



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 7/8 CYCLING AND PEDESTRIAN BRIDGE
CITY OF KITCHENER, ONTARIO
W.O. 2019-11001**

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Geocres No. 40P8-263

Report to

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PART 1: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the site of a proposed cycling and pedestrian bridge in the City of Kitchener, Ontario. The proposed bridge will span Highway 7/8 between Avalon Place and Chandler Drive and will connect the Avalon Place neighbourhood on the north side to the Laurentian Power Centre and Grand River Transit hub on the south side of the highway. The proposed bridge is located approximately 600 m west of Homer Watson Boulevard.

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide borehole logs, a borehole location plan, stratigraphic profile, and written descriptions of the subsurface conditions.

Thurber carried out the investigation as a sub-consultant to BT Engineering.

2. SITE DESCRIPTION

The proposed cycling and pedestrian bridge is located approximately 600 m west of Homer Watson Boulevard at Highway 7/8 in Kitchener, Ontario. The bridge will span Highway 7/8 between Avalon Place and Chandler Drive. At this location, Highway 7/8 is a six lane highway consisting of three westbound lanes and three eastbound lanes separated by a median barrier.

The surrounding area is relatively flat and consists of residential properties to the north and commercial properties to the south. A Grand River Transit facility is located immediately south of Chandler Drive and the Laurentian Power Centre exists to the southeast. .

The site is located in the Waterloo Hills physiographic region as delineated in *The Physiography of Southern Ontario* (Chapman and Putnam, 1984). This region consists of sandy hills composed



of sandy till ridges, kames, or kame moraines, with outwash sands occupying the intervening hollows. Bedrock is expected to be at a depth in the order of 60 m.

3. INVESTIGATION PROCEDURES

3.1 Field Investigation

The site investigation at the proposed bridge location was carried out during the period February 13 to 21, 2018, during which time seven boreholes (Boreholes 18-01 to 18-07) were drilled to depths of 12.8 m to 26.5 m at the site. The borehole designation and depths are listed as follows:

Table 3.1 – Borehole Designations and Depths

Borehole No.	MTM NAD83 Northing (m)	MTM NAD83 Easting (m)	Ground Surface Elevation (m)	Borehole Depth (m)
18-01	4,810,087.5	224,388.2	331.6	12.8
18-02	4,810,099.7	224,435.9	329.5	12.8
18-03	4,810,113.4	224,481.7	328.0	25.0
18-04	4,810,042.7	224,489.3	332.5	26.5
18-05	4,810,052.1	224,524.6	332.1	12.8
18-06	4,810,067.9	224,561.6	329.7	12.8
18-07	4,810,039.5	224,571.2	331.1	12.8

The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing provided in Appendix E.

Prior to the commencement of drilling, all borehole locations were cleared of utilities and road occupancy permits were obtained. The boreholes were repositioned as necessary in consideration of the utility locations and surface features.

The boreholes were advanced using a rubber-track mounted CME850 drilling rig. Hollow stem augers were used to advance the boreholes in the overburden. Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT).

The drilling and sampling 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.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Standpipe piezometers consisting of 32 mm diameter PVC pipe were installed and enclosed in



filter sand in selected boreholes to permit groundwater level monitoring. The details of the piezometers are shown in Table 3.2.

Table 3.2 – Piezometer Details

Borehole	Piezometer Tip		Instrument Type	Slotted Screen Length (m)
	Depth (m)	Elevation (m)		
18-01	12.2	319.4	32 mm Piezometer	3.0
18-03	24.4	303.6	32 mm Piezometer	3.0
18-04	22.9	309.6	32 mm Piezometer	3.0
18-06	12.2	317.5	32 mm Piezometer	3.0

The boreholes in which no piezometers were installed were backfilled with bentonite and cuttings to the ground surface in general accordance with MOE Regulation 903.

3.2 Laboratory Testing

All recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A.

Selected samples were subjected to gradation analysis and Atterberg Limits testing. The results of this testing program are shown on the Record of Borehole sheets and on the laboratory test result figures attached in Appendix B.

Four samples of soil were submitted for laboratory testing to evaluate the potential for soil corrosion and sulphate attack on buried concrete structures. The results of the testing are provided in Appendix C.

4. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference should be made to the Record of Borehole sheets in Appendix A. Details of the encountered soil stratigraphy are presented in Appendix A and on the “Borehole Locations and Soil Strata” drawing in Appendix E. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

The stratigraphic boundaries shown on the borehole records and on the interpreted stratigraphic profile and cross-sections are inferred observations of drilling progress and from non-continuous



sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In general, the subsurface conditions at the site consist of surficial topsoil and fill layers underlain by a discontinuous layer of firm to very stiff silty clay, which is underlain by a deposit of loose to dense silty sand to sandy silt. The sand/silt generally grades to clayey silt with depth, and is in turn underlain by a loose to very dense sand to silty sand deposit.

A more detailed description of the individual strata encountered in the boreholes is provided in the following sections.

4.1 Topsoil

A layer of topsoil was encountered at the ground surface in all boreholes with the exception of Borehole 18-06. The thickness of the topsoil ranged from 125 to 400 mm.

The topsoil thickness may vary between and beyond the locations investigated, and the reported values are not intended for estimating quantities.

4.2 Cohesionless Fill

A 0.6 m to 2.6 m thick layer of cohesionless fill was encountered beneath the topsoil in Boreholes 18-03, 18-04, 18-05, and 18-07, and from ground surface in Borehole 18-06. The fill consists of silty sand to sandy silt containing trace to some gravel, trace to some clay, and trace organics. Wood pieces, asphalt and possible coal particles were noted locally. The lower boundary of the fill was encountered between Elev. 330.3 m and 327.3 m.

The measured SPT “N” values within the cohesionless fill ranged from 6 to 27 blows per 0.3 m of penetration, indicating a loose to compact relative density. The natural water content ranged from 8% to 23%.

The results of grain size distribution tests carried out on selected samples of the cohesionless fill are shown on Figure B1 in Appendix B. The results of the grain size distribution analyses are summarized below:

Soil Particle	Percentage (%)
Gravel	8 to 15
Sand	58 to 60
Silt	21 to 26
Clay	4 to 8



4.3 Cohesive Fill

A 0.7 m thick layer of cohesive fill was encountered beneath the cohesionless fill in Borehole 18-03. The cohesive fill consists of sandy clayey silt containing some gravel and trace organics. The lower boundary of the cohesive fill was encountered at Elev. 326.5 m.

An SPT “N” value of 10 blows per 0.3 m of penetration was measured within the fill, indicating a stiff consistency. The natural water content measured on a sample was 23%.

4.4 Silt

A 0.8 m thick deposit of brown silt, containing some clay and trace sand, was encountered underlying the cohesionless fill in Borehole 18-07. The surface of the deposit was encountered at a depth of 1.5 m (Elev. 329.6 m).

An SPT “N” value of 13 blows per 0.3 m of penetration was measured in the silt, suggesting a compact relative density. The natural water content measured on a sample was 15%.

The results of a grain size distribution test carried out on a sample of the silt are shown on Figure B2 in Appendix B, and are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	5
Silt	82
Clay	13

4.5 Silty Clay

A 1.1 m to 2.8 m thick layer of brown silty clay, containing trace to some sand and trace gravel, was encountered underlying the fill in Boreholes 18-03 and 18-06, and underlying the silt deposit in Borehole 18-07. The surface of the deposit was encountered at depths ranging between 1.5 m and 2.3 m (Elev. 328.8 m and 326.5 m).

The SPT “N” values measured within the silty clay deposit ranged from 7 to 17 blows per 0.3 m of penetration, suggesting a firm to very stiff consistency. The natural water content measured on samples ranged from 14% to 32%.

The results of grain size distribution tests carried out on samples of the silty clay are shown on Figure B3 in Appendix B. The results are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 2
Sand	0 to 18
Silt	47 to 70
Clay	30 to 33

Atterberg limits testing was carried out on two selected samples of the silty clay and measured plastic limits of 12% and 15%, liquid limits of 21% and 26%, and corresponding plasticity indices of 9% and 11%. These results, which are plotted on Figure B7 in Appendix B, indicate that the deposit consists of silty clay of low plasticity (CL).

4.6 Upper Silty Sand to Sandy Silt

A 1.4 m to 6.5 m thick deposit of brown silty sand to sandy silt, containing trace to some clay, trace to some gravel was encountered underlying the topsoil in Boreholes 18-01 and 18-02, underlying the silty clay in Boreholes 18-03, 18-06 and 18-07, and underlying the fill in Boreholes 18-04 and 18-05. The surface of the deposit was encountered at depths ranging between 0.2 m and 4.3 m (Elev. 331.4 m and 323.7 m).

The SPT “N” values measured within the silty sand to sandy silt deposit ranged from 4 to 45 blows per 0.3 m of penetration, indicating a variable loose to dense relative density. The natural water content measured on samples ranged from 5% to 20%.

The results of grain size distribution tests carried out on selected samples of the silty sand to sandy silt are shown on Figure B4 in Appendix B. The results are summarized below:

Soil Particle	Percentage (%)
Gravel	0 to 15
Sand	33 to 63
Silt	17 to 49
Clay	5 to 15

4.7 Clayey Silt

The upper silty sand and sandy silt graded to a clayey silt, some sand to sandy, at depths ranging between 4.4 m and 9.1 m (Elev. 327.7 m and 320.6 m) in Boreholes 18-03 to 18-07. This deposit was 1.6 m to 3.5 m thick and described as brown to grey.



The SPT “N” values measured within the clayey silt zone ranged from 5 to 26 blows per 0.3 m of penetration, indicating a firm to very stiff consistency. In general, the SPT “N” values ranged between 15 and 25 blows per 0.3 m penetration (very stiff). The natural water content measured on samples ranged from 9% to 20%.

The results of grain size distribution tests carried out on selected samples of the clayey silt are shown on Figure B5 in Appendix B. The results are summarized below:

Soil Particle	Percentage (%)
Gravel	0
Sand	15 to 30
Silt	52 to 62
Clay	18 to 23

Atterberg limits testing was carried out on two samples of the clayey silt and measured plastic limits of 10%, liquid limits of 15% to 17%, and corresponding plasticity indices of 5% to 7%. These results, which are plotted on Figure B8 in Appendix B, indicate that the deposit consists of clayey silt of slight to low plasticity (CL-ML).

4.8 Sand to Silty Sand

A deposit of brown to grey sand to silty sand, containing trace amounts of gravel and clay, was encountered underlying the silty sand to sandy silt deposit in Boreholes 18-01 and 18-02, and underlying the clayey silt deposit in Boreholes 18-03 to 18-07. Locally this deposit graded to silt and sand below 24 m depth in Borehole 18-04. The surface of the deposit was encountered at depths ranging between 2.2 m and 12.2 m (Elev. 327.5 m and 318.8 m).

The SPT “N” values measured within the deposit ranged from 8 to 118 blows per 0.3 m of penetration, indicating a loose to very dense relative density. In general, the SPT “N” values ranged from about 20 to 60 blows per 0.3 m of penetration (compact to very dense), ranging lower from 8 to 24 blows per 0.3 m (loose to compact) in Borehole 18-04. The natural water content measured on samples typically ranged from 10% to 21%, locally 3% to 5% above the groundwater level in Boreholes 18-01 and 18-02.

The results of grain size distribution testing carried out on selected samples of the sand to silty sand are shown on Figure B6 in Appendix B. The results are summarized below:



Soil Particle	Percentage (%)
Gravel	0 to 1
Sand	36 to 95
Silt	4 to 51
Clay	3 to 13

4.9 Groundwater Conditions

The groundwater depths and elevations observed in the boreholes upon completion of drilling and measured in the piezometers after the drilling are summarized in the following table.

Table 4.1 – Groundwater Measurements

Borehole No.	Date	Ground Surface Elevation (m)	Water Level (m)		Remark
			Depth	Elevation	
18-01	Feb. 16, 2018	331.6	8.8	322.8	Open borehole Piezometer
	March 6, 2018		8.1	323.5	
18-02	Feb. 20, 2018	329.5	8.8	320.7	Open borehole
18-03	Feb. 20, 2018	328.0	5.6	322.4	Open borehole Piezometer
	March 6, 2018		4.8	323.2	
18-04	Feb. 15, 2018	332.5	9.8	322.7	Open borehole Piezometer
	March 6, 2018		9.2	323.3	
18-05	Feb. 14, 2018	332.1	10.1	322.0	Open borehole
18-06	Feb. 14, 2018	329.7	8.4	321.3	Open borehole Piezometer
	March 6, 2018		6.3	323.4	
18-07	Feb. 13, 2018	331.1	8.5	322.6	Open borehole

The above water level measurements are short-term observations and seasonal fluctuations of the groundwater level are to be expected.



5. MISCELLANEOUS

BT Engineering staked out the programmed borehole locations in the field prior to drilling. Subsequently, BT Engineering determined the co-ordinates and ground surface elevations at the as-drilled borehole locations following completion of drilling.

Aardvark Drilling of Guelph, Ontario, supplied and operated the drilling and sampling equipment for the field program.

The field investigation was supervised by Mr. Saeed Bastan of Thurber. Overall planning and supervision of the investigative program, including obtaining utility clearances, was carried out by Mr. Stephane Loranger of Thurber Engineering.

Interpretation of the field data and preparation of the report was performed by Mr. Geoff Lay, P.Eng. The report was reviewed by Mr. Murray Anderson, P.Eng., and Dr. P.K. Chatterji, P.Eng.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6. GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical recommendations to assist selection and design of the foundation system for the proposed Highway 7/8 cycling and pedestrian bridge.

Based on the Alignment and Profile drawings provided by BT Engineering (Draft V3 provided in April 2018), the proposed bridge will comprise a 47.5 m long single-span structure with a minimum clearance of 5.4 m above the highway. The bottom of the bridge deck will be approximately 6.2 m and 7.3 m above existing grade at the south and north abutments, respectively. The bridge will be accessed by a stairwell and a ramp at each abutment. The south ramp will extend easterly from the south abutment then bend southerly to Chandler Drive, on an elevated structure for a distance of 69.1 m from the abutment then on fill for a further 20.5 m. The north ramp will extend westerly along the south side of Avalon Place, on an elevated structure for a distance of 81.0 m from the abutment then on fill for a further 10.9 m.

The discussion and recommendations presented in this report are based on the information provided by BT Engineering and on the factual data obtained in the course of the investigation.

The interpretation and recommendations are intended for the use of the design consultant and the Region of Waterloo, and shall not be relied upon by any other parties including the construction contractor, or used for any purposes other than development of the project design. Comments on construction methodology and equipment, where presented, are provided only to highlight those aspects that could affect the design of the project. Contractors must make their own assessment of the factual information presented in Part 1 of the report, and the implications on equipment selection, construction methodology, and scheduling.



6.1 Foundation Design

In general, the subsurface conditions at the site consist of surficial topsoil and fill layers underlain by a discontinuous layer of firm to very stiff silty clay, which is underlain by a deposit of loose to dense silty sand to sandy silt. The sand/silt generally grades to clayey silt with depth, and is in turn underlain by a loose to very dense sand to silty sand deposit.

The groundwater levels measured in piezometers installed during the investigation ranged from 4.8 m to 9.2 m below the ground surface (Elev. 323.5 to 323.2).

Based on the subsurface conditions at the site, initial consideration was given to supporting the structure using the following foundation types:

- Spread footings on native soil or engineered fill
- Driven steel H-piles
- Drilled shafts (Caissons)

A comparison of the technical advantages and disadvantages of the alternative foundation schemes is presented in Appendix D. Recommendations for feasible foundation alternatives are presented in the following sections. A foundation scheme preferred from a geotechnical perspective is then recommended.

6.1.1 Spread Footings on Native Soil

Based on the subsurface conditions encountered at this site, consideration may be given to supporting the proposed bridge abutments and access structures on spread footings founded on the native compact to dense sands and silts and/or the firm to very stiff silty clay.

The highest founding levels and corresponding geotechnical resistances recommended at each foundation unit, based on the borehole data, are presented in the following table. Footings should be founded at or below these elevations, subject to minimum requirements for frost protection.

Table 6.1 – Highest Recommended Founding Levels

Location	Borehole	Minimum Depth (m)	Highest Recommended Founding Level	Founding Soil Type	Factored Geotechnical Resistance	
					ULS (kPa)	SLS (kPa)
North Ramp	18-01	1.4	330.2	Compact Sand and Silt	400	250
	18-02	1.4	328.1	Compact Sandy Silt	400	250
North Abutment	18-03	1.5	326.5	Very Stiff to Stiff Silty Clay	200	135
South Abutment	18-04	2.2	330.3	Compact Silty Sand	350	200
South Ramp	18-05	3.0	329.1	Compact Sandy Silt	350	200
	18-06	1.5	328.2	Firm to Stiff Silty Clay	200	125
	18-07	1.5	329.6	Compact Silt	225	150

The factored geotechnical resistance at SLS is based on an estimated settlement not exceeding 25 mm. This settlement should be essentially complete by the end of construction.

The factored geotechnical resistance at ULS was assessed assuming a consequence factor equal to 1 (typical), and a resistance factor equal to 0.5 (typical degree of understanding), as per CHBDC 2014. The factored geotechnical resistance at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions.

The resistance values assume a minimum 1.5 m wide footing subjected to vertical concentric loading. Where eccentric or inclined loads are applied, the resistance values used in design must be reduced in accordance with the CHBDC Clause 6.10.3 and Clause 6.10.4.

The lateral resistance developed along the base of concrete footings founded on the native sands, silts and silty clay may be computed using a factored friction coefficient of 0.32, which includes a geotechnical resistance factor of 0.8 (typical degree of understanding).

All footings should be provided with a minimum of 1.4 m of earth cover over the footing base as protection against frost action.

The bases of the foundation excavations should be inspected by a geotechnical engineer to confirm that the exposed surface conforms to the design requirements, has been adequately prepared to receive concrete, and consists of competent undisturbed native soil.



Founding surfaces should be protected from disturbance during construction. The exposed surface should be protected from deterioration by placing a minimum 75 mm thick working mat of concrete immediately following approval of the founding surface.

6.1.2 Spread Footings on Engineered Fill

It is understood that the geotechnical resistance values provided above for spread footings on native soils will generally be adequate for practical foundation design, and therefore the additional cost of engineered fill construction is not warranted. However in view of the lower resistance values available at the north abutment, consideration may be given to constructing the footings at this location on engineered fill to increase the geotechnical resistance and reduce the footing size.

To achieve factored geotechnical resistances of 350 kPa at ULS and 200 kPa at SLS at the north abutment (Borehole 18-03), the engineered fill pad should have a minimum thickness equivalent to 75% of the footing width. The underside of the engineered fill pad should be placed on stiff to very stiff silty clay below the level of all existing fill. The engineered fill must consist of OPSS Granular "A" placed in 150 mm lifts and compacted to 100% of its SPMDD at $\pm 2\%$ of optimum moisture content. The fill pad must extend laterally beyond the edge of the footings a minimum distance of 1.0 m plus the thickness of engineered fill.

The resistance values are for vertical, concentric loads. Where eccentric or inclined loads are applied, the resistance used in design must be reduced in accordance with the CHBDC Clause 6.10.3 and Clause 6.10.4.

For footings designed on the basis of the geotechnical resistance values given above, total settlement under a footing is not expected to exceed 25 mm.

The lateral resistance of the footings founded on engineered fill may be computed using a factored friction coefficient of 0.48, which includes a geotechnical resistance factor of 0.8 (typical degree of understanding).

6.1.3 Driven Steel H-Pile Foundations

The use of steel H-piles driven into the compact to very dense sand to silty sand deposit may be considered for supporting the higher foundation loads at the bridge abutments. The axial



geotechnical resistances recommended for approximate 20 m long HP310x79 H-piles driven to elevation 310 in the underlying sand to sandy silt are as follows:

	<u>HP310x79</u>
Factored Geotechnical Resistance at ULS =	700 kN
Factored Geotechnical Resistance at SLS =	475 kN
Factored Geotechnical Resistance at ULS for Uplift =	300 kN

The factored geotechnical resistance at ULS was assessed assuming a consequence factor equal to 1 (typical), and a resistance factor equal to 0.4 (typical degree of understanding), as per CHBDC 2014. The factored geotechnical resistance at SLS was assessed assuming a factor of 0.8 for typical degree of understanding of the subsurface conditions. The assumed resistance factor for uplift was 0.3.

Pile installation should be in accordance with OPSS.PROV 903.

The actual pile tip elevations will be controlled by the Hiley Formula and an ultimate pile resistance should be specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of the Structural Manual. The appropriate pile driving note is "Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of "R" kN per pile". "R" must have a value of two times the design load at ULS calculated by the structural engineer.

Due to the variable blow counts obtained in the boreholes, the piles may achieve the specified resistance at different elevations. Variable pile lengths and the need for additional splicing and/or cutting of piles must be anticipated during installation.

As the underlying soils consist primarily of cohesionless sands and silts, downdrag on the piles is not an issue at this site.

To minimize the potential for disturbance of existing underground services in the area, it is recommended that the pile installations be pre-augered with a 200 mm diameter hole to a depth of at least 3 m below the level of the deepest utility. A preconstruction condition survey of existing structures and utilities should be carried out prior to commencement of pile installation. Vibration monitoring should be carried out during pile driving to limit potential impacts on existing facilities, and conditions carefully monitored for signs of disturbance.

Driving of piles will induce noise and vibrations which may be disruptive to residents and businesses in the area. For this reason, driven piles may not be the preferred foundation option.



6.1.4 Drilled Shafts (Caissons)

Caisson installation at this site would extend through the cohesionless silts and sands and below the groundwater table. The soils would be susceptible to hydraulic disturbance/heave and measures such as the use of drilling mud and/or a permanent liner to support the caisson sidewalls would be required to maintain stability of the excavation. Inspection of the caisson base to confirm the caisson capacity would not be possible in these conditions. The use of caissons is therefore not recommended and design recommendations have not been developed.

6.1.5 Recommended Foundation

From a geotechnical perspective and based on the subsurface conditions, spread footings founded on the native undisturbed sands and silts and/or the silty clay are the recommended foundation option. Alternatively, if higher geotechnical resistances are required, driven piles or footings founded on engineered fill may be considered to support the higher abutment loads.

6.1.6 Lateral Pile Resistance

The geotechnical lateral resistance of a pile in cohesionless soil may be calculated using a coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

	k_s	=	$n_h z / D$	(kN/m ³)
	p_{ult}	=	$3 \gamma' z K_p$	(kPa)
Where	z	=	depth of embedment along pile (m)	
	D	=	pile width or diameter (m)	
	n_h	=	coefficient related to soil density (kN/m ³)	
	γ'	=	effective unit weight (kN/m ³)	
	K_p	=	coefficient of passive lateral earth pressure	

The geotechnical lateral resistance acting on a pile in cohesive soils may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

	k_s	=	$67 S_u / D$	(kN/m ³)
	p_{ult}	=	$9 S_u$	(kPa)
Where	S_u	=	undrained shear strength (kPa)	
	D	=	pile width or diameter in metres	

The above equations and recommended parameters in Table 6.2 below may be used to analyse the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis must not exceed the ultimate lateral resistance.

Table 6.2 – Soil Parameters for Lateral Pile Design

Foundation Unit	Soil Type	Elevation (m)		γ' (kN/m ³)*	n_h (kN/m ³)	K_p	S_u (kPa)
		Top	Bottom				
North Abutment	Silty Clay – Very Stiff to Stiff	326.5	323.7	19	-	2.8	70
	Sandy Silt - Loose	323.7	321.9	10	1,500	2.9	-
	Clayey Silt - Firm to Stiff	321.9	318.8	9	-	2.6	45
	Sand - Compact to Very Dense	318.8	310.0	11	6,000	3.7	-
South Abutment	Silty Sand - Compact	330.3	326.9	20	5,000	3.2	-
	Sandy Silt - Compact	326.9	323.8	20	5,000	3.2	-
	Clayey Silt - Very stiff	323.8	320.3	9	-	3.0	140
	Sand - Compact	320.3	310.0	10	3,500	3.2	-

*Buoyant unit weight below the water table.

The spring constant, K_s , for analysis may be obtained by the expression, $K_s = k_s L D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m³), D is the pile width (m) and L is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance, P_{ult} , may be obtained from the expression, $P_{ult} = p_{ult} L D$. This represents the ultimate load at which geotechnical failure of the pile occurs and will not support any additional load at greater displacement.

The modulus of subgrade reaction may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Figures C6.11.3(r) and C6.11.3(s) of the Commentary to the CHBDC 2014.

Consideration may be given to the use of battered piles if lateral pile capacities higher than the available geotechnical lateral resistances are required.

6.2 Frost Cover

The depth of frost penetration at this site is 1.4 m. The base of footings or pile caps must be provided with a minimum of 1.4 m of earth cover or equivalent insulation as protection against frost action.

6.3 Retaining Wall Backfill and Lateral Earth Pressures

Low retaining walls will be required to support the fill under the lower end of the access ramps. Backfill to the retaining walls should consist of free-draining granular material conforming to OPS Granular A or B Type II specifications. Compaction should be carried out in accordance with OPSS 501. Heavy compaction equipment should not be used adjacent to the walls.

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

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

Where:

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

The earth pressure coefficients are dependent on the material used as backfill. Recommended unfactored values are shown in Table 6.3.

Table 6.3– Lateral Earth Pressure Coefficients

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 $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$	
	Horizontal Backfill	Sloping Backfill (2H:1V)	Horizontal Backfill	Sloping Backfill (2H:1V)
Active (Unrestrained Wall)	0.27	0.39*	0.31	0.47*
At-rest (Restrained Wall)	0.43	-	0.47	-
Passive	3.7	-	3.3	-



The parameters in the table correspond to full mobilization of active and passive earth pressures, and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC.

In accordance with Clause 6.12.3 of the CHBDC, 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.

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

6.4 Seismic Considerations

In accordance with the CHBDC, the selection of the seismic site class is based on the average soil conditions encountered in the upper 30 m of the ground profile. The stratigraphy at this site generally consists of successive deposits of firm to stiff silty clay, loose to dense silty sand to sandy silt, firm to very stiff clayey silt, and compact to very dense sand to silty sand. The depth to bedrock is expected to exceed 30 m. As per Table 4.1 of the CHBDC, the site may be classified as Seismic Site Class D.

Based on the National Building Code of Canada (NBCC 2015), the peak horizontal ground acceleration (PGA), corresponding to a design earthquake having a 2 percent probability of being exceeded in 50 years (i.e. 2,475 year return period) is 0.074 g at the site.

Based on review of the SPT data, seismically-induced liquefaction of foundation soils is not anticipated under the design earthquake.

6.5 Excavation and Groundwater Control

The excavations for the structure foundations are expected to extend through silty sand to sandy silt fill, clayey silt fill, and locally into the native sands, silts, and silty clay. The excavations are expected to remain above the groundwater table.

All temporary excavations must be carried out in accordance with OPSS 902 and the Occupational Health and Safety Act (OHSA). For the purposes of assessing excavation slope



requirements in compliance with the OHSA, the fill, native loose to compact sand/silt deposits, and firm to stiff silt clay are classified as Type 3 soils.

Use of a hydraulic excavator should be suitable for foundation excavation in the overburden soils. The selection of the method of excavation is the responsibility of the contractor and must be based on their equipment, experience and interpretation of the site conditions. Provision must be made for the handling of pavement materials and potential obstructions in the fill.

Roadway protection should be provided in accordance with OPSS 539 and designed for Performance Level 2. Based on available subsurface information, a shoring system consisting of sheet piling or steel H-piles with timber lagging may be considered if space is not available for sloped excavation sidewalls. Temporary shoring should be designed by a licensed Professional Engineer experienced in design of shoring with consideration of adjacent traffic loads and any sloping retained surfaces.

Groundwater control by pumping from filtered sumps should be adequate to remove any accumulation of water within the excavation prior to placing concrete. Localized zones of perched water should be anticipated in the granular materials or sand/silt fill above less permeable silty clay layers. All footings/pile caps must be constructed in the dry.

6.6 Pavement Reinstatement

Reinstatement of the pavement on Avalon Place should consist of construction of the following pavement structure:

Hot Mix HL3 Surface Course	40 mm
Hot Mix HL4 Binder Course	60 mm
OPSS Granular A Base	150 mm
OPSS Granular B Type I Subbase	450 mm

All HMA materials should meet the requirements of the City of Kitchener Standard Specifications and/or OPSS requirements. An minimum asphalt cement binder grade of PG 58-28 is required for all asphalt mixes. The new granular material should meet the requirements of OPSS.Muni 1010 or City of Kitchener specifications. All granular material should be compacted in accordance with the requirements of OPSS.Muni 501 to at least 100 percent of the SPMDD.

Smooth transitions are required in all areas where the new pavement meets the existing asphalt surface. All longitudinal and transverse joints should meet the requirements of OPSS 310.



Longitudinal joints should be staggered between the asphalt lifts. The staggering of the longitudinal joints should be accomplished by offsetting the paving edge and the upper asphalt course by a minimum of 150 mm.

Pavement subgrade preparation should include compaction and proofrolling of the exposed surface with a heavy roller and examination to identify any areas of unstable subgrade. Any soft/wet areas identified should be subexcavated and replaced with approved material within 2% of optimum moisture content and compacted to at least 98% of SPMDD.

The top of the compacted subgrade should be graded smooth with a minimum crossfall of 3% towards subdrains. Continuous subdrains should be installed below or just behind the curb line and consist of 150 mm diameter perforated pipe placed in a clear stone trench wrapped with geotextile, as per OPSD 216.021. Continuity of drainage should be maintained at transitions from existing pavement to new pavement.

6.7 Soil Corrosion Potential

Four samples of soil were submitted for laboratory testing to evaluate the potential for soil corrosion and sulphate attack on buried concrete structures. The results of the testing are provided in Appendix C and are summarized as follows:

Table 6.4 – Results of Corrosivity Testing

Borehole	Depth (m)	Resistivity (ohm-cm)	pH	Redox Potential (mV)	Chlorides (µg/g)	Sulphates (µg/g)
18-03	1.5-2.1	2080	8.1	256	185	12
18-03	6.1-6.7	3130	8.9	207	88	76
18-04	1.5-2.1	2790	8.5	240	132	42
18-07	0.8-1.4	4120	7.7	247	5	6

The resistivity values and chloride concentrations measured in the samples indicate that the soils are moderately corrosive to gray and ductile cast-iron pipe as well as steel pipes and fittings. Protective measures to resist corrosion should be provided.

The measured sulphate concentrations indicate that buried concrete structures will not be subject to sulphate attack. A negligible to mild exposure to chlorides is indicated, however the corrosion potential from the use of road salt should be considered.



6.8 Construction Concerns

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

- The proposed north ramp and bridge abutment will be located in close proximity to an existing watermain which runs in an east-west direction along the south side of Avalon Place. Similarly, the proposed south ramp will cross a buried sanitary sewer and watermain. To avoid damaging the existing municipal services and provide a suitable foundation subgrade, foundations for the bridge abutments and ramp retaining walls must not be founded over the existing services or associated trench backfill.

The locations and elevations of these and any other underground utilities in the area should be confirmed during design and prior to construction. Where conflict with the existing utilities is anticipated, mitigation measures should be implemented, such as extending foundations to the native soils below the level of the pipe trenches, relocation of the utilities and backfilling of existing trenches with Granular A engineered fill, and/or incorporating protection of the conduits (ie., bridging over) in the design.

- If driven piles are chosen as the foundation option, vibration monitoring is recommended during pile driving to limit potential impacts on existing facilities and residents, and conditions carefully monitored for signs of disturbance. A preconstruction condition survey of existing structures and utilities should be carried out prior to commencement of pile installation.
- Driven steel H-piles may develop the design resistance at varying depths in the loose to very dense sand and silty sand deposits at this site.
- The depth of the fill materials may vary from that encountered in the boreholes, necessitating additional subexcavation for footing construction.

The successful performance of the structure will depend largely on good workmanship and quality control during construction. It is therefore recommended that geotechnical inspection and testing by qualified personnel be provided during construction. The inspection and testing should include observation and inspection of foundation subgrade conditions, compaction testing of backfill and pavement granular materials, and concrete and asphalt testing.



7. CLOSURE

Engineering analysis and preparation of the foundation design report were carried out by Mr. Geoff Lay, P.Eng. and reviewed by Mr. Murray Anderson, P.Eng. and Dr. P.K. Chatterji, P.Eng., Designated Principal Contact for MTO Foundations Projects.

Thurber Engineering Ltd.

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Geotechnical Engineer



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Senior Geotechnical Engineer



P.K. Chatterji, P.Eng.
Review Principal

STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

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5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

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Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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


4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

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

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

 Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

RECORD OF BOREHOLE No 18-01

1 OF 2

METRIC

W.P. _____ LOCATION N 4 810 087.5 E 224 388.2 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.16 - 2018.02.16 CHECKED BY MRA

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 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
331.6	GROUND SURFACE																
0.0	TOPSOIL: (150mm)																
0.2	SAND and SILT, trace to some clay Compact to Dense Brown Moist		1	SS	18												
			2	SS	25											0 53 41 6	
			3	SS	26												
			4	SS	33												
			5	SS	41											0 45 42 13	
327.5																	
4.1	SAND, trace silt, trace gravel Compact to Dense Brown to Grey Moist to Wet		6	SS	37												
			7	SS	34												
			8	SS	27												
			9	SS	32											1 95 4 (SI+CL)	

Continued Next Page

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

RECORD OF BOREHOLE No 18-01

2 OF 2

METRIC

W.P. _____ LOCATION N 4 810 087.5 E 224 388.2 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.16 - 2018.02.16 CHECKED BY MRA

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									
							20	40	60	80	100						
	Continued From Previous Page																
			10	SS	22		321										
							320										
			11	SS	23		319										
318.8 12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL AT 8.8m UPON COMPLETION. Piezometer installation consists of 32mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.03.06 8.1 323.5																

ONTMT4S MTO-17844.GPJ 2017TEMPLATE(MTO).GDT 4/20/18

RECORD OF BOREHOLE No 18-02

1 OF 2

METRIC

W.P. _____ LOCATION N 4 810 099.7 E 224 435.9 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.20 - 2018.02.20 CHECKED BY MRA

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 (%) W _p W W _L				
329.5	GROUND SURFACE															
0.0	TOPSOIL: (150mm)															
0.2	Sandy SILT, some clay, trace gravel Loose to Compact Brown Moist		1	SS	4											
			2	SS	12											
			3	SS	22										3 33 49 15	
327.3	SAND, trace to some silt Compact to Very Dense Brown to Grey Moist to Wet		4	SS	26											
2.2			5	SS	32											
			6	SS	45											
			7	SS	59											
			8	SS	99										0 89 11 (SI+CL)	
			9	SS	65											

Continued Next Page

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

RECORD OF BOREHOLE No 18-02

2 OF 2

METRIC

W.P. _____ LOCATION N 4 810 099.7 E 224 435.9 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.20 - 2018.02.20 CHECKED BY MRA

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 (%) W _p W W _L				
	Continued From Previous Page																
			10	SS	28		319										
							318										
316.7			11	SS	84		317										
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE CAVED TO 8.3m AND WATER LEVEL AT 8.8m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																

ONTMT4S MTO-17844.GPJ 2017TEMPLATE(MTO).GDT 4/20/18

RECORD OF BOREHOLE No 18-03

1 OF 3

METRIC

W.P. _____ LOCATION N 4 810 113.4 E 224 481.7 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.20 - 2018.02.21 CHECKED BY MRA

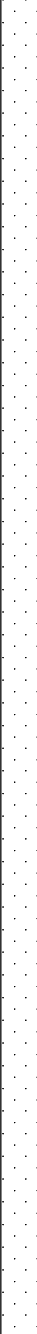


SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
328.0	GROUND SURFACE							20	40	60	80	100							
0.0	TOPSOIL: (125mm)																		
0.1	Sandy SILT , trace to some gravel, trace asphalt, trace organics Compact		1	SS	25														
327.3	Brown Moist (FILL)																		
0.7	Clayey SILT , sandy, some gravel, trace organics Stiff		2	SS	10		327												
326.5	Brown Moist (FILL)																		
1.5	Silty CLAY , some sand, trace gravel, trace organics, iron oxide staining Very Stiff to Stiff		3	SS	17		326												
	Brown Moist																		
			4	SS	11		325											2 18 47 33	
			5	SS	11		324												
323.7	Sandy SILT , some clay, trace gravel Loose Grey Wet		6	SS	6		323												
4.3																			
							322												
321.9	Clayey SILT , sandy Firm to Stiff Grey Wet		7	SS	5		321												
6.1																			
			8	SS	9		320											0 23 55 22	
318.8	SAND , trace silt, trace gravel Very Dense Grey Wet		9	SS	52		319												
9.2																			

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

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15
10
(%) 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 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						
	SAND, trace silt, trace gravel Compact to Very Dense Grey Wet		10	SS	41			317													
								316													
			11	SS	40			315													
			12	SS	118			314													
								313													
			13	SS	62			312													
								311													
			14	SS	16			310													
			15	SS	45																
													309								

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 18-03

3 OF 3

METRIC

W.P. _____ LOCATION N 4 810 113.4 E 224 481.7 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.20 - 2018.02.21 CHECKED BY MRA

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 (%) W _p W W _L				
	Continued From Previous Page																
	SAND , trace silt, trace gravel Compact to Dense Grey Wet																
			16	SS	35												
			17	SS	28												
303.0																	
25.0	END OF BOREHOLE AT 25.0m. WATER LEVEL AT 5.6m UPON COMPLETION. Piezometer installation consists of 32mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.03.06 4.8 323.2																





ONTMT4S MTO-17844.GPJ 2017TEMPLATE(MTO).GDT 4/20/18

RECORD OF BOREHOLE No 18-04

1 OF 3

METRIC

W.P. _____ LOCATION N 4 810 042.7 E 224 489.3 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.14 - 2018.02.15 CHECKED BY MRA

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						
332.5	GROUND SURFACE							20 40 60 80 100						
0.0	TOPSOIL: (250mm)							20 40 60 80 100						
332.2														
0.3	Silty SAND , some gravel, trace clay, trace rootlets Loose to Compact Brown Moist (FILL)		1	SS	10		332							
			2	SS	6									
			3	SS	13									
330.3														
2.2	Silty SAND , some gravel, trace clay Compact Brown Moist		4	SS	16		330							
			5	SS	19		329							
			6	SS	24		328							
326.9														
5.6	Sandy SILT , trace to some clay, some gravel, iron oxide staining Compact Brown Moist		7	SS	17		326							
			8	SS	23		325							
							324							
323.8														
8.7	Clayey SILT , sandy Very Stiff Grey Moist		9	SS	19		323							

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 18-04

3 OF 3

METRIC

W.P. _____ LOCATION N 4 810 042.7 E 224 489.3 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.14 - 2018.02.15 CHECKED BY MRA

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			
	Continued From Previous Page		16	SS	20												
			17	SS	12												
			18	SS	9												
	Becoming silt and sand, some clay		19	SS	17												
	Dense		20	SS	44												
306.0																	
26.5	END OF BOREHOLE AT 26.5m. WATER LEVEL AT 9.8m UPON COMPLETION. Piezometer installation consists of 32mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.03.06 9.2 323.3																

ONTMT4S MTO-17844.GPJ 2017TEMPLATE(MTO).GDT 4/20/18

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

ONTMT4S MTO-17844.GPJ 2017TEMPLATE(MTO).GDT 4/20/18

RECORD OF BOREHOLE No 18-05

2 OF 2

METRIC

W.P. _____ LOCATION N 4 810 052.1 E 224 524.6 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.14 - 2018.02.14 CHECKED BY MRA

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						PLASTIC LIMIT W _P NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%)
	Continued From Previous Page					▽		20 40 60 80 100						
319.3	Silty SAND , trace clay Compact to Dense Grey Wet						322							0 67 30 3
			10	SS	33		321						○	
			11	SS	17		320						○	
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE CAVED TO 10.4m AND WATER LEVEL AT 10.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.													

RECORD OF BOREHOLE No 18-06

1 OF 2

METRIC

W.P. _____ LOCATION N 4 810 067.9 E 224 561.6 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.13 - 2018.02.14 CHECKED BY MRA

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							
329.7	GROUND SURFACE							<div><div>20406080100</div><div>○ UNCONFINED + FIELD VANE</div><div>● QUICK TRIAXIAL × LAB VANE</div></div>							
0.0	Silty SAND to Sandy SILT , trace to some clay, some gravel, trace organics, trace possible coal Compact Brown Moist (FILL)		1	SS	15		329								
			2	SS	19										
328.2															
1.5	Silty CLAY , some sand, iron oxide staining Firm to Stiff Brown Moist		3	SS	7		328								
			4	SS	12		327								
326.8															
2.9	Silty SAND to Sandy SILT , some gravel, trace clay Loose to Dense Brown to Grey Moist to Wet		5	SS	7		326								
			6	SS	9		325								
							324								
			7	SS	45		323								
							322								
			8	SS	22		321								
320.6															
9.1	Clayey SILT , some sand Very Stiff Grey Moist		9	SS	20		320								

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-06

2 OF 2

METRIC

W.P. _____ LOCATION N 4 810 067.9 E 224 561.6 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.13 - 2018.02.14 CHECKED BY MRA

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									
	Continued From Previous Page																
319.0																	
10.7	Silty SAND , trace gravel Very Dense Grey Wet		10	SS	53												
			11	SS	81												
316.9																	
12.8	END OF BOREHOLE AT 12.8m. WATER LEVEL AT 8.4m UPON COMPLETION. Piezometer installation consists of 32mm diameter Schedule 40 PVC pipe with a 3.0m slotted screen. WATER LEVEL READINGS DATE DEPTH(m) ELEV.(m) 2018.03.06 6.3 323.4																

ONTMT4S MTO-17844.GPJ 2017TEMPLATE(MTO).GDT 4/20/18

RECORD OF BOREHOLE No 18-07

1 OF 2

METRIC

W.P. _____ LOCATION N 4 810 039.5 E 224 571.2 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.13 - 2018.02.13 CHECKED BY MRA

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	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
331.1	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL: (300mm)						331										
330.8			1	SS	6												
0.3	Sandy SILT , some clay, trace sand, trace gravel, trace wood pieces and roots Loose Brown Moist (FILL)		2	SS	10		330										
329.6																	
1.5	SILT , some clay, trace sand Compact Brown Moist		3	SS	13		329									0 5 82 13	
328.8																	
2.3	Silty CLAY , trace sand Stiff Brown Moist		4	SS	15		328									0 0 70 30	
327.7			5	SS	18												
3.4	Sandy SILT , trace gravel, trace clay Compact Brown to Grey Moist		6	SS	24		327										
			7	SS	23		326										
							325										
							324										
			8	SS	23												
323.0							323										
8.1	Clayey SILT , some sand Very Stiff Grey Moist to Wet																
							322										
			9	SS	17											0 15 62 23	

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-07

2 OF 2

METRIC

W.P. _____ LOCATION N 4 810 039.5 E 224 571.2 ORIGINATED BY SB
 HWY 7/8 BOREHOLE TYPE Hollow Stem Augers COMPILED BY MP
 DATUM Geodetic DATE 2018.02.13 - 2018.02.13 CHECKED BY MRA

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
	Continued From Previous Page							20	40	60	80	100	20	40	60				
320.7							321												
10.4	Silty SAND , trace clay Dense to Very Dense Brown Wet		10	SS	42		320												
318.3			11	SS	55		319												
12.8	END OF BOREHOLE AT 12.8m. BOREHOLE CAVED TO 7.6m AND WATER LEVEL AT 8.5m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.																		



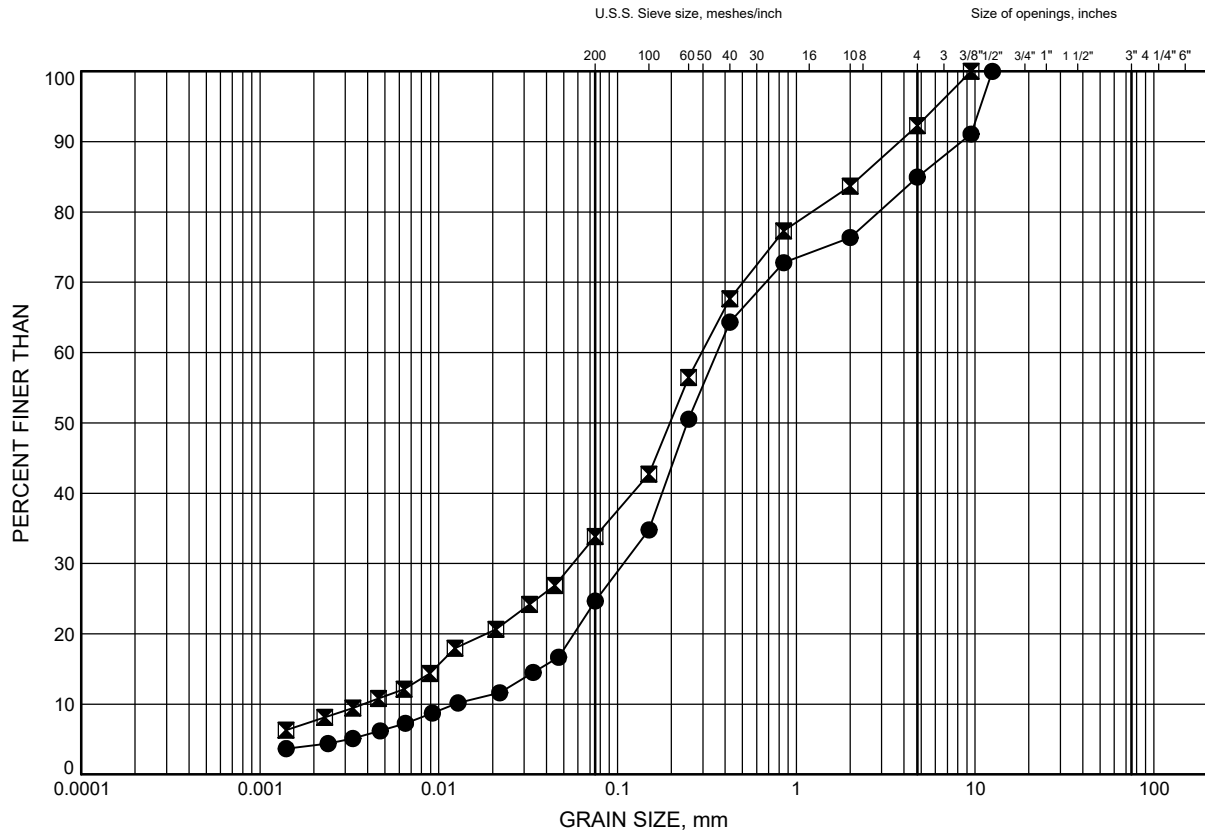
Appendix B

Laboratory Test Results

Highway 7 & 8 Multi-Use Trail GRAIN SIZE DISTRIBUTION

FIGURE B1

Cohesionless FILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-04	1.1	331.4
◻	18-05	1.8	330.3

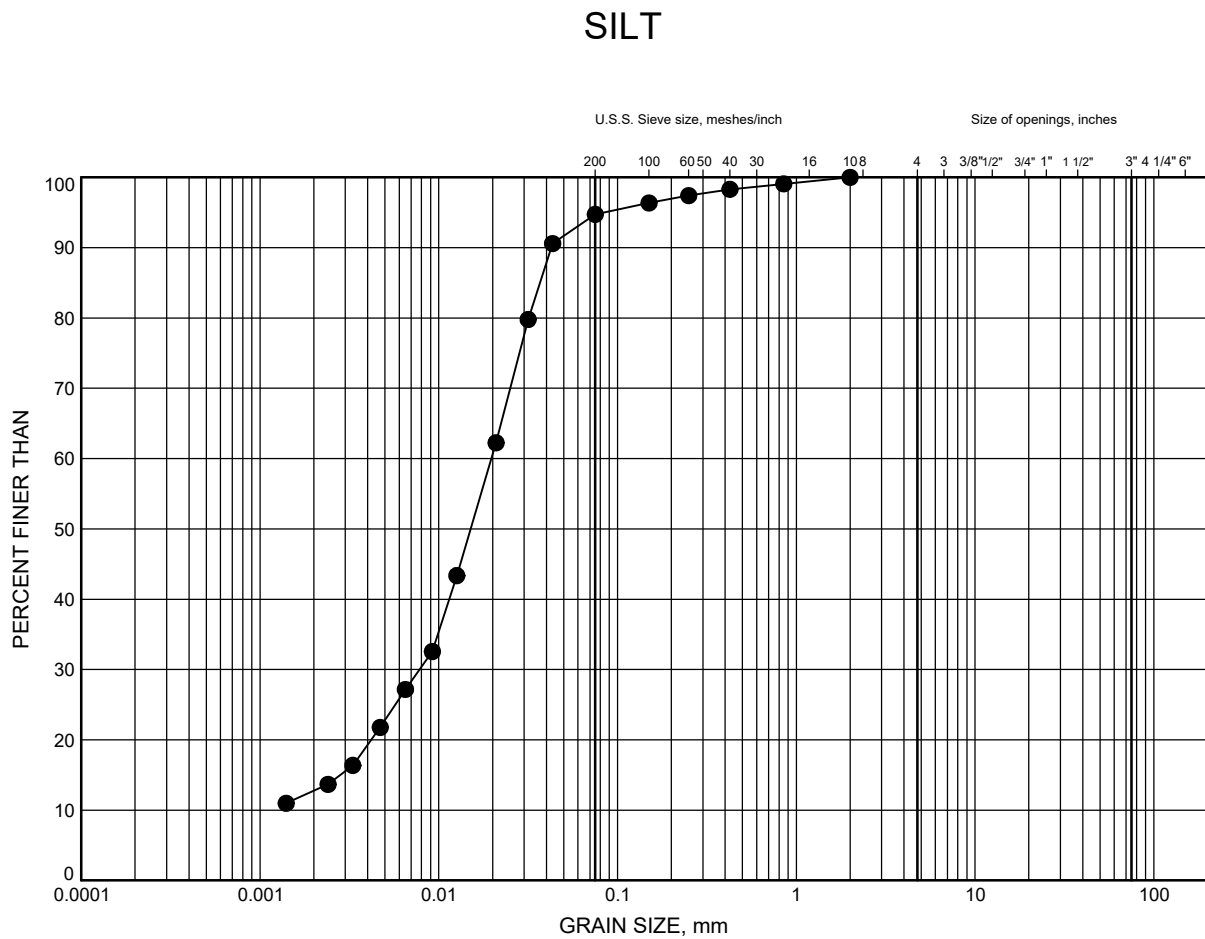
Date April 2018
W.P. _____



Prep'd AN
Chkd. GRL

Highway 7 & 8 Multi-Use Trail GRAIN SIZE DISTRIBUTION

FIGURE B2



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-07	1.8	329.3

Date April 2018
W.P.



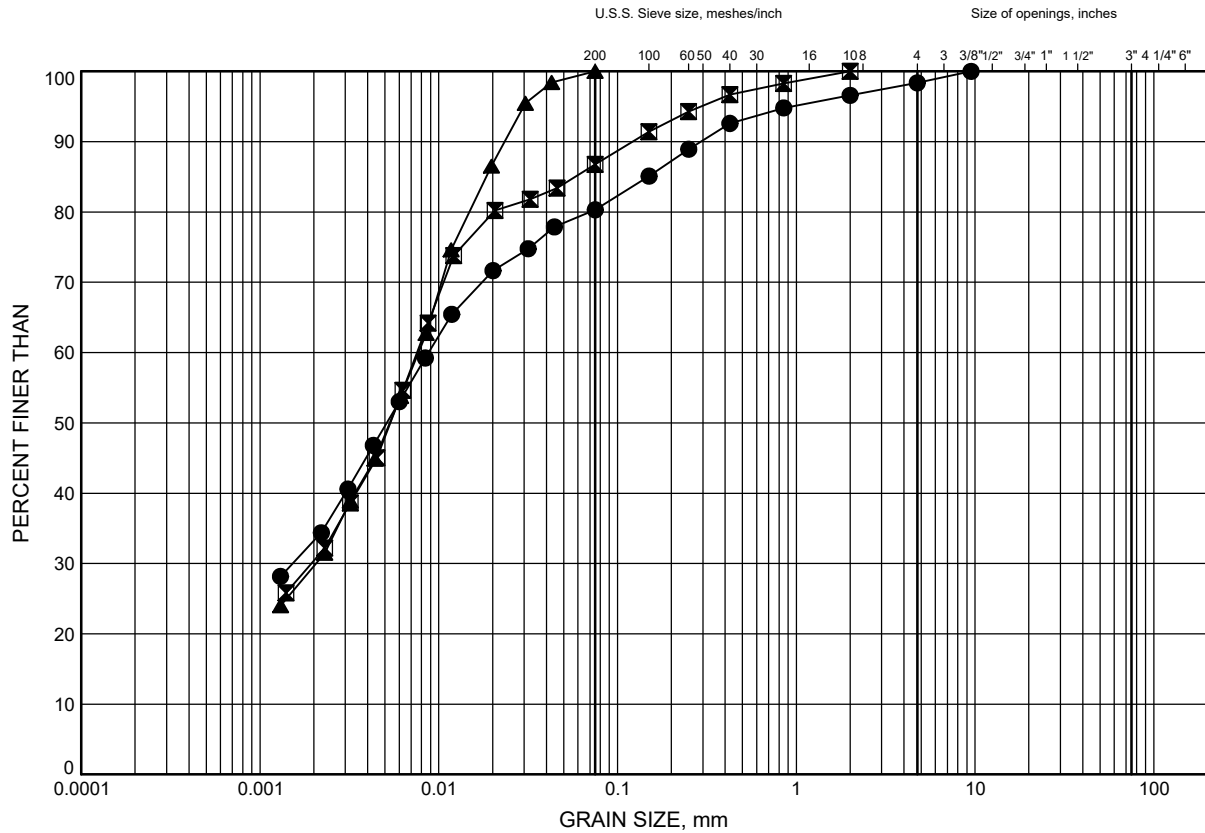
Prep'd AN
Chkd. GRL

Highway 7 & 8 Multi-Use Trail

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)
●	18-03	2.6	325.4
⊠	18-06	1.8	327.9
▲	18-07	2.6	328.5

Date April 2018
W.P.

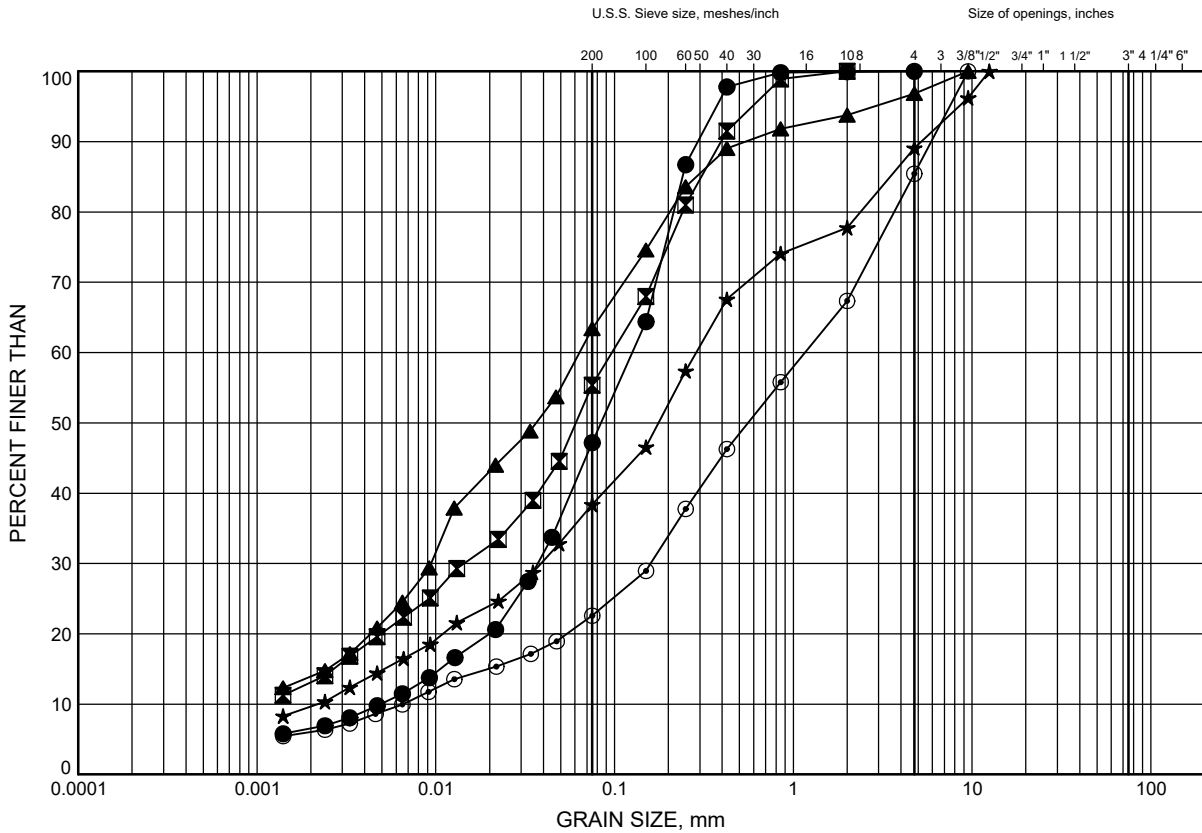


Prep'd AN
Chkd. GRL

Highway 7 & 8 Multi-Use Trail GRAIN SIZE DISTRIBUTION

FIGURE B4

Silty SAND to Sandy SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-01	1.1	330.5
⊠	18-01	3.4	328.2
▲	18-02	1.8	327.7
★	18-04	3.4	329.1
⊙	18-06	6.4	323.3

Date April 2018
W.P.

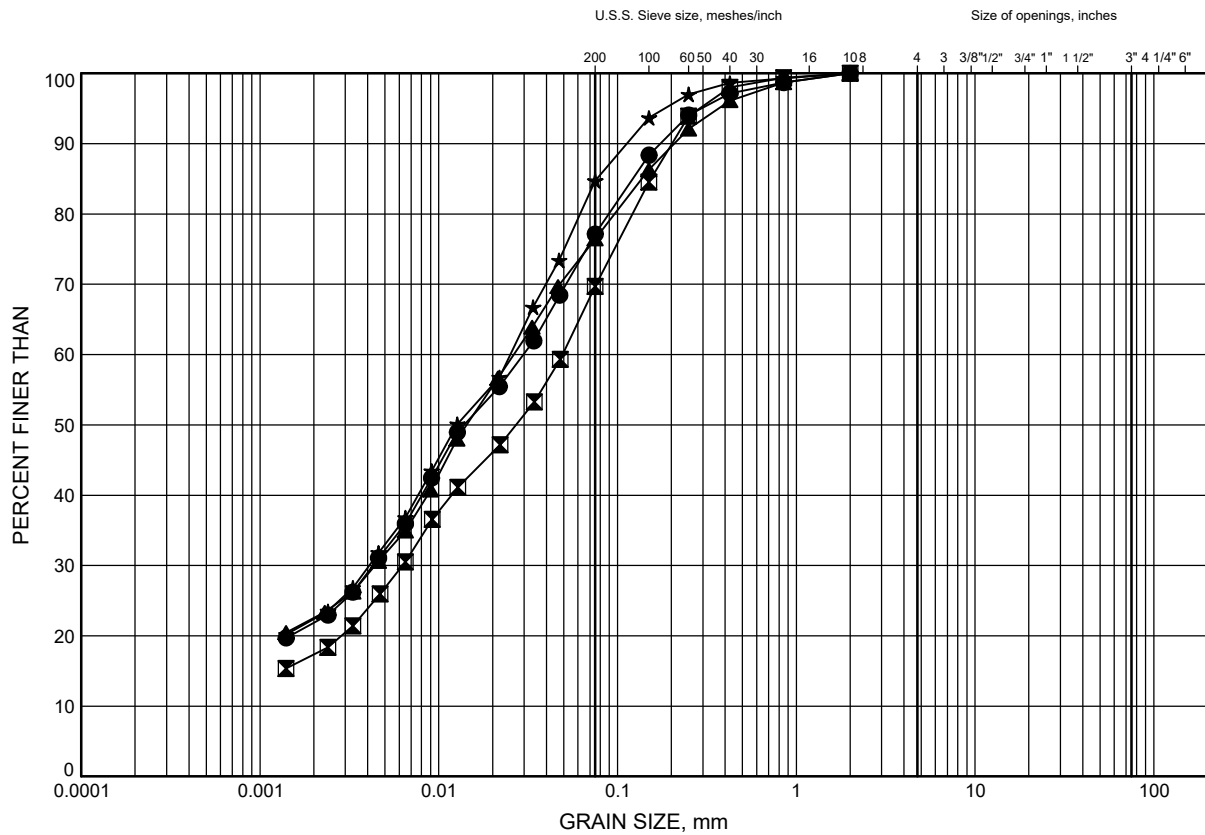


Prep'd AN
Chkd. GRL

Highway 7 & 8 Multi-Use Trail GRAIN SIZE DISTRIBUTION

FIGURE B5

Clayey SILT



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-03	7.9	320.1
⊠	18-04	9.4	323.1
▲	18-05	4.9	327.2
★	18-07	9.4	321.7

Date April 2018
W.P. _____



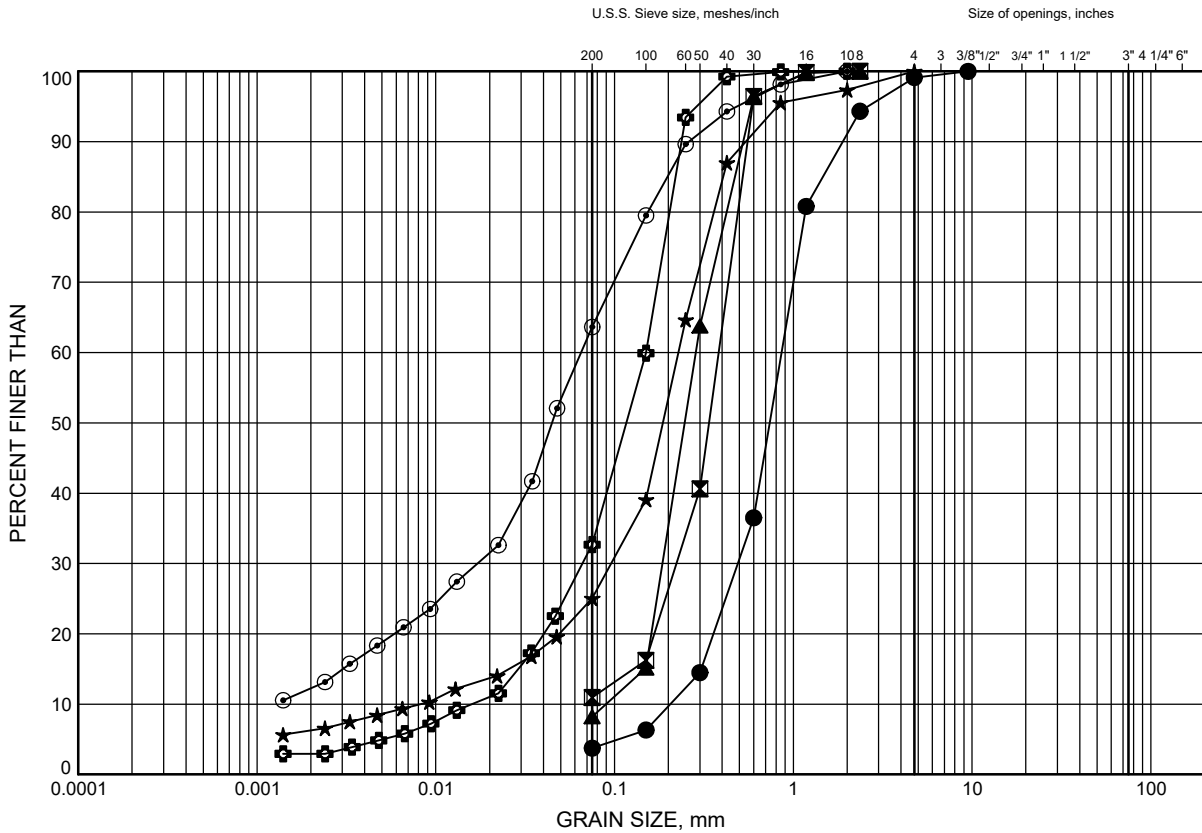
Prep'd AN
Chkd. GRL

Highway 7 & 8 Multi-Use Trail

GRAIN SIZE DISTRIBUTION

FIGURE B6

SAND to SILT and SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-01	9.4	322.2
⊠	18-02	7.9	321.6
▲	18-03	18.6	309.4
★	18-04	17.1	315.4
⊙	18-04	24.7	307.8
⊕	18-05	11.0	321.1

Date April 2018
W.P.

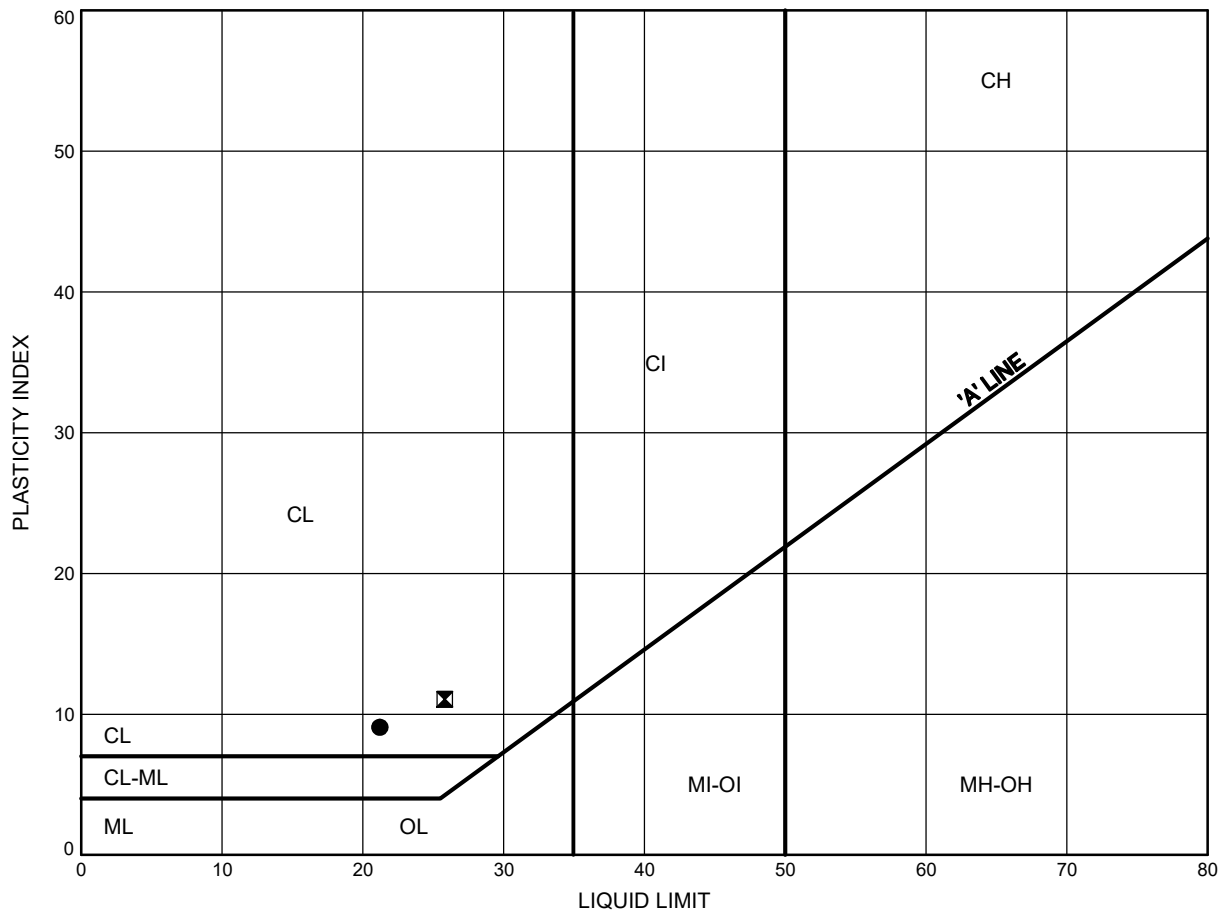


Prep'd AN
Chkd. GRL

Highway 7 & 8 Multi-Use Trail ATTERBERG LIMITS TEST RESULTS

FIGURE B7

Silty CLAY



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-03	2.6	325.4
⊠	18-06	1.8	327.9

Date April 2018
W.P.

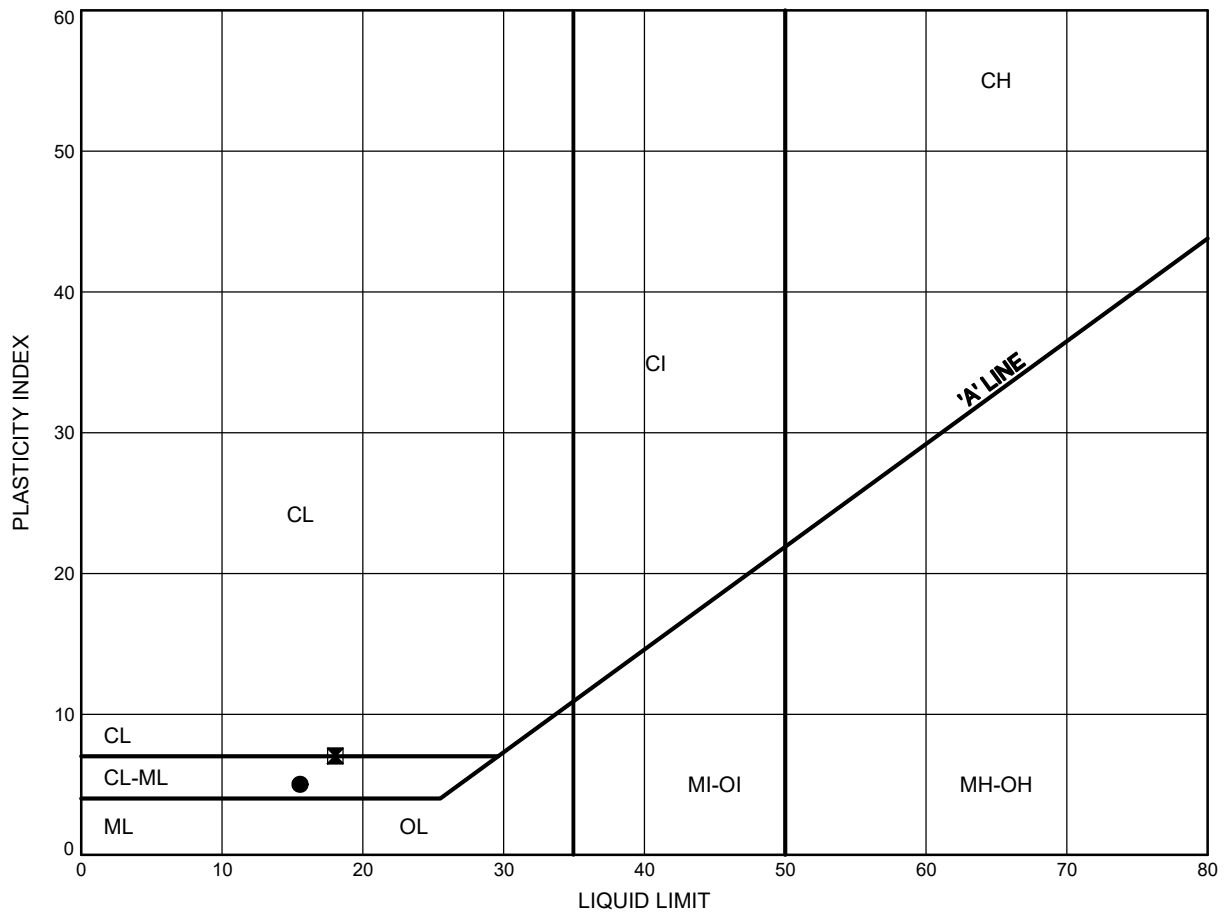


Prep'd AN
Chkd. GRL

Highway 7 & 8 Multi-Use Trail ATTERBERG LIMITS TEST RESULTS

FIGURE B8

Clayey SILT



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18-03	7.9	320.1
⊠	18-07	9.4	321.7

Date April 2018
W.P.



Prep'd AN
Chkd. GRL



Appendix C

Soil Corrosivity Analysis Results



Certificate of Analysis

AGAT WORK ORDER: 18T315954

PROJECT: Highway 7&8 Multi-Use Trail 17844

5835 COOPERS AVENUE
MISSISSAUGA, ONTARIO
CANADA L4Z 1Y2
TEL (905)712-5100
FAX (905)712-5122
<http://www.agatlabs.com>

CLIENT NAME: THURBER ENGINEERING LTD

ATTENTION TO: Geoff Lay

SAMPLING SITE:

SAMPLED BY:

Corrosivity Package

DATE RECEIVED: 2018-03-01

DATE REPORTED: 2018-03-09

		SAMPLE DESCRIPTION:		18-03 SS#2	18-03 SS#7	18-04 SS#3	18-07 SS#2
		SAMPLE TYPE:		Soil	Soil	Soil	Soil
		DATE SAMPLED:		2018-02-20	2018-02-20	2018-02-14	2018-02-13
Parameter	Unit	G / S	RDL	9095410	9095411	9095412	9095413
Sulfide (S2-)	%		0.05	<0.05	0.13	<0.05	<0.05
Chloride (2:1)	µg/g	NA	2	185	88	132	5
Sulphate (2:1)	µg/g		2	12	76	42	6
pH (2:1)	pH Units		NA	8.14	8.85	8.52	7.70
Electrical Conductivity (2:1)	mS/cm	1.4	0.005	0.481	0.319	0.358	0.243
Resistivity (2:1)	ohm.cm		1	2080	3130	2790	4120
Redox Potential (2:1)	mV		5	256	207	240	247

Comments: RDL - Reported Detection Limit; G / S - Guideline / Standard: Refers to Table 3: Full Depth Generic Site Condition Standards in a Non-Potable Ground Water Condition - Soil - Industrial/Commercial/Community Property Use - Coarse Textured Soils
Guideline values are for general reference only. The guidelines provided may or may not be relevant for the intended use. Refer directly to the applicable standard for regulatory interpretation.
9095410-9095413 EC/Resistivity, pH, Chloride, Sulphate and Redox Potential were determined on the extract obtained from the 2:1 leaching procedure (2 parts DI water: 1 part soil).
*Sulphide analyzed at AGAT 5623 McAdam

Certified By:

Amanjot Bhela



Appendix D

Foundation Comparison

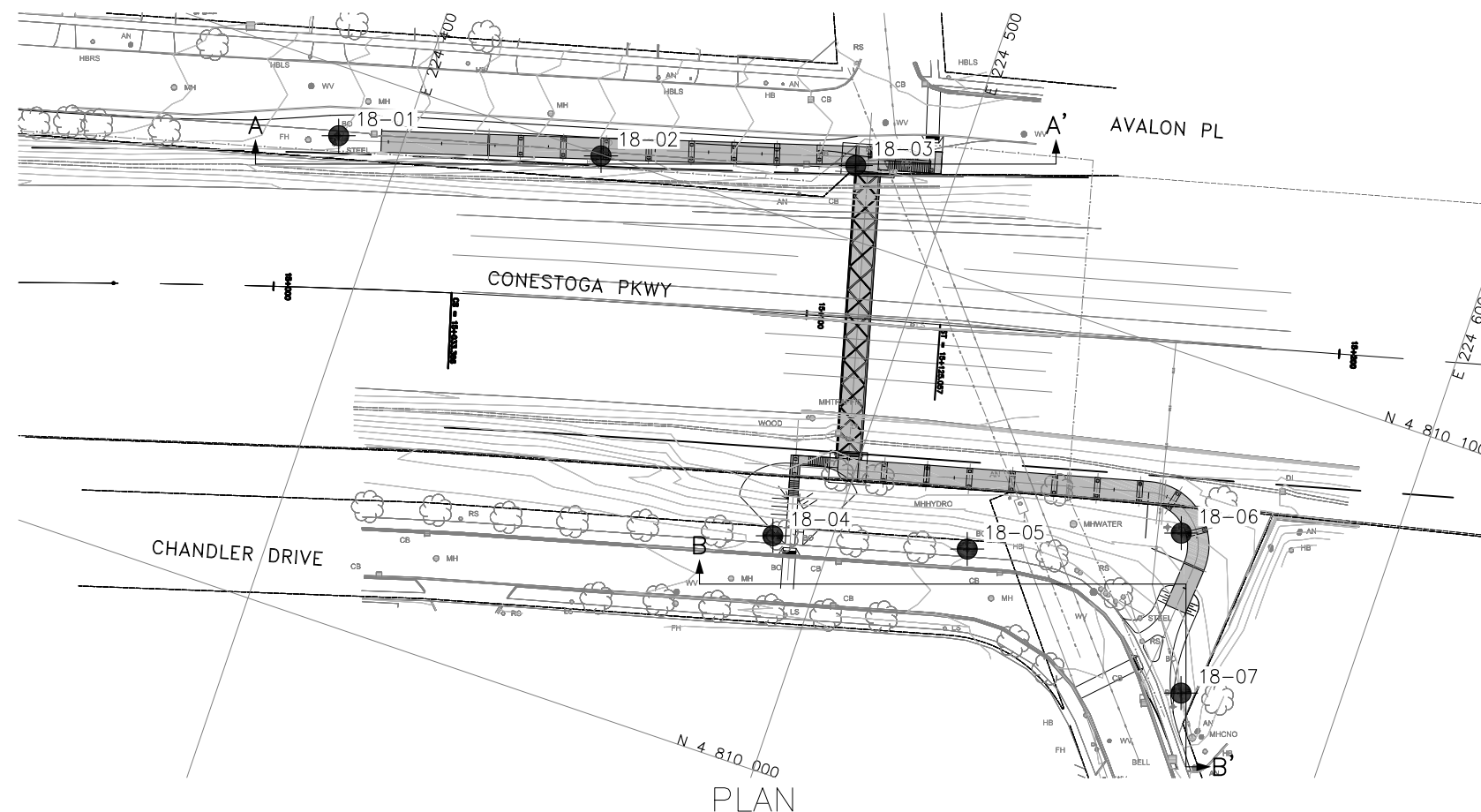
COMPARISON OF FOUNDATION ALTERNATIVES

Footings on Native Soil	Footings on Engineered Fill	Driven Piles	Caissons
<p>Advantages:</p> <ul style="list-style-type: none"> i. Ease of construction. ii. Lower cost than deep foundations. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Variable geotechnical resistance in native overburden soils. ii. Excavation must extend below existing fill materials. iii. The depth of fill materials may vary. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Ease of construction. ii. Higher geotechnical resistance than footings on native soil. iii. Generally lower cost than deep foundations. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Additional cost of engineered fill placement. ii. Additional excavation and disposal of on-site materials. iii. Potential impact on existing buried utilities. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. Higher geotechnical resistances developed by piles may decrease the required size of the foundation envelope. ii. Pile installation may continue in freezing weather. iii. Requires less excavation than footing construction. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost than footings. ii. Vibrations resulting from pile driving activities may impact adjacent utilities and nearby residents. 	<p>Advantages:</p> <ul style="list-style-type: none"> i. High resistance is available for caissons founded in the compact to very dense sand to silt and sand. ii. Construction could continue in freezing weather. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Much higher cost than shallow footings or driven piles. ii. Temporary steel liners will be required to install caissons through cohesionless soils below groundwater table. iii. Potential for base instability and hydraulic disturbance. iv. Difficulty in cleaning and inspecting bases.
RECOMMENDED	FEASIBLE	FEASIBLE	NOT RECOMMENDED



Appendix E

Borehole Locations and Soil Strata Drawing



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

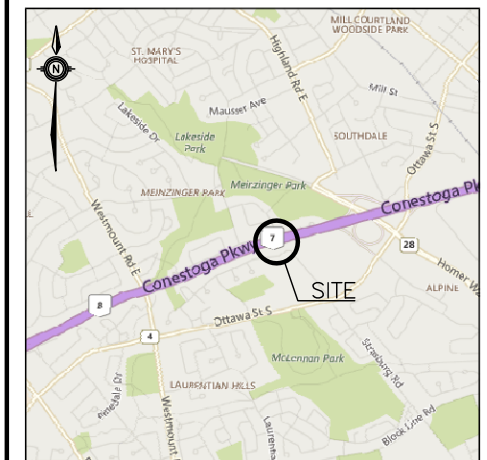
CONT No
WP No

HIGHWAY 7/8
CYCLING & PEDESTRIAN
BRIDGE
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET







THURBER ENGINEERING LTD.



KEYPLAN

LEGEND

- | | |
|---|---------------------------------------|
|  | Borehole |
|  | Borehole and Cone |
| N | Blows /0.3m (Std Pen Test, 475J/blow) |
| CONE | Blows /0.3m (60° Cone, 475J/blow) |
| PH | Pressure, Hydraulic |
|  | Water Level During Drilling |
|  | Water Level In Piezometer |
| 90% | Rock Quality Designation (RQD) |
| A/R | Auger Refusal |

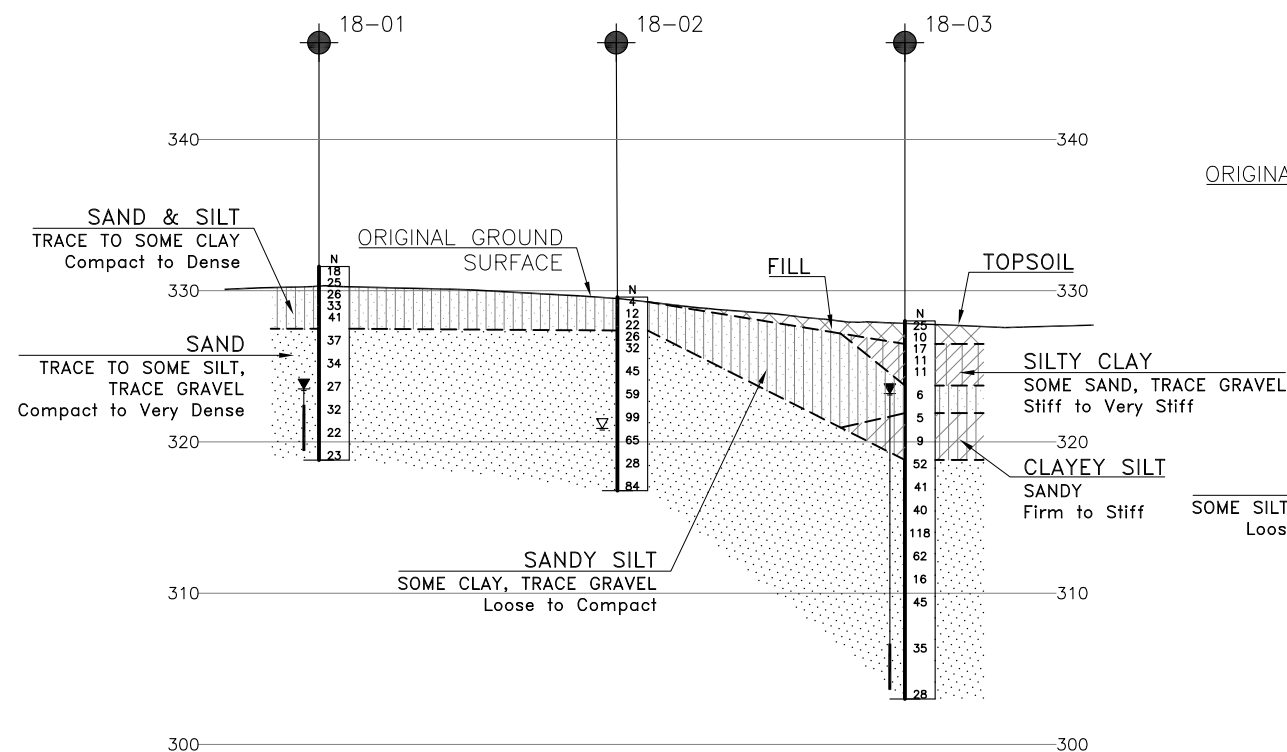
NO	ELEVATION	NORTHING	EASTING
18-01	331.6	4 810 087.5	224 388.2
18-02	329.5	4 810 099.7	224 435.9
18-03	328.0	4 810 113.4	224 481.7
18-04	332.5	4 810 042.7	224 489.3
18-05	332.1	4 810 052.1	224 524.6
18-06	329.7	4 810 067.9	224 561.6
18-07	331.1	4 810 039.5	224 571.2

-NOTES-

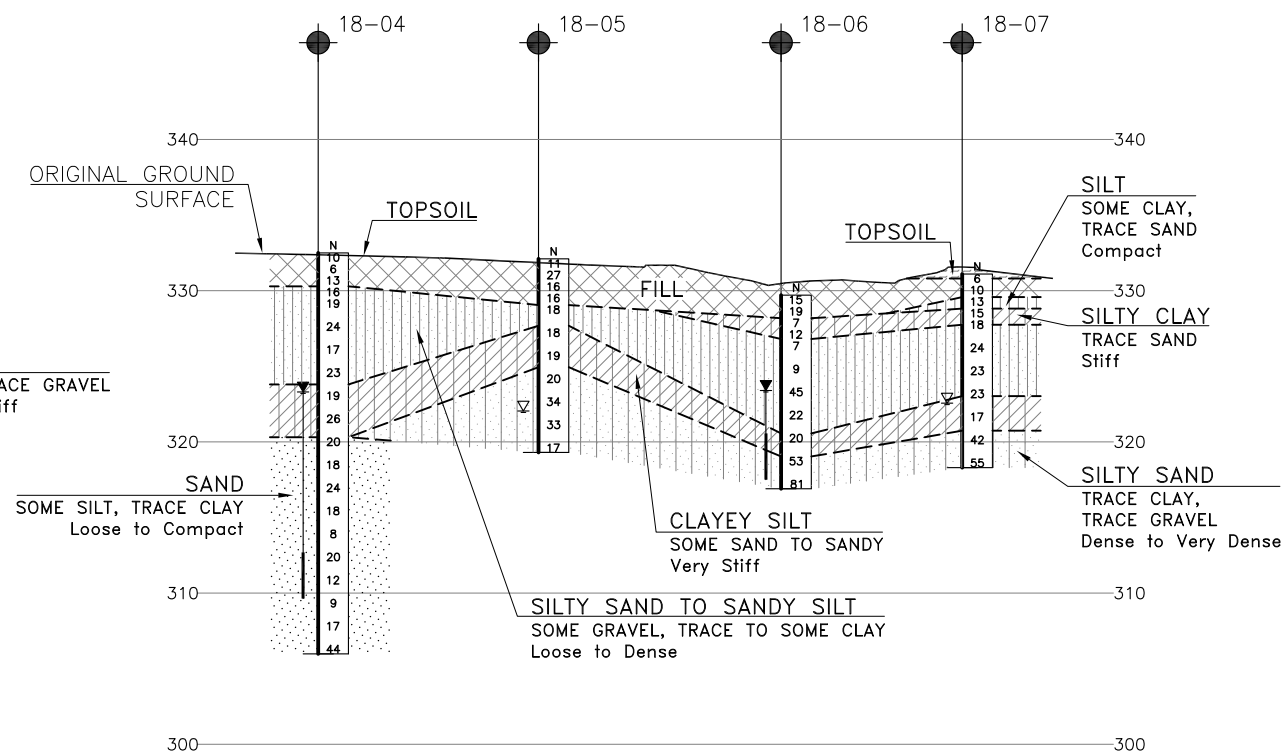
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 10.

GEOCRES No. 40P8-263

SECTION ALONG A-A'



SECTION ALONG B-B'



H 1:1250

V 1:500

REVISIONS									
	DATE	BY	DESCRIPTION						
DESIGN	GRL	CHK	MRA	CODE	LOAD	DATE	FEB 2019		
DRAWN	AN	CHK	GRL	SITE	STRUCT	DWG	1		