



THURBER ENGINEERING LTD.



**FOUNDATION INVESTIGATION AND DESIGN REPORT
CHESTNUT STREET NBL OVERPASS REPLACEMENT
SITE NO. 18-175/1
ON-RAMP SPEED CHANGE LANE EXTENSION AND
NOISE BARRIER WALL REPLACEMENT
HIGHWAY 406
ST. CATHARINES, ONTARIO
G.W.P. 2259-15-00**

GEOCRES NO. 30M3-295

Report

to

WSP

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Appendix A	Hwy 406 Chestnut Street NBL Overpass Bridge Boreholes CS16-01 to CS16-04, CH16-01 and CH16-02
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Appendix B	On-Ramp Speed Change Lane (SCL) Extension and Noise Barrier Wall Replacement Boreholes SC16-01 to SC16-08
Appendix C	Roadway Protection Boreholes RP16-01 to RP16-04
Appendix D	Record of Borehole sheets of previous investigations
Appendix E	Selected photographs of the site
Appendix F	Comparison of Foundation Alternatives for Highway 406 Chestnut Street NBL Overpass Bridge
Appendix G	List of OPSS Documents and NSSP Wordings
Appendix H	Slope Stability Analysis Results

Each of Appendices A to C includes:

- Record of Borehole Sheets
- Laboratory Test Results
- Drawings titled “Borehole Locations and Soil Strata”

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual data obtained from a foundation investigation conducted by Thurber Engineering Ltd. (Thurber) for the proposed replacement of the existing northbound lane (NBL) overpass bridge located on Highway 406 at Chestnut Street, on-ramp speed change lane (SCL) extension at Highway 406/Glendale Avenue (W/E-N Ramp), and replacement of the Highway 406 NBL noise barrier wall in St. Catharines, Ontario. Roadway protection required during the overpass bridge replacement will be addressed.

The purpose of this investigation was to explore the subsurface conditions at the specific location of each of the proposed project components and, based on the data obtained, to provide borehole location plans and soil strata drawings with stratigraphic profiles and cross-sections, records of boreholes, laboratory test results and written descriptions of the subsurface conditions. A model of the subsurface conditions was developed for the site based on the data obtained from the present investigation.

Thurber was retained by WSP Canada Inc. (WSP) to carry out this foundation investigation under the MTO Assignment Number 2014-E-0030.

During the preparation of this report and in addition to the boreholes drilled, general reference has been made to information on subsurface conditions contained in previous foundation reports in the area. The titles of these reports are listed as follows:

- D.H.O. Foundation Investigation Report, Overpass Structure for Highway #58, Line 'B' at Chestnut Street West, District #4, W.J. 60-F-89, W.P. 44-61, dated May 7, 1961, (Reference 1).
- Foundation Investigation Report for N-EW Ramp, Chestnut St. Widening, Geocres No. 30M3-178, W.P. 90-74-03, Site 18-175, Hwy #406, District #4, Hamilton. (Reference 2).

2 SITE DESCRIPTION

The site is located at the Highway 406 crossing at Chestnut Street in St. Catharines, Ontario. The existing structures are concrete single-span twin bridges carrying the Highway 406 northbound lanes (NBL) and southbound lanes (SBL) over Chestnut Street. Existing concrete retaining walls extend between and beyond the footprint of the twin bridges along both sides of Chestnut Street.

The terrain adjacent to the structure is generally flat. Residential dwellings are located on the east and northwest quadrants of the site. The Pen Centre mall is located on the southwest quadrant of the site. Existing noise barrier walls are located adjacent to the Highway 406 NBL and SBL travel lanes. Treed areas are generally located behind the noise barrier walls. Selected photographs of the immediate surroundings of the site are presented in Appendix E.

The site is situated within the physiographic region known as the Haldimand Clay Plain, which is characterized by glacio-lacustrine deposits laid down in glacial Lake Warren during the Wisconsinian Age. These deposits consist of silts and clays and are generally underlain by a glacial till, which in turn overlies bedrock.

3 PROJECT DESCRIPTION

The entire project at this site involves reconstruction of the existing NBL crossing of Highway 406 at Chestnut Street in St. Catharines, Ontario. The project components are:

- Replacement of the existing Highway 406 Chestnut Street NBL overpass bridge. The Highway NBL superstructure will be completely removed (deck, abutments), as well as the existing footings. The new structure will be a rigid frame structure to accommodate the new Highway 406 NBL alignment, which will be shifted to the east by 4.09 m, and the extended speed change lane. The approaches to the bridge and the median retaining walls will also be reconstructed.

- Extension of the on-ramp (SCL) at Highway 406/Glendale Avenue (W/E-N Ramp). The SCL extension will be from approximate Stations 26+430 to 26+936. The existing Highway 406 NBL platform will also be widened to the east. The maximum widening will be 8.3 m. The maximum height of the new embankment will be approximately 6.0 m with sideslope of 2H : 1V.
- Replacement of the existing noise barrier wall along the Highway 406 NBL extension. As result of highway platform extension and widening, the existing noise barrier wall will be relocated to the east and replaced.
- Roadway protection. Roadway protection (temporary shoring) systems will be required for bridge replacement and roadway widening.

4 INVESTIGATION PROCEDURES

The site investigation and field testing for this project were carried out from November 3, 2106 to December 19, 2016, and on May 7, 2016. Details of the site investigation and field testing for each project component are presented in Table 4.1.

Table 4.1 – Borehole Designations and Details

Design component	Borehole	Sampled borehole termination depth (m)	Sampled borehole termination elevation (m)	Appendix
Highway 406 Chestnut Street NBL Overpass Bridge, approaches and retaining walls	CS16-01 to CS16-04	15.5 to 17.0	98.3 to 100.7	A
	CH16-01 CH16-02	8.2	109.3 and 109.8	
On-ramp SCL extension and noise barrier wall	SC16-01 to SC16-08	8.2 to 12.8	103.4 to 113.1	B
Roadway protection	RP16-01 to RP16-04	8.2	112.6 to 113.6	C

The approximate locations of the boreholes drilled during the present investigation are shown on the attached Borehole Locations and Soil Strata Drawings in Appendices A to C. The coordinates and elevations of the boreholes are given on the drawings and on the individual Record of Borehole Sheets in Appendices A to C. Boreholes drilled during previous investigations in the 1990's, 1980's and 1950's near this site are included in Appendix D.

Prior to the start of drilling, the borehole locations were marked/staked in the field and utility clearances were obtained. The co-ordinates and elevations of the as-drilled boreholes were subsequently provided by WSP.

Truck-mounted D25 and D50 drill rigs were used to drill and sample the boreholes. Hollow stem augers were used to advance the boreholes until the target depth was reached. In general, soil samples were obtained at selected intervals using a 50 mm diameter split spoon sampler in conjunction with the Standard Penetration Testing (SPT). The in situ shear strength of the cohesive soils was also assessed using an MTO 'N' size shear vane, where applicable.

The drilling, sampling and in-situ testing operations were supervised on a full time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing. Results of field drilling and sampling are presented on the Record of Borehole sheets in Appendices A to C.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Seven standpipe piezometers were installed in selected boreholes (CS16-02, CS16-04, SC16-01, SC16-03, SC6-08, CH16-01 and CH16-02). Each piezometer consisted of a 25 mm Schedule 40 PVC pipe with a 1.5 m long slotted screen enclosed in a column of filter sand to permit groundwater level monitoring. Piezometer installation details, groundwater level observations and water level readings are shown on the Record of Borehole sheets. Upon completion of the drilling operations, the boreholes without piezometers were abandoned in general accordance with Ontario Regulation 903 amended by Ontario Reg. 372 (O.Reg. 903). The details of standpipe piezometer installation and borehole completion are summarized in Table 4.2. The piezometer installations have been decommissioned as per O.Reg. 903 after the last set of water level readings were obtained.

Table 4.2 – Borehole Completion Details

Project Element	Borehole No.	Borehole Depth / Base Elevation (m)	Piezometer Depth / Tip Elevation (m)	Completion Details
Highway 406 Chestnut Street NBL Overpass Bridge, approaches and retaining walls	CS16-01	15.5/100.7	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
	CS16-02	17.0/99.2	16.7/99.5	Backfilled with filter sand from 17.0 m to 13.3 m, bentonite holeplug from 13.3m to 12.7 m, bentonite holeplug and auger cuttings from 12.7 m to 0.15 m, then asphalt to surface.
	CS16-03	17.0/98.3	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
	CS16-04	16.9/98.3	16.7/98.5	Backfilled with filter sand from 16.9 m to 13.2 m, bentonite holeplug from 13.2m to 12.6 m, bentonite holeplug and auger cuttings from 12.6 m to 0.15 m, then concrete to surface.
	CH16-01	8.2/109.3	7.6/109.9	Backfilled with filter sand from 8.2 m to 5.5 m, bentonite holeplug and auger cuttings from 5.5 m to surface.
	CH16-02	8.2/109.8	7.6/110.4	Backfilled with filter sand from 8.2 m to 5.5 m, bentonite holeplug and auger cuttings from 5.5 m to surface.
On-ramp SCL extension and noise barrier wall	SC16-01	8.2/105.7	7.6/106.3	Backfilled with filter sand from 8.2 m to 5.5 m, bentonite holeplug and auger cuttings from 5.5 m to surface.
	SC16-02	9.8/103.4	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.5 m, concrete from 0.5 m to 0.2 m, then asphalt to surface.
	SC16-03	8.2/106.7	7.6/107.3	Backfilled with filter sand from 8.2 m to 5.5 m, bentonite holeplug and auger cuttings from 5.5 m to surface.
	SC16-04	11.3/104.9	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to 0.6 m, concrete from 0.6 m to 0.2 m, then asphalt to surface.
	SC16-05	8.2/107.6	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.

Project Element	Borehole No.	Borehole Depth / Base Elevation (m)	Piezometer Depth / Tip Elevation (m)	Completion Details
	SC16-06	12.8/106.4	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
	SC16-07	8.2/111.1	None installed	Borehole backfilled with bentonite holeplug and auger cuttings to surface.
	SC16-08	8.2/113.1	7.6/113.7	Backfilled with filter sand from 8.2 m to 5.5 m, bentonite holeplug and auger cuttings from 5.5 m to surface.
Roadway protection	RP16-01	8.2/112.7	None installed	Borehole backfilled with auger cuttings to surface.
	RP16-02	8.2/112.6	None installed	Borehole backfilled with auger cuttings to surface.
	RP16-03	8.2/113.4	None installed	Borehole backfilled with auger cuttings to surface.
	RP16-04	8.2/113.6	None installed	Borehole backfilled with auger cuttings to surface.

5 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size analysis and Atterberg Limits testing. All the laboratory tests were carried out in accordance with MTO and/or ASTM Standards, as appropriate. Results of the laboratory testing of the present investigation, are summarized on the Record of Borehole sheets, and presented on the figures included in Appendices A to C. Laboratory test results of the previous investigations (References 1 and 2), are presented in Appendix D.

6 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendices A to C for details of the encountered soil stratigraphy. Soil profiles and cross sections (where applicable) of the project elements (overpass bridge, retaining walls, SCL extension, noise barrier wall, roadway protection), are presented on the "Borehole Locations and Soil Strata" drawings in Appendices A to C. Overall descriptions of the stratigraphy are given in the following paragraphs. However, the factual data presented in the Record of Borehole sheets governs any interpretation of the site

conditions. It must be recognized that soil conditions may vary between and beyond the borehole locations. More detailed descriptions of the individual strata are presented below.

6.1 Highway 406 Chestnut Street NBL Overpass Bridge

A total of four boreholes, numbered CS16-01 to CS16-04, were drilled in the vicinity of the Highway 406 Chestnut Street NBL overpass bridge. The boreholes were drilled on the Chestnut Street grade, near the proposed north and south abutments. Two boreholes, numbered CH16-01 and CH16-02, were drilled along the proposed bridge approaches.

Records of boreholes, laboratory testing results, borehole location plan, stratigraphic profile and cross section drawings are contained in Appendix A.

In general, the subsurface stratigraphy encountered at this location, consists of pavement structure (asphalt and granular base) overlying cohesive embankment fill, and underlain by an extensive deposit of native silty clay overlying glacial till. The above soils are underlain by shale bedrock. More detailed descriptions of the individual strata are presented below.

6.1.1 Topsoil

Topsoil was encountered at ground surface in the Boreholes CH16-01 and CH16-02, with a thickness of 75 mm.

The topsoil thickness may vary between and beyond the borehole locations, and the limited data presented in this report should not be used for quantity estimation purposes.

6.1.2 Pavement Structure

Boreholes CS16-01 to CS16-04 encountered surficial asphalt over granular base. The thickness of the asphalt pavement was 100 mm.

The granular base consisted of gravelly sand to sand fill containing some silt and trace clay. The thickness of the granular base was 600 mm. Moisture contents of the granular fill ranged from 2 percent to 8 percent.

Three samples of the granular fill were subjected to laboratory gradation analysis. The results of these tests are summarized in the table below as well as on the Record of Borehole sheets included in Appendix A. Figures A1 and A2 in Appendix A, present the grain size distribution curves for these samples.

Soil Particles	Gravelly Sand Fill Percentage	Sand Fill Percentage
Gravel	31	17 to 18
Sand	45	57
Silt	-	19
Clay	-	7
Silt and Clay	24	25

6.1.3 Silty Clay Fill

Brown silty clay fill containing trace sand and trace gravel was contacted below the granular base in Boreholes CS16-03 and CS16-04. In Boreholes CH16-01 and CH16-02, the silty clay fill was contacted below the topsoil. The thickness of the silty clay fill was 0.7 m to 0.8 m in Boreholes CS16-03 and CS16-04, and 1.4 m and 1.3 m in Boreholes CH16-01 and CH16-02

The depth to the base of the silty clay fill was 1.4 m and 1.5 m (Elevations 113.9 and 113.7), in Boreholes CS16-03 and CS16-04, and 1.5 m and 1.4 m (Elevations 116.0 and 116.6) in Boreholes CH16-01 and CH16-02, respectively.

SPT 'N' values obtained in the silty clay fill ranged from 7 to 17 blows for 0.3 m penetration, indicating a firm to very stiff consistency. An SPT 'N' value of 38 blows per 0.3 m of penetration was measured in Borehole CH16-01, indicating a hard consistency. Natural moisture contents of the silty clay fill ranged from 12 percent to 28 percent.

6.1.4 Silty Clay

An extensive deposit of native brown to grey silty clay containing trace sand and trace gravel was encountered below the fill in all the boreholes. The silty clay was contacted at 0.7 m depth in Boreholes CS16-01 and CS16-02, and at 1.4 m and 1.5 m depths in Boreholes CS16-03 and CS16-04, respectively. The silty clay was contacted at 1.5 m and 1.4 m depths (Elevations 116.0 and 116.6) in Boreholes CH16-01 and CH16-02, drilled near the proposed approaches to the widening. The thickness of the silty clay ranged from 12.0 m to 12.6 m. The depth to the base of the silty clay varied from 13.3 m to 14.0 m (Elevations 101.2 to 102.9). Boreholes CH16-01 and CH16-02 were terminated within the silty clay at 8.2 m depth (Elevations 109.3 and 109.8).

Based on higher 'N' values, soil colour and texture, and an estimation of the over-consolidation ratio, a weathered crust between about 1 m to 3 m thick was encountered within the upper portion of the silty clay. Below the Chestnut Street grade, the base of the crust is at approximate

Elevations 112 to 113 m. At the widened south approach, the base of the crust is at approximate Elevation 114 m. The crust appears to be thicker than 3 m at the widened north approach. Within this crust, SPT 'N' values typically ranged from 12 to 26 blows for 0.3 m of penetration indicating a stiff to very stiff consistency.

Below the crust, the silty clay was found to be firm to stiff. In situ vane testing indicated that the undrained shear strength ranges from 63 to 98 kPa which corresponds to a typical stiff consistency. An SPT 'N' value of 30 blows per 0.3 m of penetration, indicating a hard consistency, was measured in Borehole CH16-02 at approximately 1.5 m depth. The SPT 'N' values ranged from 6 to 12 blows per 0.3 m penetration which indicate firm to stiff consistency. An SPT 'N' value of 2 blows per 0.3 m of penetration, indicating a soft consistency, was measured below Elevation 103.0 in Borehole CS16-03. Natural moisture contents of the silty clay ranged from 12 percent to 41 percent.

The results of grain size analyses conducted on silty clay samples are presented on the Record of Borehole sheets in Appendix A, and are illustrated in Figures A3 to A5 of Appendix A. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	0
Silt	29 to 51
Clay	49 to 71

The results of Atterberg Limits tests conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A and illustrated in Figure A7 of Appendix A. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	41 to 54
Plasticity Index	23 to 27

The results of the Atterberg Limits testing indicate the deposit is of medium to high plasticity with group symbols CI and CH.

6.1.5 Silt to Sand and Silt Till

A deposit of brown to greyish brown silt to sand and silt till, some clay, trace gravel with clayey silt seams was contacted below the silty clay at depths ranging from 13.3 m to 14.0 m. The till

was fully penetrated in Borehole CS16-03, and at this location its thickness was 1.7 m. The depth to the base of the silt till was 15.1 m (Elevation 100.2) in Borehole CS16-03. Boreholes CS16-01, CS16-02 and CS16-04 were terminated within the silt till at depths ranging from 15.5 m to 17.0 m (Elevations 98.3 to 100.7).

SPT 'N' values recorded in the till were typically greater than 100 blows for less than 0.3 m of penetration, indicating a very dense state. An SPT 'N' value of 14 blows per 0.3 m of penetration, indicating a compact state was measured in Borehole CS16-01 near Elevation 102.2. Natural moisture contents of the till ranged from 8 percent to 29 percent.

The results of grain size analyses conducted on samples of the till are provided on the Record of Borehole sheets in Appendix A, and illustrated in Figure A6 of Appendix A. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	0
Sand	19 to 51
Silt	39 to 62
Clay	10 to 19

It is noted that glacial till inherently contains cobbles and boulders.

6.1.6 Shale Bedrock

The soils described above are underlain by shale bedrock. Reddish brown shale bedrock was contacted at 15.1 m depth in Borehole CS16-03. Borehole CS16-03 was terminated within the shale bedrock at 17.0 m depth (Elevation 98.3).

SPT 'N' values measured in the shale bedrock were 100 blows for less than 0.3 m of penetration.

6.1.7 Groundwater Conditions

The water levels in the boreholes were observed during the drilling operations and measured upon completion of drilling. All boreholes were open to the depths investigated and dry upon completion of drilling. Standpipe piezometers were installed in Boreholes CS16-02, CS16-04, CH16-01 and CH16-02 to permit longer term monitoring of the groundwater level. Groundwater levels measured in the piezometers are presented in Table 6.1.

Table 6-1. Measured Groundwater Levels

Borehole Number	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
CS16-02	January 11, 2017	Frozen	-	Piezometer
	March 16, 2017	2.0	114.2	
	August 30, 2017	1.4	114.8	
CS16-04	January 11, 2017	2.0	113.2	Piezometer
	March 16, 2017	1.5	113.7	
CH16-01	January 4, 2017	4.1	113.4	Piezometer
	January 13, 2017	3.9	113.6	
	March 16, 2017	3.2	114.3	
	August 30, 2017	2.3	115.2	
CH16-02	January 4, 2017	4.1	113.9	Piezometer
	January 13, 2017	6.1	111.9	
	March 16, 2017	3.2	114.8	
	August 30, 2017	2.8	115.2	

The values shown in Table 6-1 are short-term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation.

6.2 On-ramp Speed Change Lane (SCL) Extension and Noise Barrier Wall

A total of eight boreholes, numbered SC16-01 to SC16-08, were drilled along Highway 406 NBL from Stations 26+550 to 27+000. The boreholes were located along the alignment of the proposed on-ramp SCL extension. The replacement noise barrier wall has an alignment along the shoulder of the widened NBL.

Records of boreholes, laboratory testing results, borehole location plan and stratigraphic profile drawing are contained in Appendix B.

In general, the subsurface stratigraphy encountered in these boreholes consists of topsoil or pavement structure overlying silty clay fill which is underlain by native silty clay. More detailed descriptions of the individual strata are presented below.

6.2.1 Topsoil

Topsoil was encountered at ground surface in Boreholes SC16-01, SC16-03, SC16-05, SC16-07 and SC16-08. The thickness varies from 50 mm to 75 mm.

The topsoil thickness may vary between and beyond the borehole locations, and the limited data presented in this report should not be used for quantity estimation purposes.

6.2.2 Pavement Structure

In Boreholes SC16-02, SC16-04 and SC16-06 drilled from the Highway 406 grade, a pavement structure consisting of 75 mm to 100 mm of asphalt overlying 0.6 m to 1.0 m of brown to grey gravelly sand was encountered. The base of the pavement structure ranged from 0.7 m to 1.1 m depths (Elevations 112.1 to 118.5). Moisture contents of the gravelly sand were measured at about 3 percent to 5 percent.

6.2.3 Silty Clay Fill

Brown to grey silty clay fill containing trace sand and trace gravel, occasional roots, rootlets and topsoil, was contacted below the topsoil in Boreholes SC16-01, SC16-03, SC16-05, SC16-07 and SC16-08, and below the gravelly sand fill at 0.7 m depth (Elevation 115.5) in Borehole SC16-04. Silty clay fill was not encountered in Borehole SC16-02. The thickness of the silty clay fill varied from 0.6 m to 1.3 m, and locally at 2.2 m in Borehole SC16-01.

The depth to the base of the silty clay fill varied from 0.7 m to 1.5 m (Elevations 113.5 to 119.9), and locally at 2.3 m (Elevation 111.6) in Borehole SC16-01.

SPT 'N' values obtained in the silty clay fill ranged from 7 to 27 blows for 0.3 m penetration indicating a firm to very stiff consistency, except in Borehole SC16-04 where an 'N' value of 32 blows per 0.3 m penetration was recorded indicating a hard consistency. Moisture contents of the silty clay fill were 17 percent to 36 percent.

6.2.4 Silty Clay

An extensive deposit of brown to grey silty clay containing trace sand and trace gravel was encountered below the fill in all the boreholes. The silty clay was contacted at depths typically ranging from 0.7 m to 1.5 m (Elevations 112.1 to 119.9) and at 2.3 m depth (Elevation 111.6) in Borehole SC16-01. The eight boreholes were terminated within the silty clay at 8.2 m to 12.8 m depths (Elevations ranging from 103.4 to 113.1).

The majority of SPT 'N' values obtained in the silty clay layer ranged from 8 to 29 blows for 0.3 m penetration indicating a stiff to very stiff consistency. Occasional 'N' values of 6 to 7 blows indicated the firm zones within this deposit. In Boreholes SC16-04 and SC 16-06, 'N' values greater than 30 blows per 0.3 m penetration were recorded which indicate a hard consistency.

In general, the silty clay above approximate Elevations 112 to 113 m may be considered as the weathered crust. Natural moisture contents of the silty clay ranged from 15 percent to 34 percent.

The results of grain size analyses conducted on silty clay samples are presented on the Record of Borehole sheets in Appendix B, and are illustrated in Figures B1 to B3 of Appendix B. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	0
Silt	30 to 54
Clay	46 to 70

The results of Atterberg Limits tests conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix A and illustrated in Figures B4 and B5 of Appendix B. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	47 to 54
Plasticity Index	26 to 30

The results of the Atterberg Limits testing indicate the silty clay deposit to be of medium to high plasticity with group symbols CI and CH.

6.2.5 Groundwater Conditions

The water levels in the boreholes were observed during the drilling operations and upon completion of drilling. All boreholes were open to the depths investigated and dry upon completion of drilling. Three standpipe piezometers were installed in Boreholes SC16-01, SC16-03 and SC16-08 to permit longer term monitoring of the groundwater level. Groundwater levels measured in the piezometers are presented in Table 6.2.

Table 6-2. Measured Groundwater Levels

Borehole Number	Date	Groundwater Level		Comment
		Depth (m)	Elevation (m)	
SC16-01	January 13, 2017	7.2	106.7	Piezometer
	March 16, 2017	6.3	107.6	
	August 30, 2017	6.1	107.8	
SC16-03	January 13, 2017	5.8	109.1	Piezometer
	March 16, 2017	4.9	110.0	
	August 30, 2017	4.7	110.2	
SC16-08	January 13, 2017	3.0	118.3	Piezometer
	March 16, 2017	1.5	119.8	
	August 30, 2017	1.6	119.7	

The values shown in Table 6-2 are short term readings and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation.

6.3 Roadway Protection

A total of four boreholes, numbered RP16-01 to RP16-04, were drilled in the vicinity of the existing abutments where roadway protection will likely be required during the replacement of the existing Highway 406 NBL overpass bridge at Chestnut Street.

Records of boreholes, laboratory testing results, borehole location plan and stratigraphic profile drawing are contained in Appendix C.

In general, the subsurface stratigraphy encountered at these locations consists of pavement structure overlying granular (abutment) fill and silty clay embankment fill, which are underlain by native silty clay. More detailed descriptions of the individual strata are presented below.

6.3.1 Asphalt and Concrete

The four boreholes were drilled on Highway 406 NBL roadway and encountered surficial asphalt over concrete. The thickness of the asphalt pavement was 75 mm where encountered, and asphalt was not encountered in Borehole RP16-03. The thickness of the concrete underlying the asphalt varies from 150 mm to 375 mm.

6.3.2 Granular Fill

Granular fill consisting of gravelly sand overlying sand was encountered in Boreholes RP16-01, RP16-02 and RP16-04. The grey gravelly sand fill was contacted immediately below the concrete in Boreholes RP16-02 and RP16-04. The thickness of the upper gravelly sand fill was 0.4 m and 0.9 m. The sand fill containing trace gravel, some silt and trace to some clay was contacted immediately below the concrete in Borehole RP16-01, and below the gravelly sand fill in Boreholes RP16-02 and RP16-04. The thickness of the sand fill varied between 4.5 m and 6.1m, with the depth to the base of the granular fill ranging from 5.0 m to 7.5 m (Elevations 114.3 to 115.9).

An SPT 'N' value of 24 blows per 0.3 m of penetration, measured in the gravelly sand fill, indicated a compact state. SPT 'N' values measured in the sand fill varied from 11 to 46 blows per 0.3 m of penetration indicating a compact to dense condition. An SPT 'N' value of 80 blows for less than 0.3 m of penetration, indicating a very dense state, was measured in Borehole RP16-02 near Elevation 118.5. Measured moisture contents in the granular fill ranged from 4 percent to 8 percent.

Selected samples of the granular fill were subjected to laboratory gradation analysis. The results of these tests are summarized in the table below as well as on the Record of Borehole sheets included in Appendix C. Figure C1 in Appendix C, present the grain size distribution curves for these samples.

Soil Particles	Sand Fill Percentage
Gravel	1 to 19
Sand	58 to 81
Silt	12 to 19
Clay	4 to 6
Silt and Clay	17 to 23

6.3.3 Silty Clay Embankment Fill

Grey silty clay embankment fill containing some sand and some gravel, was contacted below the concrete in Borehole RP16-03. The thickness of the silty clay fill was 3.8 m with a depth to the base of the silty clay fill of 4.0 m (Elevation 117.6).

SPT 'N' values obtained in the silty clay fill ranged from 8 to 13 blows for 0.3 m penetration

indicating a stiff consistency. Moisture contents of the silty clay fill ranged from 19 percent to 27 percent.

The results of grain size analyses conducted on a silty clay fill sample are presented on the Record of Borehole sheets in Appendix C, and are illustrated in Figure C2 of Appendix C. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	0
Silt	36
Clay	64

6.3.4 Silty Clay

A deposit of brown silty clay containing trace sand and trace gravel was encountered below the fill in Boreholes RP16-01 to RP16-04. The silty clay was contacted at depths ranging from 4.0 m to 7.5 m. All four boreholes were terminated within the silty clay at 8.2 m depth (Elevations 112.6 to 113.6).

SPT 'N' values ranged from 21 to 51 blows per 0.3 m of penetration indicating a very stiff to hard consistency. Natural moisture contents of the silty clay ranged from 20 percent to 27 percent.

The results of grain size analyses conducted on silty clay samples are presented on the Record of Borehole sheets in Appendix C, and are illustrated in Figure C3 of Appendix C. The laboratory test results are summarized in the following table.

Soil Particle	Percentage (%)
Gravel	0
Sand	0 to 8
Silt	32 to 40
Clay	60 to 67

The results of Atterberg Limits tests conducted on samples of the silty clay are provided on the Record of Borehole sheets in Appendix C and illustrated in Figure C4 of Appendix C. The results are summarized as follows:

Index Property	Percentage (%)
Liquid Limit	46 to 54
Plasticity Index	26 to 33

The results of the Atterberg Limits testing indicate the silty clay to be of medium to high plasticity with group symbols CI and CH.

6.3.5 Groundwater Conditions

The water levels in the boreholes were observed during the drilling operations and measured upon completion of drilling. These four boreholes were open to the depths investigated and dry upon completion of drilling.

Seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant or prolonged precipitation.

7 MISCELLANEOUS

Thurber staked and/or marked the borehole locations in the field and obtained utility clearances prior to drilling. Thurber obtained the coordinates of the boreholes using a GPS device. WSP provided the ground surface elevations.

Walker Drilling of Utopia, Ontario, supplied and operated truck-mounted D25 and D50 drill rigs to carry out the drilling, sampling and in-situ testing operations for the boreholes.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Omar Ali of Thurber. Geotechnical laboratory testing was carried out by Thurber in its MTO-approved laboratory. Overall supervision of the field program was carried out by Mr. Stephane Loranger, CET.

Overall project management was provided by Dr. Sydney Pang, P.Eng. Interpretation of the field data and preparation of this report was completed by Ms. R. Palomeque Reyna, P. Eng. and Dr. Sydney Pang, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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**FOUNDATION INVESTIGATION AND DESIGN REPORT
CHESTNUT STREET NBL OVERPASS REPLACEMENT
SITE NO. 18-175/1
ON-RAMP SPEED CHANGE LANE EXTENSION AND
NOISE BARRIER WALL REPLACEMENT
HIGHWAY 406
ST. CATHARINES, ONTARIO
G.W.P. 2259-15-00**

GEOCRES NO. 30M3-295

PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8 GENERAL

This report presents interpretation of the geotechnical data presented in the factual report, and provides geotechnical design recommendations related to the following project components at the crossing of Highway 406 and Chestnut Street in St. Catharines, Ontario:

- Replacement and widening of the Highway 406 northbound lane (NBL) overpass bridge over Chestnut Street; reconstruction of the associated retaining walls
- On-ramp SCL extension of Highway 406/Glendale Avenue (W/E-N Ramp)
- Replacement and relocation of the noise barrier wall associated with the on-ramp SCL extension
- Roadway protection system likely required for the replacement of the existing Highway 406 NBL overpass bridge at Chestnut Street.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The existing NBL overpass bridge carries the Highway 406 NB lanes over Chestnut Street. The bridge is a one-span structure supported on two abutments. Based on historical GA and

foundation layout drawings provided by WSP, both abutments are supported on spread footings founded on native soils at approximate Elevation 114.0 m. The length of the span is approximately 18.3 m, and the length of the approach slabs is approximately 6 m. The Chestnut Street grade under the overpass bridge is at approximate Elevations 115.5 to 116 m. The Highway 406 grade at the NBL bridge is at approximate Elevations 121 to 121.5 m. The height of the north and south approach fills are up to 5.6 m and 6.2 m, respectively. The retaining walls on the west and east sides of the bridge are founded at approximate Elevations 114.1 and 115.2m, respectively.

The terms of reference include the option to replace the NBL overpass bridge and to reconstruct the associated retaining walls. The works will involve demolition and removal of the bridge deck, retaining walls, as well as the existing abutments and footings. The new bridge will be a rigid frame structure supported on new footings. The new NBL bridge deck will be approximately 17m in width which is wider than the existing one in order to accommodate the extended speed change lane (SCL) (see below). The abutment alignments will remain unchanged with new retaining walls on both the east and west sides.

The project also includes the extension of the on-ramp SCL at Highway 406/Glendale Avenue (W/E-N Ramp) to include the easterly widening of the Highway 406 NBL platform between Stations 26+428 and 26+938. The widening will be up to a maximum width of 8.3 m. The maximum height of the widening embankment will be about 6.0 m.

It is understood that the existing noise barrier wall along the Highway 406 NBL will be removed and replaced with a new wall to accommodate the SCL extension and widening. The length of the new wall will be approximately 500 m from Stations 26+428 to 26+938. The height of the wall will not exceed 8.0 m.

The discussions and recommendations presented in this report are based on information provided by WSP and on the factual data obtained during the course of this investigation.

9 OVERPASS BRIDGE FOUNDATIONS

9.1 Foundation Conditions

In general, the subsurface conditions below the Chestnut Street grade consist of pavement structure overlying native stiff to very stiff silty clay. Below the weathered crust, the silty clay becomes firm to stiff with depth. Below the highway grade at the approaches, the silty clay embankment fill or granular abutment fill overlie native stiff to very stiff silty clay. The silty clay

deposit is underlain by a typically very dense silt to sand and silt till. Shale bedrock was encountered at depth below the till. The groundwater level is within 2 m depth below the Chestnut Street grade.

It is understood that spread footings are the proposed foundation system for the new bridge. The reconstructed retaining walls should also be founded on footings. The design and construction of spread footings at this site should take into consideration the potential disturbance of the footing subgrade during removal of the existing foundations.

Deep foundations are not currently considered but are alternatives for providing support to the new bridge. Further details on evaluation of foundation alternatives are presented in the following sections of this report.

9.2 Structural Classification

In accordance with the currently applicable CHBDC (2014) CSA S6-14, the analysis and design of structures depend on its importance category and consequence classification. Such designations are defined by the Regulatory Authority which, in this case, is the Ministry of Transportation (MTO).

For the purpose of reporting, this structure has been classified as a Major-Route Bridge with Typical Consequence based on CHBDC S6-14 Sections 4.4.2 and 6.5.2, respectively. A typical degree of understanding is also identified for this project.

Based on the above classification and Table 6.1 in Section 6.5.2 in the CHBDC, a consequence factor, ψ , of 1.0 has been used for assessing ULS and SLS geotechnical resistances. Should the consequence classification changes, the geotechnical assessment and recommendations will need to be reviewed and revised as necessary.

9.3 Foundation Alternatives

Consideration was given to alternate foundation options taking into consideration the general layout of the site, subsurface stratigraphy and the proposed works. These options are listed below:

- Spread footings on native, undisturbed silty clay
- Spread footings on engineered fill
- Driven steel H-piles

- Augered caissons (drilled shafts)

New NBL Overpass Bridge

Spread footings founded on native, undisturbed silty clay are feasible for providing foundation support to the proposed rigid frame replacement structure at this site. In order to minimize the loading on the firm to stiff silty clay below the upper weathered crust, the footings should be founded as high as possible within the crust such that post construction settlement can be maintained within acceptable limits.

Given the site and subsurface conditions, spread footings on engineered fill pads are not suitable for providing foundation support for the replacement structure. Recommendations are therefore not further developed in this report.

Deep foundations including driven steel H-piles or augered caissons (drilled shafts) may be considered. Recommendations for H-pile foundations are provided in this report. Given the proposed rigid frame structure and the presence of the end-bearing stratum at depth, however, it would not be cost effective to use augered caissons at this site.

New Retaining Walls

The new retaining walls should also be supported by spread footings founded on the silty clay.

Preferred Foundation Alternative

From a foundations technical and cost effectiveness perspective, spread footings founded on the native, undisturbed silty clay should be used for supporting the replacement bridge and the retaining walls.

More detailed comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix F.

10 NBL OVERPASS BRIDGE

10.1 Spread Footings on Native Soils

It is understood that the existing footings will be removed as part of this project. Based on archived design drawings, the base of the existing footings is near Elevation 114, therefore the excavation to remove the footings will extend to or slightly below Elevation 114. The soils at this elevation consist of native very stiff silty clay. However, there is a potential for the founding subgrade to be disturbed by the demolition and footing removal operations.

Based on Boreholes CS16-03 and CS16-04, the founding level of the existing footings on the west side of the bridge is at approximately 1.1 to 1.2 m below existing Chestnut Street grade. The groundwater level on the west side is at approximately 1.5 m depth. Based on Boreholes CS16-01 and CS16-02, the founding level of the existing footings on the east side of the bridge is at approximately 2.2 m depth below the existing Chestnut Street grade. The groundwater level on the east side ranged between 1.3 m and 2.0 m depths.

It is recommended that all new footings be founded at or below frost depth, not below the existing footing level, and as shallow as possible below the groundwater level. In cases where the founding level of the new footings are higher than that of the existing footings, it is recommended mass concrete of the same strength and class as that for the footings be used to partially backfill the subexcavation and raise the grade to the design founding level. The foundations of the existing SBL structure and retaining walls must not be undermined during construction of the new NBL structures.

The new spread footings must bear on the native, undisturbed silty clay, or mass concrete resting on the same silty clay. Based on a foundation layout drawing dated June 2017, the new spread footings are designed to be founded at Elevation 114.2 on the east side, and at Elevation 114.0 on the west side. Stepped footings may be used between the two sides if required. It is noted that the mass concrete serves multiple purposes including mitigation of adverse effects of disturbed subgrade due to demolition and removal of existing footings, provision of a more uniform pressure distribution between previously loaded and unloaded areas, and raising of the founding subgrade level where required. Any disturbed subgrade material or debris must be removed prior to placing the mass concrete.

Abutment footings up to a width of 4.0 m and founded on the native, undisturbed silty clay or mass concrete resting on the same silty clay within the founding elevations quoted above may be designed for the following values:

- Factored geotechnical resistance of 300 kPa at Ultimate Limit States (ULS)
- Geotechnical resistance of 200 kPa at Serviceability Limit States (SLS)

The above footing design values are generally consistent with those recommended on the GEOCRE documents. Reference 1 (listed in Part 1) recommended an allowable bearing capacity of about 200 kPa (2 t.s.f.) for the original structures, and Reference 2 (listed in Part 1) recommended a factored capacity at ULS of 340 kPa and a capacity at SLS of 200 kPa for the SB structure widening.

The geotechnical resistances quoted above are for concentric, vertical loads only. In the case of eccentric or inclined loading, the geotechnical resistance must be calculated as illustrated in the CHBDC 2014, Clause 6.10.3 and Clause 6.10.4.

The geotechnical SLS resistance values given above are based on an estimated total settlement not exceeding 25 mm. This settlement is expected to be substantially complete by the end of construction. Differential settlements are not expected to exceed 20 mm across the width of the structure.

The sliding resistance of cast-in-place concrete placed on the native, undisturbed stiff silty clay may be computed based on an ultimate coefficient of friction, $\tan \delta$, of 0.4. This is an “ultimate” value and requires a degree of sliding movement to occur to fully mobilize the resistance.

10.2 Subgrade Preparation

The footing excavations will extend through the pavement granulars into cohesive soils, and the excavation base will be at or just above the groundwater level. Surface water and/or seepage may take place from perched zones in the granular fill. It will be necessary for the contractor to implement groundwater control measures during construction. Footings must be constructed in the dry to prevent sloughing of the sides or disturbance of the excavation base due to the inflow of groundwater. Unwatering must remain operational and effective until the footing excavation is backfilled.

In order to avoid undermining the existing foundations of Highway 406 SBL, it is important that all temporary excavations for the Highway 406 NBL overpass bridge replacement, be carried out with care and be adequately supported by protection systems, where required, which will also serve to limit adjacent ground movements.

The subgrade must not be allowed to soften or otherwise disturbed by ponding water, personnel and construction traffic. After removal of the existing footings, the upper portion of the exposed silty clay subgrade may become disturbed.

The bases of the foundation excavations should be inspected by a geotechnical engineer to confirm that the exposed subgrade surface conforms to the design requirements and has been adequately prepared to receive concrete. Once approved, the subgrade should be protected by a working mat with a minimum thickness of 100 mm and consisting of mass concrete of the same strength and class as that of the footing. Where subexcavation is required to remove unsuitable material from below the design founding level, the founding surface should be re-established using the same mass concrete. At locations where the design founding level is higher than that

of the removed footing, the same mass concrete will be required to raise and establish the founding subgrade.

The contractor must be advised of these issues in the tender documents so that he may modify his operations to suit the subgrade conditions and project requirements. Suggesting wording for an NSSP to this effect is included in Appendix G.

10.3 Frost Protection

Frost protection should be provided to all spread footings and may take the form of 1.2 m of earth cover in any direction, or equivalent thermal insulation, over the underside of the footings.

10.4 Driven Steel H-Piles

As an alternative, the replacement bridge could be supported on steel H-piles driven to practical refusal within the underlying very dense silt to sand and silt till, or weathered shale bedrock.

A standard HP 310 x 110 section or a heavier HP 360 x 132 section may be used. Tills and other glacially derived soils inherently contain cobbles and/or boulders. The pile tips should, therefore, be reinforced to enhance driving (see Section 10.4.4).

For planning and design purposes, the recommended design founding elevations are as follows:

Table 10.1 – Design Pile Tip Elevations

Foundation Unit	Reference Borehole	Pile Tip Elevation (m)	Soil
North Abutment			
East Side	CS16-01	100.0 or lower	Sand and Silt till
West Side	CS16-04		Silt till
South Abutment			
East Side	CS16-02	101.0 or lower	Silt till
West Side	CS16-03	100.0 or lower	Silt Till / Shale Bedrock

The pile tip elevations shown in Table 10.1 should be used for estimating purposes only. The actual pile tip elevations will be controlled as described in Section 10.4.4 Pile Installation.

10.4.1 Axial Resistance

For steel H-piles driven to the estimated elevations given above, the following axial design geotechnical resistances per pile may be used.

Table 10.2 – Pile Axial Resistances

Foundation Unit	Pile Section			
	HP 310 x 110		HP 360 x 132	
	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Resistance at SLS (kN)	Factored Geotechnical Resistance at ULS (kN)	Geotechnical Resistance at SLS (kN)
Abutments	1,200	1,000	1,400	1,200

The SLS values correspond to a maximum pile settlement of 25 mm.

The structural capacity of a pile must not be exceeded and should be confirmed by the structural designer.

10.4.2 Downdrag on Piles

Downdrag forces could be induced on piles embedded within the silty clay deposit due to consolidation of the silty clay under the weight of the new wedge of fill to be placed against the new abutment walls. Reference should be made to the CHBDC (2014) Clauses 6.11.4.10 and C6.11.4.10 (commentary) for downdrag considerations.

The location of the neutral plane for a pile or pile group should be determined by using unfactored loads and unfactored geotechnical parameters. As a design check based on the SLS (unfactored) loads quoted above and using a load factor of 1.25 as per the CHBDC, it is estimated that a factored downdrag load in the order of 180 kN may act on each pile. In accordance with the CHBDC, the sum of the factored downdrag load and the factored permanent loads acting on the pile should not exceed the structural resistance of the pile. In geotechnical analysis of downdrag, live load effects should not be considered.

10.4.3 Lateral Resistance

The lateral resistance of a pile may be calculated using values for the coefficient of horizontal subgrade reaction (k_s) and the pressures obtained from the analysis should not exceed the ultimate values given in the following relationships:

$$\frac{\text{Silt Till}}{k_s} = n_h z / B \quad (\text{kN/m}^3)$$

$$p_{ult} = 3 \gamma' z K_p \quad (\text{kPa})$$

where z = pile embedment depth, m
 B = pile width, m
 n_h = coefficient related to soil density, kN/m^3
 γ' = submerged soil unit weight (below water), kN/m^3
 K_p = passive earth pressure coefficient

Silty Clay

$$k_s = 67 C_u / B \quad (\text{kN/m}^3)$$

$$p_{ult} = 9 C_u \quad (\text{kPa})$$

where p_{ult} = ultimate lateral resistance mobilized by a pile, kPa
 C_u = undrained shear strength of cohesive soils, kPa
 γ = total unit weight of soil, kN/m^3
 B = pile width, m

For pile lateral resistance design, soil-pile interaction analyses may be carried out using the coefficient of horizontal subgrade reaction values provided in Table 10.2 below.

Table 10.2 – Recommended Geotechnical Parameters for Lateral Resistance Design

Location	Reference Boreholes	Approx. Elevation (m)	Undrained Shear Strength C_u (kPa)	n_h (kN/m^3)	K_p	Unit Weight γ (kN/m^3)	Soil Conditions
Abutments	CS16-01 to CS16-04	116 to 115	-	2,500	3.0	20	Sand Fill
		115 to 114	100	-	-	19	Silty clay fill, stiff to very stiff
		114 to 112	100	-	-	19	Silty clay, Stiff to very stiff
		112 to 102	65	-	-	19	Silty clay, firm to stiff
		102 to 99.5	-	8,000	3.3	21	Silt Till, very dense

The spring constant, K , for analysis may be obtained by the expression, $K = k_s \times d_z \times B$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m^3), B is the pile width (m), d_z is the

length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance on any one segment of pile, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} \times d_z \times B$. This represents the ultimate load at the contact between the soil and the pile above which additional load cannot be supported at greater displacements.

For lateral soil-pile group interaction analysis, the values for k_s should be reduced based on pile spacing.

Where a pile group is oriented **perpendicular** to the direction of loading, group action may be considered by reducing values of k_s using a reduction factor R as follows:

Pile Spacing Perpendicular to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
4 B	1.00
1 B	0.50

where B is the width of the pile, and spacing is measured centre to centre.

Where a pile group is oriented **parallel** to the direction of loading, group action may be considered by reducing values of k_s using a reduction factor R as follows:

Pile Spacing Parallel to Direction of Loading	Horizontal Subgrade Reaction Reduction Factor, R
8 B	1.00
6 B	0.70
4 B	0.40
3 B	0.25

Intermediate values may be obtained by interpolation.

10.4.4 Frost Protection

Frost protection should be provided to all the pile caps and may take the form of 1.2 m of earth cover in any direction, or equivalent thermal insulation, over the underside of the footing.

10.4.5 Pile Installation

All piles shall be installed in accordance with OPSS 903.

The appropriate pile driving note to be shown on the contract drawing is “Piles to be driven in accordance with Standard Provision SS103-11 using an ultimate geotechnical resistance equal to two times the maximum factored design load at ULS”, but must be driven below the elevations shown on the subsequent table:

Foundation Unit	Reference Borehole	Highest Pile Tip Elevation (m)
North Abutment		
East Side	CS16-01	101
West Side	CS16-04	101
South Abutment		
East Side	CS16-02	103
West Side	CS16-03	102

Glacially derived soils inherently contain cobbles and boulders. In order to be able to penetrate boulders, cobbles and harder/dense zones to achieve the required tip elevations and soil resistance, it is recommended that the pile tips be reinforced with driving shoes such as the Titus Standard Points for H Piles or an approved equivalent.

11 RETAINING WALLS

The existing retaining walls adjacent to the Chestnut Street NBL overpass bridge will also be removed as part of the reconstruction. Four new retaining walls will be constructed at each quadrant of the replacement bridge beside the wingwalls. It is understood that the new walls will be similar to the existing ones, which consist of cantilever type, cast-in-place, concrete walls.

RSS walls are technically possible but require larger excavations and associated shoring on the retained side of the wall to accommodate the reinforcing strips. In addition to the fact that it would be aesthetically incompatible with the existing cantilever walls adjacent to the SBL bridge, the designer has selected the concrete cantilever wall option and recommendations are not developed for the RSS option. Standard MTO concrete toe walls are unsuitable for this project since the retained height exceeds any of those in the standard designs stipulated on OPSD 3120.100.

Based on historical drawings, the base of the existing retaining wall footings is at approximate Elevation 114.1 m on the west side and at approximate Elevation 115.2 m on the east side. The soils at these elevation consist of native very stiff silty clay. However, there is a potential for the founding subgrade to be disturbed by the demolition and footing removal operations.

From a foundations perspective and based on the subsurface conditions, it is recommended that retaining wall footings be founded on the undisturbed native stiff to very stiff weathered crust of the silty clay deposit. The highest permitted founding elevations for the retaining wall spread footings are given in Table 12.1.

Table 12.1 – Highest Permitted Founding Elevations

Location Relative to Retaining Wall	Borehole	Depth below existing ground surface (m)	Founding Elevation (m)	Soil Conditions
Northeast quadrant	CS16-01	1.2*	115.0	Very stiff to stiff Silty Clay
Southeast quadrant	CS16-02	1.2*	115.0	
Northwest quadrant	CS16-04	1.5	113.7	
Southwest quadrant	CS16-03	1.5	113.7	

* Design frost depth

Provided a minimum footing width of 2 m is maintained, the design of spread footings bearing on native undisturbed very stiff to stiff silty clay at or below elevations indicated in Table 12.1 should be designed using a Factored Geotechnical Resistance at ULS of 300 kPa, and a Geotechnical Resistance at SLS of 200 kPa which corresponds to settlement not exceeding 25 mm.

Frost protection should be provided to all retaining wall footings and may take the form of 1.2 m of earth cover in any direction, or equivalent thermal insulation, over the underside of the footings.

Effects of load inclination and eccentricity, and resistance to lateral forces / sliding resistance should be addressed based on the recommendations in Section 10.1 above.

Subgrade preparation for footing construction outlined in Section 10.2 above should also be followed.

12 ON-RAMP SPEED CHANGE LANE (SCL) EXTENSION

The existing on-ramp SCL at Highway 406/Glendale Avenue (W/E-N Ramp) will be extended from approximate Stations 26+430 to 26+936. The ramp extension involves widening of the existing Highway 406 NBL platform. Design information from WSP indicates that new fill will be placed on the east side of Highway 406 NBL to extend and widen the ramp up to a maximum width of

about 8.3 m. The new embankment fill will have a maximum height of about 6.0 m at the approaches to the overpass bridge at Chestnut Street.

12.1 Settlement Analysis

The new fills for ramp widening and approach fill reconstruction will induce immediate (elastic) settlement in the fill and re-compression of the weathered crust of the native silty clay. The elastic settlement is anticipated to occur as the fill is placed. Post construction (consolidation) settlement will occur within the silty clay below the crust. Settlement analysis was carried out using the elastic theory and Terzaghi's one-dimensional consolidation theory.

The estimated subgrade settlements due to the embankment loads at the new fill locations are presented in Table 12.1.

Table 12.1 – Embankment Subgrade Settlements

Embankment Height (m)	Immediate Settlement (mm)	Post Construction Settlement (mm)	Total Settlement (mm)
2	5	10	15
4	10	20	30
6	15	30	45

In a transverse direction perpendicular to the highway centreline, placement of new fill for embankment widening could induce foundation settlement during construction. It is estimated that the effects of settlement on the highway platform would be small. Should asphalt cracking occur on the shoulder pavement, temporary patching may be required. The pavement will eventually be reconstructed to accommodate the future travelled lanes.

In addition, the estimated settlement of well compacted granular and SSM fill due to self-compression is 0.5% of the embankment height (up to 10 to 20 mm within the widened travelled lane) and is expected to be completed within one to two years after construction.

The above estimated settlements satisfy the post construction settlement limits for freeway embankment widening stipulated in the MTO Embankment Settlement Criteria for Design (March 2010).

To mitigate post construction settlement, it is recommended that the new fill be placed at least three months in advance of pavement construction. Embankment and platform width design should allow for the anticipated foundation and embankment compression settlements.

12.2 Stability Analyses

Stability analyses were carried out for the embankment widening under static conditions. The soils involved are essentially cohesive, and both short-term (undrained) and long-term (effective stress) conditions were assessed. Embankment slope inclination of 2H : 1V for compacted fill was assumed.

As per typical MTO requirements, a Factor of Safety (F.S.) of 1.3 is acceptable for short term (undrained) conditions. A F.S. of 1.5 is acceptable for long term (drained) conditions.

The computed factors of safety for permanent slope configurations under drained and undrained conditions are summarized in Table 12.2. The analysis was conducted for a representative scenario where there is a maximum embankment height of 6.0 m and a maximum embankment widening of about 8.3 m.

The input parameters and soil model used in the stability analyses, including soil stratigraphy, engineering properties, groundwater conditions, embankment geometry, and slope stability results are presented on Figures H1 and H2 in Appendix H. The soil parameters are summarized in the table below.

Table 12.2 - Soil Parameters for Slope Stability Analysis

Soil Type	Unit Weight (kN/m ³)	Undrained Shear Strength (kPa)	Angle of Internal Friction (degrees)	Effective Cohesion (kPa)
New Fill (SSM or granular)	20	-	30	-
Existing Sand Fill	20	-	30	-
Silty Clay (Weathered Crust)	20	100	29	-
Silty Clay	19	50	28	-

The slope stability analysis results are summarized in the table below.

Table 12.3 – Computed Factors of Safety

Condition	Material	Factor of Safety	Figure
Drained (Short-term)	New fill	1.8	H1
Undrained (Long-Term)	New fill	2.5	H2

The above results indicate that the F.S. acceptance criteria are satisfied for the cases analysed.

12.3 Embankment Design and Construction

It is recommended that MTO approved Select Subgrade Material (SSM) or granular materials satisfying OPSS.PROV 1010 requirements be used for constructing the on-ramp widening and approach embankments at this site. Based on the above analyses, the permanently widened embankment constructed using these materials will be stable at a slope inclination not steeper than 2H : 1V.

All embankment fill must be constructed with adequate quality control in accordance with OPSS.PROV 206 and OPSS.PROV 501 requirements. Inorganic earth fill, especially those with large proportions of clayey materials, is not recommended for embankment construction at this site due to potentially higher post construction settlement, difficulties in achieving the specified compaction and potential embankment stability issues. Benching of existing fill slopes should be carried out as per OPSD 208.010 prior to placing new fill.

It is also recommended that all permanent and temporary slope surfaces be vegetated and seeded in accordance with current MTO practice with reference to OPSS.PROV 804. It is important to note that slopes steeper than 2H : 1V will be subject to surficial instability which may include sloughing and gullying. Surface runoff and precipitation must be prevented from flowing perpendicularly down any slope surface. Erosion protection measures will have to be taken as necessary to avoid adverse impacts on the highway.

13 FORWARD SLOPES

The existing north and south forward slopes at the Chestnut overpass are typically vegetated with grass. Available information indicates that these slopes have been designed to have an inclination of 2H : 1V.

It is anticipated that removal of the existing bridge deck, abutments and footings may require temporary excavation of portions of the existing embankment fills. Provided that the exposed slopes are reinstated to a final configuration of 2H : 1V or flatter in accordance with the recommendations in this report, the forward slopes will remain stable. Disturbed or regraded earth slopes must be provided with erosion protection in accordance with OPSS.PROV 804.

14 LATERAL PRESSURES

Earth pressures acting on the structure may be assumed to be triangular and to be governed by the characteristics of the abutment backfill. For a fully drained condition, the pressures should be computed in accordance with the CHBDC 2014 but are generally given by the expression:

$$p_h = K (\gamma h + q)$$

where: p_h = horizontal pressure on the wall at depth h (kPa)
 K = earth pressure coefficient (see Table 14.1)
 γ = unit weight of retained soil (see Table 14.1)
 h = depth below top of fill where pressure is computed (m)
 q = value of any surcharge (kPa).

In accordance with Clause 6.12.3 of the CHBDC 2014, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I, or 1.7 m for Granular A or Granular B Type II. Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS.PROV 501.

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 14.1.

Table 14.1 – Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)	Horizontal Surface Behind Wall	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.40	0.31	0.48
At rest (Restrained Wall)	0.43	-	0.47	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-

If the support system allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the structure. If the support system does not allow yielding (restrained system), at-rest horizontal earth pressures should be used.

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall.

The factors in Table 14.1 are “ultimate” values and require certain movements for the respective conditions to be mobilized. The values to be used in design can be estimated from Figure C6.16 in the Commentary to the CHBDC 2014.

It is recommended that perforated sub-drains and/or weep holes be installed, where applicable, to provide positive drainage of the granular backfill behind the abutment walls. Reference may be made to OPSD 3102.100 where appropriate.

15 FOUNDATION DESIGN PARAMETERS FOR NOISE BARRIER WALL

A new noise barrier wall will be constructed adjacent to the shoulder of the Highway 406 NBL widening embankment. Use of a proprietary post-and-panel noise barrier wall supported by small diameter augered caissons (drilled shafts) is considered feasible at the wall locations. Installation of the foundations is expected to be carried out primarily through the new embankment fill into the underlying native stiff to very stiff silty clay.

For design of the noise barrier wall foundations, reference may be made to the following document:

- Canadian Highway Bridge Design Code and Commentary (2014). CAN/CSA-S6-14 and S6.1-14 (Reference 3).
- Ministry of Transportation, Ontario (2004) “Guidelines for the Design of High Mast Pole Foundation”, Fourth Edition, BRO-009, Engineering Standards Branch, Bridge Office (Reference 4).

It is anticipated that the proposed noise barrier walls will be supported on conventional augered caissons with typical diameters ranging from 0.45 to 0.9 m. Table 1 immediately following the text of this report presents the recommended geotechnical design parameters for the augered caisson foundations.

In order to take into account frost action and surficial disturbance, the ultimate lateral passive resistance of a caisson within the upper 1.2 m below final grade should be neglected in the

foundation design. It is recommended that all surficial weak soils, including topsoil and organics, be neglected in determining lateral resistance. Sloping highway embankments in front of a caisson will result in reduced lateral passive resistance that must be taken into consideration during design.

Where downward sloping fill or native soil exists in front of a caisson, reduction of lateral passive resistance should be taken into consideration during design. For design of the caissons, it should be assumed that full lateral resistance can only be mobilized where the width of the soil in front of or behind the caisson is equal to or greater than approximately four (4) times the diameter of the caissons. For sloping ground in front of a caisson, the magnitude of the mobilized passive resistance can be estimated by interpolating between zero passive resistance at the level where the slope face intersects the pile, and full passive resistance at the level where the horizontal distance between the slope face and the caisson is equal to or greater than four (4) times the diameter of the caisson.

Where an undrained shear strength, C_u , is provided for a cohesive soil (silty clay fill, silty clay), the ultimate lateral passive resistance should be calculated in conjunction with the total soil unit weight. When designing for portions of the caissons below the groundwater level in cohesionless soils (sands and silts) and fills, the submerged soil unit weight, γ' , should be used. The required depth of the drilled shaft will be governed by lateral loads, including wind loads, acting on the wall. The embedded length of the caisson should also be sufficient to counteract frost jacking (upward) forces.

An equivalent caisson width equal to 2 times the caisson diameter may be assumed for lateral resistance calculations. Appropriate load and resistance factors should be applied for caisson design.

15.1 Caisson Installation for Noise Barrier Wall

Caisson installation should generally be carried out in accordance with OPSS 903.

It should be anticipated that obstructions are present within the embankment fill. Caisson installation equipment must be able to dislodge, handle, remove, and to penetrate other obstructions within the fill, where encountered.

Groundwater levels are at variable depths below existing ground surface. Soil sloughing and water seepage may occur in unsupported holes especially at depths below the groundwater level. Temporary liners must be available to support the caisson sidewalls and provide seepage cut-off where required. Any accumulated water may have to be pumped out from the hole prior to placing

concrete. Should it be considered impractical to remove the accumulated water inside the hole, it is recommended that the concrete be placed by the tremie method. Suggested wordings for an NSSP to cover the above aspects are provided in Appendix G.

16 ROADWAY PROTECTION

Roadway protection (temporary shoring) will be required during demolition and removal of the existing structures, and construction of the replacement overpass bridge and associated retaining walls. An item titled "Protection System" as per OPSS.PROV 539 should be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.01.01 and the alignment of the roadway protection be specified on the contract drawings.

The design of roadway protection is the responsibility of the Contractor. However, one option that is considered to be suitable for use as temporary shoring at this site is a soldier pile and lagging wall. It is anticipated that the protection system will need to be extended predominantly through the existing embankment fill (gravelly sand fill and silty clay fill), into the underlying native very stiff to stiff silty clay to develop the required toe resistance. Installation of roadway protection should consider that the existing embankment fill may contain obstructions. It is anticipated that the shoring system may be stiffened by cross bracings, where applicable.

A soldier pile and lagging wall may be designed using the parameters given below:

Soil Bulk Unit Weight	γ	=	20 kN/m ³
Submerged Unit Weight (below gwl)	γ'	=	10 kN/m ³
Coefficient of Active Pressure	K_a	=	0.33 (fill)
		=	0.35 (silty clay)
Coefficient of Passive Pressure	K_p	=	3.0 (fill)
		=	2.8 (silty clay)

It is recommended that lateral earth pressures acting on the wall be computed in accordance with the CHBDC 2014. The surcharge should include soil loadings above the retained soil and other loadings adjacent to the wall. A properly designed and constructed soldier pile and lagging wall will be permeable and therefore water pressure acting on the retained height may be set to zero. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the roadway protection system.

The designer of the roadway protection system should check whether the depth of the soldier piles is sufficient to provide base fixity.

All roadway protection systems should be designed by a Professional Engineer experienced in such designs.

17 FOUNDATION AND TEMPORARY EXCAVATIONS

All excavations at this site must be carried out in accordance with the Occupational Health and Safety Act (OHSA). The excavation and backfilling for foundations must be carried out in accordance with OPSS.PROV 902.

For the purposes of the OHSA, the fill and the native soils at this site may be classified as Type 3 materials.

Excavation for foundation construction will extend through the pavement structure, gravelly sand fill, sand fill and silty clay fill, and into the native silty clay.

The selection of the method of excavation is the responsibility of the contractor and must be based on his equipment, experience and interpretation of the site conditions. Excavations should be inspected regularly for evidence of instability if they have been left open for extended periods of time and following periods of heavy rain or thawing. If required, remedial actions must be taken to ensure the stability of the excavation and the safety of workers. Exposed soil slopes should be covered with plastic sheetings to protect against precipitation and surface runoff.

18 GROUNDWATER AND SURFACE WATER CONTROL

Piezometric levels obtained along the alignment of the proposed on-ramp SCL extension indicate that the groundwater elevations at this site decreases from south to north from Elevations 119.8 to 107.6 m, or between 1.5 m and 6.3 m depths.

Piezometric levels obtained from Chestnut Street grade indicate that the groundwater level ranges between Elevations 113.9 and 114.8, or 1.3 m to 1.4 m depth below existing road grade. Excavation for footing construction may extend slightly below the groundwater level at some locations.

In general, seepage or perched water from the granular fill is to be expected. The amount of perched water within the fill is expected to be limited. For temporary foundation excavations at this site, groundwater control will likely be limited to diverting surface runoff and preventing precipitation from entering the excavations, and supplemented by sump pumping. Filtered sumps must be designed properly so that construction drainage water containing eroded soil and fines does not flow onto existing roadways. Unwatering must remain operational and effective until the footings are backfilled.

The design of the dewatering system that may be required is the responsibility of the Contractor and the Contract Documents must alert him to this responsibility.

19 SEISMIC CONSIDERATIONS

According to Clause 4.4.4 of the CHBDC 2014, an earthquake with a 2475-year return period or 2% probability of exceedance in 50 years should be used for seismic design.

In accordance with the CHBDC 2014, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy, which consists of firm to very stiff silty clay overlying very dense silt to sand and silt till, which is underlain by shale bedrock.

The seismic site classification for this site is based on the N_{60} criteria. The harmonic mean of the typical N_{60} values provided above is 23 blows, which corresponds to a Seismic Site Class D in accordance with Table 4.1, Clause 4.4.3.2 of the CHBDC. The peak ground acceleration, PGA, for a 2% in 50 year probability of exceedance at this site is 0.067 g as per the National Building Code of Canada (NBCC). The above PGA value should be assigned a site coefficient of 1.29 based on Table 4.8 of the CHBDC.

In accordance with Clause 4.6.5 of the CHBDC 2014, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading. The coefficients of horizontal earth pressure for seismic loading presented in Table 19.1 may be used:

Table 19.1 – Earth Pressure Coefficients for Earthquake Loading

Condition	Earth Pressure Coefficient (K)	
	OPSS Granular A or Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$
Active (K_{AE})*	0.30	0.34
Passive (K_{PE})	3.6	3.1
At Rest (K_{OE})**	0.54	0.59

* After Mononobe and Okabe, passive case assumes a horizontal surface in front of the wall.

** After Woods

The site is underlain by typically stiff silty clay and liquefaction is not considered to be a concern at this site.

20 ADJACENT STRUCTURES AND BURIED UTILITIES

Buried utilities are present within the new foundation construction areas. It is recommended that the exact locations and elevations of the utilities be established by the designer, and compared with the extent of the potential work zones related to the foundations of the proposed bridge replacement and associated works. These utilities must not be damaged during construction of the new overpass bridge and the associated on-ramp SCL extension. If necessary, relocation of, and/or special protective measures for, affected utilities may be required. The settlement and displacement/rotation tolerances of the utilities should also be established.

At this site is recommended that the following be carried out prior to the commencement of construction:

- Carry out pre-construction condition survey including documentation of any existing distress associated with the existing SBL bridge foundations and utilities in the vicinity. Any distress should be reported to and discussed with the owners of these facilities.
- Carry out post-construction condition survey of the existing SBL bridge foundations and utilities.

21 CONSTRUCTION CONCERNS

Potential construction concerns include, but are not necessarily limited to, the following:

- In order to avoid undermining the existing foundations of Highway 406 SBL, it is important that all temporary excavations for the Highway 406 NBL overpass bridge replacement, be carried out with care and be adequately supported by protection systems, where required, which will also serve to limit adjacent ground movements.
- Care must be taken during excavation to avoid disturbing and undermining travelled lanes of the roadways that will remain open.
- Settlement monitoring of the existing bridge foundations and buried utilities close to the work areas during construction is recommended. Settlement monitoring, where required, should be provided by qualified personnel.
- The embankment fill may contain cobbles and boulders. Equipment selected for excavation must be capable of penetrating, handling and/or removing these obstructions.

- The native silty clay at this site is susceptible to disturbance by seepage, ponding water, construction and personnel traffic. Particular attention/measures will be required for groundwater and surface water control, and to limit traffic on the exposed subgrade.
- Erosion protection should be provided to the exposed embankment surfaces after construction. Where necessary, remedial measures such as re-vegetation and/or placement of gravel sheeting may be required for erosion control.
- Concerns during caisson construction and installation for the noise barrier wall, mainly involve the handling and removal of any possible obstructions in the existing till, soil sloughing and water seepage from caisson sidewalls.

22 CLOSURE

Engineering analysis and preparation of this foundation design report was carried out by Ms. Rocío Palomeque Reyna, P.Eng and Dr. Sydney Pang, P.Eng.

Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects, reviewed the report.



60 YEARS

Thurber Engineering Ltd.



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TABLE 1
GEOTECHNICAL DESIGN PARAMETERS
NOISE BARRIER WALLS
HIGHWAY 406 ON-RAMP SCL EXTENSION
ST. CATHARINES, ONTARIO

Approximate Location along Wall Alignment	Borehole Number	Reference Simplified Subsurface Stratigraphy for Design	Depth Below Existing Highway Grade (m)	Geotechnical Design Parameters				
				C_u (kPa)	ϕ' (deg.)	γ (kN/m ³)	γ' (kN/m ³)	Groundwater Depth (m)
Station 27+000 to Station 26+750	SC16-01 to SC16-05	Silty Clay Fill (Firm to Very Stiff)	0.1 – 1.5	60	-	19	-	5 (below existing ground surface)
		Silty clay (Very Stiff)	1.5 – 4.0	120	-	19	-	
		Silty clay (Stiff)	5.0 – 8.0	75	-	19	-	
Station 26+750 to Station 26+550	CH16-01 to SC16-06 to SC16-08	Silty Clay Fill (Firm to Very Stiff)	0.1 – 1.5	60	-	19	-	3 (below existing ground surface)
		Silty clay (Very Stiff)	1.5 – 8.0	120	-	19	-	
Entire Alignment	-	Embankment Widening Fill	Above existing ground	-	30	20	-	-

Legend:

C_u = undrained shear strength = unconfined compressive strength, $q_u / 2$
 ϕ' = angle of internal friction
 γ = bulk unit weight
 γ' = submerged unit weight

Notes:

- This table must be read in conjunction with the report. In order to take into account frost action and surficial disturbance, the ultimate lateral passive resistance in front of the caisson within the upper 1.2 m below final grade should be neglected in the foundation design.

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
 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.

EXPLANATION OF ROCK LOGGING TERMS


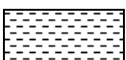

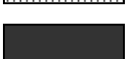

ROCK WEATHERING CLASSIFICATION

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.

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

SYMBOLS

	CLAYSTONE
	SILTSTONE
	SANDSTONE
	COAL
	BEDROCK

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

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 % 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.

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			



Appendix A

Hwy 406 Chestnut Street NBL Overpass Bridge and Approaches

Boreholes CS16-01 to CS16-04

Boreholes CH16-01 to CH16-02

- Record of Borehole Sheets
- Laboratory Test Results
- Drawings titled “Borehole Locations and Soil Strata”

RECORD OF BOREHOLE No CH16-01

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Widening Approaches N 4 777 726.6 E 327 533.2 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.25 - 2016.11.25 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
117.5	GROUND SURFACE															
0.0 0.1	TOPSOIL: (75mm) Silty CLAY , trace sand, trace gravel Firm to Hard Greyish Brown Moist (FILL)		1	SS	7											
			2	SS	38											
116.0																
1.5	Silty CLAY , trace sand, trace gravel Very Stiff Brown Moist		3	SS	26											
			4	SS	22											
			5	SS	22											
			6	SS	21											
			7	SS	22											
109.3			8	SS	21											
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.01.04 4.1 113.4 2017.01.13 3.9 113.6 2017.03.16 3.2 114.3 2017.08.30 2.3 115.2															

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CH16-02

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Widening Approaches N 4 777 677.5 E 327 531.9 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.03 - 2016.11.03 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa														
								<div><div>20406080100</div><div></div><div>20406080100</div></div>					<div><div>PLASTIC LIMIT</div><div>NATURAL MOISTURE CONTENT</div><div>LIQUID LIMIT</div></div> <div><div>W_P</div><div>W</div><div>W_L</div></div> <div>WATER CONTENT (%)</div>									
								<div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>														
118.0	GROUND SURFACE																					
0.0 0.1	TOPSOIL: (75mm)																					
	Silty CLAY , trace sand, trace gravel, occasional organics Stiff to Very Stiff Brown Moist (FILL)		1	SS	12																	
			2	SS	17																	
116.6																						
1.4	Silty CLAY , trace sand, trace gravel Very Stiff Brown Moist		3	SS	30										0 0 50 50							
			4	SS	21																	
			5	SS	17																	
113.9																						
4.1	Stiff		6	SS	13																	
112.4																						
5.6			7	SS	15																	
			8	SS	24																	
109.8																						
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE OPEN AND DRY UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.01.04 4.1 113.9 2017.01.13 6.1 111.9 2017.03.16 3.2 114.8 2017.08.30 2.8 115.2																					

ONTMT4S MTO-11336.GPJ 2017TEMPLATE(MTO).GDT 9/12/17

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS16-01

1 OF 2

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Overpass N 4 777 704.1 E 327 524.8 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.28 - 2016.11.28 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
116.2	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALT: (100mm)																			
0.1	Gravelly SAND, some silt, some clay		1	GS			116												31 45 24 (SI+CL)	
115.5	Brown																			
	Moist																			
0.7	(FILL)																			
	Silty CLAY, trace sand, trace gravel		2	SS	16		115													
	Very Stiff to Stiff																			
	Brown																			
	Moist																			
			3	SS	16		114													
			4	SS	14														0 0 34 66	
			5	SS	12		113													
							112													
			6	SS	10		111													
							110													
	Becoming grey		7	SS	16															
							109													
			8	SS	11		108												0 0 39 61	
							107													
			9	SS	11															

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS16-01

2 OF 2

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Overpass N 4 777 704.1 E 327 524.8 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.28 - 2016.11.28 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE								
	Continued From Previous Page						20	40	60	80	100	20	40	60		
	Silty CLAY , trace sand, trace gravel Stiff Grey Moist															
			10	SS	8								○			
										+						
			11	SS	8								○			0 0 45 55
										+						
102.9																
13.3	SAND and SILT , some clay, trace gravel Compact to Very Dense Grey Moist (TILL)															
			12	SS	14								○			
													○			
100.7			13	SS	50/								○			0 51 39 10
15.5	END OF BOREHOLE AT 15.5m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO SURFACE.				0.100											

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS16-02

1 OF 2

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Overpass N 4 777 695.7 E 327 525.2 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.29 - 2016.11.29 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				W _P W W _L WATER CONTENT (%)				GR	SA	SI	CL		
116.2	GROUND SURFACE							20	40	60	80	100									
0.0	ASPHALT:(100mm)							20	40	60	80	100									
0.1	Gravelly SAND , some silt, trace clay Brown Moist (FILL)		1	GS			116							○							
115.5																					
0.7	Silty CLAY , trace sand, trace gravel Very Stiff to Stiff Brown Moist		1	SS	18		115							○							
			2	SS	19		114							○				0	0	51	49
			3	SS	13		113							○							
			4	SS	13		112														
			5	SS	8		111							○	—			0	0	36	64
110.6	Becoming grey Firm																				Vane pushed to 5.2m depth, did not turn
5.6			6	SS	6		110							○							Vane pushed to 6.7m depth, did not turn
109.0							109														
7.2			7	SS	10		108							○							Vane pushed to 8.2m depth, did not turn
			8	SS	7		107							○				0	0	36	64

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No CS16-03

1 OF 2

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Overpass N 4 777 694.8 E 327 500.0 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.29 - 2016.11.30 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				
115.3	GROUND SURFACE											
0.0	ASPHALT: (100mm)											
0.1	SAND, some gravel, some silt, trace clay Brown Moist (FILL)		1	GS			115					18 57 25 (SH+CL)
114.6												
0.7	Silty CLAY Very Stiff Brown Moist (FILL)		1	SS	16		114					
113.9												
1.4	Silty CLAY, trace sand, trace gravel Very Stiff to Stiff Brown Moist		2	SS	16		113					
			3	SS	9		112					0 0 29 71
			4	SS	9		111					
111.2	Becoming grey Firm		5	SS	6		110					Vane pushed to 5.2m depth, did not turn
109.7			6	SS	9		109					Vane pushed to 6.7m depth, did not turn
5.6												
			7	SS	8		108					
							107					
			8	SS	8		106					0 0 29 71

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS16-03

2 OF 2

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Overpass N 4 777 694.8 E 327 500.0 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.29 - 2016.11.30 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								20 40 60 80 100				w _P w w _L				
								○ UNCONFINED + FIELD VANE								
								● QUICK TRIAXIAL × LAB VANE								
								20 40 60 80 100				20 40 60				

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS16-04

1 OF 2

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Overpass N 4 777 703.3 E 327 500.1 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.30 - 2016.12.01 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa												
115.2	GROUND SURFACE							20	40	60	80	100								
0.0	ASPHALT: (100mm)																			
0.1	SAND, some gravel, some silt, trace clay Brown Moist (FILL)		1	GS			115												17 57 19 7	
114.5																				
0.7	Silty CLAY, trace sand, trace gravel Stiff Brown Moist (FILL)		1	SS	11		114													
113.7																				
1.5	Silty CLAY, trace sand, trace gravel Very Stiff to Stiff Brown Moist		2	SS	17		113													
			3	SS	12		112												0 0 36 64	
			4	SS	11		111													
			5	SS	8		110													
			6	SS	9		109													
							108													
	Firm		7	SS	7		107													
			8	SS	8		106													

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No CS16-04

2 OF 2

METRIC

GWP# 2259-15-00 LOCATION Chestnut St Overpass N 4 777 703.3 E 327 500.1 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.30 - 2016.12.01 CHECKED BY SKP

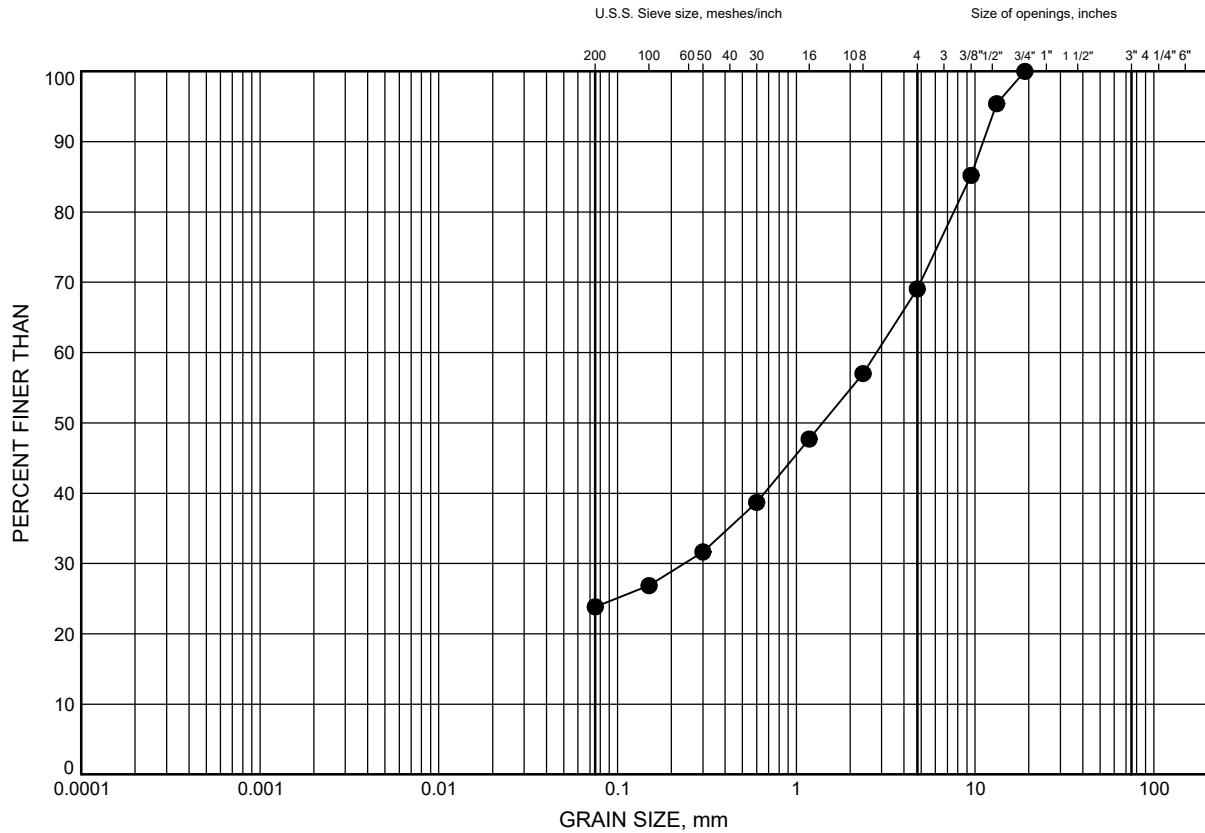
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT		NATURAL MOISTURE CONTENT		LIQUID LIMIT		UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W P		W		W L			GR SA SI CL				
	Continued From Previous Page							20 40 60 80 100													
	Silty CLAY , trace sand, trace gravel Stiff Brown Moist		9	SS	11																
			10	SS	8																
101.2			11	SS	100/ 0.200																
14.0	SILT , some sand, some clay, trace gravel Very Dense Greyish Brown Moist (TILL)																				
			12	SS	100/ 0.150																
98.3			13	SS	100/ 0.150																
16.9	END OF BOREHOLE AT 16.9m. BOREHOLE DRY UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.01.11 2.0 113.2 2017.03.16 1.5 113.7 2017.08.30 1.3 113.9																				

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Chestnut St Overpass GRAIN SIZE DISTRIBUTION

FIGURE A1

Gravelly SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CS16-01	0.3	115.9

Date September 2017
GWP# 2259-15-00

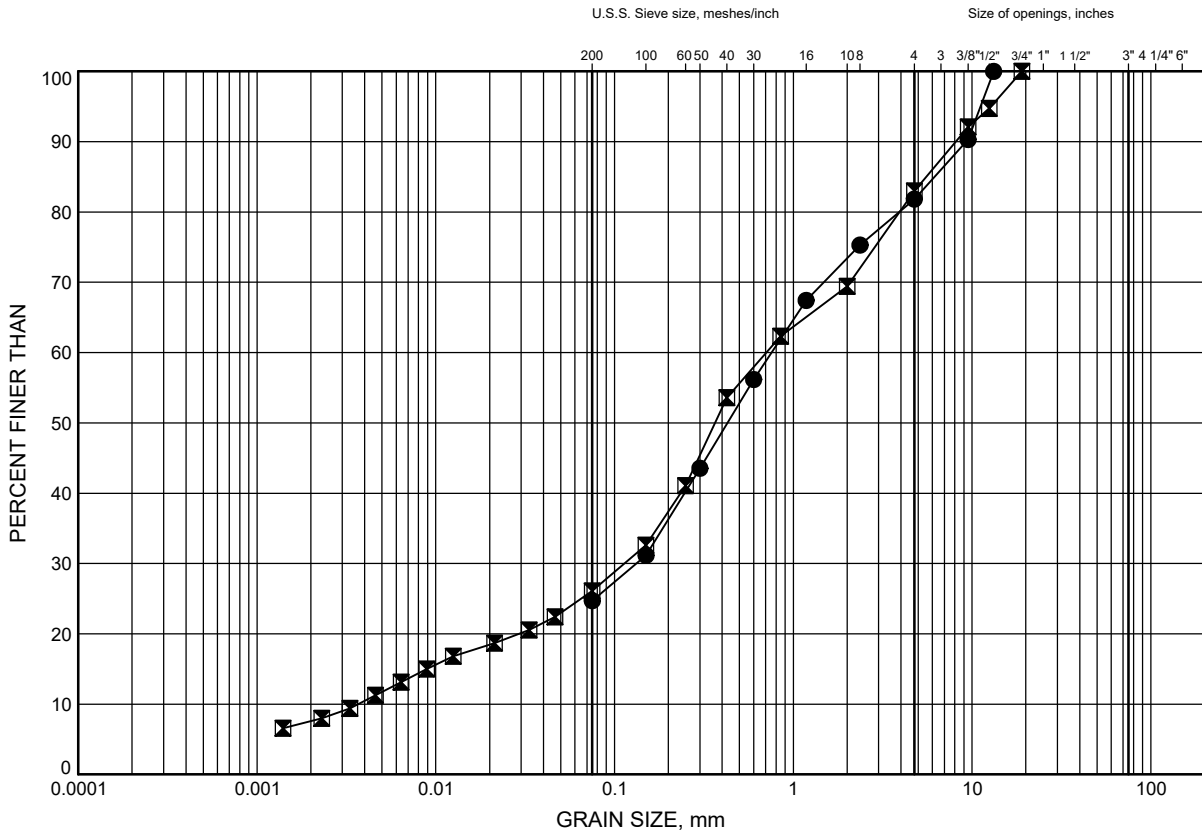


Prep'd AN
Chkd. RPR

Chestnut St Overpass GRAIN SIZE DISTRIBUTION

FIGURE A2

SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CS16-03	0.3	115.0
◻	CS16-04	0.3	114.9

Date September 2017

GWP# 2259-15-00



Prep'd AN

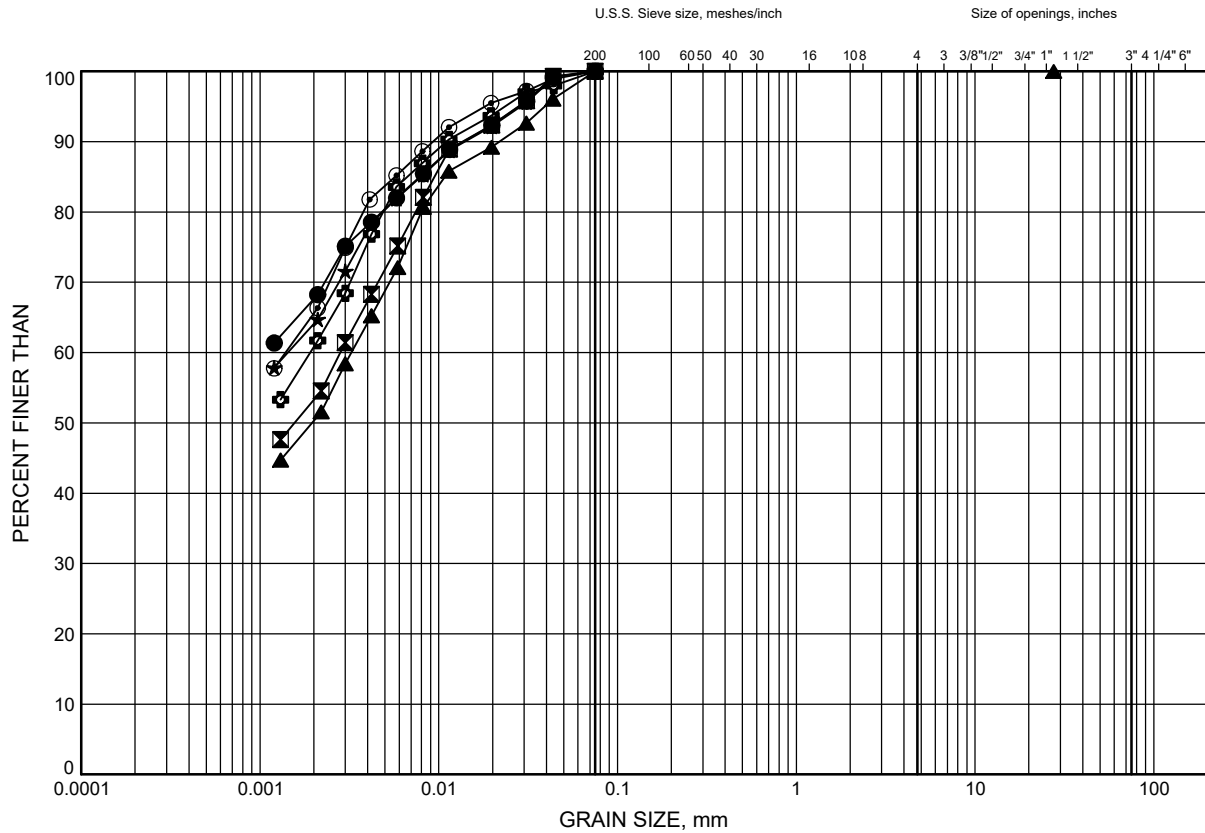
Chkd. RPR

Chestnut St Overpass

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)
●	CH16-01	3.4	114.1
⊠	CH16-01	6.4	111.1
▲	CH16-02	1.8	116.2
★	CH16-02	4.9	113.1
⊙	CS16-01	2.6	113.6
⊕	CS16-01	7.9	108.3

Date September 2017

GWP# 2259-15-00



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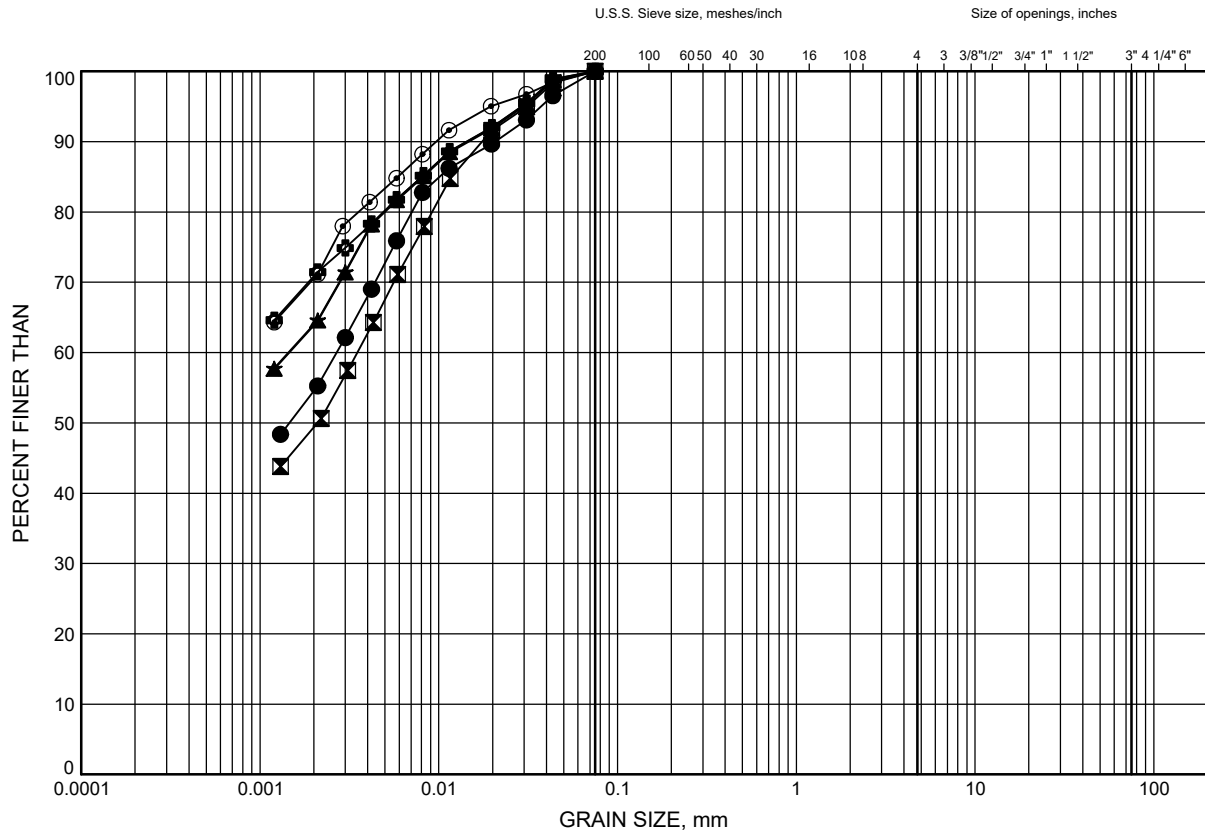
Chkd. RPR

Chestnut St Overpass

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)
●	CS16-01	12.5	103.7
⊠	CS16-02	1.8	114.4
▲	CS16-02	4.9	111.3
★	CS16-02	9.4	106.8
⊙	CS16-03	3.4	111.9
⊕	CS16-03	9.4	105.9

Date September 2017

GWP# 2259-15-00



Prep'd AN

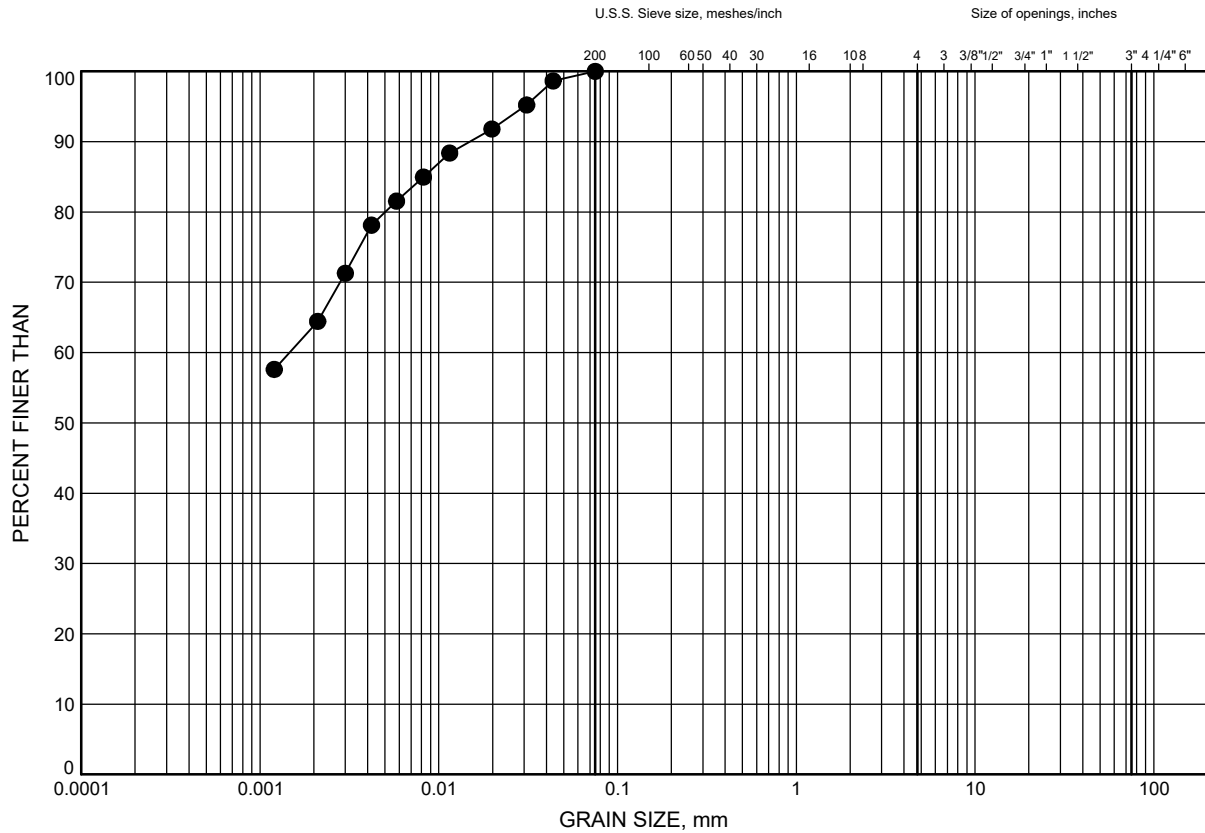
Chkd. RPR

Chestnut St Overpass

GRAIN SIZE DISTRIBUTION

FIGURE A5

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CS16-04	3.4	111.8

Date September 2017

GWP# 2259-15-00



Prep'd AN

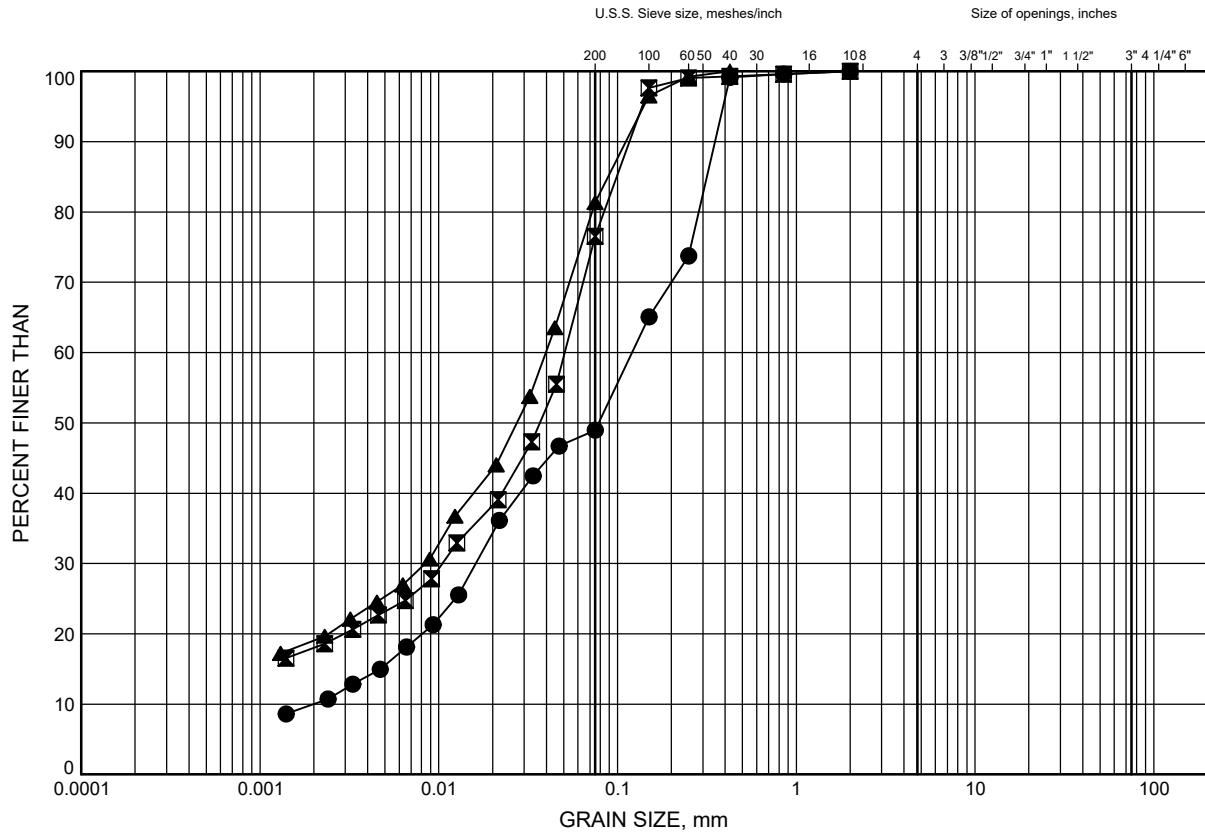
Chkd. RPR

Chestnut St Overpass

GRAIN SIZE DISTRIBUTION

FIGURE A6

SILT to SAND and SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CS16-01	15.4	100.8
⊠	CS16-02	15.4	100.8
▲	CS16-03	14.0	101.3

Date September 2017

GWP# 2259-15-00



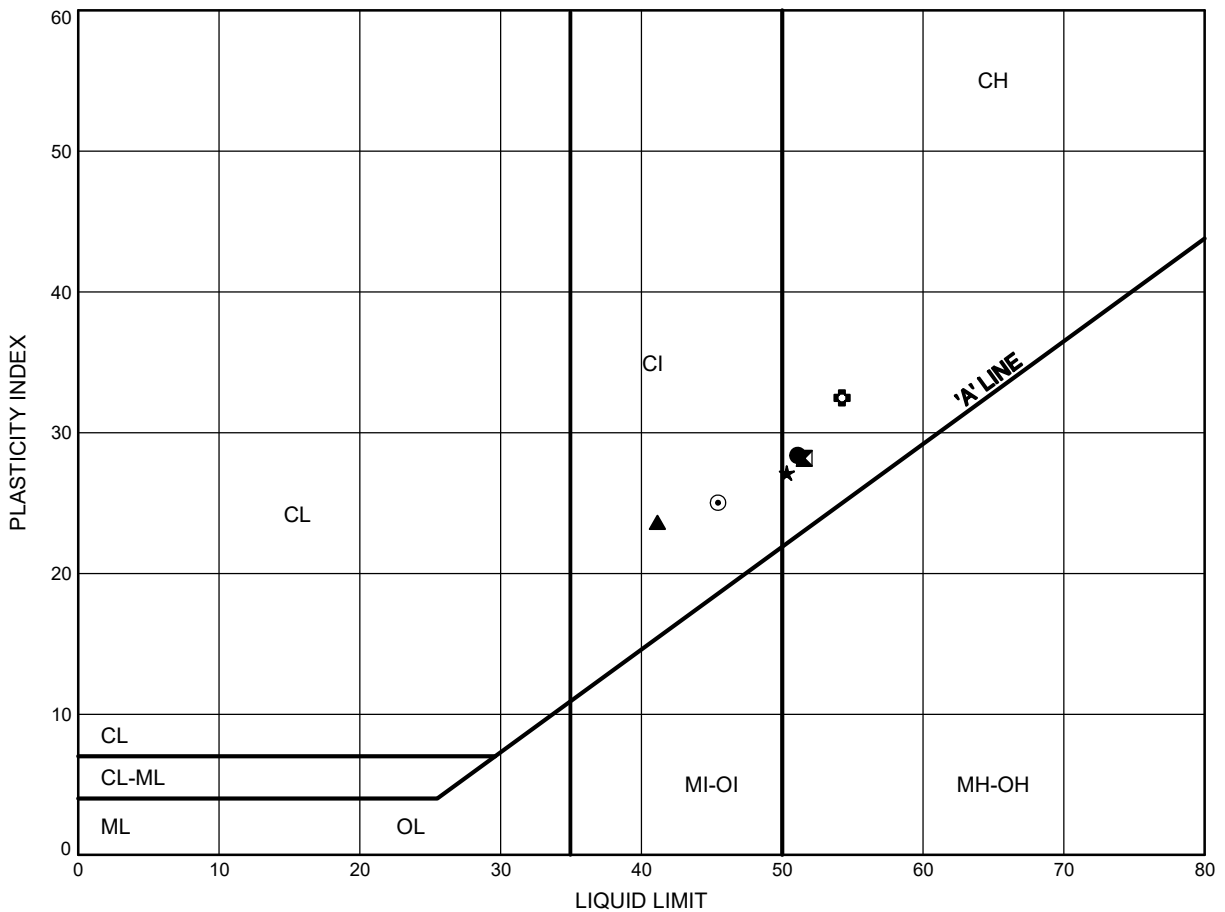
Prep'd AN

Chkd. RPR

Chestnut St Overpass
ATTERBERG LIMITS TEST RESULTS

FIGURE A7

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	CH16-01	3.4	114.1
⊠	CH16-02	4.9	113.1
▲	CS16-01	7.9	108.3
★	CS16-02	4.9	111.3
⊙	CS16-03	9.4	105.9
⊕	CS16-04	3.4	111.8

Date September 2017

GWP# 2259-15-00



Prep'd AN

Chkd. RPR

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 2259-15-00



HIGHWAY 406
CHESTNUT ST NBL OVERPASS
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

- Borehole (Current Investigation)
- ⊕ Borehole (Previous Investigation)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- ▽ Water Level
- ⊕ Head Artesian Water
- ⊕ Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
1	117.2	4 777 720.5	327 521.3
2	116.5	4 777 719.5	327 491.3
3	118.1	4 777 679.6	327 492.4
4	118.0	4 777 680.5	327 520.8
CH16-01	117.5	4 777 726.6	327 533.2
CH16-02	118.0	4 777 677.5	327 531.9
CS16-01	116.2	4 777 704.1	327 524.8
CS16-02	116.2	4 777 695.7	327 525.2
CS16-03	115.3	4 777 694.8	327 500.0
CS16-04	115.2	4 777 703.3	327 500.1
RP16-01	120.9	4 777 716.4	327 515.2
RP16-02	120.8	4 777 711.6	327 507.9
RP16-03	121.6	4 777 683.5	327 507.8
RP16-04	121.8	4 777 682.4	327 516.7

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCREs No. 30M3-295

DATE	BY	DESCRIPTION
DESIGN	RPR	CHK SKP
DRAWN	AN	CHK RPR
		CODE
		LOAD
		DATE
		SEP 2017
		STRUCT
		DWG 1

FILENAME: H:\Working\11000\11336\11336-11336-PLR-CSU.dwg
PLOTDATE: 9/12/2017 11:06 AM

HWY 406 SBL
TO ST. CATHARINES

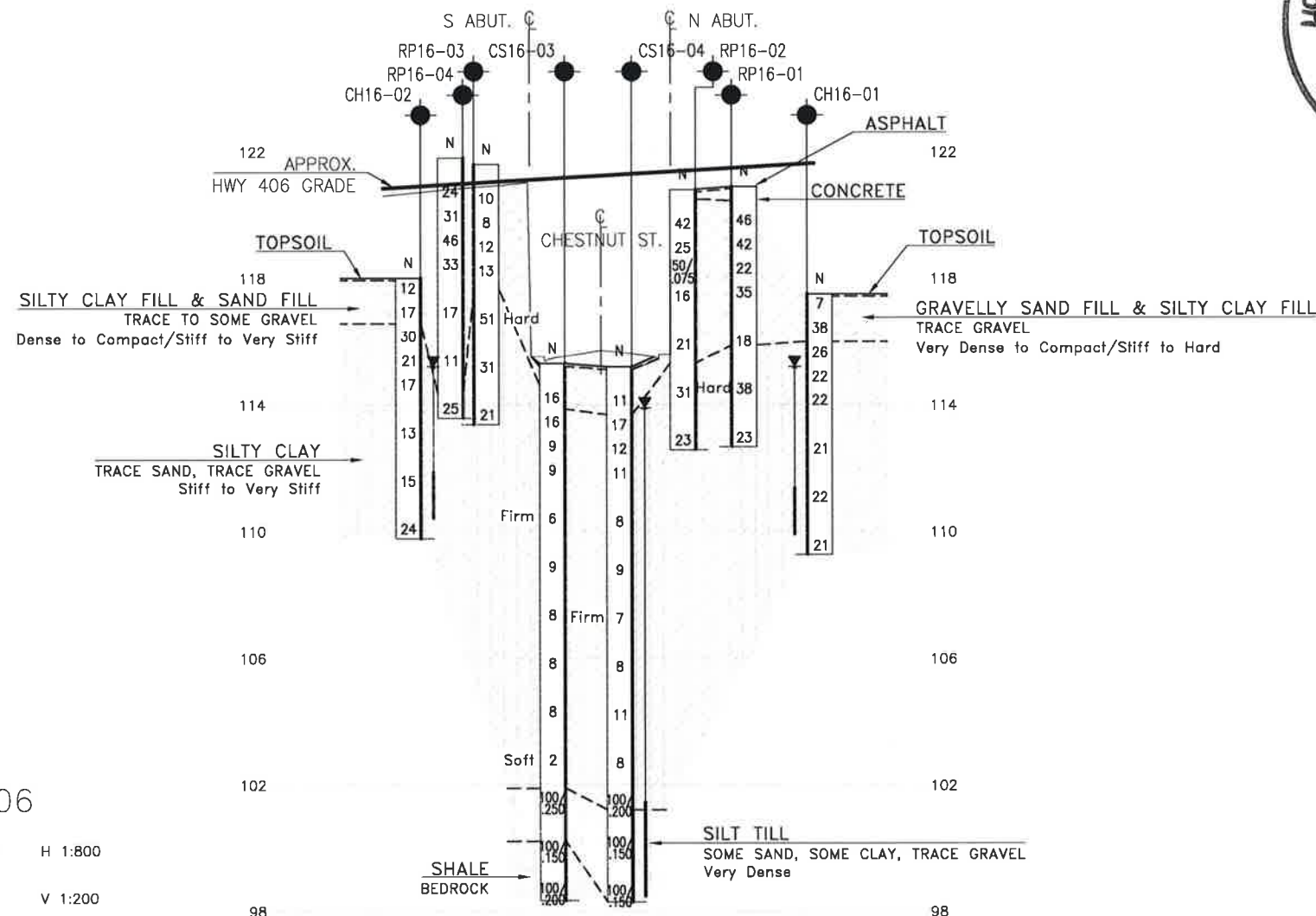
E 327 500

E 327 550



PLAN

SCALE 1:800



PROFILE ALONG C HWY 406



H 1:800

V 1:200

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

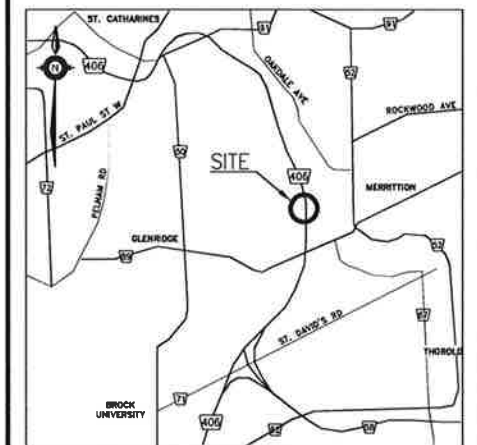
CONT No
GWP No 2259-15-00

HIGHWAY 406
CHESTNUT ST NBL OVERPASS
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

	Borehole (Current Investigation)
	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
1	117.2	4 777 720.5	327 521.3
2	116.5	4 777 719.5	327 491.3
3	118.1	4 777 679.6	327 492.4
4	118.0	4 777 680.5	327 520.8
CH16-01	117.5	4 777 726.6	327 533.2
CH16-02	118.0	4 777 677.5	327 531.9
CS16-01	116.2	4 777 704.1	327 524.8
CS16-02	116.2	4 777 695.7	327 525.2
CS16-03	115.3	4 777 694.8	327 500.0
CS16-04	115.2	4 777 703.3	327 500.1
RP16-01	120.9	4 777 716.4	327 515.2
RP16-02	120.8	4 777 711.6	327 507.9
RP16-03	121.6	4 777 683.5	327 507.8
RP16-04	121.8	4 777 682.4	327 516.7

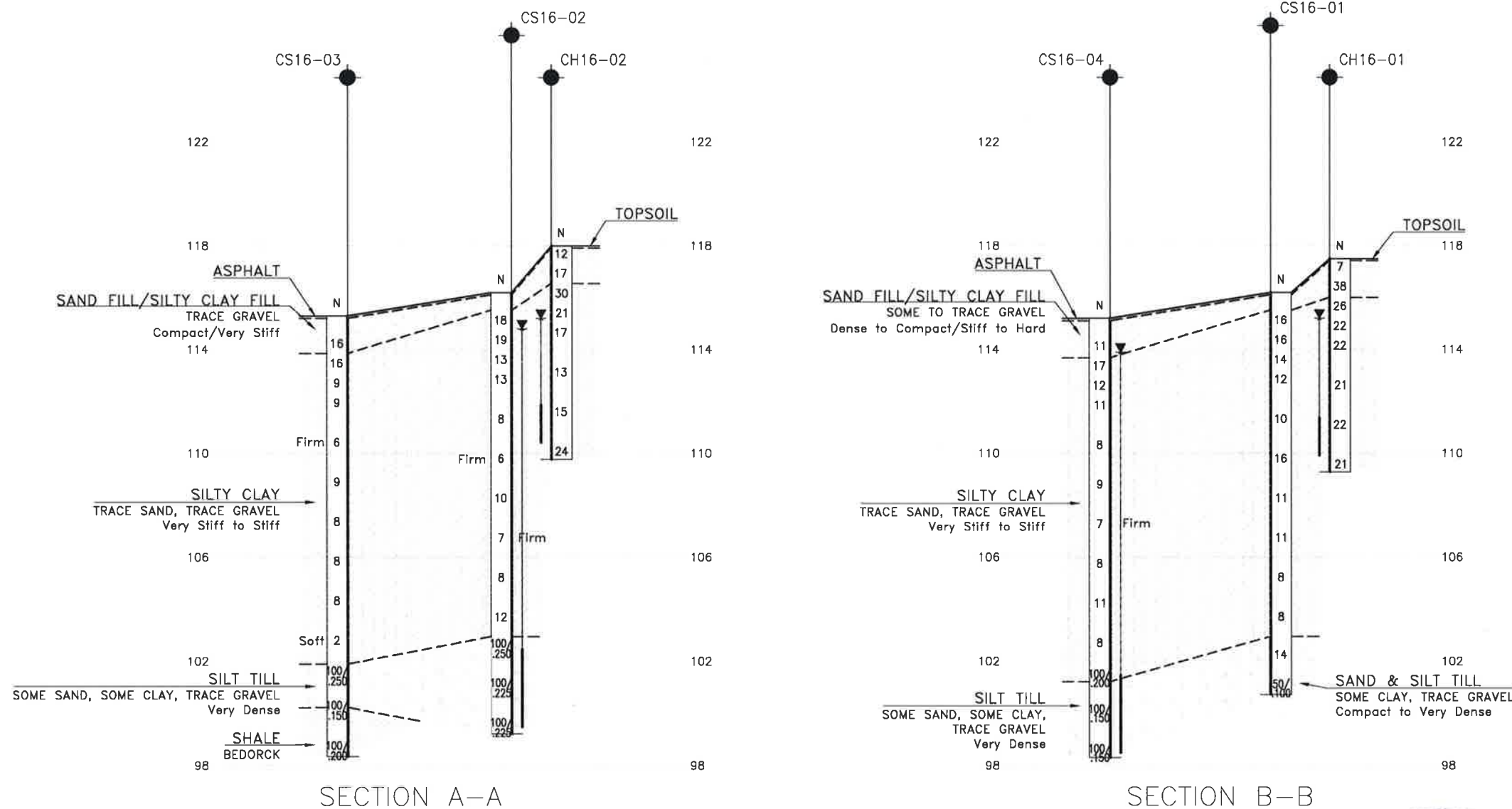
-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 30M3-295

REVISIONS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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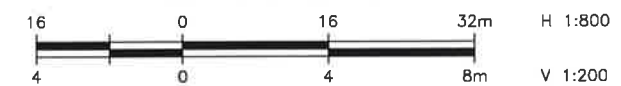


	Borehole (Current Investigation)
	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

-NOTES-

- GEOCRES No. 30M3-295**

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Appendix B

On- Ramp Speed Change Lane (SCL) Extension and Noise Barrier Wall Replacement Boreholes SC16-01 to SC16-08

- Record of Borehole Sheets
- Laboratory Test Results
- Drawings titled “Borehole Locations and Soil Strata”

RECORD OF BOREHOLE No SC16-01

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 778 024.4 E 327 470.8 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.24 - 2016.11.24 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
113.9	GROUND SURFACE							20 40 60 80 100						
0.0 0.1	TOPSOIL , with roots and rootlets: (75mm) Silty CLAY , trace gravel, occasional roots and rootlets and organic inclusions Firm to Very Stiff Dark Grey Moist (FILL)		1	SS	7		113	20 40 60 80 100						
			2	SS	19			20 40 60 80 100						
			3	SS	17		112	20 40 60 80 100						
111.6								20 40 60 80 100						
2.3	Silty CLAY , trace sand, trace gravel Very Stiff Greyish Brown Moist		4	SS	19		111	20 40 60 80 100						0 0 32 68
			5	SS	17			20 40 60 80 100						
			6	SS	16		110	20 40 60 80 100						
								20 40 60 80 100						
			7	SS	20		109	20 40 60 80 100						0 0 39 61
								20 40 60 80 100						
			8	SS	29		108	20 40 60 80 100						
								20 40 60 80 100						
105.7							107	20 40 60 80 100						
								20 40 60 80 100						
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.01.13 7.2 106.7 2017.03.16 6.3 107.6 2017.08.30 6.1 107.8						106	20 40 60 80 100						

+³, ×³: Numbers refer to
Sensitivity

20
15
10
5
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC16-02

1 OF 2

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 971.4 E 327 466.2 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.12.19 - 2016.12.19 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						WATER CONTENT (%)			
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						w _P w w _L			
113.2	GROUND SURFACE						20	40	60	80	100						
0.0	ASPHALT: (100mm)																
0.1	Gravelly SAND Brown Moist (FILL)		1	GS													
112.1	Silty CLAY , trace sand, trace gravel Very Stiff Brown Moist		1	SS	23											0 0 54 46	
1.1	Becoming stiff		2	SS	14												
			3	SS	10												
			4	SS	8											0 0 35 65	
			5	SS	9												
			6	SS	10												
103.4	END OF BOREHOLE AT 9.8m.																
9.8																	

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC16-02

2 OF 2

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 971.4 E 327 466.2 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.12.19 - 2016.12.19 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Continued From Previous Page													
	WATER LEVEL AT 8.7m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.5m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.													

ONTMT4S MTO-11336.GPJ 2017TEMPLATE(MTO).GDT 9/12/17

RECORD OF BOREHOLE No SC16-03

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 927.7 E 327 495.5 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.24 - 2016.11.24 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
114.9	GROUND SURFACE													
0.0 0.1	TOPSOIL: (75mm)													
	Silty CLAY , trace sand, trace gravel, occasional organic inclusions Stiff to Very Stiff Brown Moist (FILL)		1	SS	12									
			2	SS	27									
113.5														
1.4	Silty CLAY , trace sand, trace gravel Very Stiff Brown Moist		3	SS	20									
			4	SS	15									0 0 49 51
			5	SS	16									
	Becoming stiff													
			6	SS	10									
			7	SS	7									
														Vane pusehd to 7.3m depth, did not turn
			8	SS	11									0 0 30 70
106.7														
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. Piezometer installation consists of 125mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.													
	WATER LEVEL READINGS													
	DATE DEPTH(m) ELEV.(m)													
	2017.01.13 5.8 109.1													
	2017.03.16 4.9 110.0													
	2017.08.30 4.7 110.2													

ONTMT4S MTO-11336.GPJ 2017TEMPLATE(MTO).GDT 9/12/17

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC16-04

1 OF 2

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 874.5 E 327 489.3 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.12.13 - 2016.12.19 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT w _P	NATURAL MOISTURE CONTENT w		
116.2	GROUND SURFACE											
0.0	ASPHALT: (75mm)											
0.1	Gravelly SAND Brown to Grey Moist		1	GS								
115.5	(FILL)											
0.7	Silty CLAY , trace sand, trace gravel Hard Grey Moist (FILL)		1	SS	32							
114.7												
1.5	Silty CLAY , trace sand, trace gravel Hard to Very Stiff Brown Moist		2	SS	52							
			3	SS	27							
			4	SS	15							
			5	SS	15							
	Becoming stiff		6	SS	12							
	Grey											
			7	SS	14							
			8	SS	13							

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC16-04

2 OF 2

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 874.5 E 327 489.3 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.12.13 - 2016.12.19 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					WATER CONTENT (%)				
							20	40	60	80	100	W _p	W	W _L			
104.9	Continued From Previous Page Silty CLAY , trace sand, trace gravel Stiff Grey Moist		9	SS	14		106										
11.3	END OF BOREHOLE AT 11.3m. BOREHOLE OPEN AND WATER LEVEL AT 10.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND AUGER CUTTINGS TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT TO SURFACE.						105										

RECORD OF BOREHOLE No SC16-05

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 828.6 E 327 516.6 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.25 - 2016.11.25 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
115.8	GROUND SURFACE							20	40	60	80	100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
0.0	TOPSOIL: (75mm)							20	40	60	80	100	WATER CONTENT (%)			
0.1	Silty CLAY , trace sand, trace gravel, organic inclusions Stiff		1	SS	8											
115.1	Greyish Brown Moist (FILL)															
0.7	Silty CLAY , trace sand, trace gravel Very Stiff Brown Moist		2	SS	25		115									
			3	SS	27		114									0 0 32 68
			4	SS	21		113									
			5	SS	19		112									
			6	SS	17		111									
110.2							110									
5.6																
	Stiff		7	SS	11		109									0 0 36 64
108.6							108									
7.2			8	SS	27											
107.6																
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.															

ONTMT4S MTO-11336.GPJ 2017TEMPLATE(MTO).GDT 9/12/17

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC16-06

1 OF 2

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 776.1 E 327 503.9 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.12.12 - 2016.12.13 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa										
119.2	GROUND SURFACE							20	40	60	80	100						
0.0	ASPHALT: (75mm)																	
0.1	Gravelly SAND Grey Moist (FILL)		1	GS			119											
118.5																		
0.7	Silty CLAY, trace sand, trace gravel Very Stiff to Hard Grey Moist		1	SS	20		118											
			2	SS	17		117											
			3	SS	36		116											
			4	SS	43		115											
			5	SS	43		114											
			6	SS	29		113											
			7	SS	22		112											
							111											
			8	SS	18		110											

Continued Next Page

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC16-06

2 OF 2

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 776.1 E 327 503.9 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.12.12 - 2016.12.13 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
	Continued From Previous Page							20 40 60 80 100						
	Silty CLAY , trace sand, trace gravel Very Stiff Grey Moist		9	SS	21		109							
							108							
							107							
106.4			10	SS	13									
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.													

+³, ×³: Numbers refer to Sensitivity
 20
 15
 10
 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC16-07

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 627.5 E 327 534.0 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.23 - 2016.11.23 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L				GR	SA	SI	CL
119.3	GROUND SURFACE																		
0.0 0.1	TOPSOIL , trace roots and rootlets: (75mm) Silty CLAY , some sand, trace gravel Firm to Very Stiff Brown Moist (FILL)		1	SS	7		119												
			2	SS	26		118												
117.9			3	SS	27		117												
1.4	Silty CLAY , trace sand, trace gravel Very Stiff Brown Moist		4	SS	17		116										0	0	
			5	SS	16		115												
			6	SS	20		114												
			7	SS	18		113										0	0	
			8	SS	17		112												
111.1																			
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.																		

ONTMT4S MTO-11336.GPJ 2017TEMPLATE(MTO).GDT 9/12/17

RECORD OF BOREHOLE No SC16-08

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION On Ramp SCL Extension N 4 777 576.6 E 327 531.2 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Hollow Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.11.24 - 2016.11.24 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _p w w _L				GR	SA	SI	CL		
121.3	GROUND SURFACE							20	40	60	80	100									
0.0	TOPSOIL: (50mm) Silty CLAY , trace sand, trace roots, topsoil inclusions Stiff to Very Stiff Brown Moist (FILL)		1	SS	8		121														
			2	SS	20		120														
119.9																					
1.4	Silty CLAY , trace sand, trace gravel Very Stiff Brown Moist		3	SS	20		119										0	0	44	56	
			4	SS	19		118														
			5	SS	17		117														
			6	SS	22		116														
			7	SS	15		115														
							114														
			8	SS	16																
113.1																					
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. Piezometer installation consists of 25mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2017.01.13 3.0 118.3 2017.03.16 1.5 119.8 2017.08.30 1.6 119.7																	0	0	39	61

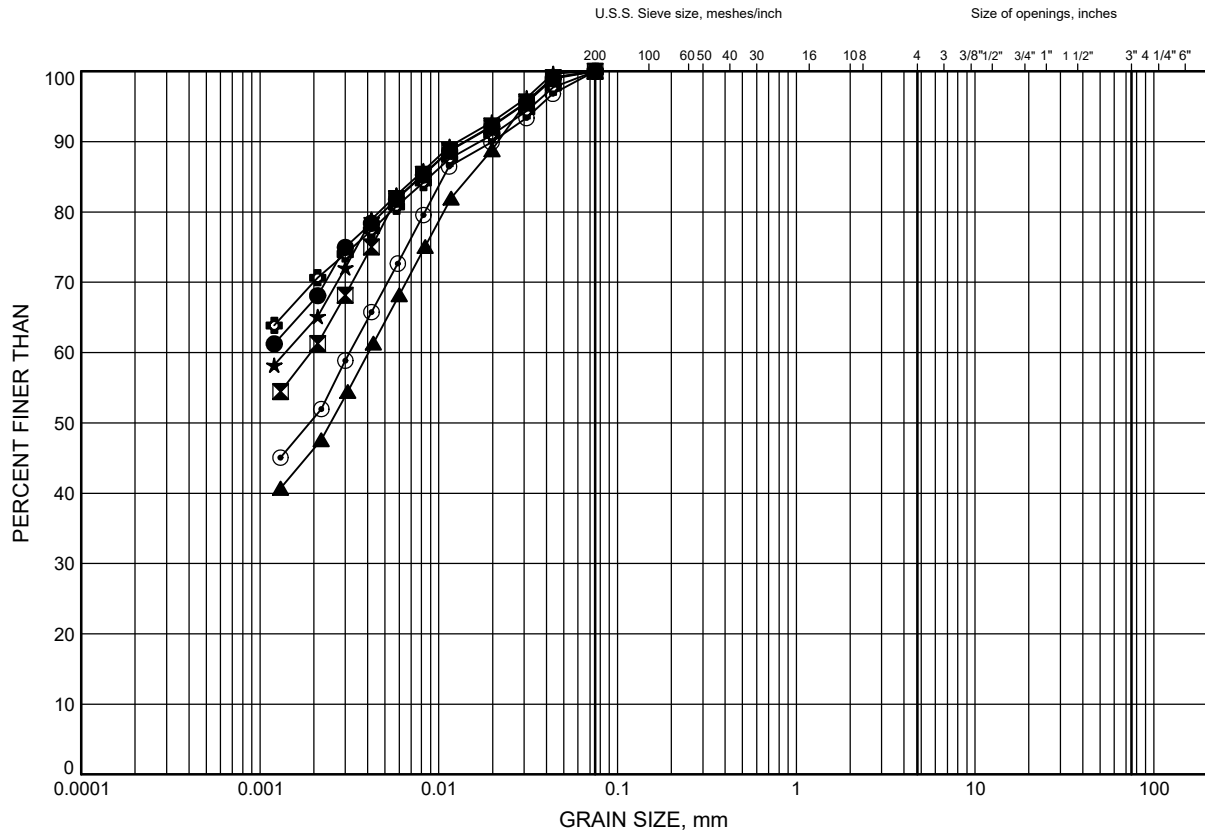
ONTMT4S MTO-11336.GPJ 2017TEMPLATE(MTO).GDT 9/12/17

+³, ×³: Numbers refer to Sensitivity
 20
15
10
5
0
5
10
(%) STRAIN AT FAILURE

On Ramp SCL Extension GRAIN SIZE DISTRIBUTION

FIGURE B1

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC16-01	2.6	111.3
⊠	SC16-01	6.4	107.5
▲	SC16-02	1.8	111.4
★	SC16-02	6.4	106.8
⊙	SC16-03	2.6	112.3
⊕	SC16-03	7.9	107.0

Date September 2017

GWP# 2259-15-00



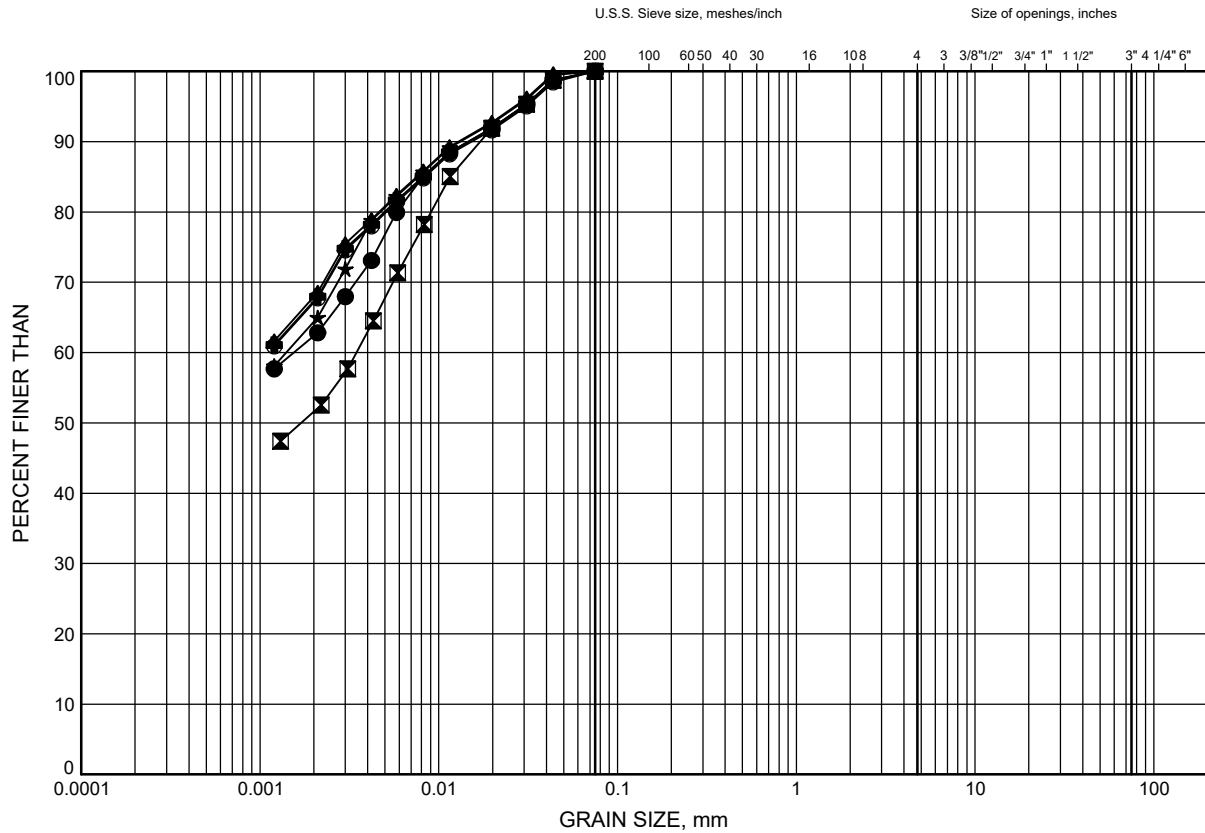
Prep'd AN

Chkd. RPR

On Ramp SCL Extension GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC16-04	2.6	113.6
⊠	SC16-04	7.9	108.3
▲	SC16-05	1.8	114.0
★	SC16-05	6.4	109.4
⊙	SC16-06	3.4	115.8
⊕	SC16-06	7.9	111.3

Date September 2017

GWP# 2259-15-00



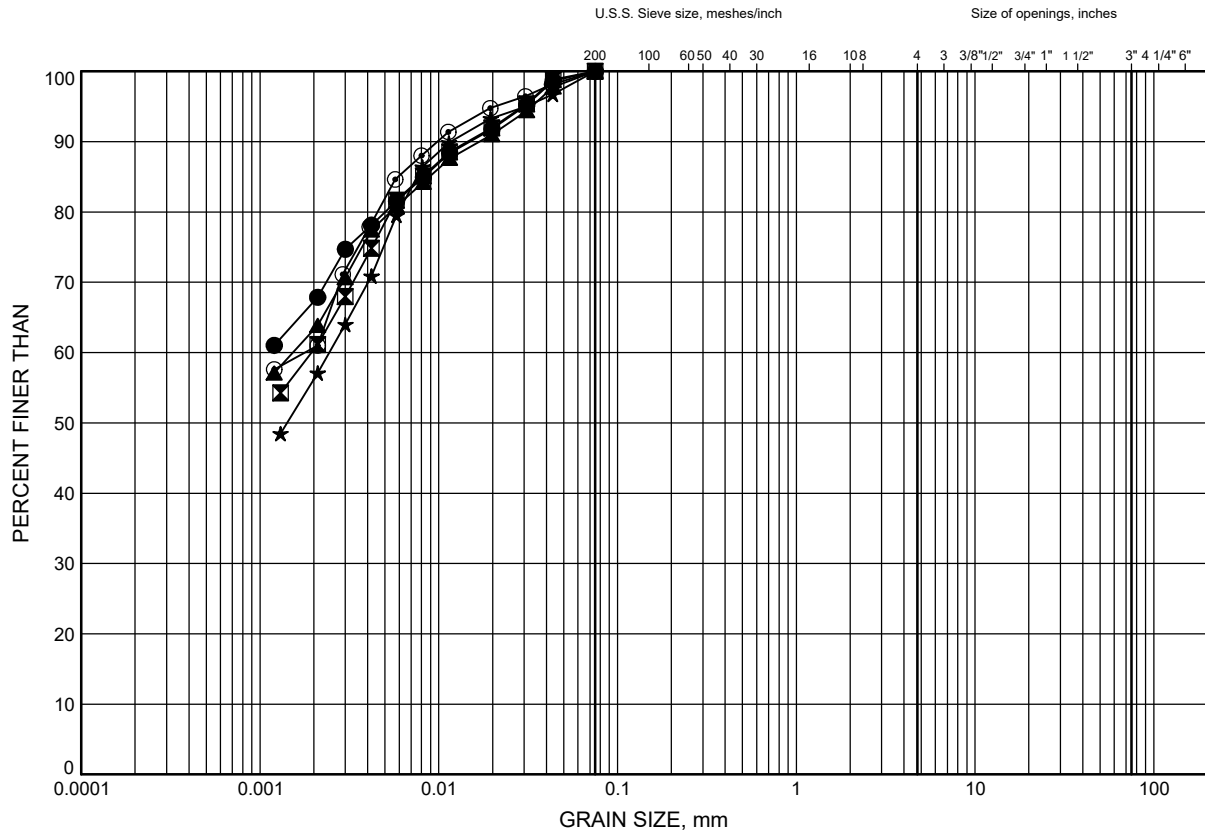
Prep'd AN

Chkd. RPR

On Ramp SCL Extension GRAIN SIZE DISTRIBUTION

FIGURE B3

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC16-06	11.0	108.2
⊠	SC16-07	2.6	116.7
▲	SC16-07	6.4	112.9
★	SC16-08	1.8	119.5
⊙	SC16-08	7.9	113.4

Date September 2017

GWP# 2259-15-00



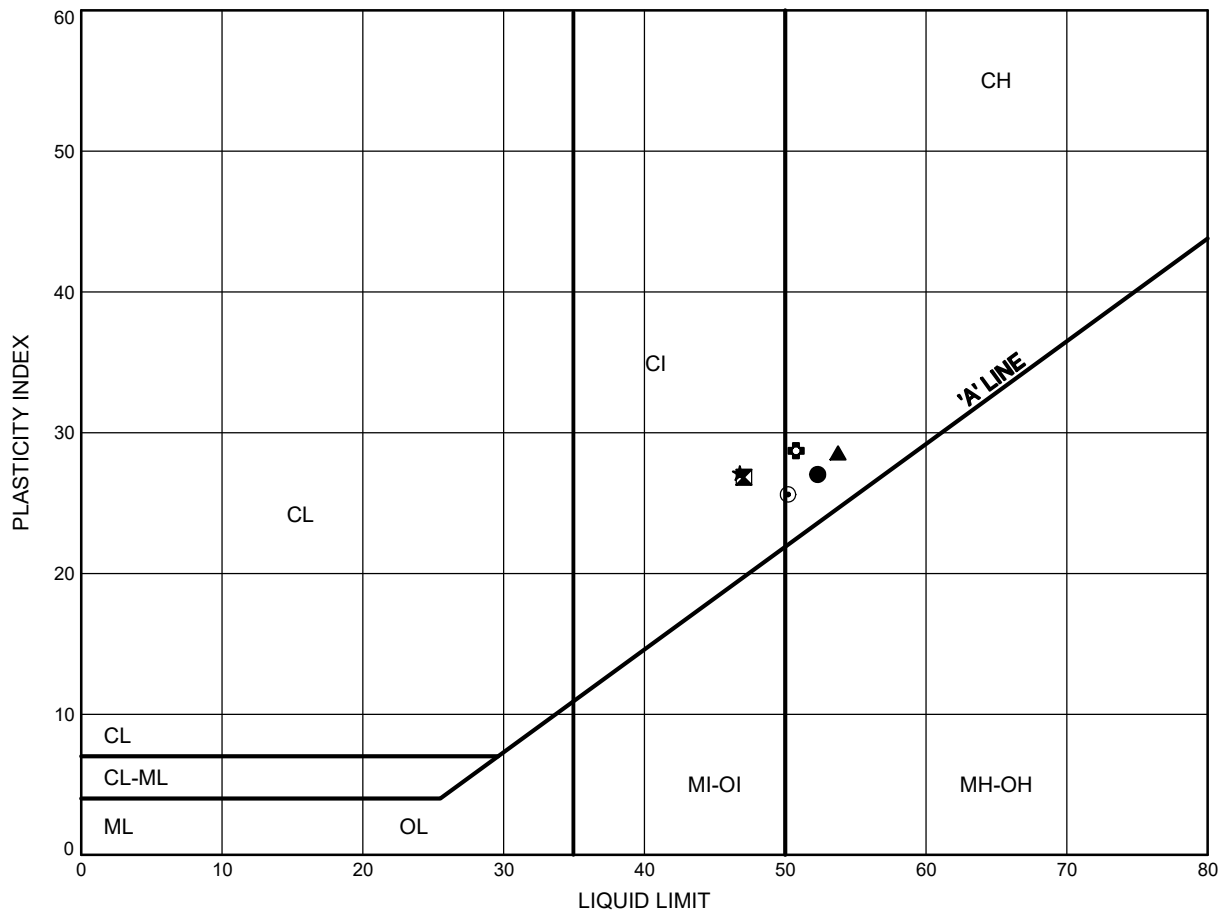
Prep'd AN

Chkd. RPR

On Ramp SCL Extension
ATTERBERG LIMITS TEST RESULTS

FIGURE B4

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC16-01	6.4	107.5
⊠	SC16-02	6.4	106.8
▲	SC16-03	7.9	107.0
★	SC16-04	7.9	108.3
⊙	SC16-05	6.4	109.4
⊕	SC16-06	7.9	111.3

Date September 2017
 GWP# 2259-15-00

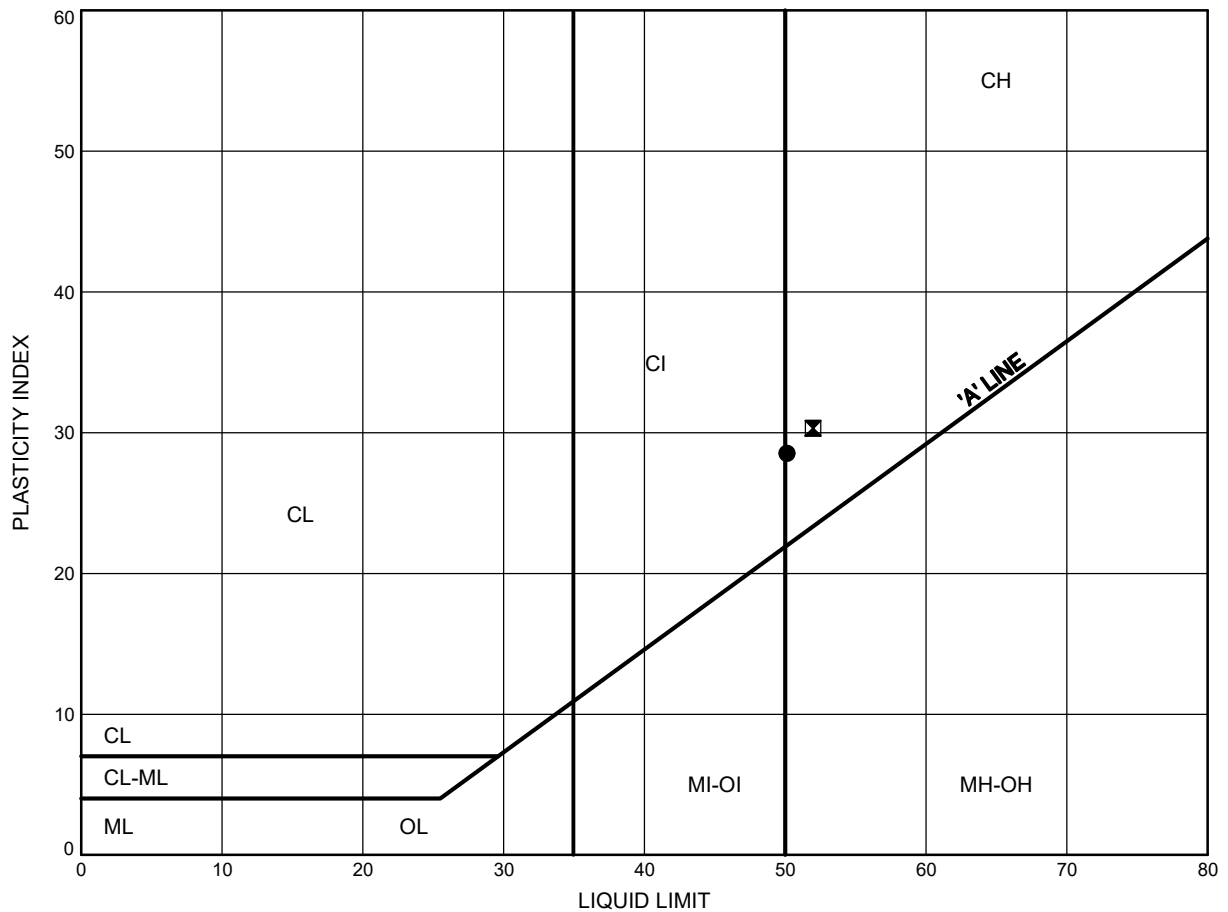


Prep'd AN
 Chkd. RPR

On Ramp SCL Extension
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC16-07	6.4	112.9
⊠	SC16-08	7.9	113.4

Date September 2017
 GWP# 2259-15-00



Prep'd AN
 Chkd. RPR

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 2259-15-00

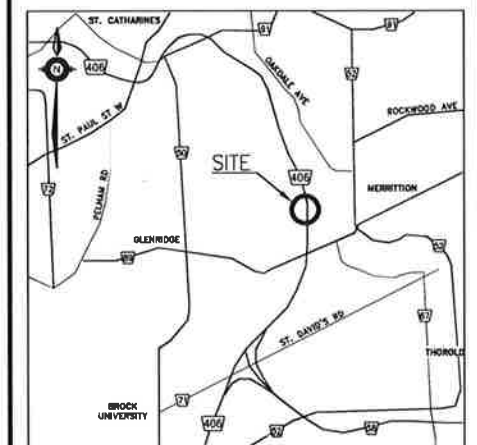


HIGHWAY 406
ON RAMP SPEED CHANGE
LANE EXTENSION
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

- Borehole (Current Investigation)
- Borehole (Previous Investigation)
- Blows /0.3m (Std Pen Test, 475J/blow)
- Blows /0.3m (60' Cone, 475J/blow)
- Pressure, Hydraulic
- Water Level
- Head Artesian Water
- Piezometer
- Rock Quality Designation (RQD)
- Auger Refusal

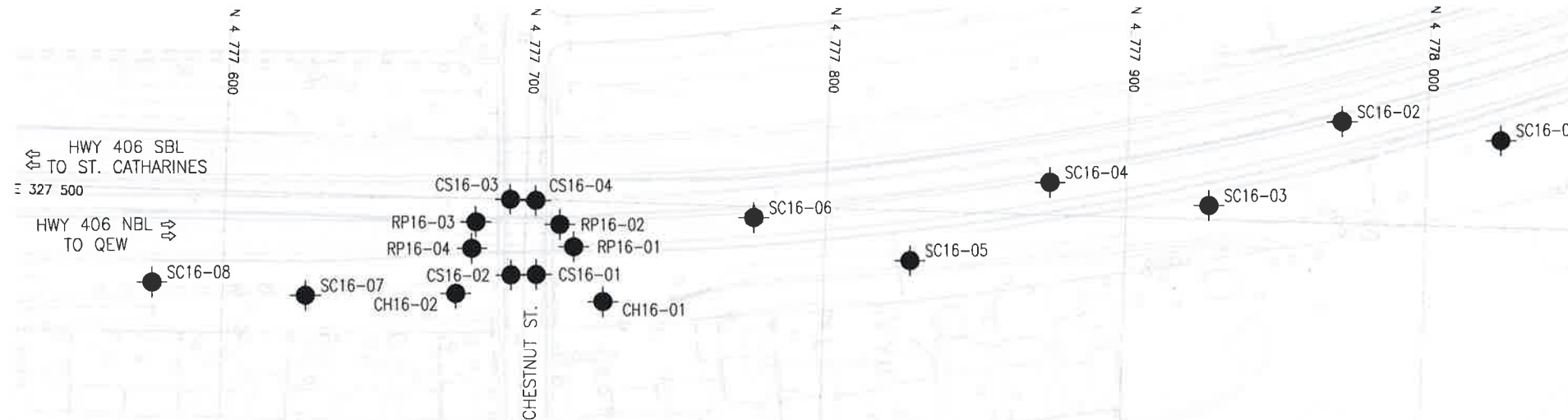
NO	ELEVATION	NORTHING	EASTING
CH16-01	117.5	4 777 726.6	327 533.2
CH16-02	118.0	4 777 677.5	327 531.9
CS16-01	116.2	4 777 704.1	327 524.8
CS16-02	116.2	4 777 695.7	327 525.2
CS16-03	115.3	4 777 694.8	327 500.0
CS16-04	115.2	4 777 703.3	327 500.1
RP16-01	120.9	4 777 716.4	327 515.2
RP16-02	120.8	4 777 711.6	327 507.9
RP16-03	121.6	4 777 683.5	327 507.8
RP16-04	121.8	4 777 682.4	327 516.7
SC16-01	113.9	4 778 024.4	327 470.8
SC16-02	113.2	4 777 971.4	327 466.2
SC16-03	114.9	4 777 927.7	327 495.5
SC16-04	116.2	4 777 874.5	327 489.3

NOTES

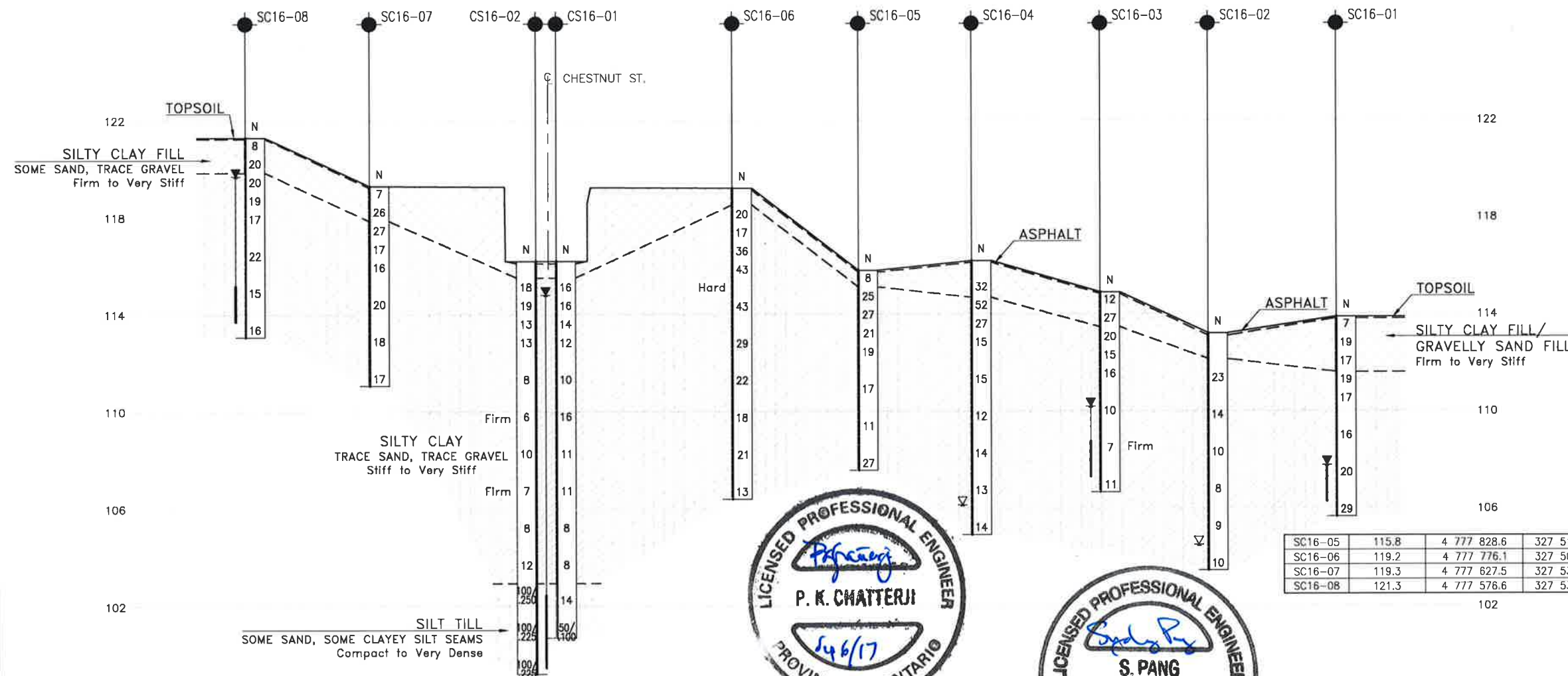
- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 30M3-295

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK	SKP
DRAWN	AN	CHK	RPR
LOAD	DATE	SEP	2017
STRUCT	DWG	1	



PLAN
SCALE 1:2000



PROFILE ALONG C HWY 406

H 1:800
V 1:200





Appendix C

Roadway Protection Boreholes RP16-01 to RP16-04

- Record of Borehole Sheets
- Laboratory Test Results
- Drawings titled "Borehole Locations and Soil Strata"

RECORD OF BOREHOLE No RP16-01

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION Roadway Protection N 4 777 716.4 E 327 515.2 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.12.12 - 2016.12.12 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
120.9	GROUND SURFACE							20 40 60 80 100						
0.0	ASPHALT: (75mm)							○ UNCONFINED + FIELD VANE						
0.1	CONCRETE: (375mm)		1	GS				● QUICK TRIAXIAL × LAB VANE						
120.4								20 40 60 80 100						
0.5	SAND , trace to some gravel, some silt, trace clay Dense to Compact Brown Moist (FILL)						120							
			1	SS	46									
			2	SS	42		119							10 72 12 6
			3	SS	22		118							
			4	SS	35									19 58 19 4
							117							
			5	SS	18		116							
115.9														
5.0	Silty CLAY , trace sand, trace gravel Hard to Very Stiff Brown Moist						115							
			6	SS	38		114							0 8 32 60
							113							
112.7														
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.													

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No RP16-02

1 OF 1



METRIC

GWP# 2259-15-00 LOCATION Roadway Protection N 4 777 711.6 E 327 507.9 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.12.05 - 2016.12.05 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
120.8	GROUND SURFACE													
0.0	ASPHALT: (75mm)													
120.5	CONCRETE: (300mm)													
0.3	Gravelly SAND		1	GS										
120.1	Grey Moist (FILL)		1	SS	42									
0.7	SAND, trace to some clay, some silt, trace gravel Dense to Compact Grey Moist		2	SS	25									
118.6														
2.2	Very Dense		3	SS	80/ 0.225									
117.9														
2.9	Compact		4	SS	16									
			5	SS	21									
115.3														
5.5	Silty CLAY, trace sand, trace gravel Hard to Very Stiff Brown Moist		6	SS	31									
			7	SS	23									
112.6														
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.													

+³, ×³: Numbers refer to Sensitivity
 20
15
10
5
0 (%) STRAIN AT FAILURE

METRIC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES							
								SHEAR STRENGTH kPa				WATER CONTENT (%)
121.6	GROUND SURFACE						○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20 40 60 80 100 20 40 60	kN/m ³	GR SA SI CL		

SOIL PROFILE					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES	GROUND WATER CONDITIONS	DYNAMIC CONE PENETRATION RESISTANCE PLOT
121.6	GROUND SURFACE	A A	NUMBER TYPE "N" VALUES		0 20 40 60 80 100
0.0	CONCRETE: (150mm)				WATER CONTENT (%) W _p W W _L
0.2	Silty CLAY, some sand, some gravel Stiff Grey Moist (FILL)	X X	1 GS		UNCONFINED + FIELD VANE QUICK TRIAXIAL x LAB VANE
			1 SS 10		
			2 SS 8		
			3 SS 12		
			4 SS 13		
117.6					
4.0	Silty CLAY, trace sand, trace gravel Hard Brown Moist	X X	5 SS 51		
			6 SS 31		
	Very Stiff		7 SS 21		
113.4					
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.				

ONTMT4S MTO-11336.GPJ 2017TEMPLATE(MTO).GDT 9/12/17

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No RP16-04

1 OF 1

METRIC

GWP# 2259-15-00 LOCATION Roadway Protection N 4 777 682.4 E 327 516.7 ORIGINATED BY OA
 HWY 406 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN
 DATUM Geodetic DATE 2016.05.07 - 2016.05.07 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					
121.8	GROUND SURFACE												
0.0	ASPHALT: (75mm)												
0.1	CONCRETE: (375mm)												
121.3													
0.5	Gravelly SAND Compact Grey Moist (FILL)		1	GS			121						
			1	SS	24								
120.4													
1.4	SAND , trace gravel, some silt, trace to some clay Dense to Compact Brown Moist (FILL)		2	SS	31		120						
			3	SS	46		119						
			4	SS	33								
							118						
			5	SS	17		117						
							116						
			6	SS	11								
							115						
114.3													
7.5	Silty CLAY , trace sand, trace gravel Very Stiff Brown Moist		7	SS	25		114						
113.6													
8.2	END OF BOREHOLE AT 8.2m. BOREHOLE DRY UPON COMPLETION. BOREHOLE BACKFILLED WITH AUGER CUTTINGS TO SURFACE.												

+³, ×³: Numbers refer to
Sensitivity

20
15
10

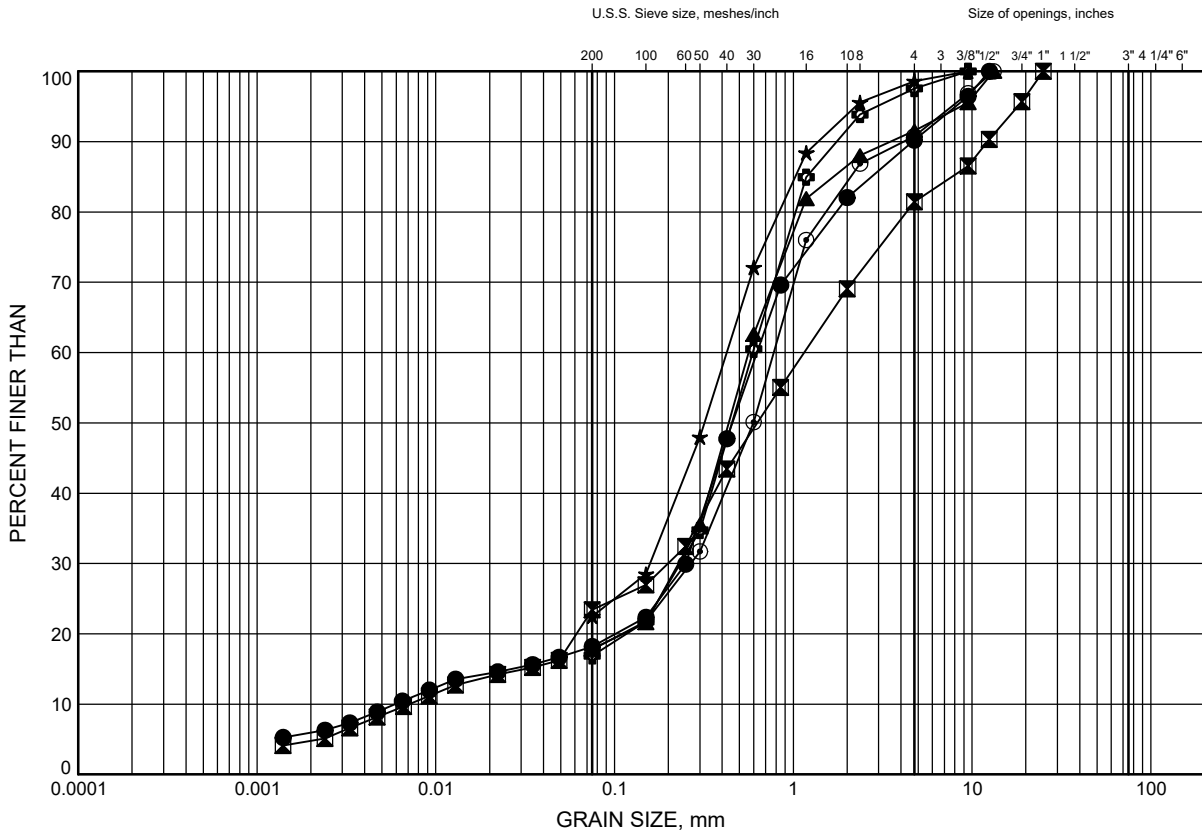
(%) STRAIN AT FAILURE

Roadway Protection

GRAIN SIZE DISTRIBUTION

FIGURE C1

SAND FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RP16-01	1.8	119.1
⊠	RP16-01	3.4	117.5
▲	RP16-02	1.8	119.0
★	RP16-02	4.9	115.9
⊙	RP16-04	2.6	119.2
⊕	RP16-04	6.4	115.4

Date September 2017

GWP# 2259-15-00



Prep'd AN

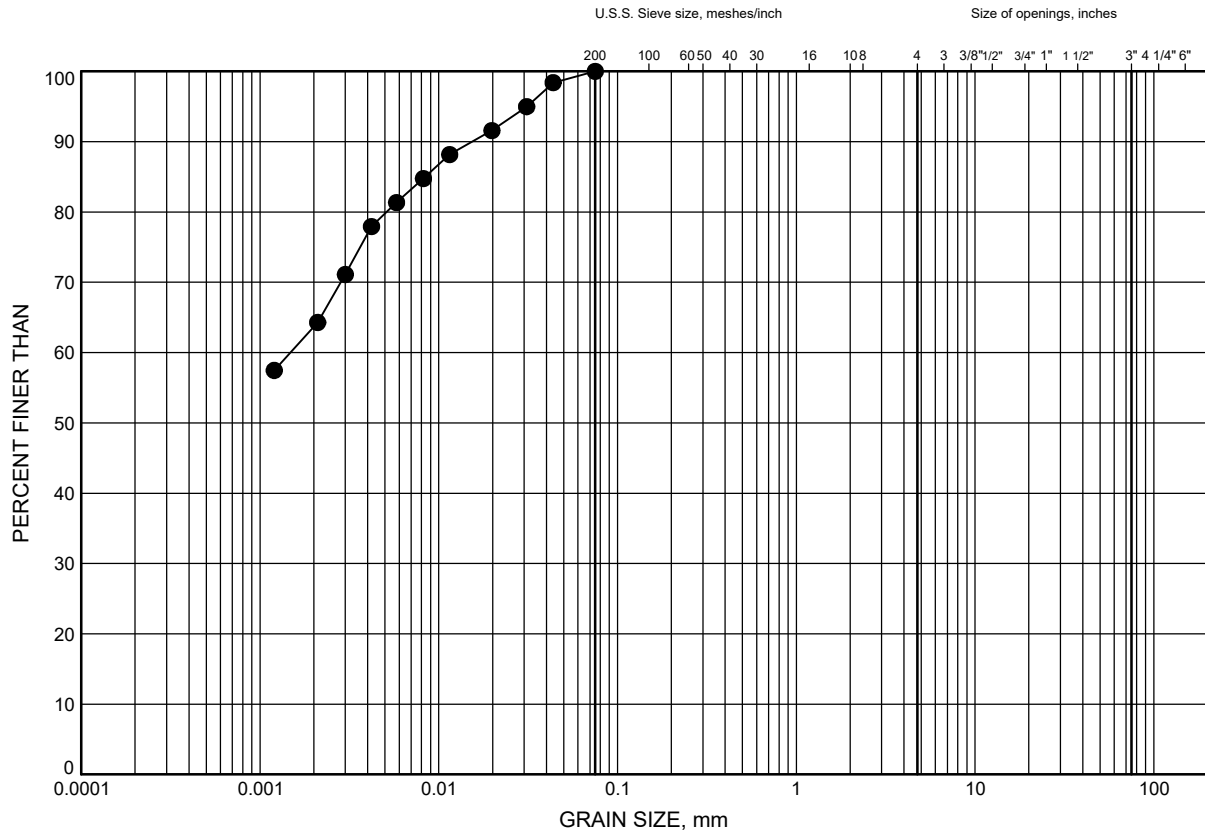
Chkd. RPR

Roadway Protection

GRAIN SIZE DISTRIBUTION

FIGURE C2

Silty CLAY FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RP16-03	3.4	118.2

Date September 2017
GWP# 2259-15-00



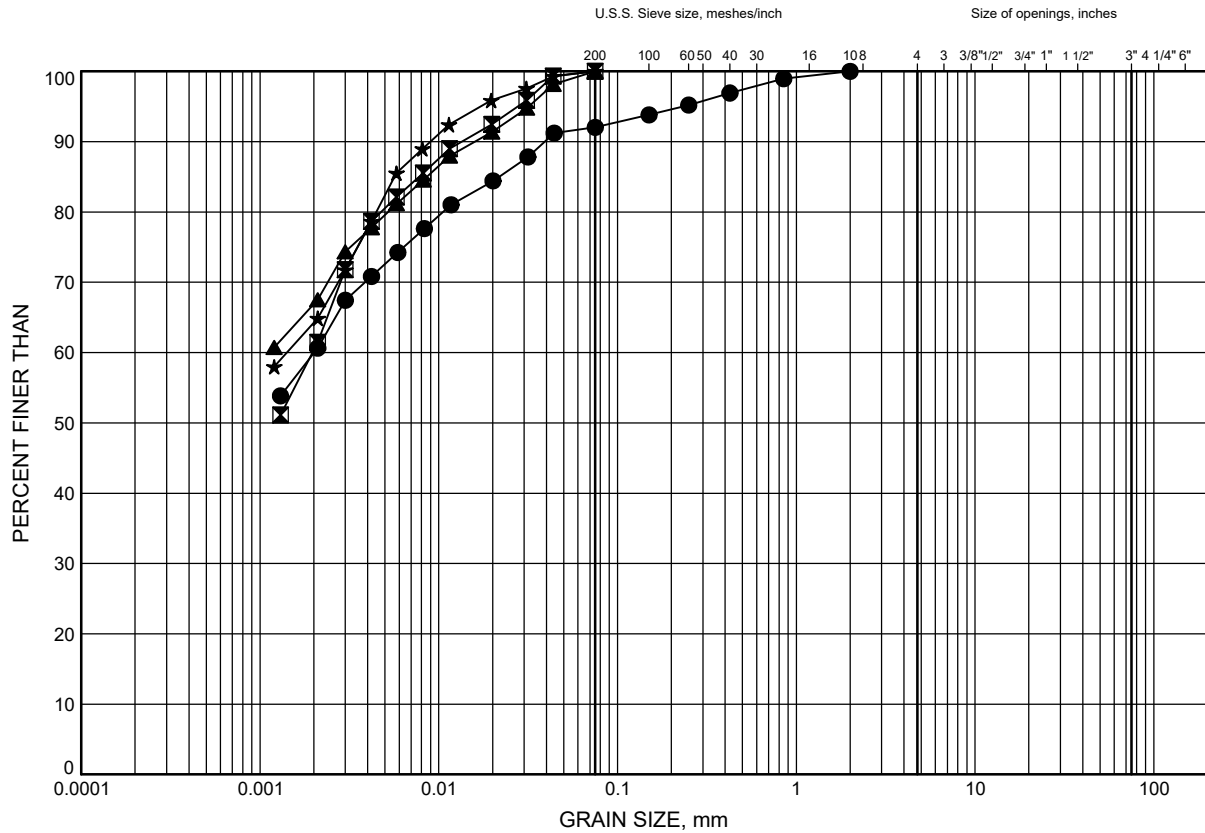
Prep'd AN
Chkd. RPR

Roadway Protection

GRAIN SIZE DISTRIBUTION

FIGURE C3

Silty CLAY



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RP16-01	6.4	114.5
⊠	RP16-02	6.4	114.4
▲	RP16-03	7.9	113.7
★	RP16-04	7.9	113.9

Date September 2017

GWP# 2259-15-00



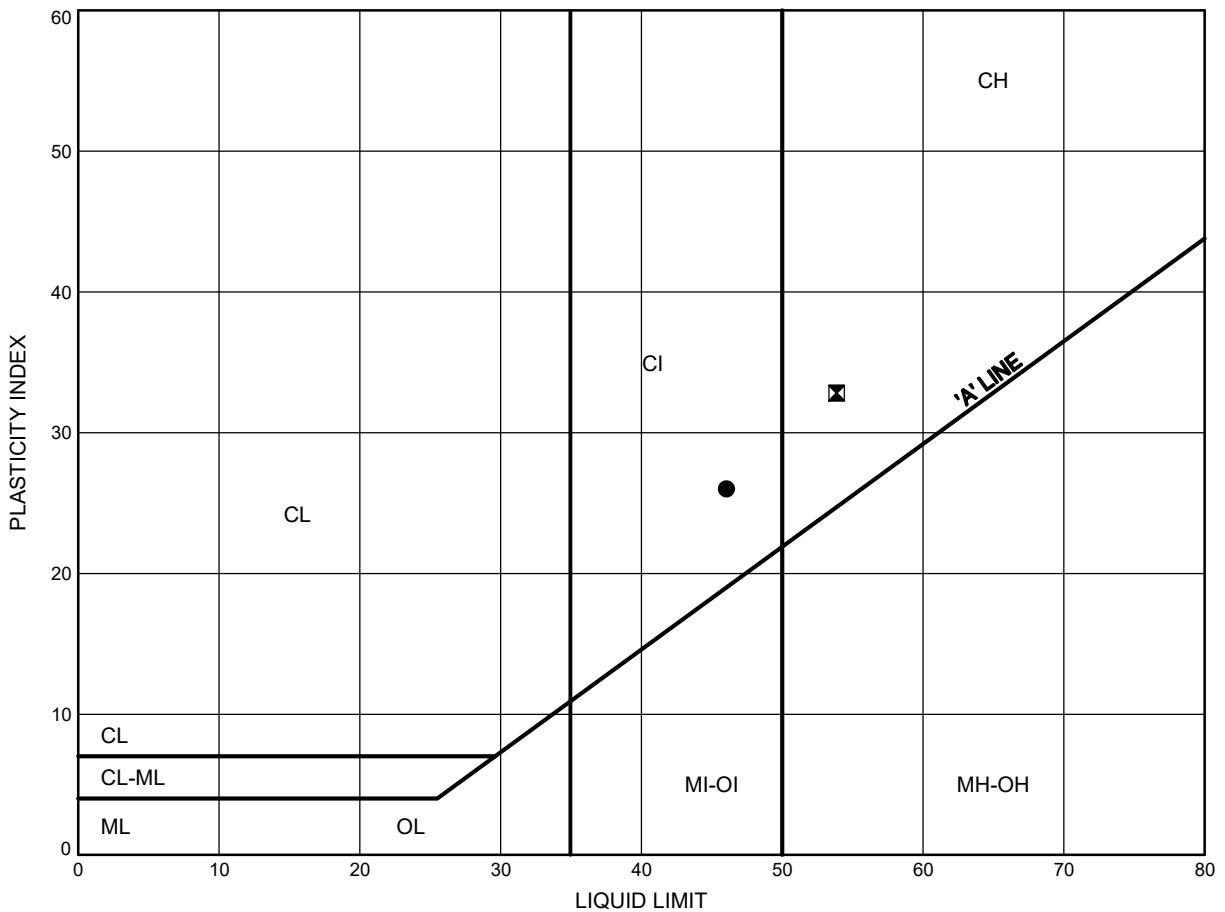
Prep'd AN

Chkd. RPR

Roadway Protection ATTERBERG LIMITS TEST RESULTS

FIGURE C4

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RP16-02	6.4	114.4
⊠	RP16-03	7.9	113.7

Date September 2017

GWP# 2259-15-00



Prep'd AN

Chkd. RPR

METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
CWP No 2259-15-00

HIGHWAY 406
ROADWAY PROTECTION
NBL BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

●	Borehole (Current Investigation)
⊕	Borehole (Previous Investigation)
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60' Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
↑	Head Artesian Water
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
1	117.2	4 777 720.5	327 521.3
2	116.5	4 777 719.5	327 491.3
3	118.1	4 777 679.6	327 492.4
4	118.0	4 777 680.5	327 520.8
CH16-01	117.5	4 777 726.6	327 533.2
CH16-02	118.0	4 777 677.5	327 531.9
CS16-01	116.2	4 777 704.1	327 524.8
CS16-02	116.2	4 777 695.7	327 525.2
CS16-03	115.3	4 777 694.8	327 500.0
CS16-04	115.2	4 777 703.3	327 500.1
RP16-01	120.9	4 777 716.4	327 515.2
RP16-02	120.8	4 777 711.6	327 507.9
RP16-03	121.6	4 777 683.5	327 507.8
RP16-04	121.8	4 777 682.4	327 516.7

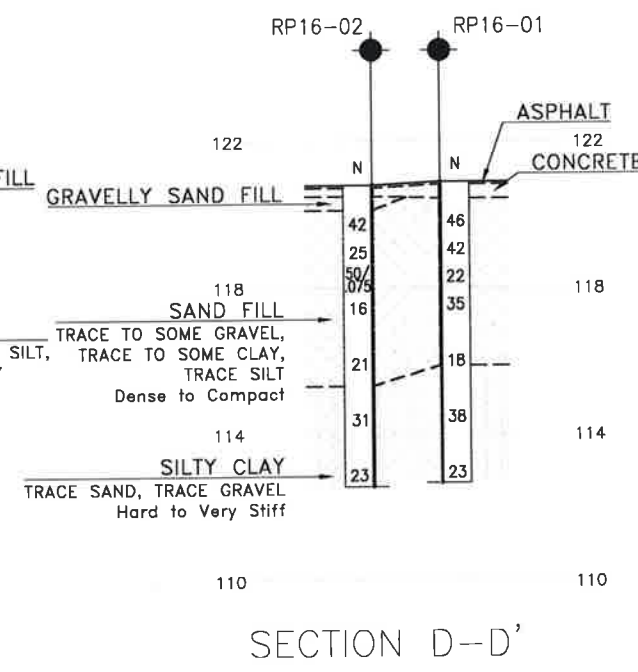
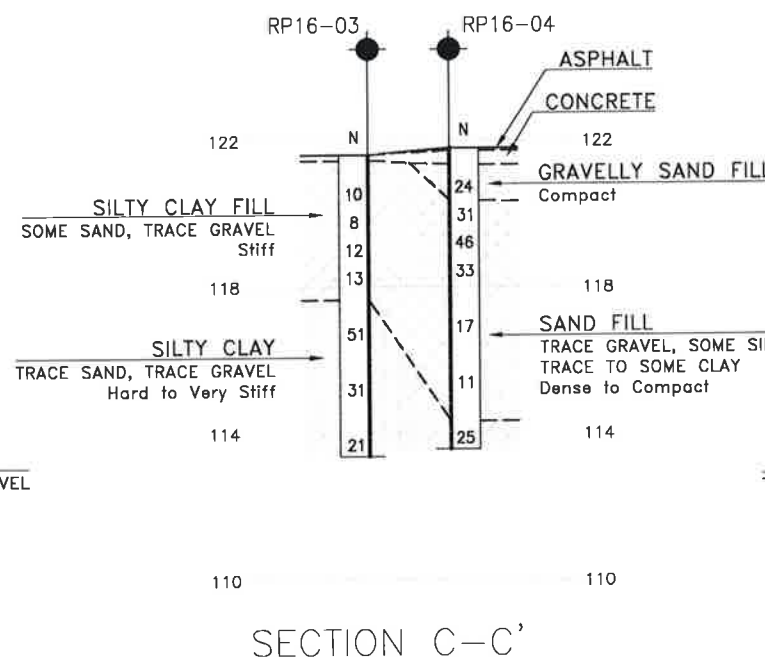
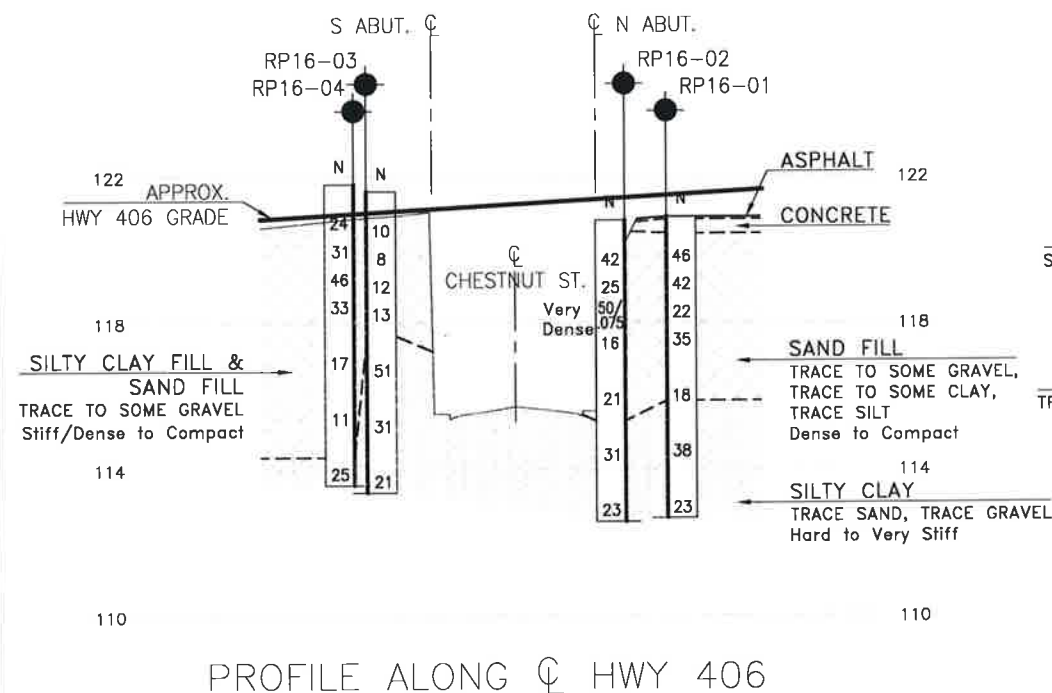
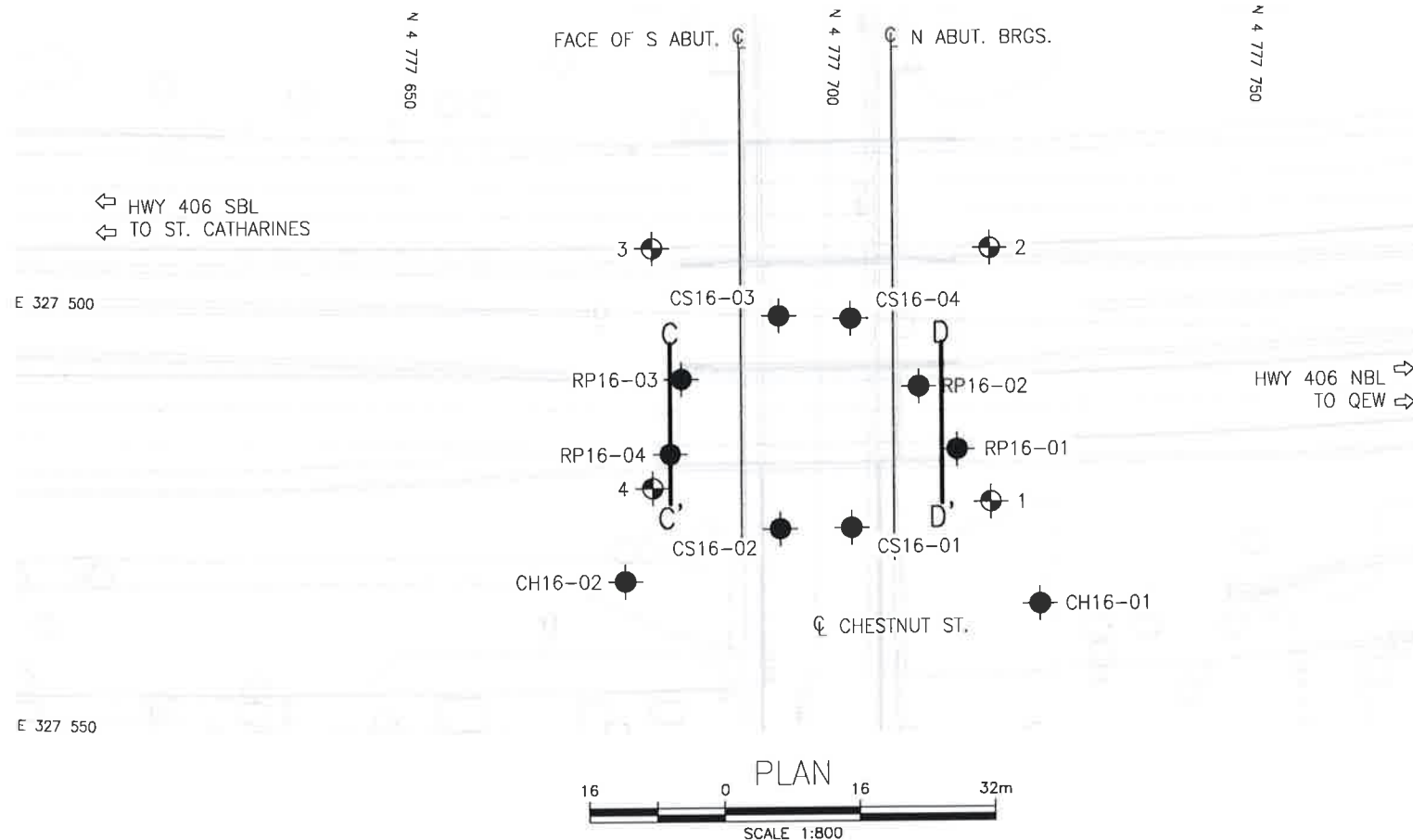
NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 30M3-295

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	RPR	CHK SKP	CODE
DRAWN	AN	CHK RPR	SITE
			LOAD
			STRUCT
			DWG 3
			DATE SEP 2017

FILENAME: H:\Dwg\1000\11336\11336-PLR-RP.dwg
PLOTDATE: 9/12/2017 11:49 AM





Appendix D

Record of Borehole of previous investigations

RECORD OF BOREHOLE No 2

W P 90-74-03 LOCATION Sta. 172+00, 47' Lt. ORIGINATED BY G.G.C.
 DIST 4 HWY 406 BOREHOLE TYPE Washboring, Cone Penetration COMPILED BY B.K.
 DATUM Geodetic DATE Nov. 25, 1960 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ PCF	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	W _p W W _L					
382.3 0.0	Ground Level							SHEAR STRENGTH PSF ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 500 1000 1500 2000 2500		WATER CONTENT (%) 15 30 45				
	Silty Clay to Clay With Pockets and Seams of Silt Trace of Sand		1	SS	38									
			2	SS	24									
	Very Stiff to Hard		3	TW	19								126	
			4	TW	PH								122	
			5	TW	PH								123	
	Stiff to Very Stiff		6	TW	PH								124	
			7	TW	PH								121	
			8	TW	PH								119	
			9	TW	PH								122	
			10	TW	PH									
			11	TW	PH									
324.3 58.0	Bandy Silt		12	SS	108/ 8"									
	Very Dense		13											
			14	SS	140									
306.3 76.0	End of Borehole		15	SS	100/ 6"									

+3, x5; Numbers refer to
Sensitivity

20
15
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5 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 3

W P 96-74-03 LOCATION Sta. 170+59, 49' Lt. ORIGINATED BY G.G.C.
 DIST 4 HWY 406 BOREHOLE TYPE Washboring, Cone Penetration COMPILED BY B.K.
 DATUM Geodetic DATE Nov. 21, 1960 CHECKED BY [Signature]

SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT			UNIT WEIGHT γ pcf	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE		20	40	60	80	100	W _p	W	W _L		
387.5	Ground Level														
0.0	Silty Clay to Clay Traces of Sand Very Stiff to Hard Pockets and Seams of Silt Firm to Very Stiff		1	SS	74									128	
			2	SS	25									121	
			3	TW	35										
			4	TW	25										
			5	SS	16									123	
			6	TW	15									120	
			7	TW	13										
			8	TW	12									123	
			9	TW	14										
			10	TW	15									128	
			11	TW	16									124	
336.0	Sandy Silt Very Dense		12	TW	12										
51.5			13	SS	100/										
			14	SS	100/										
326.0	End of Borehole		15	SS	100/										
61.5															

OFFICE REPORT ON SOIL EXPLORATION



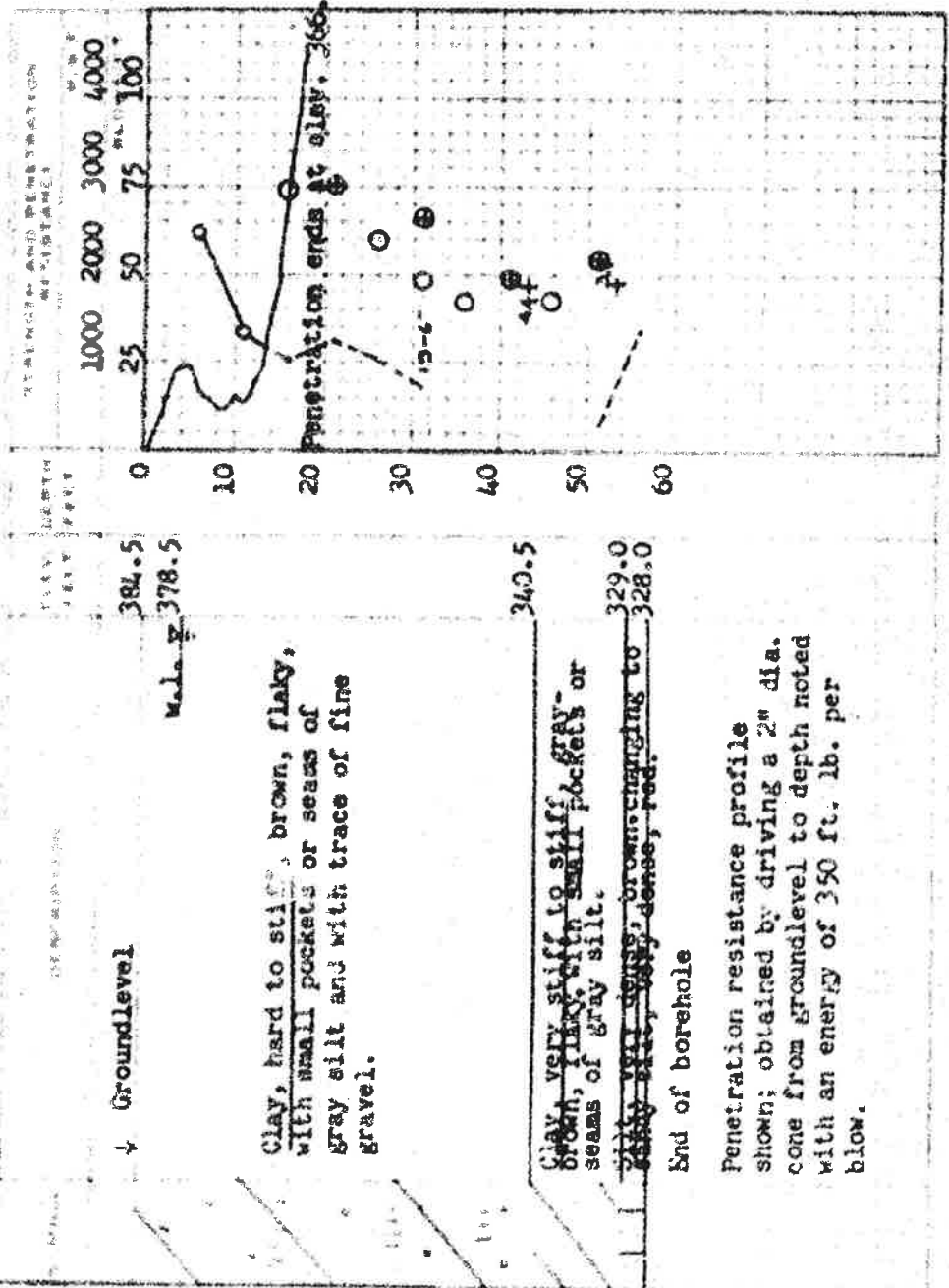
OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO

MATERIALS AND RESEARCH SECTION

W.P. 44-61 BORE HOLE NO. 1
 JOB 60-F-59 STATION 172+00 - 531 R.R.
 DATUM 384.5' COMPILED BY B.K.
 BORING DATE Nov. 24/60 CHECKED BY G.G.C.

LEGEND
 Triaxial compression
 Deviator stress
 Vane test
 Natural moisture and plasticity index
 Liquid limit
 Plastic limit
 Lab Vane

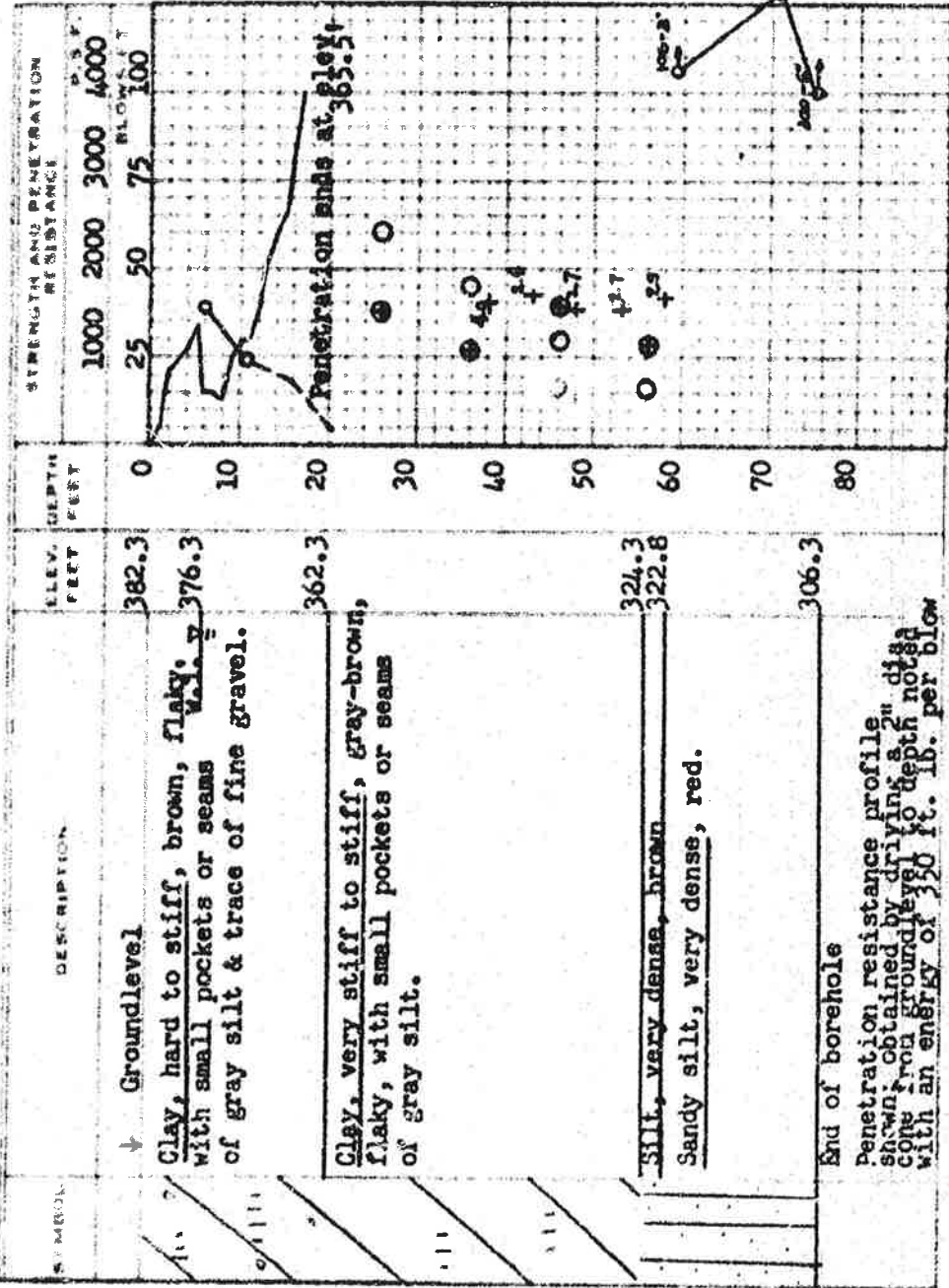


OFFICE REPORT ON SOIL EXPLORATION

DEPARTMENT OF HIGHWAYS - ONTARIO MATERIALS AND RESEARCH SECTION

W.P. 44-61 BORE HOLE NO. 2
JOB 60-F-89 STATION 172+00 - 47' 14"
DATUM 382.3' COMPILED BY B.K.
BORING DATE Nov. 25/60 CHECKED BY G.G.C.

LEGEND
2 Triaxial compression
1/2 UNCONFINED COMPRESSION (QU)
VANE TEST (C) AND SENSITIVITY (S)
NATURAL MOISTURE AND
LIQUIDITY INDEX
LIQUID LIMIT
PLASTIC LIMIT
Lab Vane



DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS AND RESEARCH SECTION

W.P. 44-61

BORE HOLE NO. 3

LOG 60-F-89

SECTION 170/59'49" L.L.

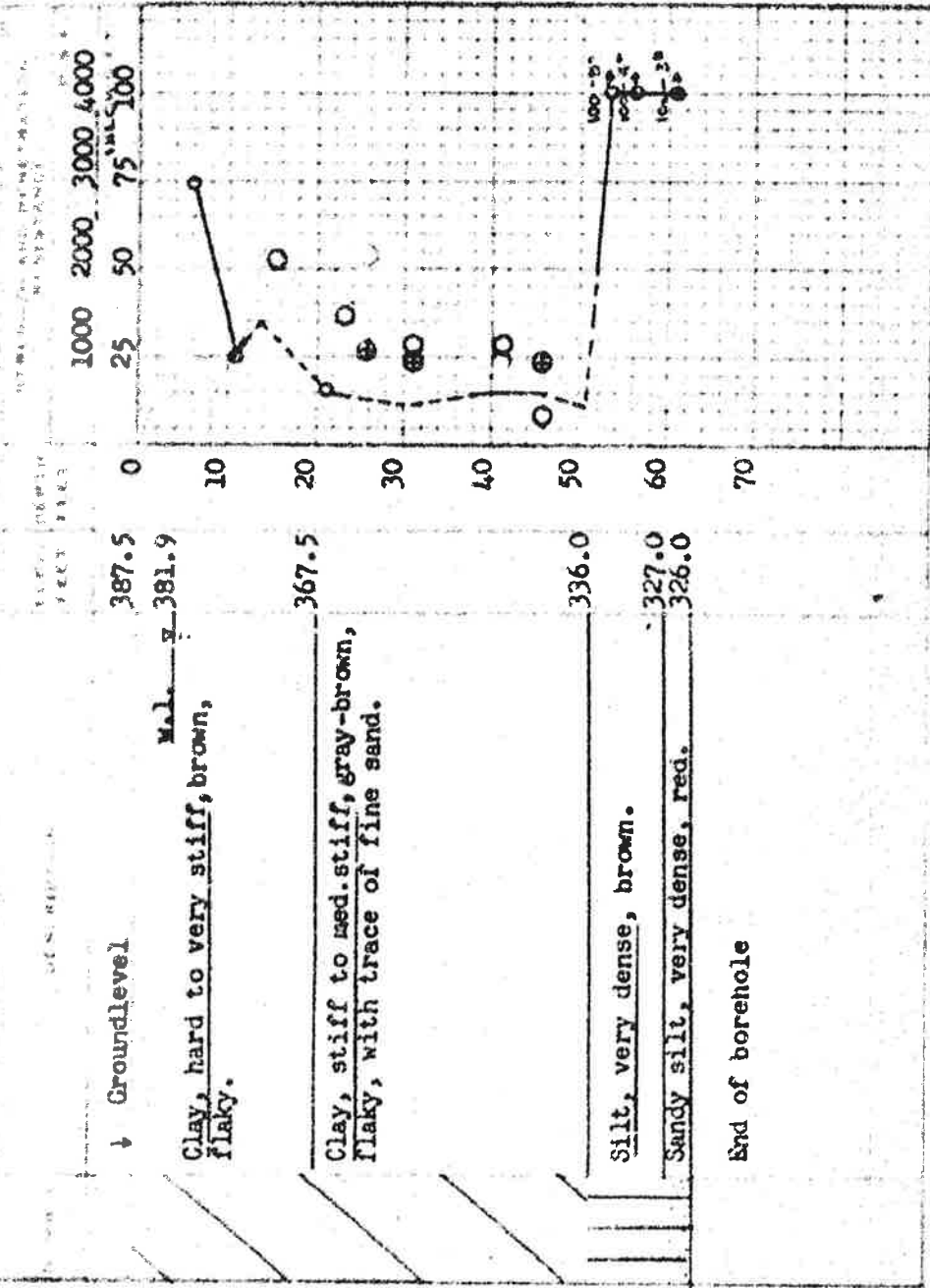
DATUM 387.5'

CONTROLLED BY B.K.

BORING DATE Nov. 21/60

COLLECTED BY G.G.C.

LEGEND
1 Triaxial compression
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Groundlevel

M.L. 381.9

Clay, hard to very stiff, brown, flaky.

367.5

Clay, stiff to med. stiff, gray-brown, flaky, with trace of fine sand.

336.0

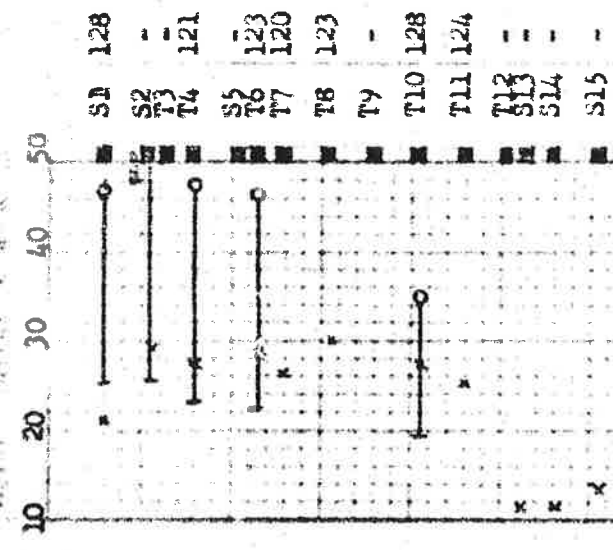
Silt, very dense, brown.

327.0

Sandy silt, very dense, red.

326.0

End of borehole



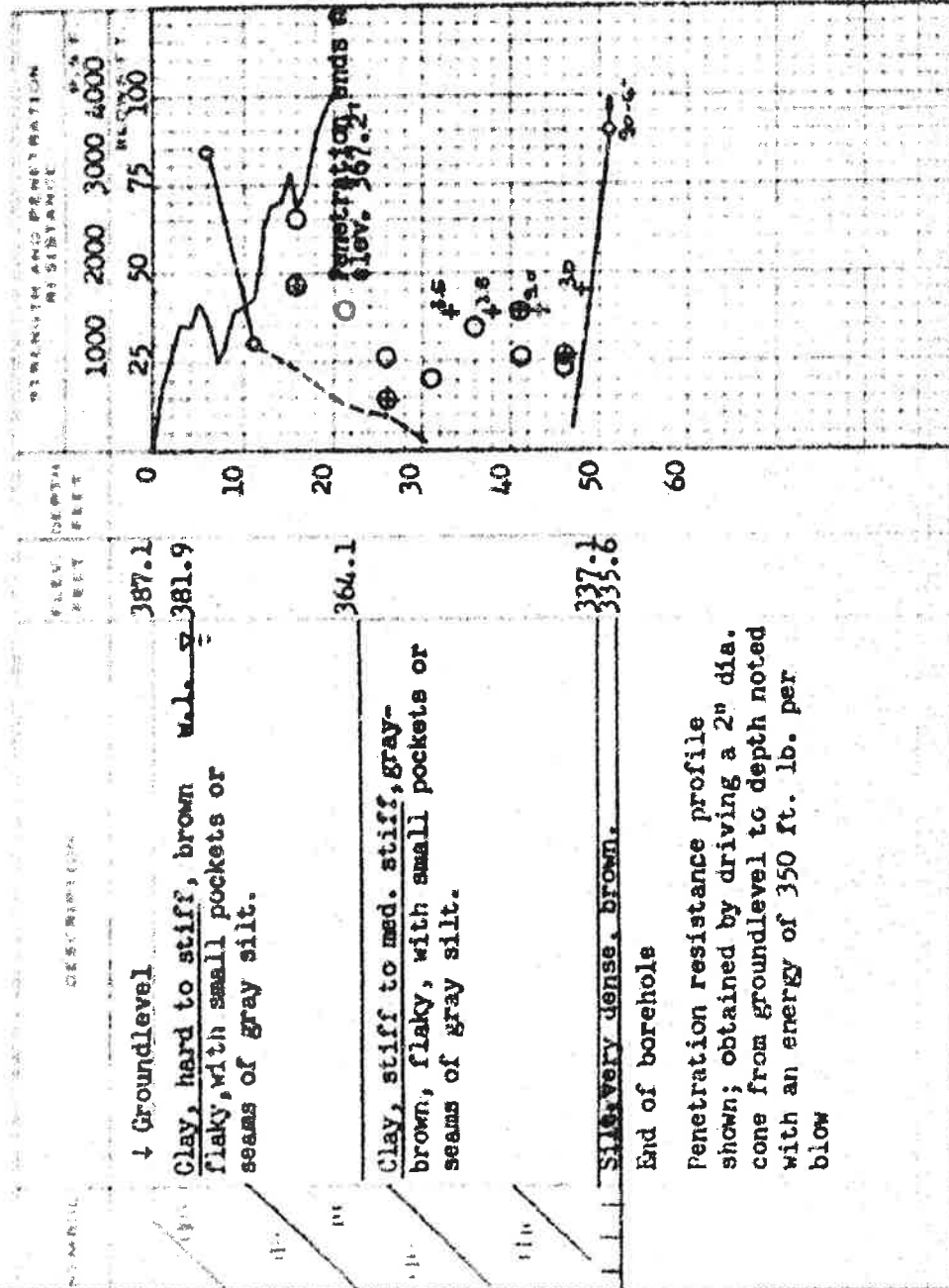
Lab Vane

SN 128
S2
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T4
S8
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S13
S14
S15

DEPARTMENT OF HIGHWAYS - ONTARIO MATERIALS AND RESEARCH SECTION

W.P. 44-61 BORE HOLE NO. 4
JOB 60-F-89 STATION 170+59.42 R.L.
DAYUM 187.1 COMPILED BY B.K.
BORING DATE NOV. 23/60 CHECKED BY G.G.C.

LEGEND
 Triaxial compression
 Unconfined compression (C_u)
 Vane testing and sensitivity (S)
 Natural moisture and
 Liquid limit
 Plastic limit
 Lab Vane



Penetration resistance profile shown; obtained by driving a 2" dia. cone from groundlevel to depth noted with an energy of 350 ft. lb. per blow

JOB 60-F-89

W.P. 44-61

SUMMARY OF FIELD & LABORATORY TESTS

HOLE NO.	SAMP NO.	SAMPLE DEPTH (FEET)	MATERIAL DESCRIPTION	PERCENT RECENT BLOW(S)	WATER CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	SHRINKAGE (%)	UNIT WEIGHT (PCF)	WATER ABSORPTION (%)	REMARKS
1	S1	5'-6.5'	Hard brown flaky clay with trace of fine gravel.	62	24.5	23.1	44.3	-	-	134	
	S2	10'-11.5'	As above.	33	24.5	22.1	45.6	-	-	136	
	T3	15'-16.5'	Very stiff brown flaky clay with small seams or pockets of gray silt and trace of fine gravel.	26-11"	26.2	21.3	35.7	T=2450		128	
	T4	20'-21.5'	Very stiff brown flaky clay with small pockets of gray silt.	31	26.8	22.3	44.7	T=3080 V=3070		124	Sens: 4.2
	T5	25'-26.5'	Very stiff brown flaky clay with trace of fine gravel.	27	21.4	24.7	47.1	T=2390		127	Triaxial specimen failed on a vertical plane thru dessication cracks
	T6	30'-31.5'	Very stiff brown flaky clay.	19-6"	26.8	22.2	46.7	T=1930 V=2620		125	Sens: 3.8 Root systems present in dessication cracks. Triaxial sample failed along dessication cracks.
	T7	35'-36.5'	Stiff brown flaky clay.	P	31.0	-	-	T=1690		122	As above.
	T8	40'-41.5'	Stiff brown flaky clay with small pockets of silt & trace of decomposed red & green shale.	P	35.0	23.6	54.1	T=1980 V=1990		117	Sens: 8.0
	WANE 43'		Stiff brown clay.	-	-	-	-	1920		-	Sens: 4.4
	T9	45'-46.5'	Stiff gray-brown flaky clay.	P	26.2	18.9	37.5	T=1700		127	
	WANE 48'		Very stiff gray-brown flaky clay.	-	-	-	-	>2000		-	

JOB 60-P-84
W.P. 44-61

SUMMARY OF FIELD & LABORATORY TESTS

NO. /	SAMP NO.	SAMPLE DEPTH (FEET)	MATERIAL DESCRIPTION	PENETIN RESIST BLAWS	MOIST CONTENT %	PLASTIC LIMIT %	LIQUID LIMIT %	SHRINK AGEING %	UNIT WEIGHT pcf	REMARKS
1	T10	50'-51.5'	Stiff gray-brown flaky silty clay- with small pockets or seams of gray silt.	P	28.2	20.4	39.2	T=1110 V=1100	122	Sens: 4.8
	VANE	53'	As above.	-	-	-	-	1920	-	Sens: 3.7
	T11	55'-56.0'	Gray-brown clay with trace of fine gravel changing to very Dense gray sandy silt.	34	13.5	-	-	-	-	
		56-56.5'	Very dense red sandy silt containing small pockets of red shale.							
2	S1	5'-6.5'	Hard brown flaky clay	38	25.8	24.0	48.5	-	-	
	S2	10'-11.5'	Very stiff brown flaky clay.	24	21.6	16.4	29.9	-	-	
	T3	15'-16.5'	Very stiff brown flaky clay with small pockets of gray silt and trace of fine gravel.	19	29.0	22.8	40.2	-	126	
	T4	20'-21.5'	Very stiff gray-brown flaky clay.	P	28.9	-	-	-	122	
	VANE	23'	As above.	-	-	-	-	>2000	-	
	T5	25'-26.5'	As above.	P	31.4	24.0	46.2	T=2400 V=1500	123	Sens: 3.2
	T6	30'-31.5'	As above.	P	27.1	20.5	40.0	-	124	

JOB 60-7-89
 WP 44-61

SUMMARY OF FIELD & LABORATORY TESTS

TEST NO.	SAMPLE DEPTH FEET	MATERIAL DESCRIPTION	PISTON RECORD NUMBER	MOISTURE CONTENT PERCENT	SHRINKAGE PERCENT	LOGS NO.	UNIT WEIGHT PCF	REMARKS
2	T7 35'-36.5'	Stiff gray-brown flaky clay.	P	29.9	20.1	40.3	T=1790 V=1080	Sens: 3.3 (1/16" piece of red shale in sample.)
	VANE 38'	As above.	-	-	-	-	1600	Sens: 4.0
	T8 40'-41.5'	Stiff gray-brown flaky clay with small pockets of fine gray sand & silt.	P	39.4	24.0	43.1	-	119
	VANE 43'	As above.	-	-	-	-	1680	Sens: 2.8
	T9 45'-46.5'	As above.	P	28.9	-	-	T=1150 V=1550	Sens: 4.5
	VANE 48'	As above.	-	-	-	-	1520	Sens: 2.7
	T10 50'-51.5'	Stiff gray-brown flaky silty clay with small pockets of gray fine sand & silt.	P	28.1	19.0	35.7	-	(1/16" piece of red shale in sample)
	VANE 53'	As above.	-	-	-	-	1520	Sens: 2.7
	T11 55'-56.5'	As above.	P	28.2	20.9	37.2	T=640 V=1126	Sens: 3.3 Plastic failure
	VANE As above.		-	-	-	-	1640	Sens: 2.9

JOB 60-P-89
W.P. 44-61

SUMMARY OF FIELD & LABORATORY TESTS

HOLE NO.	SAMP NO.	SAMPLE DEPTH (FEET)	MATERIAL DESCRIPTION	PENETROMETER (BLOWS/FT)	MOISTURE (CONT)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	SHRINKAGE (%)	UNIT WEIGHT (PCF)	REMARKS
2	S12	59.0-59.7'	Very dense red brown silt with some fine sand & trace of clay.	100-8"	10.6	-	-	-	-	Sample Lost
	S13				11.5	-	-	-	-	
	S14	70'-71.5'	Very dense red-brown sandy silt with small subrounded red & green shale particles.	140	-	-	-	-	-	
	S15	74.5'-76'		100-6"	-	-	-	-	-	
3	S1	5'-6.5'	Hard brown flaky clay.	74	21.0	25.1	47.0	-	-	Fire roots present in sample. Sample lost. Fire roots present in sample. Sample lost. Sample lost. Sens: 5.5
	S2	10'-11.5'	Very stiff brown flaky clay.	25	29.2	25.4	52.1	-	-	
	T3	12'-13.5'		35	-	-	-	-	-	
	T4	15'-16.5'	Very stiff brown flaky clay.	25	27.6	23.2	47.3	2110	121	
	S5	20'-21.5'		16	-	-	-	-	-	
	T6	22'-23.5'	Stiff gray-brown flaky clay.	15	29.0	22.4	46.5	1450	123	
	T7	25'-26.5'	Stiff gray-brown flaky clay.	13	26.2	-	-	T=1100 V=1080	120	

JOB 60-F-89
WP 44-61

SUMMARY OF FIELD & LABORATORY TESTS

HOLE NO.	SAMP NO.	SAMPLE DEPTH (FEET)	MATERIAL DESCRIPTION	PERCENT FINER THAN 200 SIEVE	MOISTURE CONTENT (%)	PLASTIC LIMIT (%)	LIQUID LIMIT (%)	SHRINKAGE (%)	WATER BURN LOSS (%)	REMARKS
3	T8	30'-31.5'	Med. stiff gray-brown flaky clay.	12	30.0	-	-	Tell30 V=902	123.1	Sens: 4.2
	T9	35'-36.5'		14	-	-	-	-	-	Sample Lost.
	T10	40'-41.5'	Med. stiff gray-brown flaky clay - trace of fine sand and fine gravel.	15	27.4	19.7	35.0	Tell25	128	Plastic failure.
	T11	45'-46.5'	Med. stiff gray brown flaky clay - with small pockets of red sandy silt.	16	25.6	-	-	T=710 V=990	124	Sens: 4.3 (Plastic failure).
	T12	50'-51.5'		12	-	-	-	-	-	Sample Lost.
	S13	52'-53.5'	Very dense light brown clayey silt with trace of fine to med. sand.	100-5"	11.8	-	-	-	-	
4	S14	55'-56.5'	As above.	100-4"	11.4	-	-	-	-	
	S15	60'-61.5'	Very dense red sandy silt.	100-3"	13.7	-	-	-	-	
	S1	5'-6.5'	Hard brown flaky clay with seams of gray silt.	83	15.8	19.7	34.8	-	134.6	
	S2	10'-11.5'	Very stiff brown flaky clay with pockets of green-brown fine sand & silt.	30	28.4	-	-	-	-	
	T3	15'-16.5'	Very stiff brown flaky clay.	23	29.4	23.8	52.8	Ta2690 V=1850	123	Sens: 3.8

JOB 60-F-89
WP 44-01

SUMMARY OF FIELD & LABORATORY TESTS

NO.	SAMP NO.	SAMPLE DEPTH (FEET)	MATERIAL DESCRIPTION	TESTS	MOISTURE (CM)	PLASTIC LIMIT	LIQUID LIMIT	SHRINKAGE (%)	UNIT WEIGHT (PCF)	SENSITIVITY
4	T4	20'-21.5'	Stiff brown flaky clay with small pockets of gray silt.	13	29.0	23.3	47.7	T=1560	123	
	T5	25'-26.5'	Stiff gray-brown clay with 1" pocket of red-brown fine sand & silt.	10	28.4	-	-	T=1064 V=594	1229	Sens: 3.4 Plastic failure.
	T6	30'-31.5'	Medium stiff gray-brown flaky silty clay.	P	29.4	19.4	39.4	T=800	123	Plastic failure.
	VANE 33'		Stiff gray-brown clay.	-	-	-	-	1520	-	Sens: 3.5
	T7	35'-36.5'	Stiff gray-brown clay with small pockets of gray silt.	P	31.7	-	-	T=1380	121.5	
	VANE 38'		Stiff gray-brown clay.	-	-	-	-	1520	-	Sens: 3.5
	T8	40'-41.5'	Stiff gray-brown clay with 1/16" thick seams of gray fine sand and trace of fine gravel.	P	30.8	20.7	44.2	T=1010 V=1511	1233	Sens: 3.9
	VANE 43'		Stiff gray-brown clay.	-	-	-	-	1520	-	Sens: 3.0
	T9	45'-46.5'	Medium stiff gray-brown clay with thin silt layers and trace of fine gravel.	P	30.2	-	-	T=968 V=1082	122.5	Sens: 3.0
	VANE 48'		Stiff gray-brown clay.	-	-	-	-	1800	-	
	S10	50'-51.5'	Very dense light brown clayey silt with trace of fine to med. sand.	90-6"	10.7	-	-	-	-	
			S denotes split spoon sample P denotes Shelby tube sample							



Appendix E

Selected photographs of the site



Photo 1. - Highway 406 NBL at Chestnut Street



Photo 2.- East side of Highway 406 NBL, from Chestnut Street



Photo 3.- West side of Highway 406 NBL, from Chestnut Street



Photo 4. – West side of north abutment of Highway 406 NBL, from Chestnut Street



Photo 5. – West side of south abutment of Highway 406 NBL, from Chestnut Street



Appendix F

Comparison of Foundation Alternatives for Chestnut NBL Overpass Bridge

COMPARISON OF FOUNDATION ALTERNATIVES

Foundation Unit	Spread Footings on Native Soils	Spread Footings on Engineered Fill	Driven Steel H-Pile into Native Glacial Till	Augered Caissons (Drilled Shafts) into Native Silty Clay/Glacial Till
	<p>Advantages:</p> <ul style="list-style-type: none"> i. Ease of construction. ii. Lower cost than deep foundations. iii. Consistent with foundations of existing bridge. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Relatively large excavations required. ii. Native soil might be disturbed after removal of existing footings. iii. Relatively low geotechnical resistance is available. iv. Potential for settlement of foundation soils. v. Dewatering may be required, depending on depth of excavation and groundwater level at time of construction vi. May increase requirements for roadway protection. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Lower cost than deep foundations. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Potential for settlement of foundation soils (firm silty clay). ii. Cost of constructing engineered fill. iii. Dewatering may be required prior to excavation. iv. May increase requirements for roadway protection. v. High cost of constructing engineered fill. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Ease of construction. ii. Higher axial resistance than footings. iii. Required for integral abutments. iv. Dewatering not required for pile installation. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost than footings. ii. Cobbles and boulders may be encountered in glacially derived soils that could impede pile penetration to required depths. iii. Monitoring of adjacent structures (Hwy 406 SBL) will be required during pile driving 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Minimal disruption to traffic since pile caps are not required. ii. Higher lateral resistance is available due to larger diameter. iii. Less number of caissons is required for each foundation element than if steel piles were used. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Not suitable for integral abutments. ii. Steel liners will be required to install caissons to minimize sidewall sloughing and water seepage. iii. Possibility of boulders being encountered during augering. iv. Potential basal instability if water-bearing soils are exposed at the base. v. Difficulty in cleaning and inspecting bases.
Abutments	RECOMMENDED	NOT RECOMMENDED	FEASIBLE	NOT COST EFFECTIVE



Appendix G

List of OPSS Documents and NSSP Wordings

1. List of Special Provisions and OPSS Documents Referenced in this Report

- OPSS.PROV 903
- OPSS.PROV 804
- OPSS.PROV 902
- OPSS.PROV 539
- OPSS.PROV 206
- OPSS.PROV.1010
- OPSD 3000.100
- OPSD 3102.100

2. Suggested Text for NSSP on “Footing Subgrade Preparation”

The Contractor is advised that the native silty clay that will be exposed at the subgrade following removal of existing substructures is moisture sensitive and may become severely disturbed or otherwise negatively impacted when subjected to construction or personnel traffic, freeze-thaw actions, ingress or ponding of water. The Contractor shall be responsible for implementing adequate groundwater control measures and providing adequate site and subgrade drainage, and to minimize construction and personnel traffic on the founding subgrade. No additional compensation shall be made to the Contractor for carrying out his operation or construction activities to suit these conditions.

Footings must be constructed in the dry. Unwatering must remain operational and effective until the footing excavation is backfilled.

The bases of the foundation excavations should be inspected by the QVE that is experienced in geotechnical inspection to confirm that the exposed subgrade surface conforms to the design requirements and has been adequately prepared to receive concrete. Once approved, the subgrade should be protected by a working mat with a minimum thickness of 100 mm and consisting of mass concrete of the same strength and class as that of the footing. Where subexcavation is required to remove unsuitable material from below the design founding level,

the founding surface should be re-established using the same mass concrete. At locations where the design founding level is higher than that of the removed footing, the same mass concrete will be required to raise and establish the founding subgrade.

3. Suggested text for NSSP on “Installation of Driven H-piles”

Installation of H-piles shall be in accordance with OPSS 903 and the following.

Cobbles and boulders are expected within the native glacial tills on site. The cobbles, and boulders may interfere with pile installation and some piles may meet refusal on boulders above the end-bearing stratum. The Contractor must be prepared to remove, dislodge or otherwise penetrate these obstructions to advance the piles to the very dense silt till or bedrock while meeting the specified deflection tolerances.

If a pile meets refusal at an elevation significantly higher than the design tip elevation, the QVE must terminate driving before the pile is damaged due to over-driving. The QVE must immediately bring it to the attention of the CA. If the CA cannot resolve the issue, it must be referred to the design team for resolution.

4. “Augered Caisson Construction for Noise Barrier Wall Foundations”

The Contractor is advised that variable types of subsurface materials may be encountered at the locations of the noise barrier wall foundations. Obstructions may be present within the embankment fill.

For bidding purposes, the Contractor shall assume the following:

1. The subsurface conditions at an augered caisson location are the same as those encountered in the borehole closest to the subject caisson location.
2. Obstructions may be encountered within the fill. Caisson installation equipment must be able to dislodge, handle, remove or otherwise penetrate these obstructions.
3. Water seepage and/or soil sloughing into the caisson hole will occur from the existing granular fill and water-bearing sands and silts interlayered within the silty clay. The cohesionless soils would be susceptible to disturbance under conditions of unbalanced



hydrostatic head. Temporary liners shall be available on site, or be made available on very short notice, to support the caisson sidewalls and provide seepage cut-off where required. All concrete shall be placed in the dry.

The Contractor is responsible for constructing the noise barrier wall foundations without disturbing the material at the sides or bases of the foundations.

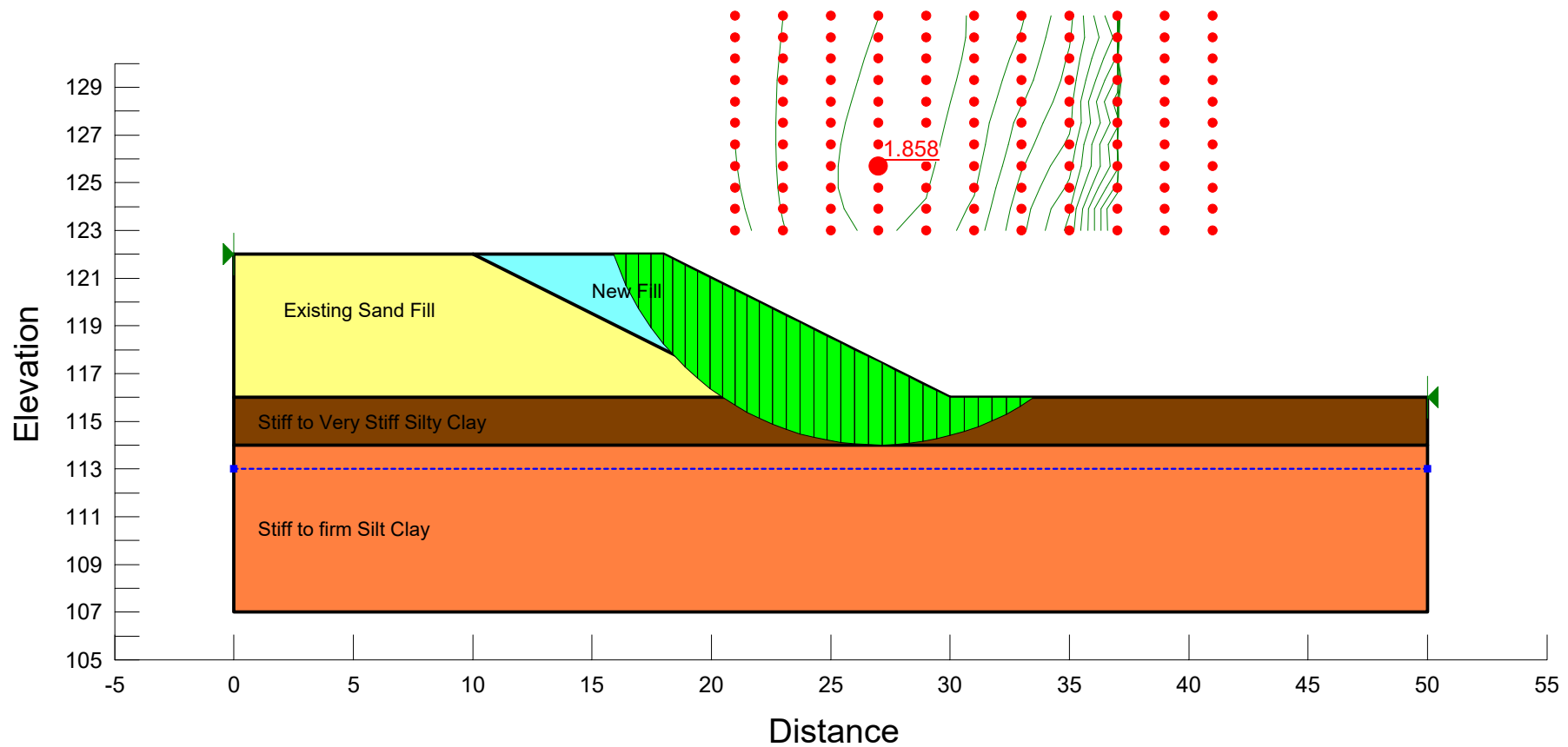


Appendix H

Slope Stability Analysis Results

Highway 406 NBL and Chesnut Street
On-Ramp Speed Change Lane (SCL) Extension
at Highway 406/Glendale Avenue (W/E-N Ramp)
New Embankment Fill- Widening
Height = 6.0 m
Drained (long term)

Name: Compact to dense Sand Fill Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Firm to Stiff Silty Clay Unit Weight: 19 kN/m³ Cohesion: 0 kPa Phi: 28 ° Phi-B: 0 ° Piezometric Line: 1
Name: Stiff to Very Stiff Silty Clay Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 29 ° Phi-B: 0 ° Piezometric Line: 1
Name: New Fill Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1



Directory: H:\10000+11336 8 Bridge Rehab Hwys 406 & 140\Reports & Memos\Chesnut St\Analysis\stability\\File Name: 11336 SCL extension- drained- 8 m wide - existing granular fill.gsz
Date: 2017-02-16Time: 8:30:22 AM

11336

Highway 406 NBL and Chesnut Street
On-Ramp Speed Change Lane (SCL) Extension
at Highway 406/Glendale Avenue (W/E-N Ramp)
New Embankment Fill- Widening
Height = 6.0 m
Undrained (short term)

Name: Compact to dense Sand Fill Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1
Name: Firm to Stiff Silty Clay Unit Weight: 19 kN/m³ Cohesion: 50 kPa Phi: 0 ° Phi-B: 0 ° Piezometric Line: 1
Name: Stiff to Very Stiff Silty Clay Unit Weight: 20 kN/m³ Cohesion: 100 kPa Phi: 0 ° Phi-B: 0 ° Piezometric Line: 1
Name: New Fill Unit Weight: 20 kN/m³ Cohesion: 0 kPa Phi: 30 ° Phi-B: 0 ° Piezometric Line: 1

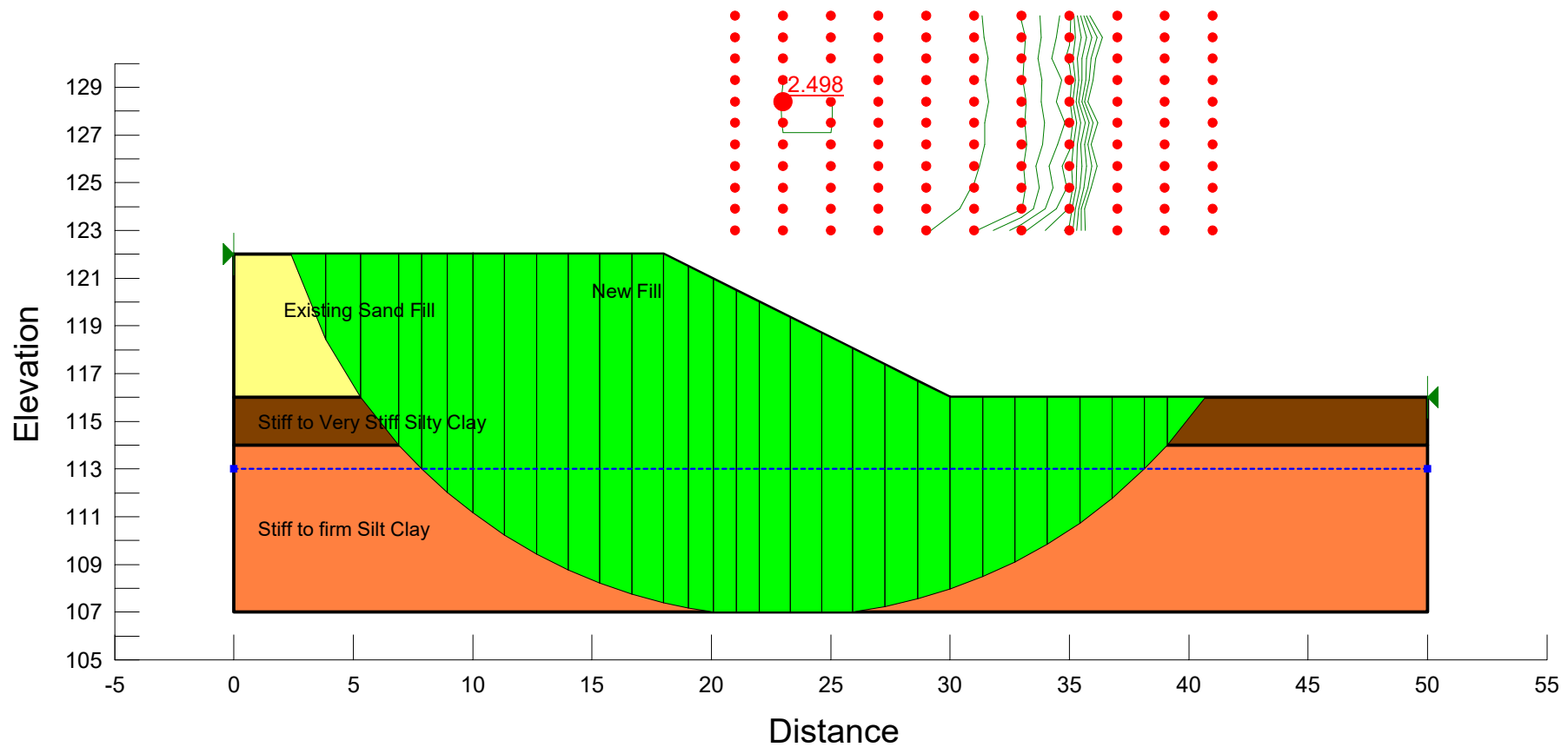


Figure H2