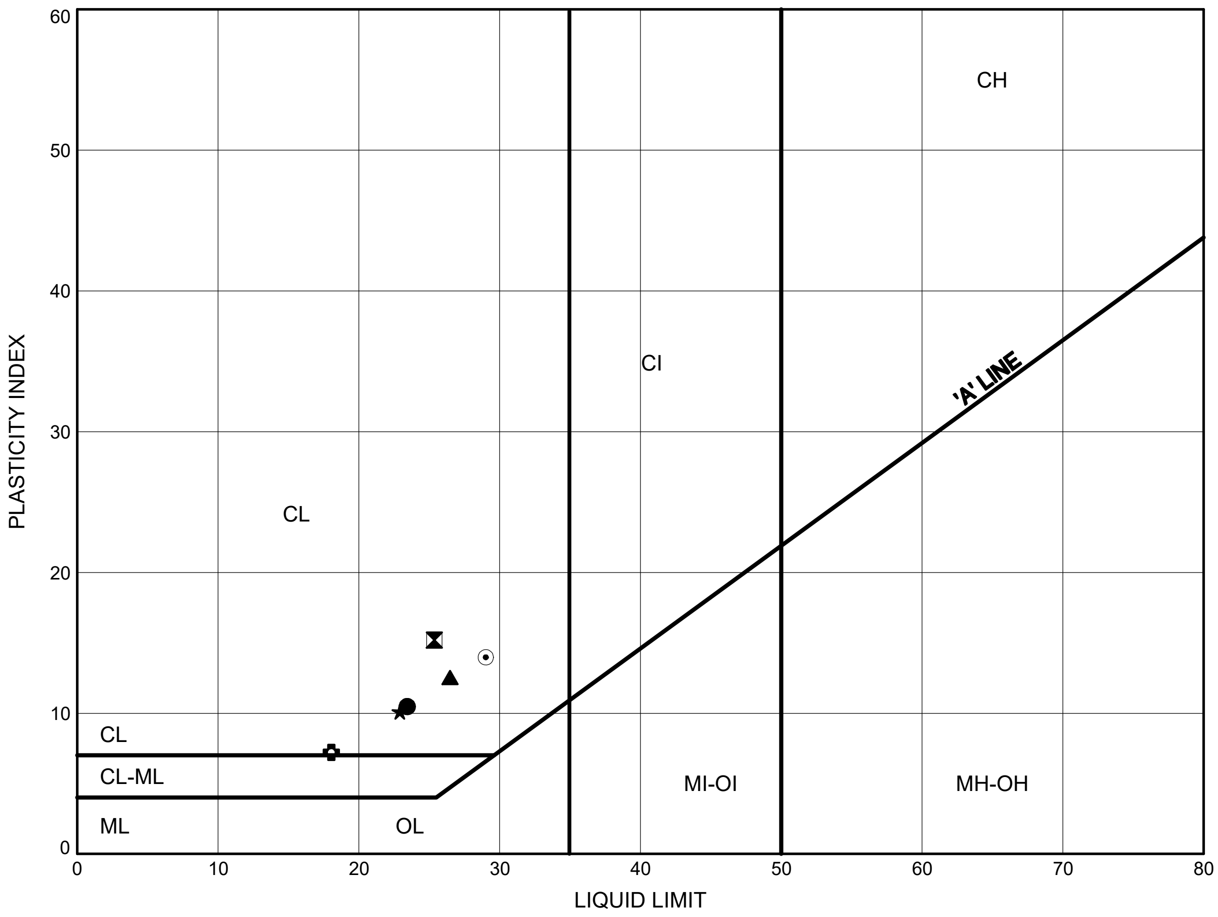
Chkd. SKP

Hwy 401 Leslie Street 2013-E-0032

ATTERBERG LIMITS TEST RESULTS

FIGURE A5

CLAYEY SILT TO CLAYEY SILT-SILT



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M-01	14.02	129.68
⧗	M-01	20.12	123.58
▲	M-02	10.97	130.23
★	M-02	18.59	122.61
⊙	M-03	15.54	129.76
✿	M-03	23.16	122.14

Date March 2016

W.P. 2061-13-00

Prep'd AN

Chkd. SKP

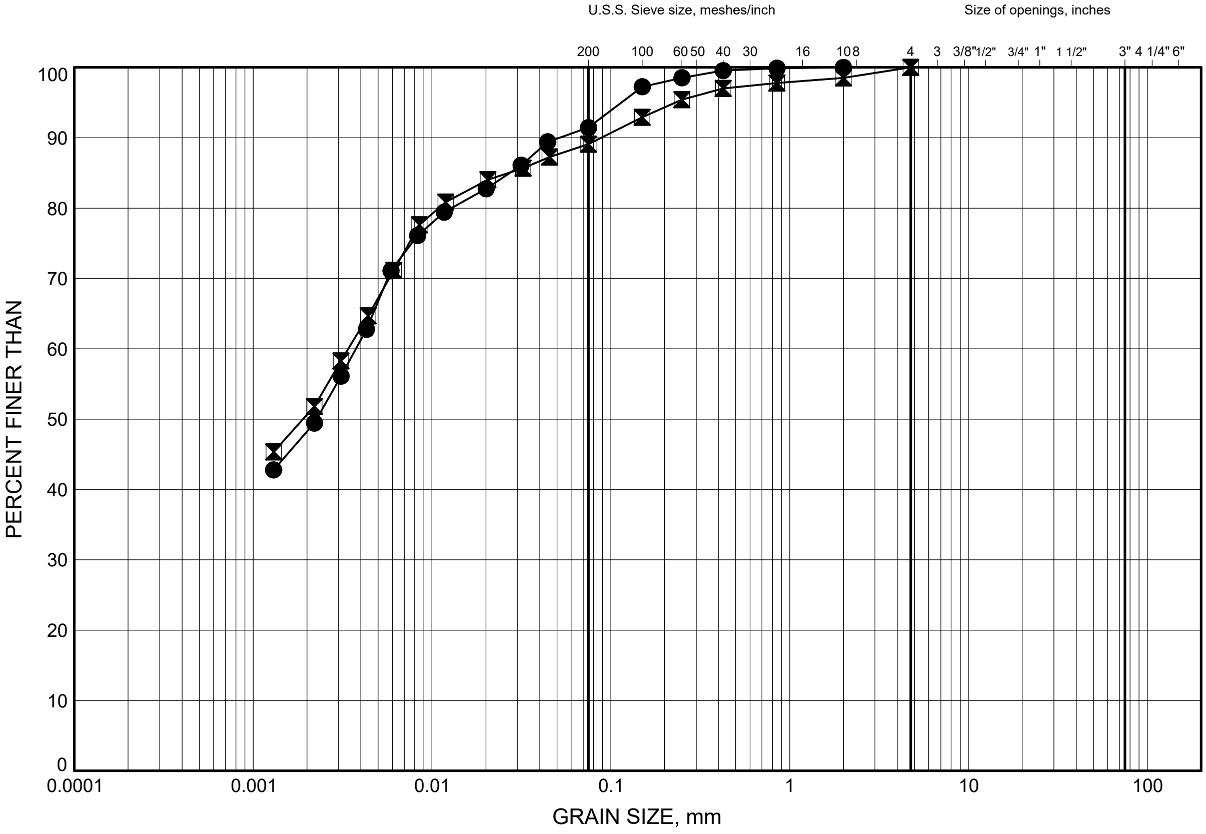
THURBALT 1205.GPJ 3/23/16

Hwy 401 Leslie Street 2013-E-0032

GRAIN SIZE DISTRIBUTION

FIGURE A6

Silty CLAY TILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	M-03	27.74	117.56
⧗	M-04	29.26	110.94

Date March 2016

W.P. 2061-13-00

THURBER

Prep'd AN

Chkd. SKP

APPENDIX B

CURRENT INVESTIGATION – RECORD OF BOREHOLE

ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS
MINISTRY OF TRANSPORTATION, ONTARIO

PARTICLE SIZES OF CONSTITUENTS

Soil Constituent	Particle Size Description	Millimetres	Inches (US Std. Sieve Size)
BOULDERS	Not Applicable	>200	>8
COBBLES	Not Applicable	75 to 200	3 to 8
GRAVEL	Coarse Fine	19 to 75 4.75 to 19	0.75 to 3 (4) to 0.75
SAND	Coarse Medium Fine	2.00 to 4.75 0.425 to 2.00 0.075 to 0.425	(10) to (4) (40) to (10) (200) to (40)
FINES	Classified by plasticity	<0.075	< (200)

MODIFIERS FOR SECONDARY COMPONENTS[1,2]

Percentage by Mass	Modifier
> 35	Use 'and' to combine primary and secondary component (*i.e.,* SAND and gravel)
> 20 to 35	Primary soil name prefixed with "gravelly, sandy" as applicable
> 10 to 20	some (*i.e.,* some sand)
≤ 10	trace (*i.e.,* trace fines)

1. Only applicable to components not described by Primary Group Name.
2. Classification of Primary Group Name based on Unified Soil Classification System (ASTM D2487) for coarse-grained soils; fine-grained soils described per current MTO Soil Classification System.

PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

Cone Penetration Test (CPT)
An electronic cone penetrometer with a 60° conical tip and a project end area of $10\ cm^2$ pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (q_t), porewater pressure (u) and sleeve friction (f_s) are recorded electronically at 25 mm penetration intervals.

Dynamic Cone Penetration Resistance (DCPT); N_d:
The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH:	Sampler advanced by hydraulic pressure
PM:	Sampler advanced by manual pressure
WH:	Sampler advanced by static weight of hammer
WR:	Sampler advanced by weight of sampler and rod

SAMPLES

AS	Auger sample
BS	Block sample
CS	Chunk sample
DD	Diamond Drilling
DO or DP	Seamless open ended, driven or pushed tube sampler – note size
DS	Denison type sample
GS	Grab Sample
MC	Modified California Samples
MS	Modified Shelby (for frozen soil)
RC / SC	Rock core / Soil core
SS	Split spoon sampler – note size
ST	Slotted tube
TO	Thin-walled, open – note size (Shelby tube)
TP	Thin-walled, piston – note size (Shelby tube)
WS	Wash sample
OD / ID	Outer Diameter / Inner Diameter
HSA / SSA	Hollow-Stem Augers / Solid-Stem Augers

SOIL TESTS

w	water content
PL , w_p	plastic limit
LL , w_L	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test[1]
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement[1]
D_R	relative density (specific gravity, Gs)
DS	direct shear test
GS	specific gravity
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO_4	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V (FV)	field vane (LV-laboratory vane test)
γ	unit weight

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

COARSE-GRAINED SOILS

Compactness[1]

Term	SPT 'N' (blows/0.3m)[2]
Very Loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	> 50

1. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.
2. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.

FINE-GRAINED SOILS

Consistency

Term	Undrained Shear Strength (kPa)	SPT 'N'[1,2] (blows/0.3m)
Very Soft	< 12	0 to 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	> 200	> 30

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

Field Moisture Condition

Term	Description
Dry	Soil flows freely through fingers.
Moist	Soils are darker than in the dry condition and may feel cool.
Wet	As moist, but with free water forming on hands when handled.

LIST OF SYMBOLS
MINISTRY OF TRANSPORTATION, ONTARIO

Unless otherwise stated, the symbols employed in the report are as follows:

I. GENERAL

π	3.1416
ln x	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

II. STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta\sigma$
ε	linear strain
ε_v	volumetric strain
η	coefficient of viscosity
υ	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
σ_1, σ_2, σ_3	principal stress (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III. SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation

* Density symbol is ρ. Unit weight symbol is γ. where $\gamma = \rho \cdot g$ (i.e., mass density multiplied by acceleration due to gravity)

(a) Index Properties (continued)

w	water content
w_L or LL	liquid limit
w_P or PL	plastic limit
I_P or PI	plasticity index $= (w_l - w_p)$
NP	non-plastic
w_s	shrinkage limit
I_L	liquidity index $= (w - w_p) / I_p$
I_C	consistency index $= (w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index $= (e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
$C_{\alpha(e)}$	secondary compression index
C_α	rate of secondary compression
$C_{\alpha(\varepsilon)}$	modified secondary compression index
m_v	coefficient of volume change
c_v	coefficient of consolidation (vertical direction)
c_h	coefficient of consolidation (horizontal direction)
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation stress
OCR	over-consolidation ratio $= \sigma'_p / \sigma'_{vo}$

(d) Shear Strength

τ_p, τ_r	peak and residual shear strength
c'	effective cohesion
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q or q'	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes:
1 $\tau = c' + \sigma' \tan \phi'$
2 shear strength = (compressive strength)/2

RECORD OF BOREHOLE No N/E RS-10 SHEET 1 OF 3 METRIC

PROJECT 1786302

G.W.P. 2130-01-00

DIST Central HWY 401

DATUM Geodetic

LOCATION N 4847313.6; E 315912.3 MTM NAD 83 ZONE 10 (LAT. 43.765707; LONG. -79.361985)

BOREHOLE TYPE Power Auger; 150 mm O.D. Hollow Stem Augers; Casing Advance (110 mm I.D.)

DATE September 4 and 5, 2019

ORIGINATED BY SEM

COMPILED BY DH

CHECKED BY RM

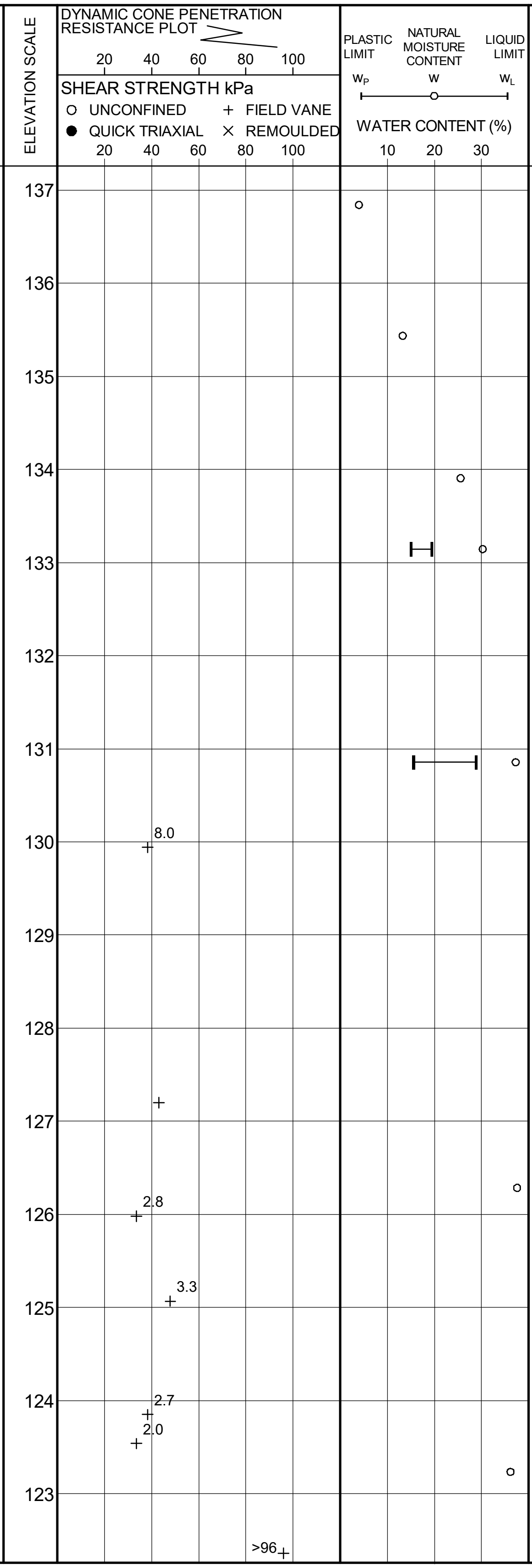
SOIL PROFILE

ELEV DEPTH	DESCRIPTION
137.3	GROUND SURFACE
0.0	TOPSOIL (230 mm)
0.2	Gravelly SAND (SP), some silt, containing rootlets, wood and asphalt pieces (FILL) Loose to compact Brown Moist
135.8 1.5	SILTY SAND (SM), containing wood fragments (FILL) Loose to compact Brown Moist
134.3 3.1	CLAYEY SILT-SILT (CL-ML), trace sand Stiff Brown to grey Wet
131.7 5.6	CLAYEY SILT (CL), trace gravel, sandy to trace sand Firm to stiff Grey Wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	22				
2	SS	8				
3	SS	5				
4	SS	13				
5	SS	11				
6	SS	8	0	3	80	17
7	SS	8				
8	SS	WH	0	3	57	40
9	SS	WH				
10	TO	-				
11	SS	2				
12	SS	WH				
13	SS	1				

STRAT PLOT | GROUND WATER CONDITIONS | UNIT WEIGHT γ kN/m³



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+3, ×3: Numbers refer to Sensitivity

○3% STRAIN AT FAILURE

PROJECT 1786302
G.W.P. 2130-01-00
DIST Central HWY 401
DATUM Geodetic

RECORD OF BOREHOLE No N/E RS-10

SHEET 2 OF 3

METRIC

LOCATION N 4847313.6; E 315912.3 MTM NAD 83 ZONE 10 (LAT. 43.765707; LONG. -79.361985)
BOREHOLE TYPE Power Auger; 150 mm O.D. Hollow Stem Augers; Casing Advance (110 mm I.D.)
DATE September 4 and 5, 2019

ORIGINATED BY SEM
COMPILED BY DH
CHECKED BY RM

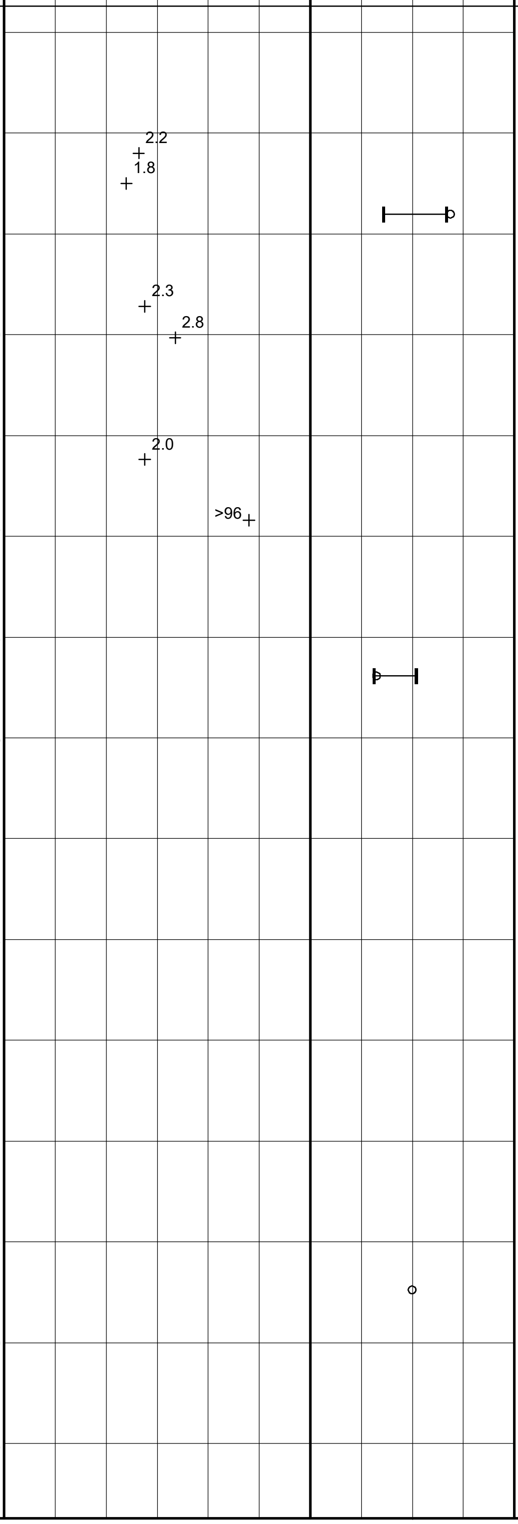
--- CONTINUED FROM PREVIOUS PAGE ---

SOIL PROFILE		SAMPLES				REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	GR	SA	SI	CL
	CLAYEY SILT (CL), trace gravel, sandy to trace sand Firm to stiff Grey Wet	14	SS	3	122				
		15	SS	4	121 / 120	2	24	42	32
		16	SS	WH	119 / 118				
117.2 20.1	Sandy CLAYEY SILT (CL), trace gravel (TILL) Hard Grey Wet	17	SS	39	117 / 116	2	27	52	19
		18	SS	47	115 / 114 / 113 / 112				
111.1 26.2	SAND (SP-SM), trace fines Very dense Grey Wet	19	SS	100	111 / 110	0	93	6	1
		20	SS	68	109 / 108				

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m³



Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity   ○ $^{3\%}$ STRAIN AT FAILURE

RECORD OF BOREHOLE No N/E RS-10

SHEET 3 OF 3

METRIC

PROJECT 1786302

G.W.P. 2130-01-00

LOCATION N 4847313.6; E 315912.3 MTM NAD 83 ZONE 10 (LAT. 43.765707; LONG. -79.361985)

ORIGINATED BY SEM

DIST Central HWY 401

BOREHOLE TYPE Power Auger; 150 mm O.D. Hollow Stem Augers; Casing Advance (110 mm I.D.)

COMPILED BY DH

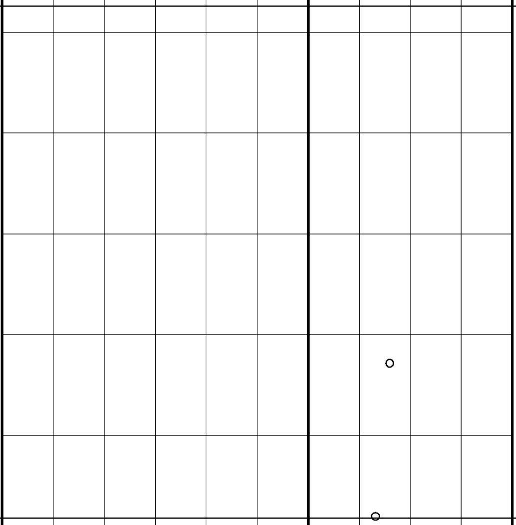
DATUM Geodetic

DATE September 4 and 5, 2019

CHECKED BY RM

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SAND (SP-SM), trace fines Very dense Grey Wet				107 106			
105.2 32.1	Sandy CLAYEY SILT (CL), trace gravel (RESIDUAL SOIL) Hard Grey Moist	21A 21B 21C	SS	100	105 104			
		22	SS	100/0.03	103	○		
102.2 35.1	END OF BOREHOLE NOTE: 1. Borehole open and dry before switching to mud rotary method at a depth of 3.7 m below ground surface (Elev. 133.6 m).	23	SS	100/0.03		○		



+³, ×³: Numbers refer to Sensitivity

○³% STRAIN AT FAILURE

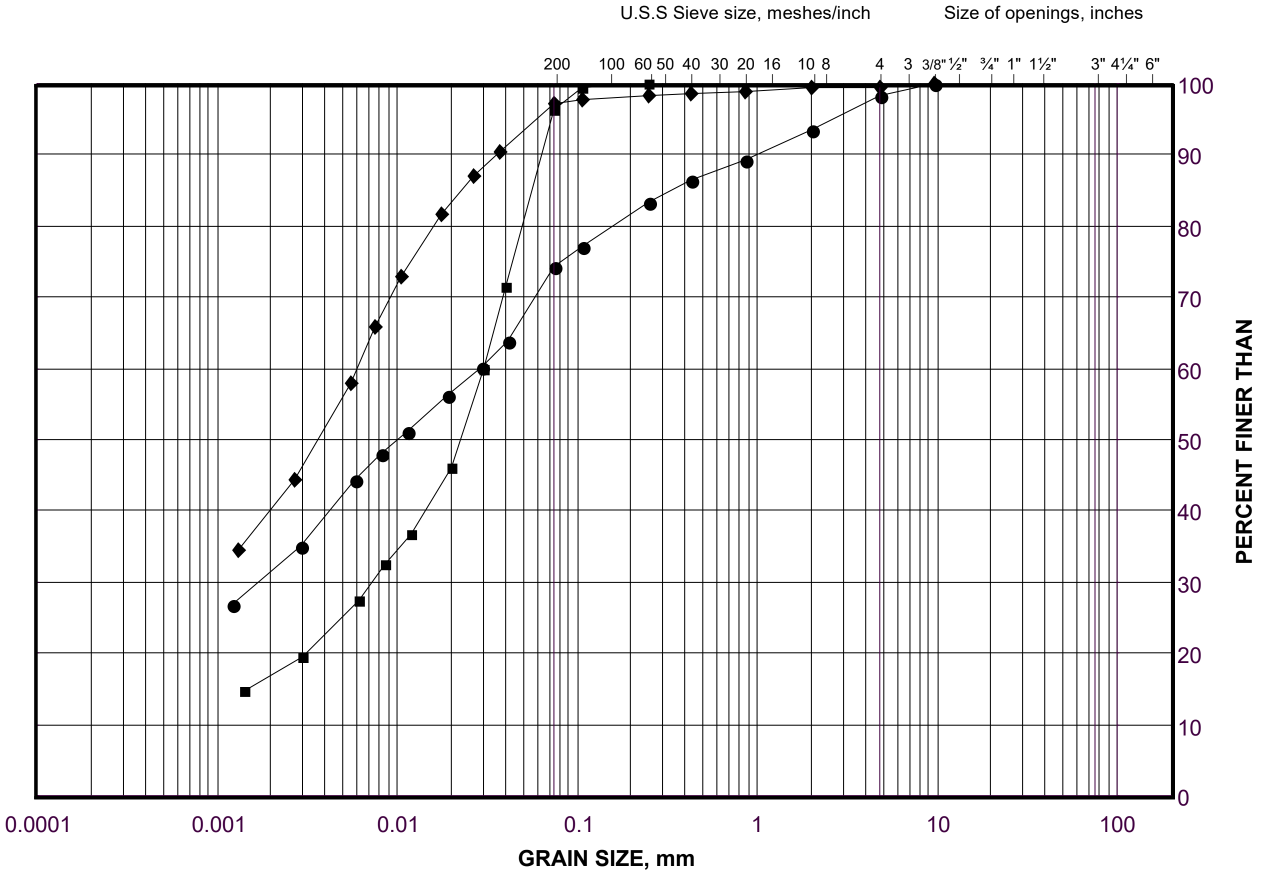
APPENDIX C

GEOTECHNICAL TEST RESULTS

GRAIN SIZE DISTRIBUTION

CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML)

FIGURE C1



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	NERS-10	15	120.2
■	NERS-10	6	133.2
◆	NERS-10	8	129.4

Project Number: 1786302

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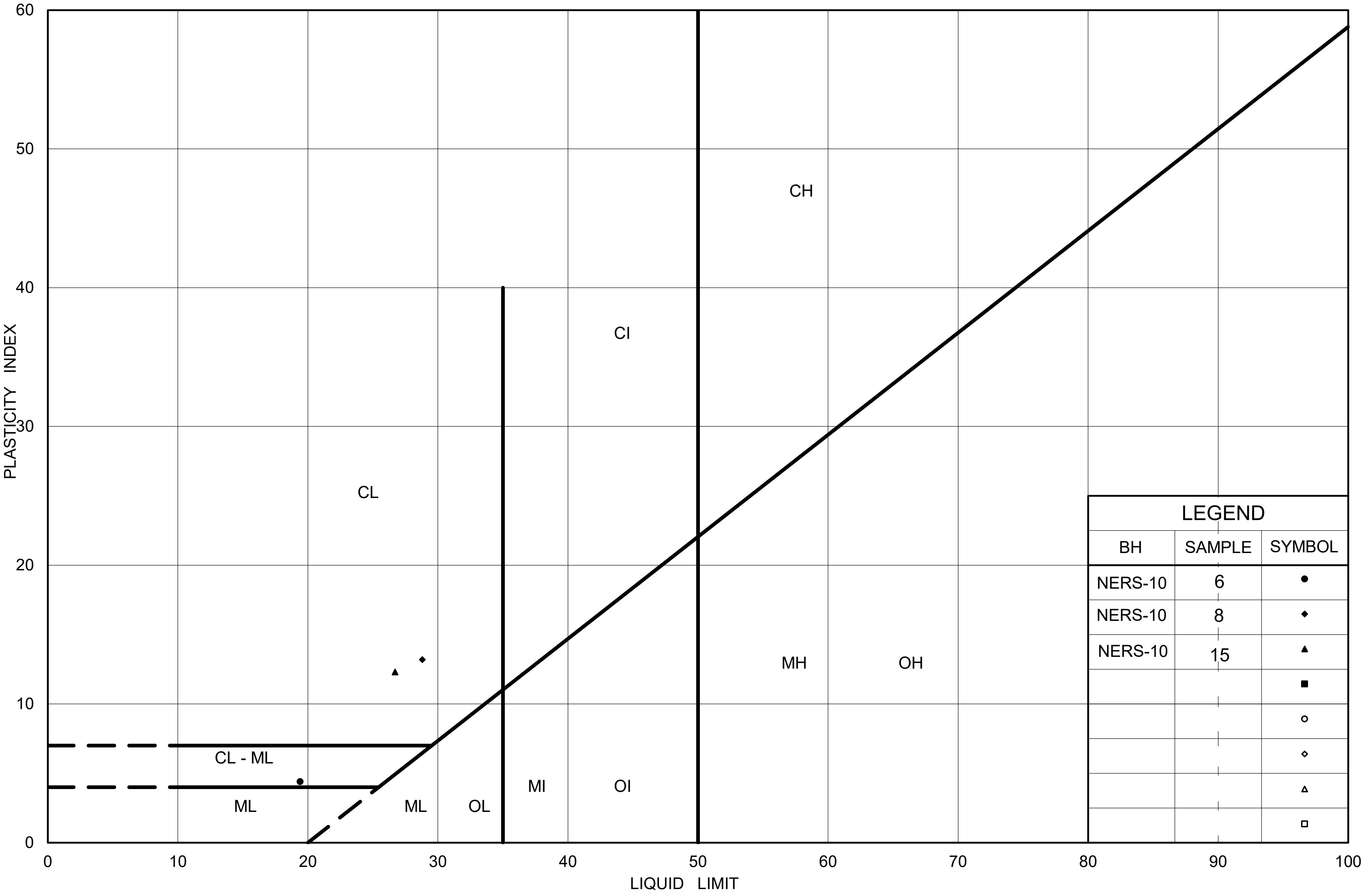
Date: 23-Aug-20

Oct 75, FF-S-21



BH	SAMPLE	SYMBOL
NERS-10	6	●
NERS-10	8	◆
NERS-10	15	▲
		■
		○
		◇
		△
		□

Ministry of Transportation

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PLASTICITY CHART
CLAYEY SILT (CL) to CLAYEY SILT-SILT (CL-ML)

Figure No. C2

Project No. 1786302

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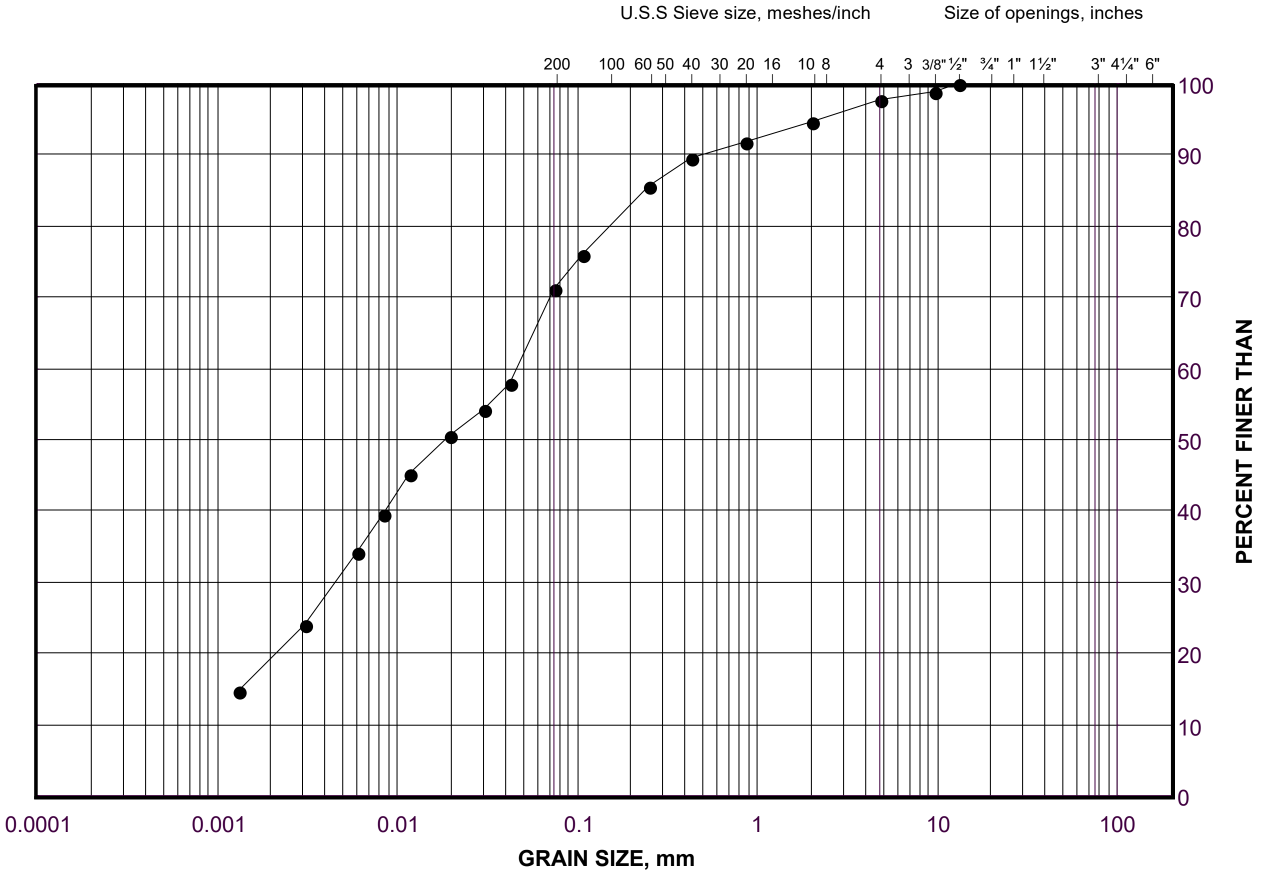
GRAIN SIZE DISTRIBUTION
Sandy CLAYEY SILT (CL) (TILL)

FIGURE C3



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	NERS-10	17	115.7

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Date: 23-Aug-20

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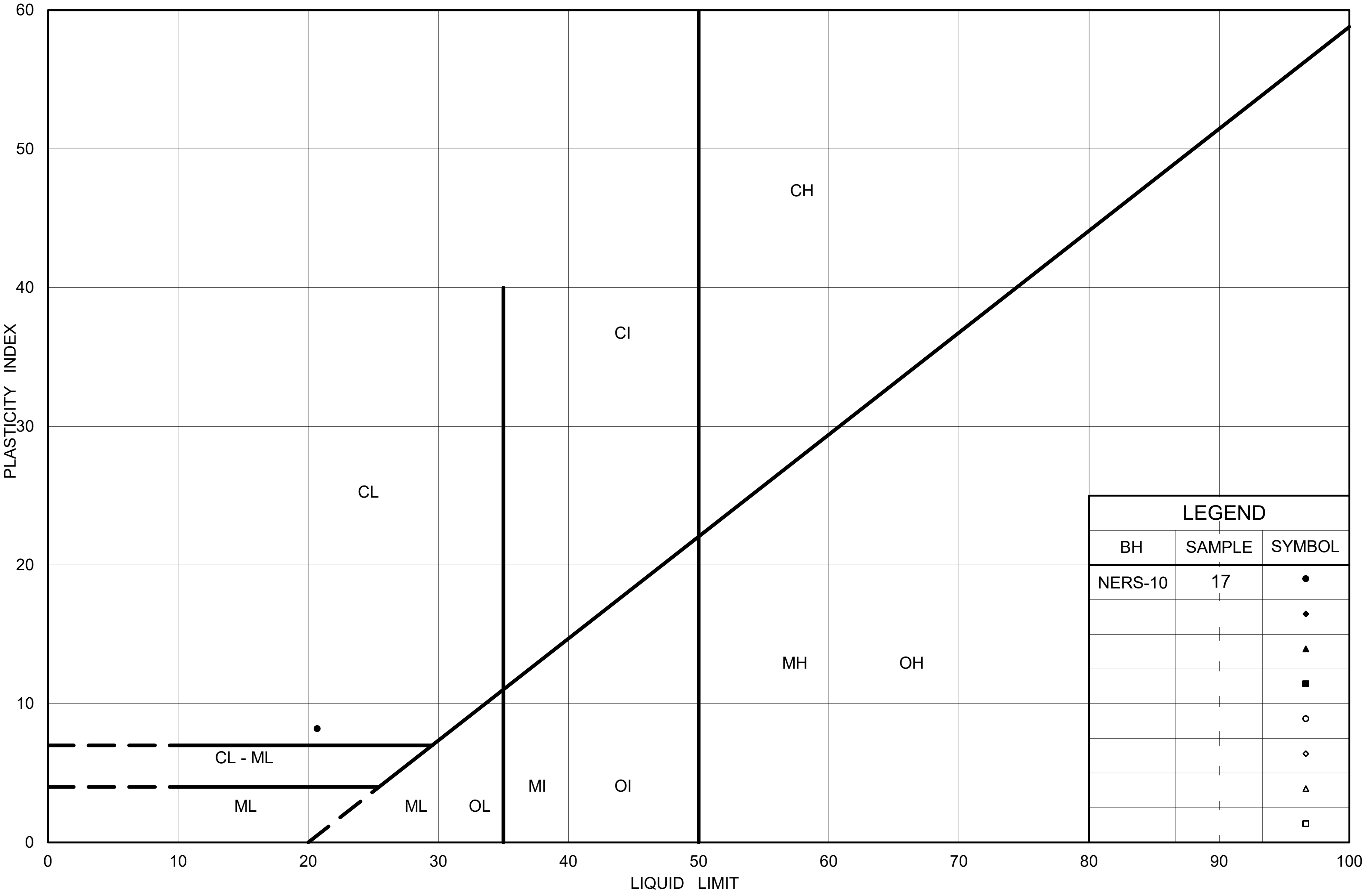

Ministry of Transportation

Ontario

PLASTICITY CHART
Sandy CLAYEY SILT (CL) (TILL)

Figure No. C4

Project No. 1786302

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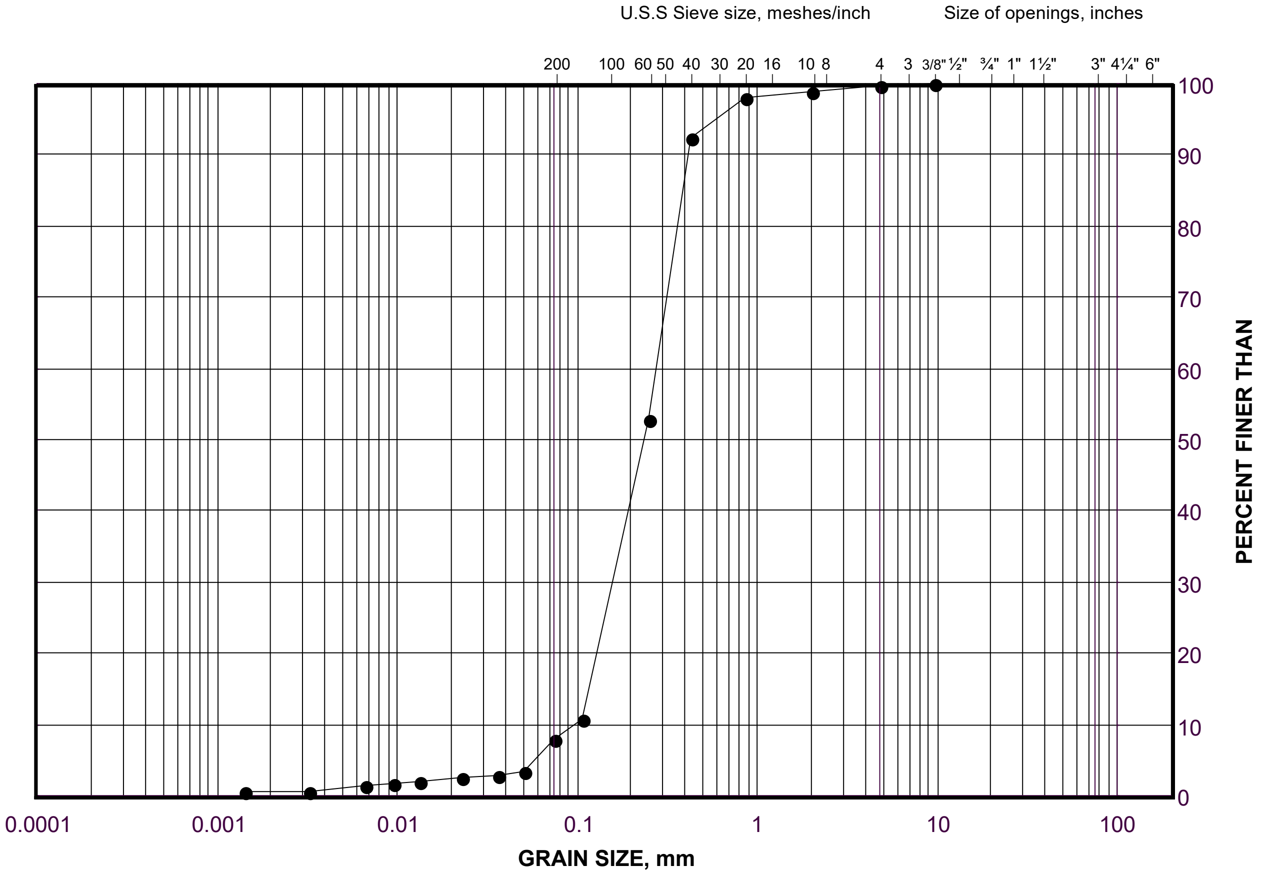
GRAIN SIZE DISTRIBUTION
SAND (SP-SM)

FIGURE C5



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	**COBBLE**
FINE GRAINED	**SAND SIZE**			**GRAVEL SIZE**		**SIZE**

LEGEND

SYMBOL	Borehole	SAMPLE	ELEVATION(m)
●	NERS-10	19	109.6

Project Number: 1786302

Checked By: CN

Golder Associates

Date: 23-Aug-20

APPENDIX D

NON-STANDARD SPECIAL PROVISIONS

CAISSON FOUNDATIONS FOR HIGH MAST LIGHTS – Item No.

Special Provision

The Contractor shall construct high mast light foundations in conformance with the design and at the locations indicated in the Contract Documents. The caisson should be installed in accordance with OPSS 903 (Deep Foundations).

The Contractor shall construct the high mast light foundations against undisturbed bases and sides of excavations. The bases of caisson excavations shall be cleaned of loosened and/or softened materials prior to pouring concrete for the foundation. The construction methods and techniques shall be the responsibility of the Contractor, but consideration could be given to using temporary liners or tremie concreting techniques where conditions warrant.

The Contractor is advised that variable subsurface conditions may be encountered at high mast light locations where included in the contract. For bidding purposes, the Contractor shall assume that the overburden has zones of non-cohesive soil and contains cobbles and boulders, and that the groundwater levels are near the surface. The Contractor is advised that non-cohesive soil is susceptible to disturbance under conditions of unbalanced hydrostatic head. As a lower priority than the above-noted instruction, the Contractor shall assume that the subsurface conditions at high mast light locations are generally similar to the closest of the boreholes, as illustrated in the Foundation Investigation Report.

Basis of Payment

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment, and materials for completion of the work.

END OF SECTION

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