FOUNDATION INVESTIGATION AND DESIGN REPORT
QUEENSVILLE SIDEROAD UNDERPASS
HIGHWAY 404 EXTENSION
FROM GREEN LANE TO WOODBINE AVENUE/RAVENSHOE ROAD
ONTARIO
G.W.P. 2109-05-00

Geocres Number: 31D-449

Report to

Philips Engineering / Hatch Mott MacDonald Joint Venture

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the location of a proposed underpass carrying Queensville Sideroad over the proposed Highway 404 extension in the Regional Municipality of York, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile and cross-sections, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the present investigation.

Thurber carried out the investigation as a sub-consultant to Philips Engineering/Hatch Mott MacDonald Joint Venture under the Ministry of Transportation Ontario (MTO) Agreement Number 2007-E-0027.

In the preparation of this report and in addition to the boreholes drilled under the current assignment, reference has been made to information on subsurface conditions contained in an earlier preliminary foundation report. The title of this report is listed as follows:

- Preliminary Foundation Investigation Report, Queensville Sideroad Underpass, Highway 404 Extension from Green Lane to Highway 12/48, Agreement No. 2005-A-000585, dated October 2006, prepared by Golder Associates. Report Reference No. 04-1111-016-3 (Reference 1).

2 SITE DESCRIPTION

The site is located on the existing Queensville Sideroad, approximately 750 m west of the intersection of Queensville Sideroad and Woodbine Avenue (York Regional Road 8), in the Town of East Gwillimbury, in the Regional Municipality of York.

Currently, the topography along Queensville Sideroad, east and west of the proposed site is a rolling/undulating terrain varying in elevation as follows:

Location	Station	Elevation
West of site	9+350 to 9+625	270 to 284.9
	9+625 to 10+075	284.9 to 257.1
Proposed Hwy 404 alignment & Queensville Sideroad intersection	10+000	259.1
East of site	10+075 to 10+280	257.1 to 264.5

The site location is within a low point/valley and the natural ground surface within the valley has a relatively flat to gently rolling/undulating topography. The underpass is on the east flank of a drumlin.

A small tributary of the Maskinonge River flows through a CSP culvert under Queensville Sideroad, near Station 9+790. The tributary flows south to north.

The lands around the site are generally undeveloped and/or agricultural. Vegetation consists mainly of tall grass, shrubs and a few mature trees. There are farmsteads to the north and south of Queensville Sideroad.

The site lies within the physiographic region known as The Peterborough Drumlin Field, characterized by drumlinized till. The till is typically sandy with shallow coverings of silt and fine sand.

Photographs in Appendix H show:

1. A view looking north of Queensville Sideroad at the proposed Highway 404 location.
2. View of the site looking northwest of Queensville Sideroad over proposed west approach to the future structure.
3. A view looking south of Queensville Sideroad at the proposed Highway 404 location.
4. A view east along existing Queensville Sideroad over the future east approach and east abutment location.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out between March 11 and April 3, 2008 and consisted of drilling and sampling a total of five boreholes (numbered 08-43 to

08-47). Three boreholes (Boreholes 08-44, 08-45 and 08-46) were drilled at the foundation elements to depths ranging from 12.3 m to 23.1 m (Elevations 233.6 to 246.8 m). One borehole was drilled at each approach embankment. Termination depths for the west and east approach embankment boreholes (Boreholes 08-43 and 08-47) were 4.7 m and 27.7 m (Elevations 259.2 and 229.7 m), respectively.

The approximate borehole locations of the current and the previous investigations are shown on the Borehole Locations and Soil Strata Drawing in Appendix I. The coordinates and elevations of the current boreholes are given on the drawing and on the individual Record of Borehole Sheets in Appendix A.

Records of Boreholes 301, 301A, 302 and 303 drilled during the previous investigation (Reference 1) and their respective laboratory test results are enclosed in Appendix C.

The borehole locations were marked in the field and utility clearances were obtained prior to drilling.

Drilling was carried out using track mounted CME 75 and D90 drill rigs. A combination of solid and hollow stem auger drilling techniques were used to advance the boreholes. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils.

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 19 mm diameter PVC pipe with slotted screens were installed and enclosed in filter sand in two boreholes to permit longer term groundwater level monitoring. The locations and completion details of the piezometers are shown in Table 3.1.

Table 3.1 – Borehole Completion Details

Foundation Unit	Borehole	Piezometer Tip Depth/ Elevation (m)	Completion Details
West Approach	08-43	None installed	Borehole backfilled to surface with bentonite holeplug.
West Abutment	08-44	12.3/246.8	Sand from 12.3 m to 10.2 m. Borehole caved in from 10.2 m to 7.0 m, bentonite holeplug from 7.0 m to surface.
Pier	08-45	21.4/236.9	Sand from 21.4 m to 19.6 m, bentonite holeplug from 19.6 m to 0.3 m, cold patch from 0.3 m to surface.
East Abutment	08-46	None installed	Borehole backfilled to surface with bentonite holeplug.
East Approach	08-47	None installed	Borehole backfilled with bentonite holeplug to 0.2 m and asphalt to surface.

4 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 distribution analyses (sieve and hydrometer) and Atterberg Limits testing where appropriate. The results of this testing program are shown on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets in Appendices A and C. Details of the encountered soil stratigraphy are presented in these sheets and on the "Borehole Locations and Soil Strata Drawing" and "Stratigraphic Sections" in Appendix I. 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.

In general, the soil stratigraphy encountered across the site consists of fill of variable composition (sand, sand and gravel, silty sand and clayey silt) overlying native deposits of dense to very dense sand and silt till and silt till, and stiff to hard clayey silt till. Fill thickness ranged from 1.5 m to 4.4 m. Interbedded layers of sand, silty sand and gravelly sand were observed within the till deposits. Asphalt was encountered at the surface in boreholes drilled on Queensville Sideroad. More detailed descriptions of the individual strata are presented below.

5.1 Pavement Structure

Pavement structure consisting of approximately 125 mm to 200 mm of asphalt overlying granular (sand and gravel fill) road base was encountered in Boreholes 08-43, 08-45 and 08-47 drilled on existing Queensville Sideroad lanes and shoulders.

5.2 Fill

Fill was contacted across the site in all the boreholes. Fill was encountered below the pavement structure in Boreholes 08-43, 08-45 and 08-47 and surficially in Boreholes 08-44, 08-46 and 301 to 303. The fill generally consists of various cohesionless soil layers such as dark brown to brown sand and gravel, sand and silty sand containing some gravel, trace of silt, trace of clay and occasional wood fibres and rootlets.

Dark brown to brown clayey silt fill was contacted surficially in Borehole 08-44 and at 0.7 m (Elevation 258.3) depth in Borehole 302.

Thickness of the fill ranged from 1.5 m to 4.2 m. The fill extended to depths ranging from 1.5 m to 2.9 m (Elevations 253.8 to 261.8) at the locations of proposed west approach, both abutments and pier. At the east approach (Borehole 08-47), fill extended to depth of 4.4 m (Elevation 253.0).

SPT 'N' values recorded in the cohesionless fill (sand and gravel and silty sand) ranged from 4 to 41 blows per 0.3 m penetration indicating a loose to dense relative density. In the clayey silt fill layer, the SPT 'N' values were 2 and 6 blows per 0.3 m of penetration, indicating a soft to firm consistency. The moisture content of the fill ranged from 2% to 21%.

Grain size distribution curves for the cohesionless fill samples of the current investigation tested are presented on the Record of Borehole sheets and on Figure B1 in Appendix B. The results of the laboratory tests are summarized as follows:

Soil	(%)
Gravel	3 to 12
Sand	55 to 57
Silt	26 to 33
Clay	7

5.3 Sand

A 0.8-m thick layer of brown sand with trace silt and trace gravel was contacted at 2.2 m depth (Elevation 256.9) in Borehole 08-44.

The depth to the base of the sand was 3.0 m (Elevation 256.0).

SPT-N value measured in the sand was 34 blows per 0.3 m of penetration, indicating a dense relative density. Moisture content was 18%.

5.4 Clayey Silt

Layers of native brown clayey silt with some sand and trace gravel were encountered below the fill in Boreholes 301 to 303. The thickness of the clayey silt layer ranged from 0.7 m to 1.5m.

The depth to the base of the clayey silt layer ranges from 2.2 m to 3.7 m (Elevations 253.8 to 258.8).

SPT-N values measured in the clayey silt ranged from 5 to 11 blows per 0.3 m of penetration, indicating a firm to stiff consistency. Moisture content ranged from 11% to 25%.

Grain size distribution curves and Atterberg Limit tests results for clayey silt samples conducted during the previous investigation are presented in Appendix C.

The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Gravel	0 to 3
Sand	21 to 28
Silt	43 to 65
Clay	7 to 33

Index Property	(%)
Liquid Limit	24 to 28
Plastic Limit	13 to 17

The above results show that the clayey silt is typically of low plasticity with a group symbol of ML-CL.

5.5 Sand and Silt Till

Layers of native brown sand and silt till containing trace to some clay and trace to some gravel were observed across the site in Boreholes 08-43 to 08-46, 302 and 303 at depths and elevations as indicated in Table 5.1.

Table 5.1 – Locations of Native Sand and Silt Till

Foundation Unit	Borehole	Depth below existing ground surface (m)	Elevation (m)	Thickness (m)
West Approach	08-43	2.1 to 4.7 (borehole termination depth)	261.8 to 259.2	At least 2.6
West Abutment	08-44	3.0 to 12.3 (borehole termination depth)	256.0 to 246.8	At least 9.3
	303	3.0 to 13.9 (borehole termination depth)	258.0 to 247.1	At least 10.9
Pier	08-45	2.4 to 21.4 (borehole termination depth)*	255.8 to 236.9	At least 19.0
	302	3.0 to 18.5 (borehole termination depth)	256.0 to 240.5	At least 15.5
East Abutment	08-46	2.9 to 7.2	253.8 to 249.5	4.3

* A gravelly sand layer was intersected between 8.7 m to 11.0 m depth

Standard Penetration tests in this deposit gave SPT 'N' values ranging from 10 blows per 0.3 m of penetration to greater than 100 blows for 0.10 m of penetration, indicating that the soil was in compact to very dense state. An SPT 'N' value measured at 3.1 m depth (Elevation 255.2) in Borehole 08-45 was 9 blows per 0.3 m of penetration, indicating a loose relative density. The high SPT 'N' values measured at the west abutment were generally encountered below Elevations 250.0 and 253.0 in Boreholes 08-44 and 303, respectively. At the pier, the high SPT 'N' values were measured below Elevations 240.0 and 243.0 in Boreholes 08-45 and 302, respectively. At the east abutment, high SPT 'N' values were encountered below Elevation 234.0. The moisture content of samples from the sand and silt till deposit varies between 5% and 18%.

Grain size distribution curves for the sand and silt till samples tested for the current investigation are presented on the Record of Borehole sheet and on Figures B2 and B3. Atterberg Limit test results are presented on Figure B9 of Appendix B.

Laboratory test results of previous investigation are presented in Appendix C.

The results of the laboratory tests are summarized as follows:

Soil Particles	**(%)**
Gravel	0 to 32
Sand	28 to 50
Silt	35 to 54
Clay	5 to 17

Index Property	**(%)**
Liquid Limit	12 to 19
Plastic Limit	9 to 11

The above results show that the clayey zone in the sand and silt till are typically of low plasticity with group symbols of CL-ML.

Although not encountered in the boreholes, glacial tills inherently contain cobbles and boulders which may account for some high blow counts and resistance to augering.

5.6 Gravelly Sand

A layer of grey gravelly sand was contacted in Borehole 08-45 at 8.7 m depth (Elevation 249.6), within the sand and silt till deposit.

The layer was 2.3 m thick. The depth to the base of the gravelly sand was 11.0 m (Elevation 247.3).

SPT-N values measured in the gravelly sand layer were 49 blows per 0.3 m of penetration and 100 blows per 0.1 m of penetration, indicating a dense to very dense relative density. The moisture content ranged from 9% to 11%.

Grain size distribution curve for a gravelly sand sample tested is presented on the Record of Borehole sheets and on Figure B4. The results of the laboratory test are summarized as follows:

Soil Particles	Gravelly Sand (%)
Gravel	22
Sand	71
Silt & Clay	7

5.7 Clayey Silt Till

Layers of native brown to grey clayey silt till containing some sand to sandy and trace gravel were observed in Boreholes 08-46, 08-47, 301 and 301A, drilled at the east abutment and east approach, at depths and elevations indicated in Table 5.2.

Table 5.2 – Depths and Elevations of Native Clayey Silt Till

Foundation Unit	Borehole	Depth below existing ground surface (m)	Elevation (m)	Thickness (m)
East Abutment	08-46	7.2 to 10.3 11.8 to 23.1 (borehole termination depth	249.5 to 246.4 244.9 to 233.6	3.1 At least 11.3
	301	3.7 to 9.6 11.6 to 15.7	253.8 to 247.9 245.9 to 241.8	5.9 At least 4.1
	301A	12.2 to 17.1	243.8 to 238.9	4.9
East Approach	08-47	4.4 to 21.8	253.0 to 235.6	17.4

Standard Penetration tests in these deposits gave SPT 'N' values ranging from 11 to 77 blows per 0.3 m of penetration, indicating a stiff to hard consistency. SPT 'N' values of 149 and 160 blows per 0.275 m of penetration were measured in Boreholes 08-46 and 08-47 at 23.1 m and 6.1 m depth (Elevations 233.6 and 251.3). The moisture content of samples from this deposit varies between 10% and 18%.

Grain size distribution curves for the samples tested for the current investigation are presented on the Record of Borehole sheet and on Figures B5 and B6. Atterberg Limit test results are presented on Figure B10 of Appendix B.

Laboratory test results of previous investigation are presented in Appendix C.

The results of gradation and Atterberg Limit Tests conducted on samples of clayey silt till are summarized below:

Soil Particles	(%)
Gravel	0 to 4
Sand	11 to 36
Silt	47 to 70
Clay	13 to 23

Index Property	(%)
Liquid Limit	12 to 20
Plastic Limit	10 to 19

The above results show that the clayey silt till is typically of low plasticity with a group symbol of ML-CL.

Although not encountered in the boreholes, glacial tills inherently contain cobbles and boulders which may account for some high blow counts and resistance to augering.

5.8 Silty Sand

Layers of native brown to grey silty sand were encountered within clayey silt till in Boreholes 08-46 and 301 (east abutment) and below the clayey silt in Borehole 303. Thickness of the silty sand layers ranged from 0.8 m to 2.0 m.

The depths to the base of the silty sand were 3.0 m, 11.6 m and 11.8 m (Elevations 258.0, 245.9 and 244.9) in Boreholes 303, 301 and 08-46, respectively.

SPT-N values measured in the silty sand ranged from 10 to 33 blows per 0.3 m of penetration, indicating a compact to dense relative density. Moisture content ranged from 10% to 18%.

Grain size distribution curve for a silty sand sample tested for the current investigation is presented on the Record of Borehole sheet and on Figure B7. The results of the laboratory test are summarized as follows:

Soil Particles	(%)
Gravel	0
Sand	64
Silt	31
Clay	5

5.9 Silt Till and Silt

Grey silt till containing trace of gravel, sand and clay was encountered in Borehole 08-47 at 21.8 m depth (Elevation 235.6), extending to borehole termination depth, 27.7 m (Elevation 229.7).

Grey silt layer with interlayered clayey silt was contacted in Borehole 301A at 17.1 m depth (Elevation 238.9), extending to borehole termination depth.

SPT 'N' values ranging from 59 to higher than 100 blows for under 0.1 m penetration were measured within the silt and silt till layer, indicating a very dense relative density.

The natural moisture content of samples recovered from the silt till and silt layers were 17% to 21%.

Grain size distribution curve for silt and silty till samples tested for the current investigation are presented on the Record of Borehole sheets and on Figure B8.

Laboratory test results of previous investigation are presented in Appendix C.

The result of the laboratory tests are summarized below:

Soil Particles	**(%)**
Gravel	0
Sand	1 to 2
Silt	89 to 92
Clay	6 to 10

Index Property	**(%)**
Liquid Limit	19 to 28
Plastic Limit	15

The above results show that the clayey zone in the silt till and silt are typically of low plasticity with group symbols of CL-ML.

5.10 Water Levels

Water levels were observed in the boreholes during and upon completion of drilling. Standpipe piezometers were installed in two boreholes during the current investigation to monitor water levels after completion of drilling. The water levels measured in the piezometers are summarized in Table 5.3, along with the measurements in the boreholes upon completion of drilling.

Table 5.3 – Water Level Measurements

Foundation Unit	Borehole	Date	Water Level (m)		Comment
			Depth	Elevation	
West Approach	08-43	March 28, 2008	4.1	259.8	Open borehole
West Abutment	08-44	April 18, 2008 June 30, 2008 July 29, 2008 October 24, 2008 March 20 , 2009 April 22, 2009 May 15, 2009 June 5, 2009 July 10, 2009	1.4 2.1 1.9 1.1 0.5* 0.5* 0.5 1.0 2.1	257.7 257.0 257.2 258.0 259.6* 259.6* 258.6 258.1 257.0	In piezometer
	303	September 29, 2004	9.1	251.9	Open borehole
Pier	08-45	April 18, 2008 April 21, 2008	2.4 2.4	255.9 255.9	In piezometer
	302	September 29, 2004	10.7	248.3	In piezometer
East Abutment	08-46	March 18, 2008	0.9	255.8	Open borehole
	301	June 11, 2004	4.9	252.6	Open borehole
	301A	September 28, 2004 October 7, 2004	2.7 0.7*	253.3 256.7*	In piezometer
East Approach	08-47	March 11, 2008	2.6	254.8	Open borehole

Water level above ground surface (artesian condition)

The piezometric readings of the current investigation indicate that the groundwater level is high and the water level decreases from west to east from Elevations 257.0 to 255.9.

At the location of Borehole 08-44, during the winter season, a relatively low artesian head was encountered at 0.5 m (Elevation 259.6) above the ground surface.

Previous geotechnical investigation (Reference 1) indicates that a relatively low artesian head was encountered in Borehole 301A, where water level was measured at 0.7 m (Elevation 256.7) above the ground surface.

The above values 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 the spring snowmelt or after periods of heavy rainfall.

6 MISCELLANEOUS

Borehole locations were selected by Thurber Engineering Ltd. Surveyors from J. D. Barnes obtained the co-ordinates and the ground surface elevations at each borehole.

Thurber obtained utility clearances for the borehole locations prior to drilling.

DBW Drilling of Ajax Ontario supplied track mounted CME 75 and D90 drill rigs and conducted the drilling, sampling and in-situ testing operations.

The field program was supervised on a full time basis by Ms. Eckie Siu of Thurber.

Routine laboratory testing was carried out by Thurber Engineering Ltd.

Overall supervision of the field program was conducted by Mr. Alastair E. Gorman, P.Eng. and Mr. Weiss Medhawi, P.Eng. Interpretation of the data and preparation of the report were carried out by Mr. Alastair E. Gorman, P.Eng and Ms. R. Palomeque Reyna, 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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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical design recommendations to assist the design team to select and design a suitable foundation system and approach embankments for the proposed underpass structure.

It is understood that the proposed underpass is to carry Queensville Sideroad over the extension of Highway 404 located in the Regional Municipality of York, Ontario.

The natural ground surface at the structure site slopes downward from west to east from approximate Elevations 263.0 m to 257.0 m.

Based on the preliminary General Arrangement (GA) drawing provided by Hatch Mott MacDonald, a two-span structure supported on two abutments and one pier is proposed. The west and east spans will be 42.0 m long. The bridge is approximately 26.3 m wide at the west abutment and 30.1 m wide at the east abutment. It is understood that the finished grade level of Highway 404 will be at about Elevations 264.0 to 265.0 m, and the existing ground surface within the limits of underpass structure varies from Elevations 259.0 to 256.7. As such, Highway 404 embankment will be about 6.0 m to 8.3 m high relative to the surrounding grade.

The proposed finished grade of Queensville Sideroad at the structure will be about Elevation 274.0 m at the west abutment and the original ground surface is near Elevation 259.1 m, resulting in an approach embankment of 14.9 m high. At the east abutment, the finished grade will be at Elevation 271.7 m and the original ground surface is at about Elevation 256.7 m, resulting in an approach embankment up to 15.0 m high.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigations.

8 STRUCTURE FOUNDATIONS

The stratigraphy encountered at the abutments and pier locations consist of pavement structure and/or fill overlying extensive deposits of native sand and silt till, clayey silt till and silt till. Interbedded layers of sand, silty sand and gravelly sand were observed within the till deposits.

The piezometric readings indicate that water level is high at this site and the water level varies from west to east from Elevations 257.0 to 255.9, and as a result most of the overburden sands, silts and clayey silt tills are below the groundwater level. Artesian conditions were encountered during previous investigation near the proposed east abutment, with water level measured 0.7 m above ground surface.

Initial consideration was given to the following foundation types:

- Spread footings on native soils
- Spread footings on engineered fill
- Augered Caissons (drilled shafts)
- Driven piles

A comparison of the foundation alternatives based on advantages and disadvantages of each is included in Appendix D.

8.1 Spread Footings on Native Ground

At both abutments and at the pier, thickness of the fill varies from 1.5 m to 2.9 m. The existing fill is not considered to be suitable for the support of spread footings. Therefore it is recommended that spread footings be extended below this fill layer and bear on the underlying competent native soils.

The highest permitted founding Elevations for spread footings are given in Table 8.1.

Table 8.1 – Highest Permitted Founding Elevations

Foundation Unit	Borehole	Footing on Native Undisturbed Soil		
		Depth below existing ground surface (m)	Founding Elevation (m)	Soil
West Abutment	08-44	2.2	256.9	Dense sand
	303	4.1		Dense silty sand
Pier	08-45	5.3	253.0	Compact sand and silt till
	302	6.0		
East Abutment	08-46	5.2	251.5	Compact Sand and Silt Till
	301	6.0		Hard clayey silt till

Provided a minimum footing width of 2 m is maintained, abutments and pier footings founded on the competent native undisturbed soils at or below the elevations shown in Table 8.1, may be designed for the following values:

- Factored geotechnical resistance of 450 kPa at Ultimate Limit States (ULS)
- Geotechnical resistance of 300 kPa at Serviceability Limit States (SLS)

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 Clause 6.7.3 and Clause 6.7.4.

Elevations indicated in Table 8.1 will be in cohesionless soils 0.1 m to 4.3 m below the groundwater table and 6.0 m to 11.0 m below the proposed Highway 404 grade.

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 mass concrete poured on the native silty sand, sand and silt till and clayey silt till may be computed on the basis of an ultimate coefficient of friction of 0.55. This is an "ultimate" value and requires a degree of sliding movement to occur to fully mobilize the resistance.

The bases of the foundation excavations should be inspected by a geotechnical engineer to confirm that the exposed surface conforms to the design requirements and has been adequately prepared to receive concrete. Where subexcavation is required to remove unsuitable material from below the design founding level, the founding surface should be re-established using engineered fill or mass concrete of the same class as the footing. The engineered fill must consist of OPSS Granular "A" placed in 150 mm lifts, compacted to 100% of its SPMDD at ±2% of optimum moisture content.

Dewatering prior to footing excavation will be required to construct the footings in the dry and to prevent sloughing of the sides or disturbance of the base of the excavation due to the inflow of groundwater.

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

Spread footings are not considered to be a cost-effective and a practical alternative at this site due to the need for a relatively deep excavation required to reach competent soils. Additionally, dewatering will be required prior to footing excavation. Accordingly, spread footings on native soils are not recommended at this site.

8.2 Spread Footings on Engineered Fill

Consideration was also given to placing spread footings on engineered fill pads. The GA indicates that proposed Highway 404 grade will be at Elevation 262.5 and placement of approximately 3.5 m to 6.0 m of fill will be required to raise the current ground surface to the proposed grade.

If an engineered fill pad is used at this site, all fill or other deleterious materials must be stripped from the footprint of the engineered fill to expose competent native subgrade material. At this site, the engineered fill will bear on native compact to dense sand, silt till or stiff clayey silt and clayey silt till. The highest permitted founding elevations at which engineered fill should be placed, are given in Table 8.2.

Table 8.2 – Highest Permitted Base Elevations for Engineered Fill

Foundation Unit	Borehole	Highest Permitted Engineered Fill Base		
		Depth below existing ground surface (m)	Fill Base Elevation (m)	Soil
West Abutment	08-44	2.2	256.9	Dense sand
	303	2.2	258.8	Dense silty sand
Pier	08-45	4.3	254.0	Compact sand and silt till
	302	3.0	256.0	Compact sand and silt till
East Abutment	08-46	4.2	252.5	Compact sand and silt till
	301	4.5	253.0	Stiff clayey silt till

The engineered fill must consist of OPSS Granular "A" placed in 150 mm lifts and compacted to 100% of its SPMDD at ±2% of optimum moisture content and generally conforming to the geometry illustrated in Figure 1 in Appendix E. The thickness of engineered fill must be a minimum of 2.0 m.

Provided a minimum footing width of 2 m is maintained footings bearing on the well compacted engineered fill may be designed for the following values:

- Factored geotechnical resistance of 900 kPa at Ultimate Limit States (ULS)
- Geotechnical resistance of 350 kPa at Serviceability Limit States (SLS)

These resistance values 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 Clause 6.7.3 and Clause 6.7.4.

For footings designed on the basis of the geotechnical resistance values given above, total settlement under a footing is expected to not exceed 25 mm. Differential settlements are not expected to exceed 20 mm across the width of the structure.

The lateral resistance of the footings founded on engineered fill may be computed using an unfactored friction of 0.7. This is an "ultimate" value and requires a degree of sliding movement to occur to fully mobilize the resistance.

The highest permitted engineered fill base elevation given in Table 8.2 is 0.1 m to 3.3 m below the groundwater table on this site.

Where the temporary excavations required to construct the engineered fill pads extend below the water table, dewatering prior to excavation must be conducted to construct the fill pad and the footing in the dry and to prevent sloughing of the sides or disturbance of the base of the excavation due to the inflow of groundwater. The dewatering method adopted must depress the groundwater level to at least 0.5 m below the base of excavation and must maintain a stable, unwatered excavation throughout the duration of the fill pad and footing construction. Dewatering must remain operational and effective until the footing is constructed and backfilled or until the engineered fill pad is completed to a level at least 0.5 m above the groundwater level.

Due to the required depth of excavation and associated dewatering requirements, the use of engineered fill to support footings is not recommended at this site.

8.3 Augered Caissons (Drilled Shafts)

Augered caisson foundations were also considered for the support of the structure. However, augered caissons (drilled shafts) are not recommended for use as foundation support at this site due to artesian and high water level conditions at the site, and potential caisson installation difficulties through a deep deposit of water bearing largely granular till deposit.

8.4 Driven Piles

The subsurface conditions at this site are considered suitable for the design of foundations supported on driven steel H-piles. The results of the investigation indicate that driven H-piles at the abutments and at the pier will develop geotechnical resistance in the very dense sand and silt till and in the hard clayey silt till.

The Elevations at which the piles are expected to develop the required resistance are given in Table 8.3.

Table 8.3 – Estimated Pile Tip Elevation

Foundation Unit	Borehole	Anticipated Pile Tip Elevation To Develop Required Resistance	Anticipated Pile Length below original ground (m)	Anticipated Founding Material
West Abutment	08-44	248.5	10.6	Very dense sand and silt till
	303	251.5	9.5	
Pier	08-45	237.8	20.5	
	302	242.0	17.0	
East Abutment	08-46	232.0	24.7	Hard clayey silt till
	301A	235.5	20.5	Very dense silt and hard clayey silt

The pile tip Elevations shown in Table 8.3 should be used for estimating purposes only. The actual pile tip Elevations will be controlled as described in Section 8.4.4 Pile Driving.

8.4.1 Axial Resistance

The vertical, factored geotechnical resistances at Ultimate Limit States (ULS) and geotechnical resistances at Serviceability Limit States (SLS) for two pile sections when driven into the very dense/hard glacial till soils are presented in Table 8.4.

Table 8.4 – Axial Resistance of Pile Sections Founded on Very Dense/Hard Glacial Till Soils

Foundation Unit	Borehole	Pile Section			
		HP 310 x 110		HP 360 x 174	
		ULS (Factored) (kN)	SLS (kN)	ULS (Factored) (kN)	SLS (kN)
West Abutment	08-44 303	1,600	1,400	1,800	1,600
Pier	08-45 302				
East Abutment	08-46 301A				

8.4.2 Pile Tips

Due to the possible presence of cobbles and boulders in the glacial till layers at the expected founding levels, the tips of all driven piles should be fitted with steel H-Pile driving shoes in accordance with OPSD 3000.100.

8.4.3 Pile Installation

Pile installation must be in accordance with Special Provision No. 903S01.

The Contract Documents must contain a NSSP alerting the Bidders to:

- The presence of cobbles and boulders in the expected bearing stratum.
- The possibility of piles within a group achieving the specified resistance at different elevations.
- The possibility of some piles meeting refusal on a large boulder.

Suggested texts for the NSSP's are included in Appendix F.

8.4.4 Pile Driving

Pile driving must be controlled by the Hiley Formula and an ultimate pile resistance to be specified by the designer in accordance with Clause 3.3.2 (b) Construction Stage of the Structural Manual. The Hiley formula need not be used until the piles are approaching the bearing stratum below Elevation 254.0 m at the west abutment and Elevations 244.0 and 238.0 at the pier and at the east abutment, respectively. 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 the minimum values shown in Table 8.5.

Table 8.5 – Ultimate Geotechnical Resistance of Piles

Pile	Ultimate Resistance (R) (kN)
HP 310x110	3,200
HP 360x174	3,600

The NSSP should require the QVE to terminate driving before the pile is damaged by overdriving.

To facilitate pile installation, embankment fill through which piles will be driven must not contain oversize material, i.e. no particles exceeding 75 mm in size.

Borehole 301A drilled during the previous investigation, show water level 0.7 m above ground surface, elevation 256.7 (artesian condition). Artesian pressure has the potential to cause flow up the pile shaft, with accompanying loss of fines.

At this site, however, Highway 404 will be constructed on a 6.0 m to 8.3 m high embankment and piles will be driven through this embankment and approach fills. Since these fills will be above the artesian water elevation, no upward flow around the piles due to artesian pressure is anticipated.

8.4.5 Downdrag

Downdrag on the piles is not considered to be an issue at this site.

8.4.6 Integral Abutment Considerations

The subsurface conditions at this site are considered suitable for an integral abutment design. The use of H-piles at the abutments allows for the design of an integral abutment structure.

After each pile is driven, the space between the pile and the CSP should be filled with sand. An NSSP must be included in the contract drawings specifying the gradation of the sand according to Table 8.6.

Table 8.6 – Integral Abutment Sand Grading

MTO Sieve Designation		Percentage Passing
2 mm	#10	100%
600 µm	#30	80%-100%
425 µm	#40	40%-80%
250 µm	#60	5%-25%
150 µm	#100	0%-6%

8.4.7 Lateral Resistance

For the cohesionless soils encountered, the lateral resistance of the pile may be calculated using a value for the coefficient of horizontal subgrade reaction (k_s) and ultimate lateral resistance (p_{ult}) as follows:

$$k_s = n_h . z / D \quad (kN/m^3)$$

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

where z = depth of embedment of pile in metres

D = pile width in metres

n_h = value from Table 8.8

γ = unit weight (Table 8.8)

K_p = passive earth pressure coefficient (Table 8.8)

The lateral resistance of the piles for 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:

$$k_s = 67*S_u/D \quad (kN/m^3)$$

p_{ult} = $9*S_u$ (kPa) at and below a depth of 3*D (m) reduced to zero at the ground surface

where

D = pile width in metres

S_u = undrained shear strength (kPa) (Table 8.8)

The above equations and recommended parameters may be used to analyze the interaction between a pile and the surrounding soil. The lateral pressures obtained from the analysis should not exceed the ultimate lateral resistance.

The spring constant, K, for analysis may be obtained by the expression, $K = k_s*L*D$ (kN/m), where k_s is the coefficient of horizontal subgrade reaction (kN/m^3), 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 on any one segment of pile, P_{ult}, may be obtained from the expression, $P_{ult} = p_{ult}*L*D$. This represents the ultimate load at which the pile fails and will not support any additional lateral load at greater displacements. It is recommended, however, that the total lateral resistance in one pile be limited to no more than 150 kN at ULS and 50 kN at SLS. Parameters for lateral pile resistance are shown in Table 8.7.

Table 8.7 – Parameters for Lateral Pile Resistance

Location	Elevation	n_h (kN/m^3)	S_u kPa	K_p	Unit Weight (kN/m^3)	Soil Conditions
West Abutment	OGL to 257.0	2,200	-	3.0	21	Clayey silt and compact sand fill
	257.0 to 251.5	8,000	-	3.3	11*	Sand and silt till, dense
	Below 251.5	10,000	-	3.7	11*	Sand and silt till, very dense
East Abutment	OGL to 253.8	1,500	-	3.0	11*	Sand Fill, loose to compact
	253.8 to 249.5	4,000	-	3.2	11*	Sand and silt till, compact to very dense
	249.5 to 233.6	-	150	3.0	10*	Very stiff to hard clayey silt till
	Below 233.5	-	200	3.3	10*	Hard clayey silt till

*Buoyant unit weight below the water table.

Pile interaction should be considered with reference to CHBDC Clause 6.8.9.2.

For lateral soil/pile group interaction analysis, the modulus of subgrade reaction (k_s) may have to be reduced based on the pile spacing.

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

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

THURBER

* D 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 for k_s by a reduction factor R as follows:

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

Intermediate values may be obtained by interpolation.

For conventional abutments, the lateral resistance may be provided by battered piles.

8.5 Recommended Foundation

From a geotechnical perspective, and based on current information, it is recommended that foundations for the bridge structure (abutments and pier) be supported on steel H-piles driven into the very dense/hard glacial till soil.

8.6 Frost Cover

The design depth of frost penetration at this site is 1.4 m.

Frost protection should be provided for the undersides of all foundation elements and should consist of a minimum of 1.4 m of soil cover, or an equivalent combination of soil cover and extruded polystyrene (EPS) insulation. A 25 mm thickness of EPS is equivalent to 600 mm of soil cover.

9 RETAINED SOIL SYSTEMS

If Retained Soil System (RSS) walls are incorporated in the design, the soil conditions encountered at the site are considered suitable for the support of RSS walls at the east and west approaches/abutments. Details of RSS walls were not provided at the time of preparation of this report.

The borehole information indicates that the foundation conditions at the possible RSS wall locations comprised approximately 1.5 m to 4.4 m of very loose to dense silty sand, sand and granular fill and soft clayey silt fill overlying native compact to very dense sand and silt till and very stiff to hard silty clay till.

The RSS walls should be specified to be "High Performance" and "High Appearance". The contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

The performance of a RSS is dependent on, among other factors, the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS and, in severe cases, to possible failure of the system. It is critical that the RSS walls are not subject to settlement due to compression of the foundation soils and embankment fill. The foundation of the entire RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

To provide an acceptable foundation performance, the RSS mass must be founded on the native undisturbed soils. The highest base levels for the underside of the wall and the soil type at the base levels are indicated in Table 9.1.

Table 9.1 – Maximum Elevation at Underside of Wall Base or Granular A Fill

Foundation Element	Borehole	Depth (m)	Elevation (m)	Soil
West	303	2.2	258.8	Dense silty sand
	08-43	2.1	261.8	Compact sand and silt till
	08-44	2.2	256.9	Dense sand
East	301	3.7	253.8	Stiff clayey silt till
	08-46	3.7	253.0	Compact sand and silt till
	08-47	4.4	253.0	Very stiff clayey silt till

A RSS wall founded on native compact sand and silt till, dense silty sand/sand or stiff to very stiff silty clay till at or below elevations shown in Table 9.1 should be designed for a factored bearing resistance of 300 kPa at ULS and a bearing resistance of 200 kPa at SLS.

Alternatively, the RSS may be founded on engineered fill founded on the native soils contacted at the above elevations. Engineered fill placed under the RSS mass to achieve the design founding level should consists of OPSS Granular "A" compacted to 100% of its SPMDD at a moisture content within 2% of optimum. The engineered pad must extend at least 500 mm beyond the limits of the RSS mass and levelling strip.

The geotechnical resistances provided above are for concentric, vertical loading. The effects of load inclination and eccentricity need to be taken into account according to the CHBDC 2006 Section 6.7.

The entire block of reinforced earth must be designed against various modes of failure including sliding and overturning. Sliding resistance along the base of the wall on engineered granular fill may be estimated using an ultimate friction coefficient of 0.55. For an RSS block founded on native cohesive or cohesionless soils, coefficient of sliding friction of 0.45 may be used.

Topsoil, loose fill, and any soft/wet native material should be stripped from the footprint of the RSS. The native soil under the RSS foundation should be proofrolled to detect and replace any soft areas.

The supplier of the proprietary RSS system must demonstrate that it will meet the Ministry's specifications for performance and appearance. The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for this site.

If a RSS wall system is selected, the global stability must be analyzed after the location of the wall is known. The global stability of the RSS wall is dependent on the characteristics of the embankment fill and the foundation soils, the geometry of the embankment and location of the RSS within the embankment. Global stability should not be a concern for a RSS wall founded on the native soils at this site.

10 EXCAVATION

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the fill is classed as Type 3 above the water table and Type 4 below the water table. The native soils within the probable depth of excavation at this site may be classed as Type 2 soils above the water table.

However, excavation of the cohesionless native foundation soils below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause boiling and sloughing of the soil below the water table making it difficult to maintain a dry, sound base on which to work.

Prior to excavation below the natural groundwater level, the groundwater must be depressed to a level below the deepest excavation level sufficient to maintain a stable base and prevent soil disturbance by construction traffic.

The excavation of the cohesionless foundation soils and backfilling for foundations must be carried out in accordance with SP 902S01.

Bidders must be alerted to the fact that excavation must be carried out through till soils, which may include cobbles and boulders.

11 UNWATERING

Piezometers installed in boreholes revealed that the groundwater level is near elevations ranging from 255.9 to 257.0. However, seepage may be experienced from perched zones in the granular fill, or from sand and silt pockets/lenses in the underlying heterogeneous till deposits.

If spread footings are the selected design for foundations, it is anticipated that excavation will extend below groundwater table and dewatering to lower the groundwater level below the footing excavation base will be required prior to start of footing excavation. The Contractor should also be prepared to pump from sumps to remove any remaining seepage water or surface water collecting in an excavation. Placement of concrete or compacting granular engineered fill must be done in the dry. Unwatering must remain operational and effective until the footing is constructed and 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 and the need to engage a dewatering specialist. While the responsibility for dewatering remains with the Contractor, suitable systems that might be employed for shallow excavations below water table, include pumping from filtered sumps. Possible use of vacuum wellpoints will be required for deeper excavations penetrating more than 0.5 m below the groundwater level.

12 APPROACH EMBANKMENTS

Approach embankment construction using either earth fill or SSM is feasible on the foundation soils encountered at this site. At the west abutment, settlement in the order of 60 mm is estimated in the foundation soils under the loading imposed by approximately 15.0 m of the approach fill. Due to the non cohesive nature of the foundation soils, these settlements will be immediate and essentially completed when construction of the fill is completed. However, it is recommended that the approach embankments be constructed at least one month in advance of pile driving in order to reduce the possible horizontal displacement of piles.

Post construction settlement of the fill mass is estimated to be as high as 0.5% of the embankment height, approximately 70 mm. Based on the above settlement estimates, it is considered prudent to overbuild the approach embankment to account for a total settlement of 150 mm.

The global, internal and surficial stability of the approach embankment fills will depend on the slope geometry and also to a large degree on the material used to construct the embankments. Embankments constructed using granular material, select subgrade material or non-cohesive earth fill will have stable side slopes at inclinations of up to 2H:1V.

For the purpose of embankment stability analyses, the commercially available slope stability program GSLOPE developed by Mitre Software Inc. was used. The Bishop's simplified method for stability analysis was employed.

Global stability analyses were conducted for 2H:1V SSM or earth fill embankments. The stability of the embankments was also checked under seismic loading assuming an acceleration of 0.08g. The computed factors of safety are as shown in Table 12.1. Slope stability computation outputs are included in Appendix G.

Table 12.1 Computed Factors of Safety

Location / Material	Condition	Factor of Safety	Figure (Appendix G)
West and East Approaches – 15 m high embankment			
Earth Fill	Normal	1.5	1
Earth Fill	Seismic = 0.08g	1.2	2

In the case of normal loading, the factor of safety against global failure was 1.5. Under the assumed seismic loading, the minimum factor of safety calculated was 1.2. These factors of safety are considered to be acceptable for the proposed embankment bearing on non-cohesive soil.

It is recommended that all topsoil or deleterious material be stripped prior to constructing the approach fills. Embankment construction should be in accordance with OPSS 206, as amended by Special Provision "Amendment to OPSS 206, December 1993", dated November 2002.

Where earth fill embankments are higher than 8 m, mid-height berms should be incorporated in each 8 m vertical interval. The berms should:

- extend for the length through which the embankment height exceeds 8 m
- be at least 2 m wide
- have 2% positive grade to shed run-off water.

Earth fill embankment slopes must be provided with erosion protection in accordance with OPSS 572.

13 BACKFILL TO ABUTMENTS

In the case of integral or semi-integral abutments, backfill to the abutment must be granular material.

In the case of a conventional abutment, granular backfill is recommended.

The backfill to the abutment walls must be in accordance with OPSS 902 as amended by Special Provision 902S01. Granular backfill must be placed to the extents shown in OPSD 3101.150. All granular material should meet the requirements of SP 110F13 Amendment to OPSS 1010, March 1993.

Compaction equipment to be used adjacent to retaining structures must be restricted in accordance with SSP 105S10.

The design of the abutment must incorporate a subdrain as shown in OPSD 3101.150 or OPSD 3101.200, as applicable.

14 EARTH PRESSURE

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 but generally are 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 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)

In accordance with Clause 6.9.3 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.

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.

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. In the case of integral abutments, material with a lower passive pressure coefficient (e.g. Granular B Type I) might be preferred as it results in lower forces acting on the ballast wall as the wall moves toward the soil mass.

The factors in Table 14.1 are "ultimate" values and require certain movements for the respective conditions to be mobilized. The values to use in design can be estimated from Figure C6.9.1 (a) in the Commentary to the Canadian Highway Bridge Design Code.

Table 14.1 – Earth Pressure Coefficient (K)

Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32°, \gamma = 21.2$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (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	-

- For wing walls.

15 SEISMIC CONSIDERATIONS

15.1 Seismic Design Parameters

The site is treated as lying in Seismic Zone 1. The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 1
- Zonal Velocity Ratio 0.05
- Acceleration Related Seismic Zone 1
- Zonal Acceleration Ratio 0.05
- Peak Horizontal Acceleration 0.08

The soil profile type at this site has been classified as Type II. Therefore, according to Table 4.4 of the CHBDC, a Site Coefficient "S" (ground motion amplification factor) of 1.2 should be used in seismic design.

15.2 Liquefaction Potential

The potential for liquefaction of the foundations soils was assessed using the Seed and Idriss (1971) method[1].

Using this method, it is estimated that the foundation soils at both abutments and pier are not prone to liquefaction.

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[1] Seed, H.B. and Idriss, I.M. 1971, "Simplified Procedure for Evaluating Soil Liquefaction Potential" *Journal of Soil Mechanics and Foundations Division*, ASCE, Vol. 101, No. SM9, September, pp. 1249-1273.

It the structure is supported on steel piles, the foundation loads will be transferred by the steel piles to very dense sand and silt till or hard clayey silt till. It is not considered likely that the vertical geotechnical resistance of the piles will be compromised.

The embankments themselves will be constructed above the groundwater level and are not considered to be in danger of undergoing liquefaction.

15.3 Retaining Wall Dynamic Earth Pressures

In accordance with Clause 4.6.4 of the CHBDC, retaining structures should be designed using active (K_{AE}) and passive (K_{PE}) earth pressure coefficients that incorporate the effects of earthquake loading.

For the design of retaining walls, the coefficients of horizontal earth pressure in Table 15.1 may be used.

Table 15.1 – Earth Pressure Coefficient (K) for Earthquake Loading

	Granular A or Granular B Type II $\phi = 35°$ $\gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32°$ $\gamma = 21.2$ kN/m^3	
Wall Condition	**Horizontal Surface Behind Wall**	**Sloping Surface Behind Wall (2H:1V)**	**Horizontal Surface Behind Wall**	**Sloping Surface Behind Wall (2H:1V)**
Active (K_{AE})*	0.3	0.47	0.34	0.58
Passive (K_{PE})	3.6	-	3.2	-
At Rest (K_{OE})**	0.53	-	0.58	-

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

16 CONSTRUCTION CONCERNS

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

1. **Pile refusal at higher elevation.**

   Although there was little direct evidence of their presence during drilling, glacial till deposits inherently contain boulders. It is possible that a pile will achieve refusal at a higher elevation than anticipated due to encountering a boulder. If it is suspected that this is happening, 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.

2. Pile fails to develop specified resistance.

If a pile has not developed the specified resistance after being driven 2 m beyond the anticipated pile tip elevation, stop driving and check the Hiley calculation and all input values. If the calculation still shows that the pile has not reached the specified resistance, the following procedure should be implemented:

a) Stop driving in that pile group for 48 hours (minimum)

b) After 48 hours, warm up the hammer on another pile then retap the subject pile and measure the resistance.

c) If the pile still does not reach the specified resistance, the QVE must immediately advise the CA who, in turn, should refer the issue to the design team.

3. Artesian water flow during pile driving.

Although groundwater levels were encountered that were above the existing ground level, they are below the design highway grade. Thus it is not anticipated that artesian groundwater flow will occur.

However, if artesian groundwater flow is observed during pile driving, or any other construction activities, the contractor or QVE must immediately advise the CA. If the CA agrees there are concerns regarding the artesian flow, the issue should be referred to the design team.

4. Destabilization of excavations

If excavation is carried out without prior implementation of adequate measures to control groundwater and surface water, there is a risk that the sides and or base of the excavation will be destabilized. This could lead to a risk to personnel working on site, or to a loss of bearing resistance in the soil.

Accordingly, it must be emphasized to the contractor that proper groundwater and surface water control measures must be in place prior to commencing excavation.

17 CLOSURE

Engineering analysis and preparation of the report were carried out by Ms. R. Palomeque Reyna, P.Eng.

The report was reviewed by Mr. Alastair E. Gorman, P.Eng and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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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.

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS

CLAYSTONE

SILTSTONE

SANDSTONE

COAL

Bedrock (general)

DISCONTINUITY SPACING

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

TERMS

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

STRENGTH CLASSIFICATION

Rock Strength	Approximate Uniaxial Compressive Strength (MPa)	(psi)	Field Estimation of Hardness*
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

THURBER

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 08-43

METRIC

G.W.P. 2109-05-00 | LOCATION N 4 889 051.2 E 309 710.3, Station 9+920, Left Shoulder | ORIGINATED BY ES

HWY 404 | BOREHOLE TYPE Solid Stem Augers | COMPILED BY WM

DATUM Geodetic | DATE 2008.03.28 - 2008.03.28 | CHECKED BY AEG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
263.9							
0.0	ASPHALT: (200mm)						
0.2	SAND, some gravel, trace to some silt, Dark Brown, Moist (FILL)						
263.1 / 0.8	Silty SAND, some gravel, trace clay, Dense to Compact, Brown, Moist (FILL)	1	SS	41		263	12 56 26 7
		2	SS	16		262	
261.8 / 2.1	SAND and SILT, trace gravel, trace clay, Compact to Very Dense, Brown, Moist (TILL)	3	SS	24		261	
		4	SS	37			1 40 52 8
					∇	260	
259.2		5	SS	100/ .125			
4.7	END OF BOREHOLE AT 4.7m. BOREHOLE OPEN AND WATER LEVEL AT 4.1m ON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH HOLE PLUG.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 40 80 120 160 200

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

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

ONTMT4S 0596.GPJ 8/26/09

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 08-44

METRIC

G.W.P. 2109-05-00	LOCATION N 4 889 053.5 E 309 751.4, Station 9+960, 10m Rt		ORIGINATED BY ES
HWY 404	BOREHOLE TYPE Hollow Stem Augers		COMPILED BY WM
DATUM Geodetic	DATE 2008.03.28 - 2008.04.02		CHECKED BY AEG

SOIL PROFILE / SAMPLES / GROUND WATER CONDITIONS / ELEVATION SCALE / DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100) / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE; 40, 80, 120, 160, 200) / PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) (20, 40, 60) / UNIT WEIGHT γ kN/m³ / REMARKS & GRAIN SIZE DISTRIBUTION (%)

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
259.1								
0.0	Clayey **SILT**, mixed with topsoil, trace sand, trace rootlets Soft Dark Brown (FILL)	1	SS	2				
258.6 0.5	Silty **SAND**, trace clay, trace gravel, occasional oxides staining Compact Brown Moist (FILL)	2	SS	15				
		3	SS	13				
256.9 2.2	**SAND**, trace silt, trace gravel Dense Brown Moist	4	SS	34	20	62	18 (SI+CL)	
256.0 3.0	**SAND and SILT**, trace clay, trace gravel Dense Brown Moist (TILL)	5	SS	33				
		6	SS	41	1	44	47	8
		7	SS	31				
	Very Dense Grey	8	SS	57	3	50	42	5
		9	SS	164				

Elevation scale: 259, 258, 257, 256, 255, 254, 253, 252, 251, 250

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 ◈ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-44

 METRIC

G.W.P. 2109-05-00 LOCATION N 4 889 053.5 E 309 751.4, Station 9+960, 10m Rt ORIGINATED BY ES

HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM

DATUM Geodetic DATE 2008.03.28 - 2008.04.02 CHECKED BY AEG

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	SAND and SILT, trace clay Very Dense Grey (TILL)				249					
		10	SS	100/.125		o	0	42	49	9
					248					
					247					
246.8		11	SS	100/.100		o				
12.3	END OF BOREHOLE AT 12.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.									

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2008.04.18	1.4	257.7
2008.06.30	2.1	257.0
2008.07.29	1.9	257.2
2008.10.24	1.1	258.0
2009.03.20	0.5*	259.6
2009.04.22	0.5*	259.6
2009.05.15	0.5	258.6
2009.06.05	1.0	258.1
2009.07.10	2.1	257.0
2009.07.16	at ground level	

* (above ground surface)

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 40 80 120 160 200

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+³, ×³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 08-45

METRIC

G.W.P.	2109-05-00	LOCATION	N 4 889 070.2 E 309 788.1, Station 10+000, 5m Rt	ORIGINATED BY	ES
HWY	404	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	WM
DATUM	Geodetic	DATE	2008.04.03 - 2008.04.03	CHECKED BY	AEG

SOIL PROFILE / SAMPLES / GROUND WATER CONDITIONS / ELEVATION SCALE / DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100) / SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE; 40, 80, 120, 160, 200) / PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) (20, 40, 60) / UNIT WEIGHT γ kN/m³ / REMARKS & GRAIN SIZE DISTRIBUTION (%)

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
258.3								
0.0	**ASPHALT**: (125mm)							
0.1	**SAND**, some gravel, trace to some silt Dark Brown to Brown Compact Moist (FILL)	1	SS	25				
	fine grained Loose	2	SS	6				
255.8 / 2.4	**SAND and SILT**, some clay, occasional oxide staining Loose Brown (TILL)	3	SS	9				
		4	SS	9	0	41	46	13
	Compact Grey	5	SS	16				
		6	SS	21				
	Very Dense	7	SS	58	0	33	52	15
249.6 / 8.7	Gravelly **SAND**, medium to coarse grained, trace silt and clay Very Dense Grey Wet	8	SS	100/ .100	16	63	22 (SI+CL)	

Elevation scale: 258, 257, 256 (water level), 255, 254, 253, 252, 251, 250, 249

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

20 / 15 -⊕- 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S 0596.GPJ 8/26/09

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 08-45

METRIC

G.W.P. 2109-05-00	LOCATION N 4 889 070.2 E 309 788.1, Station 10+000, 5m Rt		ORIGINATED BY ES
HWY 404	BOREHOLE TYPE Hollow Stem Augers		COMPILED BY WM
DATUM Geodetic	DATE 2008.04.03 - 2008.04.03		CHECKED BY AEG

Columns: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE; 40, 80, 120, 160, 200); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION
	Gravelly SAND, medium to coarse grained, trace silt and clay Dense Grey Wet
247.3 11.0	SAND and SILT, trace gravel, trace to some clay Compact to Very Dense Grey Moist (TILL)
	occasional cobbles Very Dense

Elevation scale: 248, 247, 246, 245, 244, 243, 242, 241, 240, 239

NUMBER	TYPE	"N" VALUES	GR SA SI CL
9	SS	49	22 71 7 (SI+CL)
10	SS	30	
11	SS	61	
12	SS	22	0 29 54 17
13	SS	14	
14	SS	84	
15	SS	100/	2 47 39 12

Continued Next Page

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

15-⊕-5 (20 above, 10 below) (%) STRAIN AT FAILURE

ONTMT4S 0596.GPJ 8/26/09

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 08-45

METRIC

G.W.P. 2109-05-00 LOCATION N 4 889 070.2 E 309 788.1, Station 10+000, 5m Rt ORIGINATED BY ES
HWY 404 BOREHOLE TYPE Hollow Stem Augers COMPILED BY WM
DATUM Geodetic DATE 2008.04.03 - 2008.04.03 CHECKED BY AEG

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ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE
	SAND and SILT, some clay, trace gravel, occasional cobbles Very Dense Grey Moist (TILL)			.125	238
236.9 / 21.4	END OF BOREHOLE AT 21.4m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.	16	SS	100/ .125	237

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2008.04.18	2.4	255.9
2008.04.21	2.4	255.9

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 40 80 120 160 200; PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+³, ×³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 08-46

METRIC

G.W.P. 2109-05-00	LOCATION N 4 889 096.4 E 309 821.8, Station 10+060, 10m Rt	ORIGINATED BY ES
HWY 404	BOREHOLE TYPE Solid Stem Augers / Hollow Stem Augers	COMPILED BY WM
DATUM Geodetic	DATE 2008.03.17 - 2008.03.18	CHECKED BY AEG

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
256.7 / 0.0	**SAND**, medium to coarse grained, some gravel, some silt, trace rootlets; Loose to Compact; Dark Brown; Moist; (FILL)	1	SS	5		
		2	SS	19	∇	
		3	SS	6		
254.7 / 2.0	Silty **SAND**, some gravel, occasional wood fibres; Loose; Brown; Moist; (FILL)	4	SS	7		
253.8 / 2.9	**SAND and SILT**, some clay, trace gravel, occasional oxide staining; Compact; Brown to Grey; Moist; (TILL)	5	SS	10		
		6	SS	22		2 45 41 11
	Dense to Very Dense	7	SS	120		
249.5 / 7.2	Clayey **SILT**, sandy; Hard; Grey; (TILL)	8	SS	77		0 19 63 17
		9	SS	45		

Elevation scale: 256, 255, 254, 253, 252, 251, 250, 249, 248, 247

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 40 80 120 160 200

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m³

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 08-46

METRIC

G.W.P. 2109-05-00	LOCATION N 4 889 096.4 E 309 821.8, Station 10+060, 10m Rt		ORIGINATED BY ES
HWY 404	BOREHOLE TYPE Solid Stem Augers / Hollow Stem Augers		COMPILED BY WM
DATUM Geodetic	DATE 2008.03.17 - 2008.03.18		CHECKED BY AEG

SOIL PROFILE | SAMPLES | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) | SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (40 80 120 160 200) | PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60) | UNIT WEIGHT γ kN/m³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION
	Clayey SILT, sandy, Hard, Grey (TILL)
246.4 / 10.3	Silty SAND, trace clay, Compact, Brown, Moist
244.9 / 11.8	Clayey SILT, sandy, trace gravel, Very Stiff to Hard, Grey (TILL)

NUMBER	TYPE	"N" VALUES	GR	SA	SI	CL
10	SS	10	0	63	31	5
11	SS	46				
12	SS	49	1	35	48	16
13	SS	20				
14	SS	27	0	31	51	19
15	SS	46	3	35	47	15

Elevation scale: 246, 245, 244, 243, 242, 241, 240, 239, 238, 237

Continued Next Page

$+^3, \times^3$ Numbers refer to Sensitivity   20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 08-46

METRIC

G.W.P. 2109-05-00 | LOCATION N 4 889 096.4 E 309 821.8, Station 10+060, 10m Rt | ORIGINATED BY ES

HWY 404 | BOREHOLE TYPE Solid Stem Augers / Hollow Stem Augers | COMPILED BY WM

DATUM Geodetic | DATE 2008.03.17 - 2008.03.18 | CHECKED BY AEG

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
	Continued From Previous Page												
	Clayey SILT, sandy, trace gravel Hard Grey (TILL)		16	SS	35			o		1	36	48	15
							236						
							235						
							234						
233.6			17	SS	149/ .275			o					
23.1	END OF BOREHOLE AT 23.1m. BOREHOLE OPEN TO 5.2m AND WATER LEVEL AT 0.9m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO SURFACE.												

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 40 80 120 160 200

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 08-47

METRIC

G.W.P.	2109-05-00	LOCATION	N 4 889 092.8 E 309 843.9, Station 10+040, Right Shoulder	ORIGINATED BY	ES
HWY	404	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	WM
DATUM	Geodetic	DATE	2008.03.11 - 2008.03.12	CHECKED BY	AEG

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
257.4									
0.0	ASPHALT: (150mm)								
0.2	SAND and GRAVEL, some silt, Compact to Dense, Dark brown, Moist (FILL)	1	SS	41					
		2	SS	18					
		3	SS	10					
255.2 / 2.1	Silty SAND, trace gravel, trace clay, Compact, Brown, Moist (FILL)	4	SS	19	∇	3	57	33	7
254.1 / 3.3	SAND and GRAVEL, trace clay, occasional cobbles, Compact, Brown, Moist (FILL)	5	SS	21					
253.0 / 4.4	Clayey SILT, sandy, trace gravel, oxide staining, Very Stiff, Brown (TILL)	6	SS	18					
	Hard, Grey	7	SS	160/275		1	30	52	17
		8	SS	55		4	25	53	18
		9	SS	59					

Elevation scale: 257, 256, 255, 254, 253, 252, 251, 250, 249, 248

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 40 80 120 160 200

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued Next Page

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 08-47

METRIC

G.W.P. 2109-05-00 | LOCATION N 4 889 092.8 E 309 843.9, Station 10+040, Right Shoulder | ORIGINATED BY ES
HWY 404 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY WM
DATUM Geodetic | DATE 2008.03.11 - 2008.03.12 | CHECKED BY AEG

Continued From Previous Page

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT	GR	SA	SI	CL
	Clayey SILT, sandy, trace gravel Hard Grey (TILL)				247					
		10	SS	50		o				
	Auger grinding at 11.6 to 11.9m				246					
		11	SS	59	245	o	1	13	64	23
					244					
		12	SS	65	243	o				
		13	SS	64	242	o				
					241					
		14	SS	73	240	o	1	34	48	17
		15	SS	37	239	o				
					238					

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE, 40 80 120 160 200; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 08-47

METRIC

G.W.P.	2109-05-00	LOCATION	N 4 889 092.8 E 309 843.9, Station 10+040, Right Shoulder	ORIGINATED BY	ES
HWY	404	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	WM
DATUM	Geodetic	DATE	2008.03.11 - 2008.03.12	CHECKED BY	AEG

Continued From Previous Page

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
	Clayey SILT, trace to some sand Hard Grey (TILL)	16	SS	36			0	11	70	19
						237				
						236				
235.6 21.8	SILT, trace sand, trace gravel, trace clay Very Dense Grey Moist (TILL)									
						235				
		17	SS	100/.100						
						234				
						233				
		18	SS	100/.100			0	2	92	6
						232				
		19	SS	100/.140						
						231				
						230				
229.7 27.7	END OF BOREHOLE AT 27.7m. BOREHOLE OPEN AND WATER LEVEL AT 2.6m UPON COMPLETION. BOREHOLE BACKFILLED WITH HOLEPLUG TO 0.2m THEN ASPHALT TO SURFACE.	20	SS	100/.100						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 40 80 120 160 200

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m^3

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

15-20-5-10 (%) STRAIN AT FAILURE

Appendix B

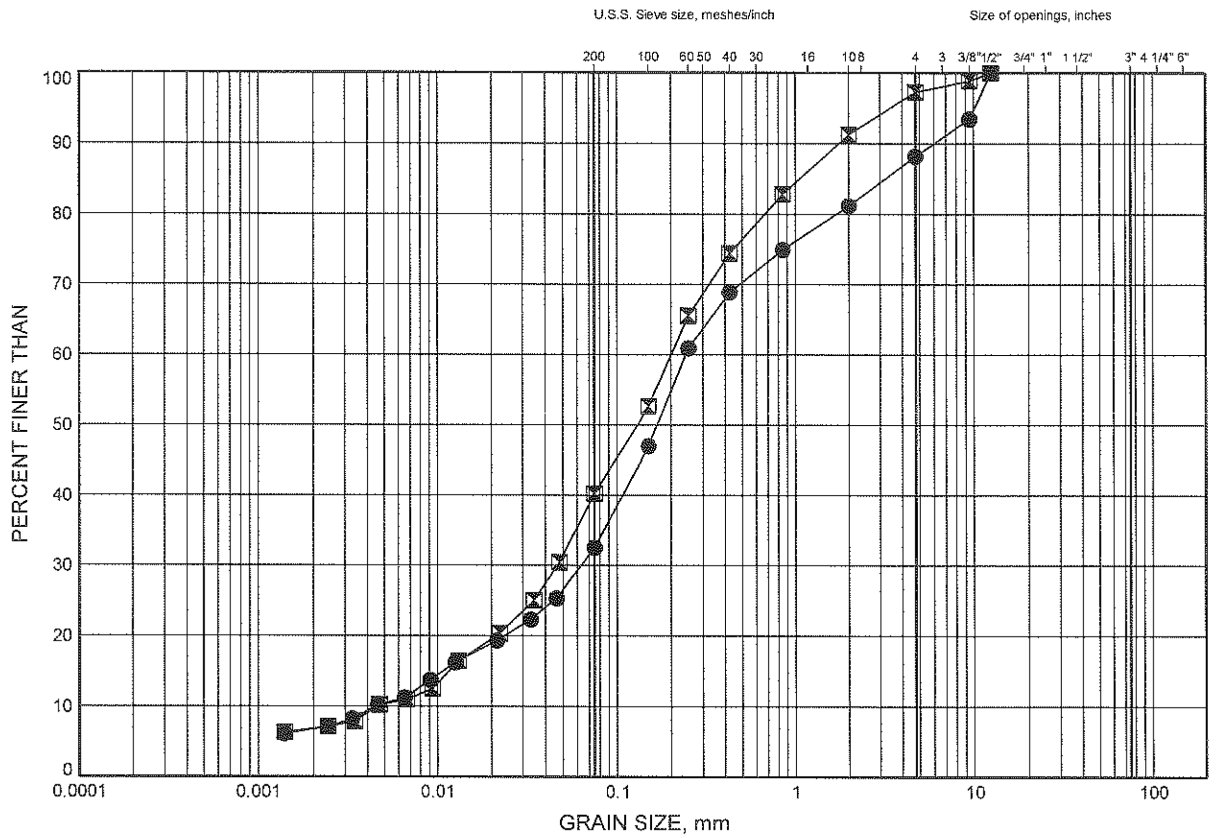
Laboratory Test Results

Hwy 404 Extension

GRAIN SIZE DISTRIBUTION

FIGURE B1

SILTY SAND (FILL)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-43	0.99	262.87
⧗	08-47	2.82	254.56

W.P.# ....

Prepared By .MFA..................

Checked By .RPR..................

THURBER

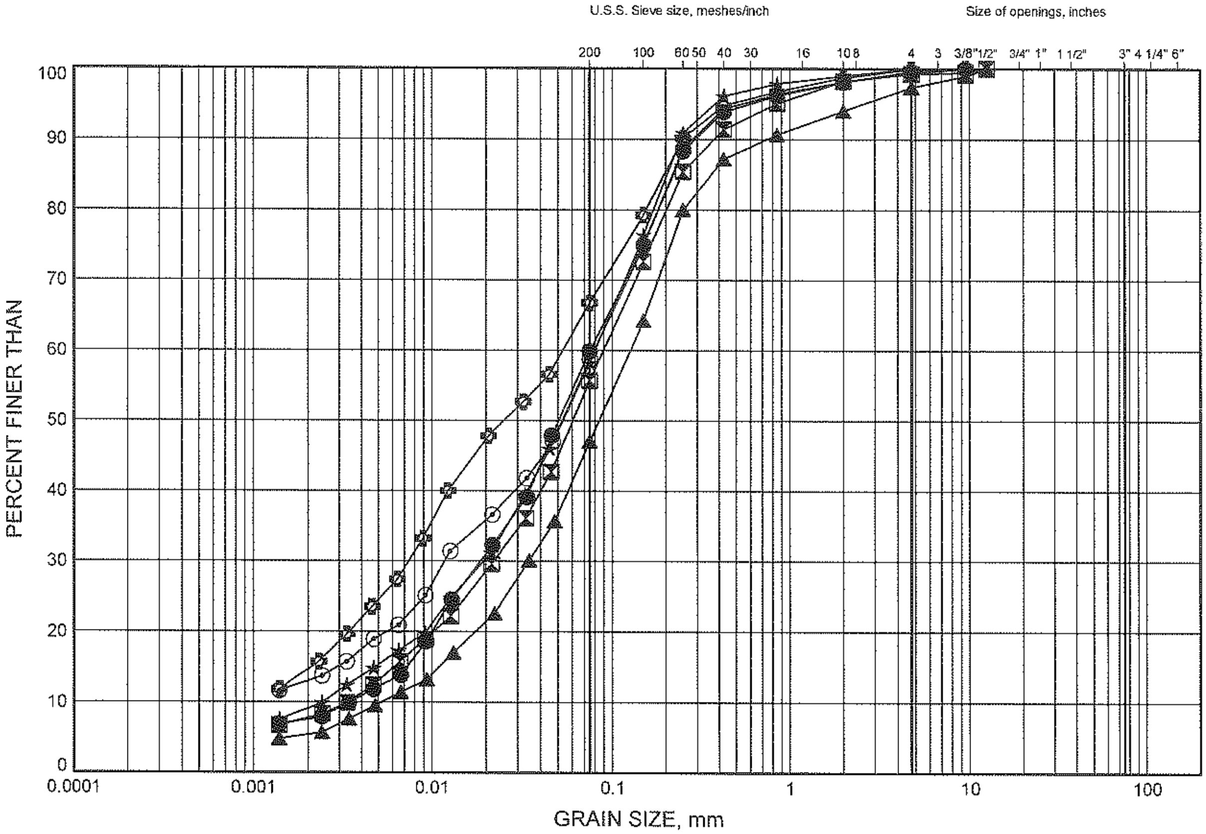
GRAIN SIZE DISTRIBUTION - THURBER 0596.GPJ 8/26/08

Hwy 404 Extension

GRAIN SIZE DISTRIBUTION

FIGURE B2

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)
●	08-43	3.28	260.58
⧗	08-44	4.80	254.29
▲	08-44	7.85	251.24
☆	08-44	10.73	248.36
⊙	08-45	3.28	254.99
✪	08-45	7.85	250.42

W.P.# ....

Prepared By MFA...................

Checked By RPR..................

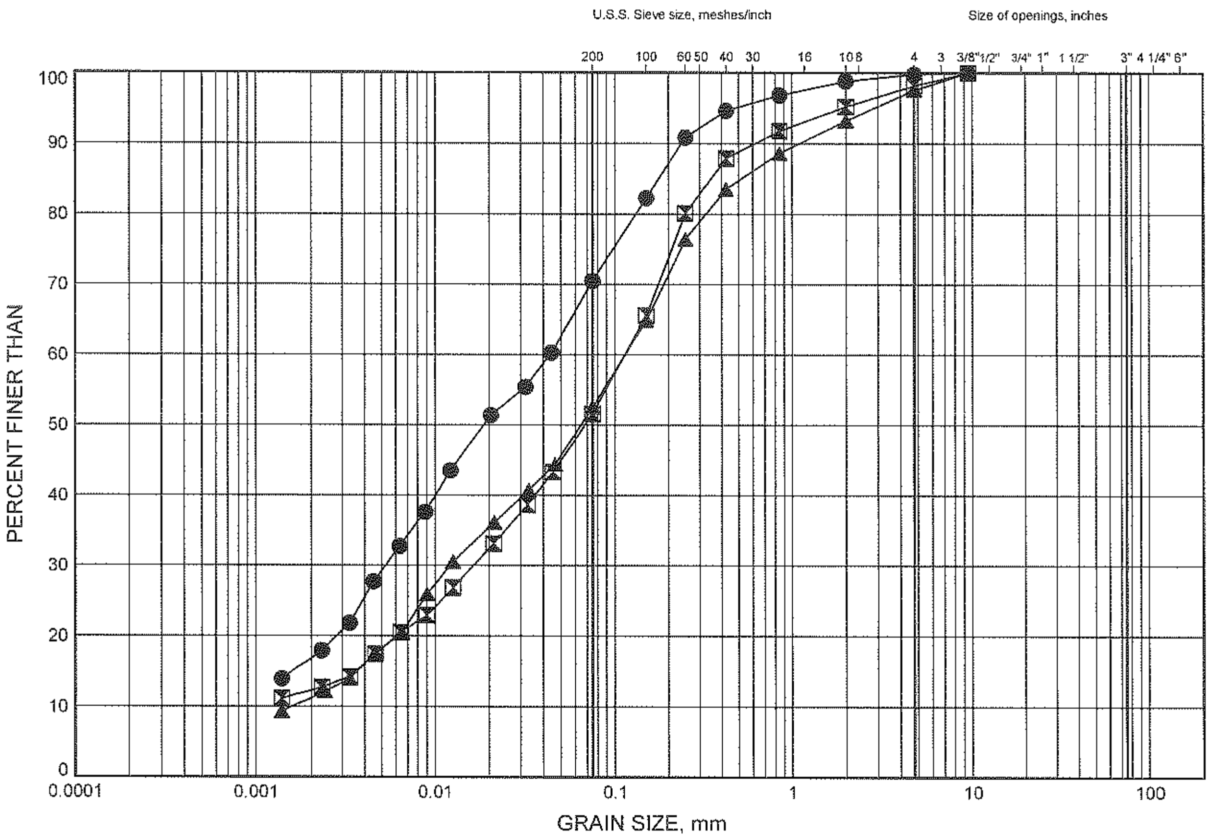
THURBER

GRAIN SIZE DISTRIBUTION - THURBER 0596.GPJ 8/26/08

Hwy 404 Extension
GRAIN SIZE DISTRIBUTION

FIGURE B3

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)
●	08-45	15.47	242.80
⊠	08-45	19.87	238.40
▲	08-46	4.88	251.82

GRAIN SIZE DISTRIBUTION - THURBER 0596.GPJ 8/26/08

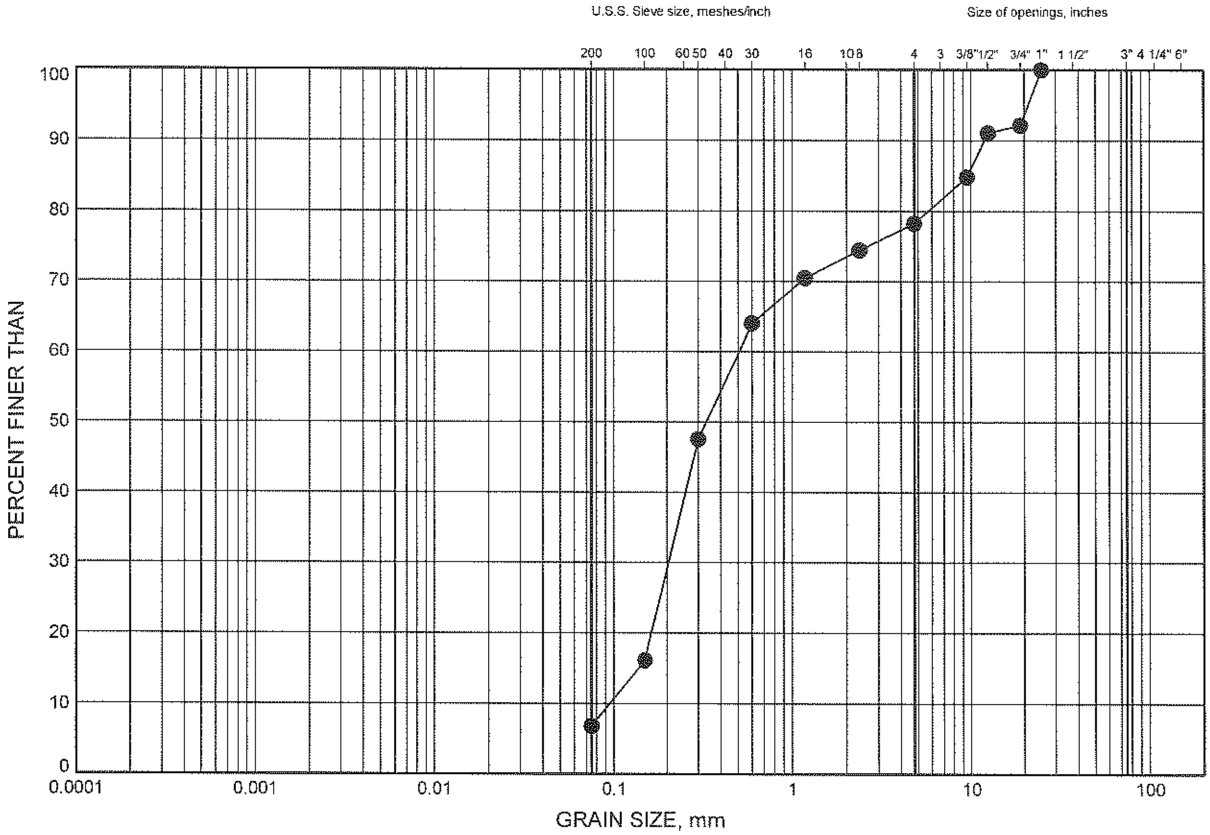
W.P.# ....
Prepared By MFA..................
Checked By RPR..................

THURBER

Hwy 404 Extension
GRAIN SIZE DISTRIBUTION

FIGURE B4

GRAVELLY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-45	10.79	247.48

THURBER

W.P.# ....

Prepared By MFA..................

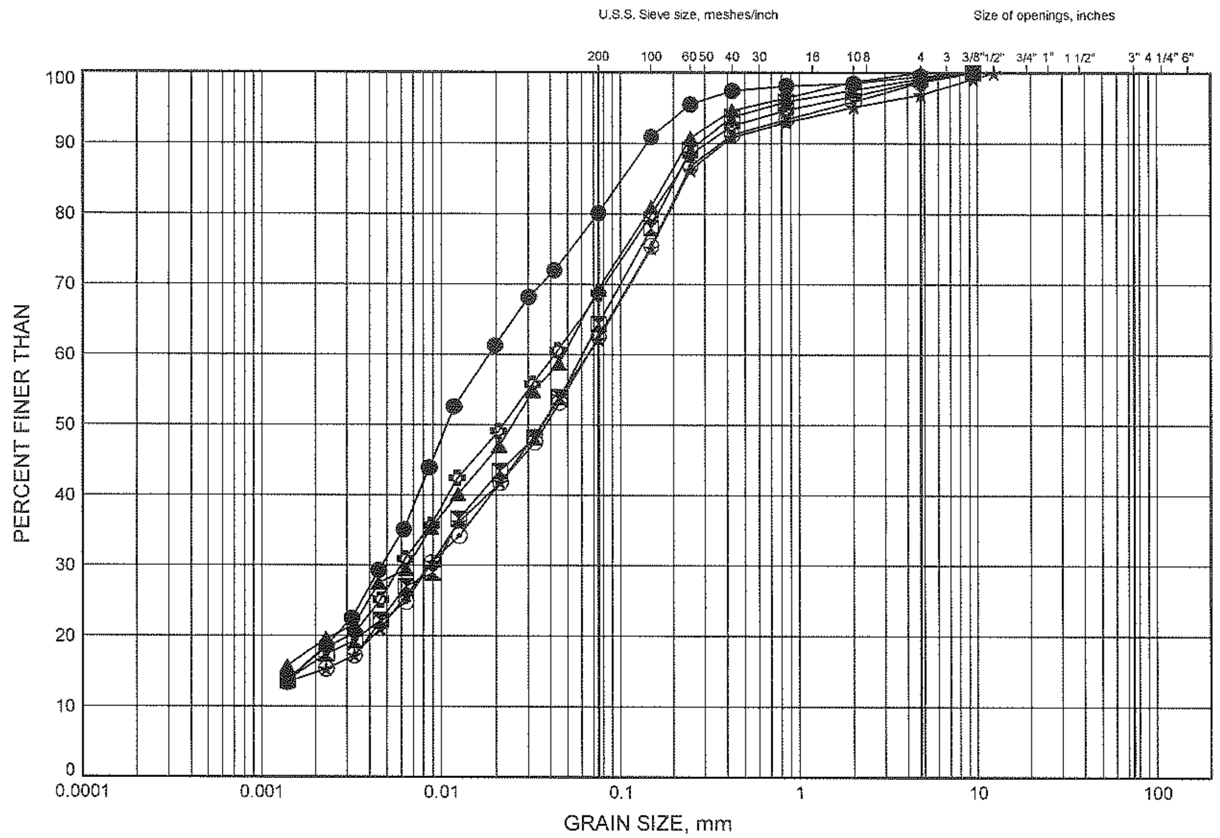
Checked By RPR..................

Hwy 404 Extension

GRAIN SIZE DISTRIBUTION

FIGURE B5

CLAYEY SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-46	7.92	248.78
⊠	08-46	14.02	242.68
▲	08-46	17.07	239.63
☆	08-46	18.52	238.18
⊙	08-46	20.12	236.58
✪	08-47	6.32	251.06

W.P.# ....

Prepared By MFA..................

Checked By RPR.................

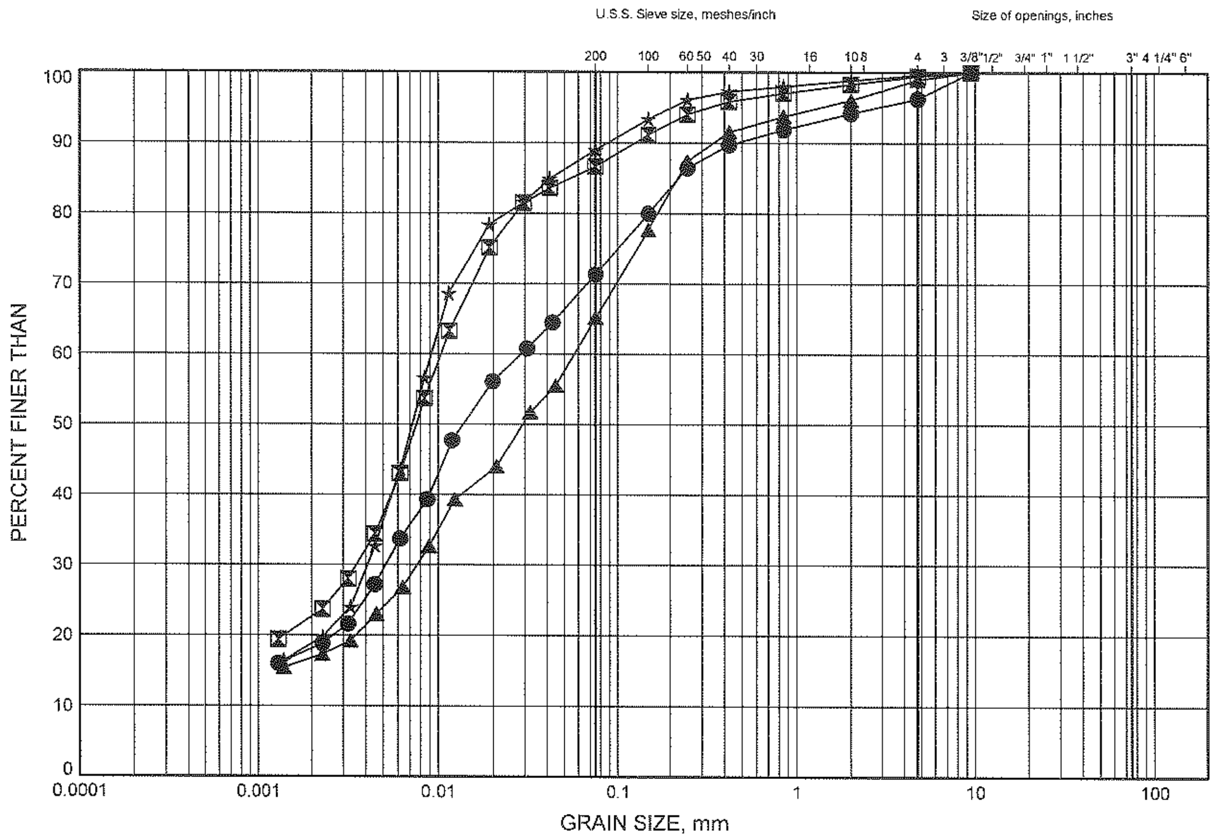
THURBER

Hwy 404 Extension

GRAIN SIZE DISTRIBUTION

FIGURE B6

CLAYEY SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-47	7.92	249.46
⌧	08-47	12.50	244.88
▲	08-47	17.07	240.31
☆	08-47	20.12	237.26

W.P.# ....

Prepared By MFA..................

Checked By RPR..................

THURBER

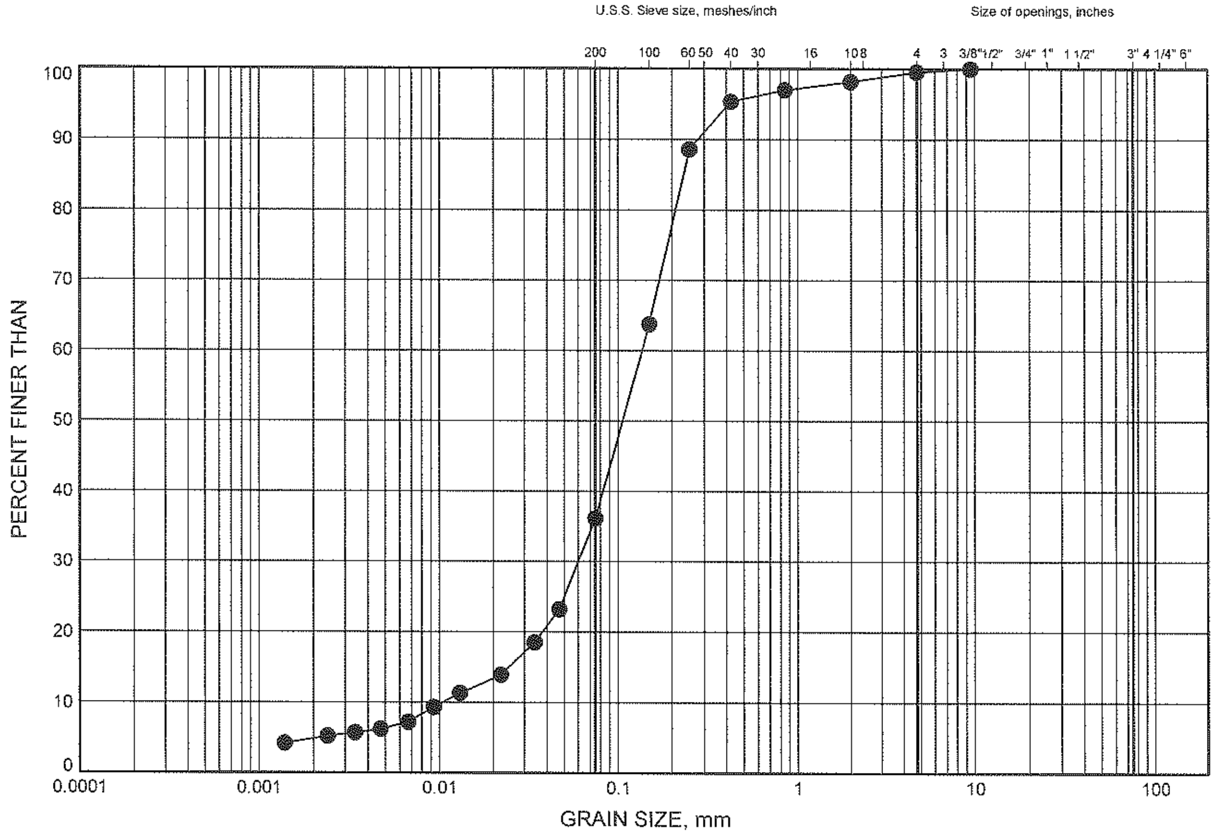
GRAIN SIZE DISTRIBUTION - THURBER 0596.GPJ 8/26/08

Hwy 404 Extension

GRAIN SIZE DISTRIBUTION

FIGURE B7

SILTY SAND



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-46	10.97	245.73

THURBER

W.P.# ....

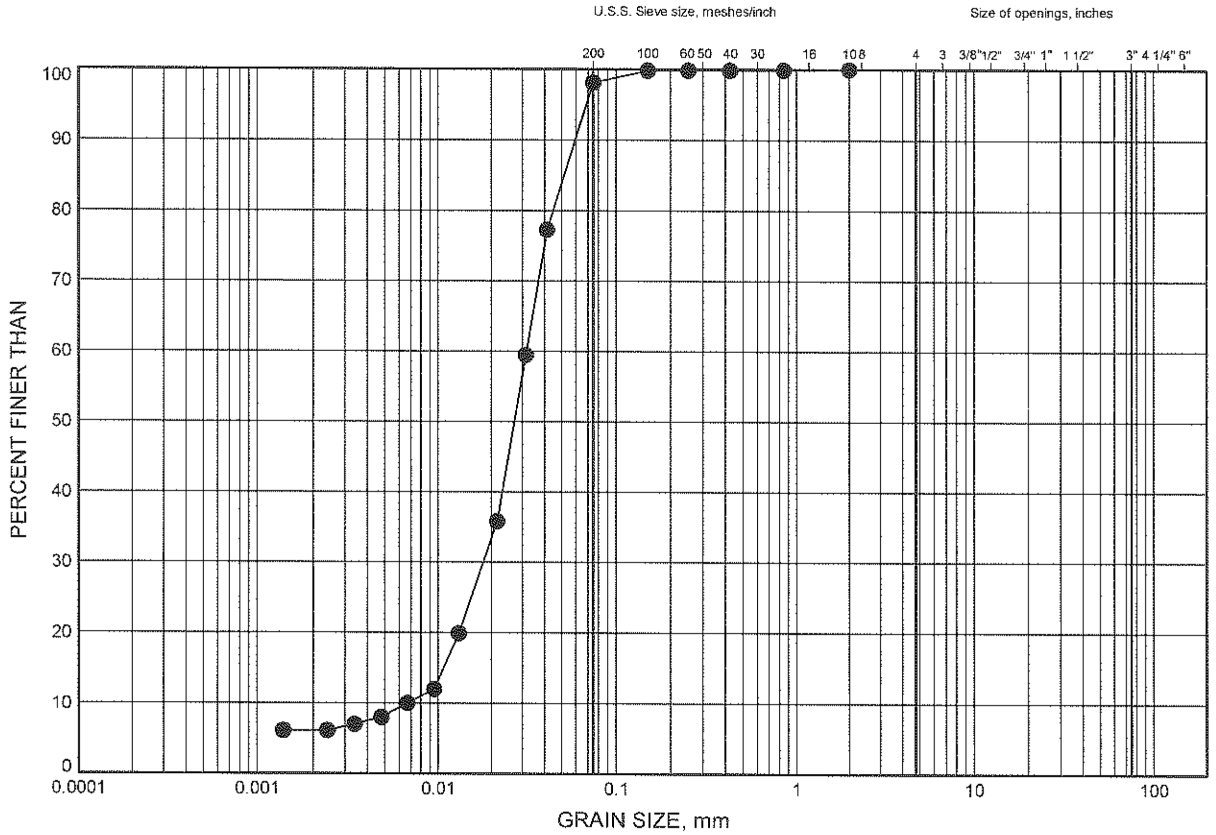
Prepared By MFA..................

Checked By RPR.................

Hwy 404 Extension
GRAIN SIZE DISTRIBUTION

FIGURE B8

SILT TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-47	24.52	232.86

THURBER

W.P.# ....
Prepared By MFA..................
Checked By RPR..................

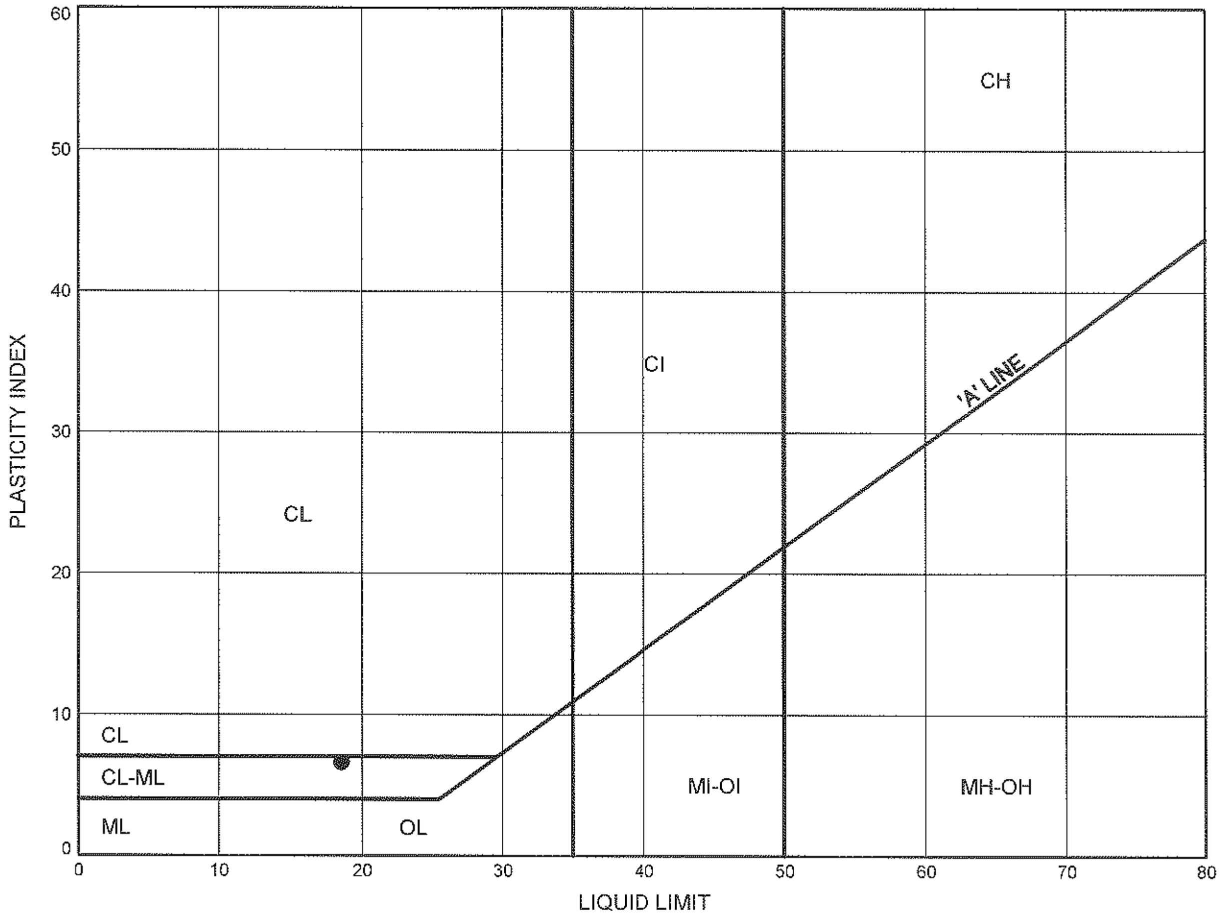
GRAIN SIZE DISTRIBUTION - THURBER 0596.GPJ 8/26/08

Hwy 404 Extension

ATTERBERG LIMITS TEST RESULTS

FIGURE B9

SAND AND SILT TILL



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-45	15.47	242.80

Date August 2008

Project

THURBER

Prep'd MFA

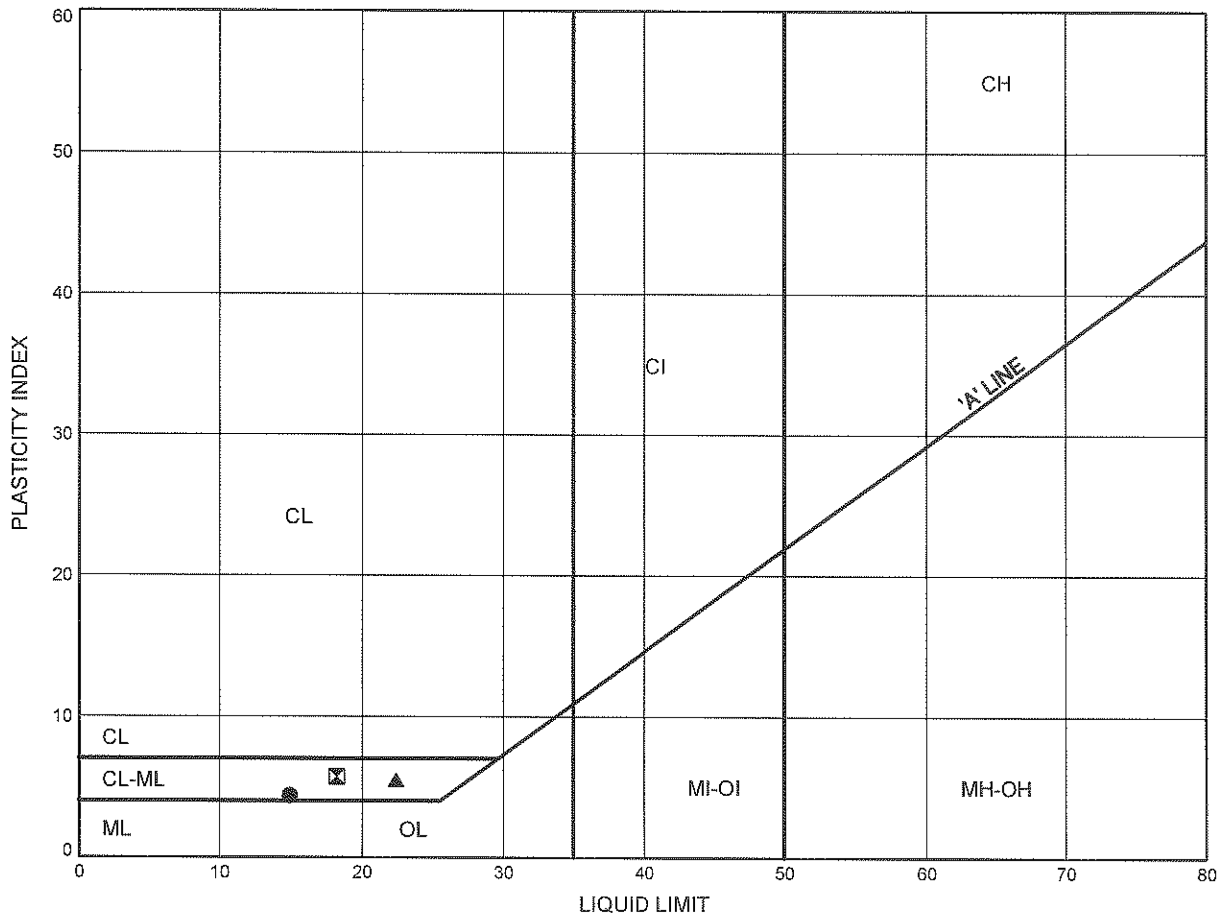
Chkd. RPR

Hwy 404 Extension

ATTERBERG LIMITS TEST RESULTS

FIGURE B10

CLAYEY SILT TILL



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-46	17.07	239.63
⊠	08-47	7.92	249.46
▲	08-47	20.12	237.26

THURBALT 0596.GPJ 8/26/08

Date August 2008

Project

THURBER

Prep'd MFA

Chkd. RPR

Appendix C

Record of Borehole Sheets and Laboratory Results (previous investigation)

RECORD OF BOREHOLE No BH 301

 METRIC

PROJECT 04-1111-016			
W.P.	LOCATION N 4889092.6 ;E 309821.8		ORIGINATED BY PKS
DIST Central	HWY 404	BOREHOLE TYPE 108 mm Diameter Solid Stem Augers	COMPILED BY DD
DATUM Geodetic	DATE JUNE 11, 2004		CHECKED BY LCC

Column headings: SOIL PROFILE (ELEV / DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED; 20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) (GR SA SI CL)

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
257.5	GROUND SURFACE
257.5 / 0.0	Sand and gravel (FILL) Compact Brown Moist
256.9 / 0.6	Silty sand, some gravel, trace clay (FILL) Compact to loose Brown Moist
255.3 / 2.2	Clayey Silt with sand, trace gravel Firm to stiff Brown Wet
253.8 / 3.7	Clayey Silt, some sand, trace gravel (TILL) Stiff to hard Brown Wet Becoming grey below 7.6 m depth
247.9 / 9.6	Silty Sand, trace gravel Compact Grey Wet
245.9 / 11.6	Clayey Silt, some sand, trace gravel (TILL) Hard Grey Moist

SAMPLES

NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS GR	SA	SI	CL
1	SS	14					
2	SS	14					
3	SS	7					
4	SS	5					
5	SS	8		0	28	65	7
6	SS	11					
7	SS	15	∇				
8	SS	40					
9	SS	56		1	15	68	16
10	SS	45					
11	SS	14					
12	SS	33					
13	SS	39					

ELEVATION SCALE: 257, 256, 255, 254, 253, 252, 251, 250, 249, 248, 247, 246, 245, 244, 243

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No BH 301

 METRIC

PROJECT 04-1111-016

W.P.

DIST Central HWY 404

DATUM Geodetic

LOCATION N 4889092.6 ;E 309821.8

BOREHOLE TYPE 108 mm Diameter Solid Stem Augers

DATE JUNE 11, 2004

ORIGINATED BY PKS

COMPILED BY DD

CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
			14	SS	32		242				
241.8 / 15.7	End of Borehole Note: Water level at 4.9 m depth (Elevation 252.6 m) upon completion of drilling										

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

MIS-MTO 001 04111016AAMTO.GPJ GAL-MISS.GDT 26/4/06

PROJECT 04-1111-016	RECORD OF BOREHOLE No BH 301A	1 OF 2	METRIC
W.P.	LOCATION N 4889107.0 ;E 309821.9		ORIGINATED BY PKS
DIST Central HWY 404	BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers		COMPILED BY DD
DATUM Geodetic	DATE SEPTEMBER 27, 28, 2004		CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	GR	SA	SI	CL
256.0	GROUND SURFACE								
0.0	Augered from 0.0 m to 12.2 m depth without sampling. Refer to Record of Borehole 301 for subsurface conditions over this interval.								
243.8 / 12.2	Clayey Silt, some sand, trace gravel (TILL) Stiff to hard Grey Moist to wet	1	SS	32					
		2	SS	11		1	29	57	13

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (255, 254, 253, 252, 251, 250, 249, 248, 247, 246, 245, 244, 243, 242); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No BH 301A

 METRIC

PROJECT 04-1111-016
W.P.
DIST Central HWY 404
DATUM Geodetic

LOCATION N 4889107.0 ;E 309821.9
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
DATE SEPTEMBER 27, 28, 2004

ORIGINATED BY PKS
COMPILED BY DD
CHECKED BY LCC

--- CONTINUED FROM PREVIOUS PAGE ---

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Clayey Silt, some sand, trace gravel (TILL) Stiff to hard Grey Moist to wet	3	SS	12	240		
238.9 17.1	Interlayered Clayey Silt, trace sand, and Silt, trace clay and sand, containing clay seams Hard/Very dense Grey Moist to wet	4	SS	59	239		
		5	SS	100	238, 237	plotted	
		6	SS	121	236, 235		
		7	SS	108	234	plotted	0 1 89 10
		8	SS	100/.18	233, 232		
231.0 25.0		9	SS	76			

End of Borehole

Notes:

1. Water level in piezometer measured at 2.7 m depth (Elevation 253.3 m) on September 28, 2004 and at 0.7m above ground surface. (Elevation 256.7m) on October 7, 2004.

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100
PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
UNIT WEIGHT γ kN/m³

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No BH 302

 METRIC

PROJECT 04-1111-016
W.P.
DIST Central HWY 404
DATUM Geodetic

LOCATION N 4889084.1 ;E 309781.5
BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers
DATE SEPTEMBER 28, 2004

ORIGINATED BY PKS
COMPILED BY DD
CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
259.0	GROUND SURFACE						
0.0 / 0.1	Topsoil						
	Silty sand (FILL) Loose Brown Moist	1	SS	6			
258.3 / 0.7	Clayey silt, some sand, trace gravel, trace asphalt fragments (FILL) Firm Dark brown Moist	2	SS	6		258	
257.5 / 1.5	Clayey Silt, some sand, trace gravel Stiff Mottled brown Moist	3	SS	10		257	3 21 43 33
		4	SS	9			
256.0 / 3.0	Sand and Silt, trace gravel, trace clay, containing lenses/interlayers of sand and gravel (TILL) Compact to very dense Brown to grey Moist	5	SS	14		256	
		6	SS	23		255	
		7	SS	23		254	
						253	
		8	SS	32		252	
		9	SS	38		251	2 38 53 7
						250	
		10	SS	39		249	
		11	SS	39	∇	248	
						247	
		12	SS	74		246	
		13	SS	81		245	

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED: 20 40 60 80 100

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

UNIT WEIGHT γ kN/m³

Continued Next Page

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

RECORD OF BOREHOLE No BH 302

 METRIC

PROJECT 04-1111-016

W.P.

LOCATION N 4889084.1 ;E 309781.5

ORIGINATED BY PKS

DIST Central HWY 404

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

COMPILED BY DD

DATUM Geodetic

DATE SEPTEMBER 28, 2004

CHECKED BY LCC

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
	--- CONTINUED FROM PREVIOUS PAGE ---									
	Sand and Silt, trace gravel, trace clay, containing lenses/interlayers of sand and gravel (TILL) Compact to very dense Brown to grey Moist	14	SS	102			1	34	54	11
					243					
		15	SS	100/.23	242					
					241					
240.5 / 18.5	End of Borehole	16	SS	100/.18						
	Note: Water level in piezometer measured at 10.7 m depth (Elevation 248.3 m) on September 29, 2004.									

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

Golder Associates

RECORD OF BOREHOLE No BH 303

 METRIC

PROJECT 04-1111-016

W.P.

LOCATION N 4889071.0 ;E 309743.7

ORIGINATED BY PKS

DIST Central HWY 404

BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers

COMPILED BY DD

DATUM Geodetic

DATE SEPTEMBER 29, 2004

CHECKED BY LCC

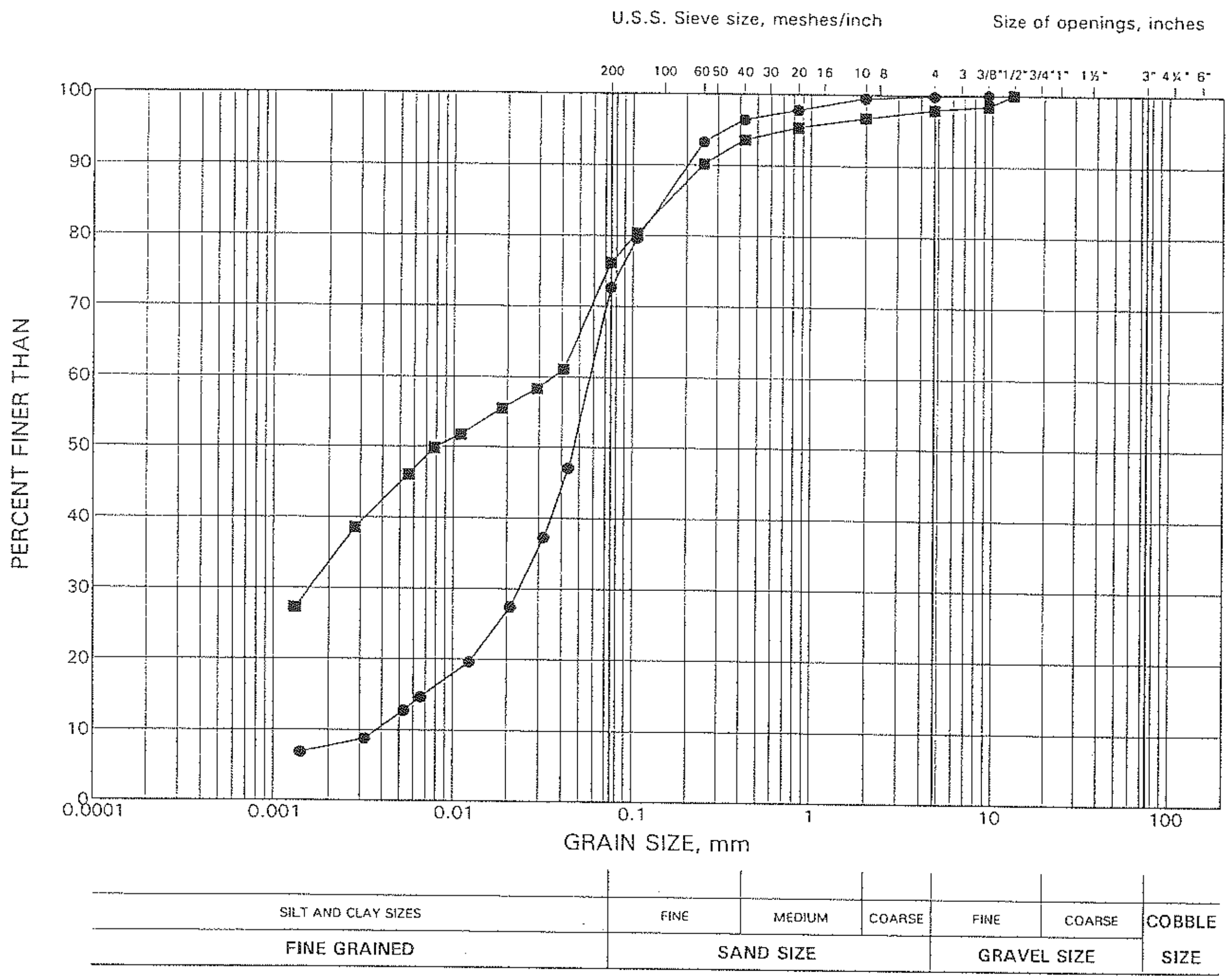
ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
261.0	GROUND SURFACE					
0.0	Silty Sand, some organics (FILL) Very loose to loose Brown Moist	1	SS	4		
		2	SS	6		
259.5 / 1.5	Clayey Silt, some sand, trace gravel, trace organics Stiff Brown Moist	3	SS	11		
258.8 / 2.2	Silty Sand, trace clay, trace gravel, trace organics Dense Brown Moist	4	SS	33		
258.0 / 3.0	Sand and Silt, trace clay, some gravel (TILL) Dense to very dense Brown, becoming grey below 9.1 m depth Moist to wet below 3.7 m depth	5	SS	36		
		6	SS	33		
		7	SS	40		32 28 35 5
		8	SS	67		
		9	SS	100/.23		
		10	SS	100/.23	∇ (El. 252)	
		11	SS	100/.13		
		12	SS	100/.18		
247.1		13	SS	100/.15		
13.9	End of Borehole Note: Water level at 9.1 m depth (Elevation 250.9 m) upon completion of drilling.					

Plot headings: ELEVATION SCALE (261 to 247); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED, 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; UNIT WEIGHT γ kN/m³.

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

GRAIN SIZE DISTRIBUTION TEST RESULTS
Surficial Clayey Silt

FIGURE 1



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	301	5	254.3
■	302	3	257.2

Date 11/2/2004

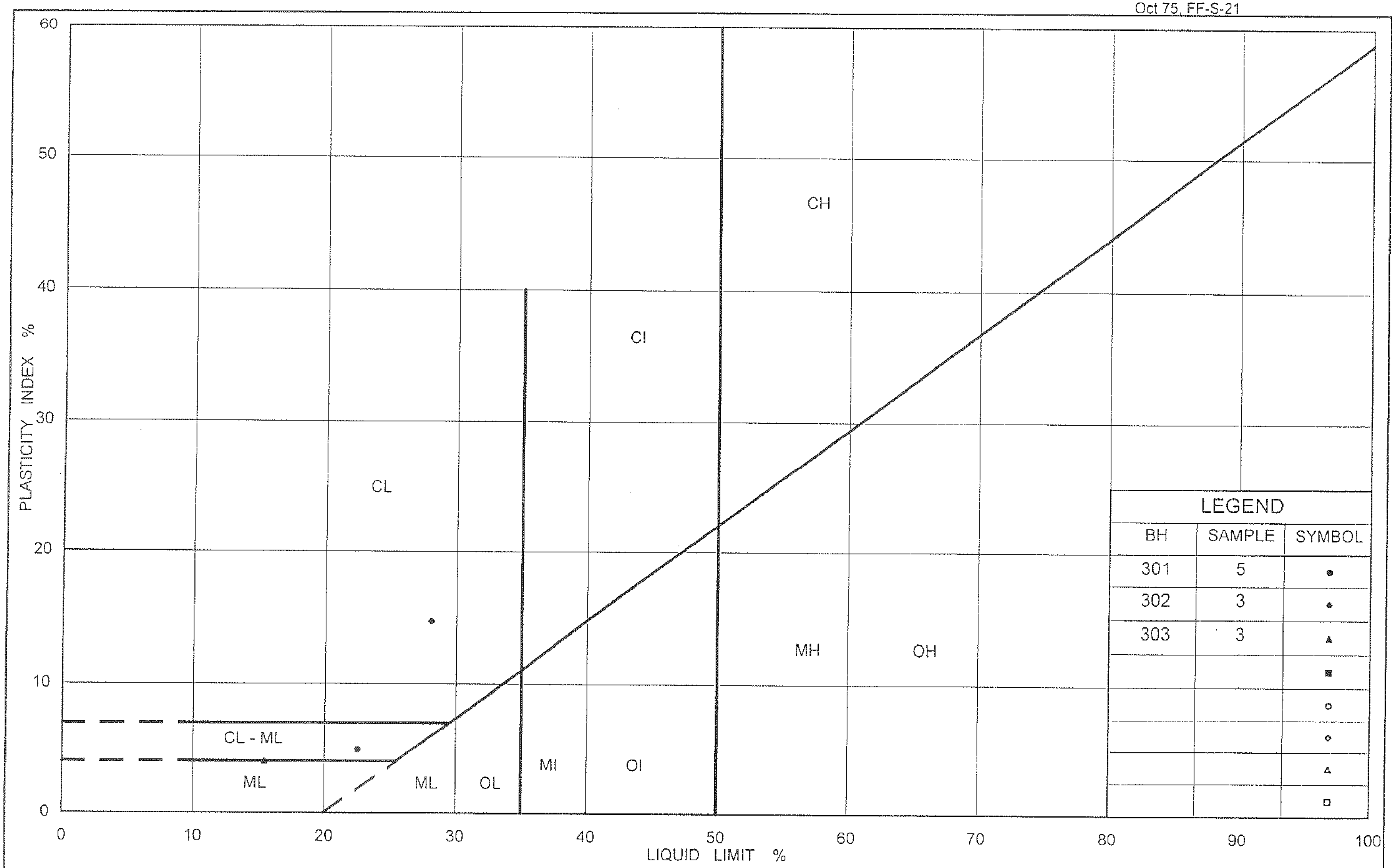
Project 04-1111-016

Golder Associates

Prepared by LG

Checked by

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART

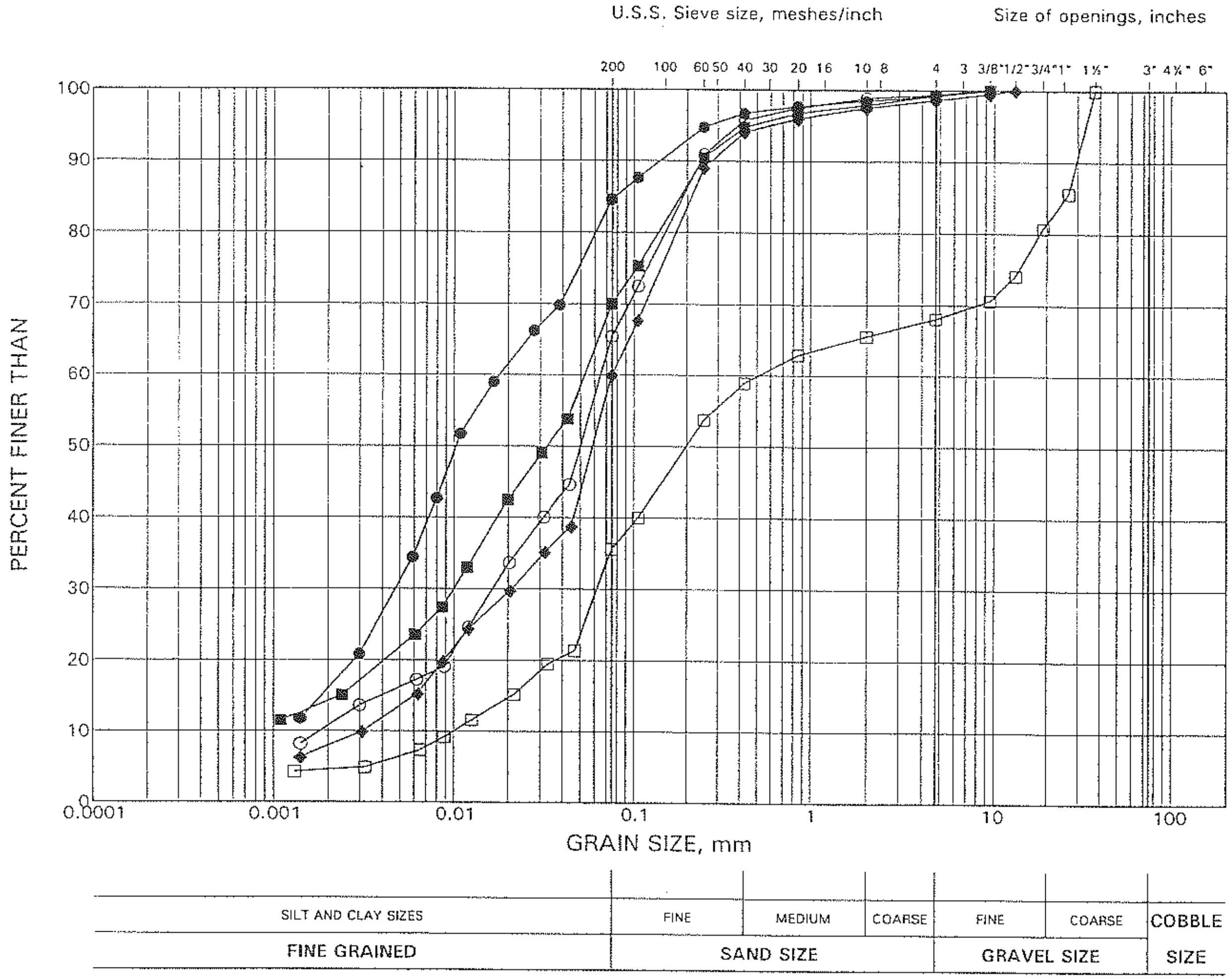
Surficial Clayey Silt

FIG No. 2

Project No. 04-1111-016

GRAIN SIZE DISTRIBUTION TEST RESULTS
Clayey Silt Till / Sand and Silt Till

FIGURE 3



LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	301	9	249.6
■	301A	2	242.0
◆	302	9	251.1
○	302	14	243.5
□	303	7	256.2

Date 11/2/2004

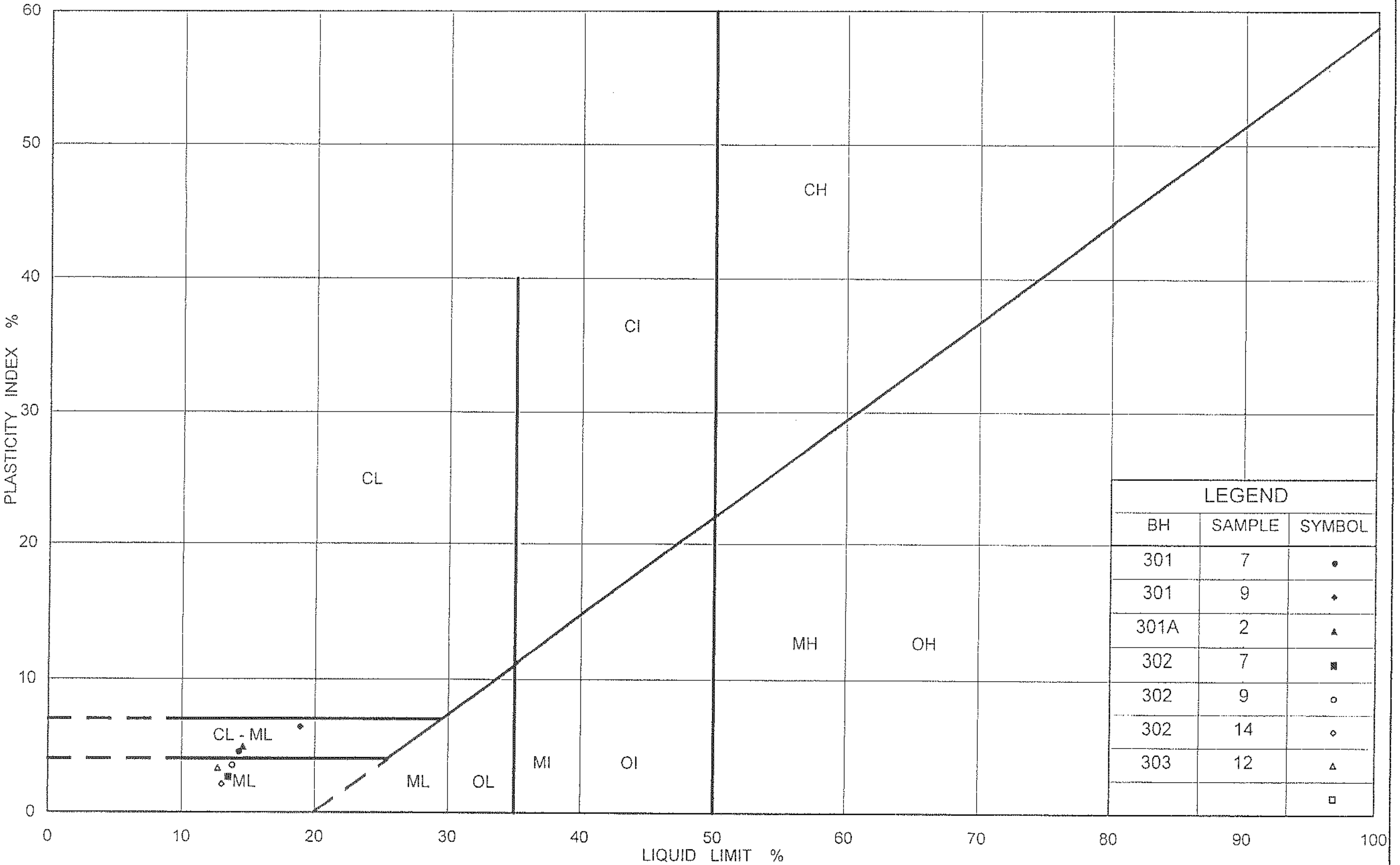
Project 04-1111-016

Golder Associates

Prepared by LG

Checked by

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
301	7	●
301	9	◆
301A	2	▲
302	7	■
302	9	○
302	14	◇
303	12	△
		□

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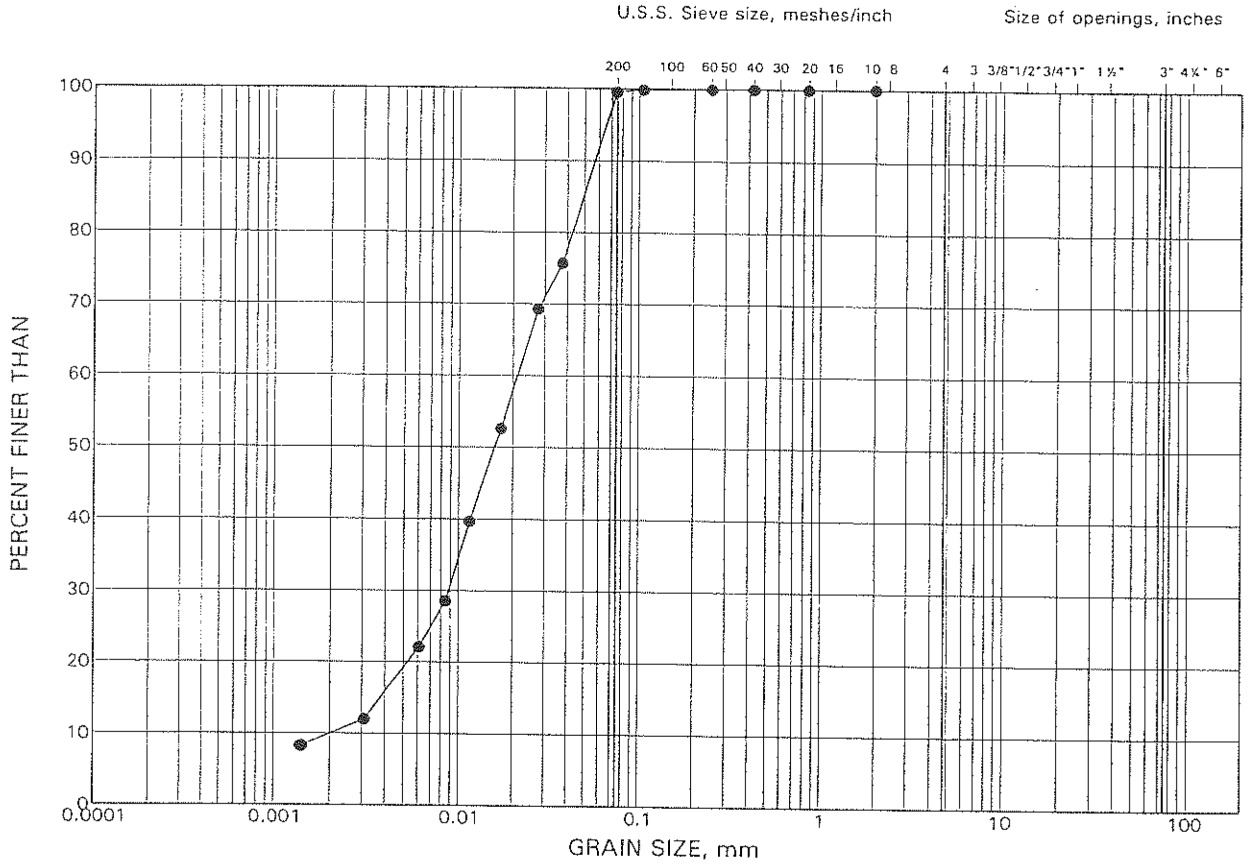
PLASTICITY CHART
Clayey Silt Till / Sand and Silt Till

FIG No. 4

Project No. 04-1111-016

GRAIN SIZE DISTRIBUTION TEST RESULT
Interlayered Clayey Silt and Silt

FIGURE 5



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

LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEVATION (m)
●	301A	7	234.5

Date 11/2/2004

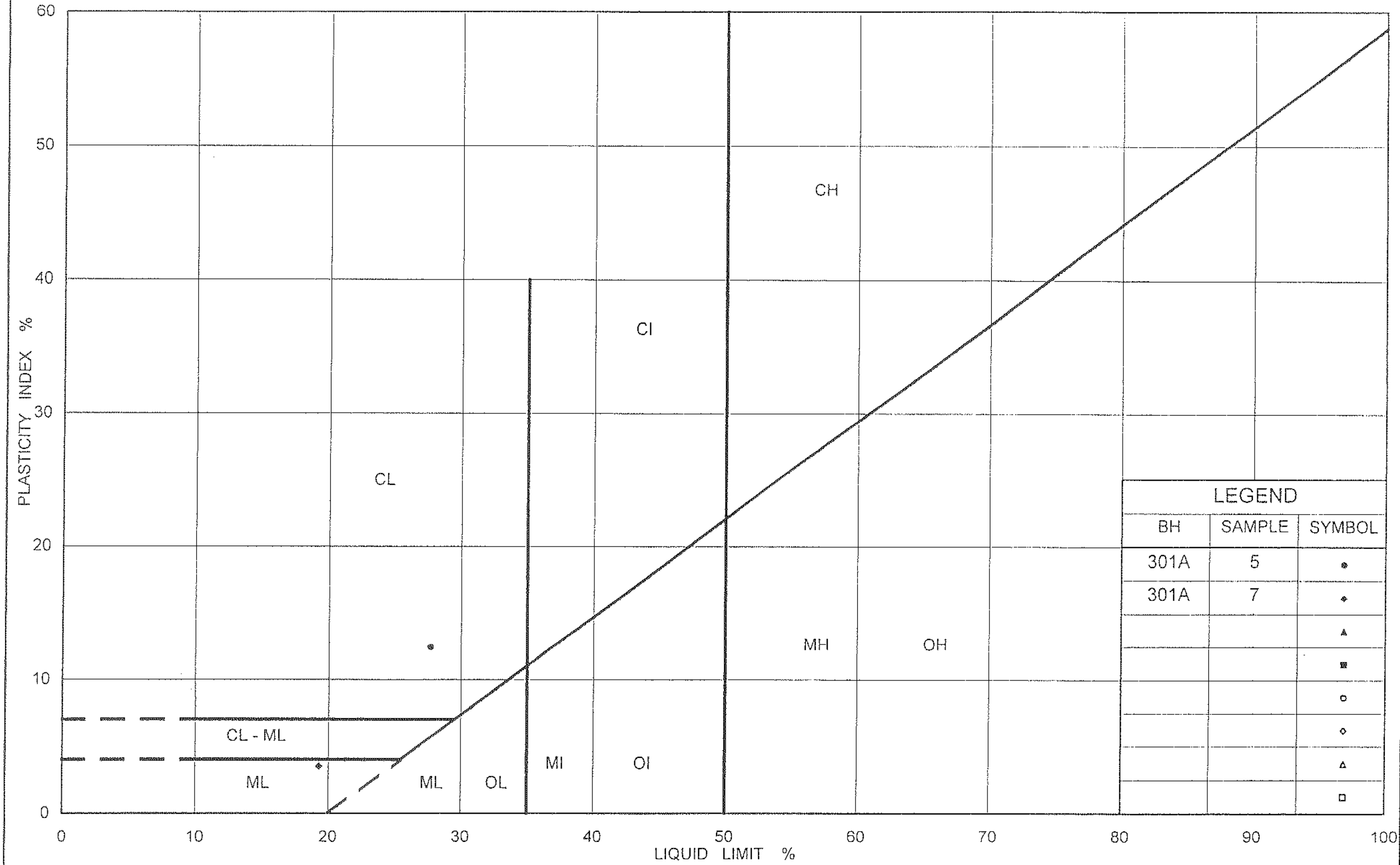
Project 04-1111-016

Golder Associates

Prepared by LG

Checked by [signature]

Oct 75, FF-S-21



Ministry of Transportation

Ontario

PLASTICITY CHART
Interlayered Clayey Silt and Silt

FIG No. 6

Project No. 04-1111-016

Appendix D

Foundation Comparison

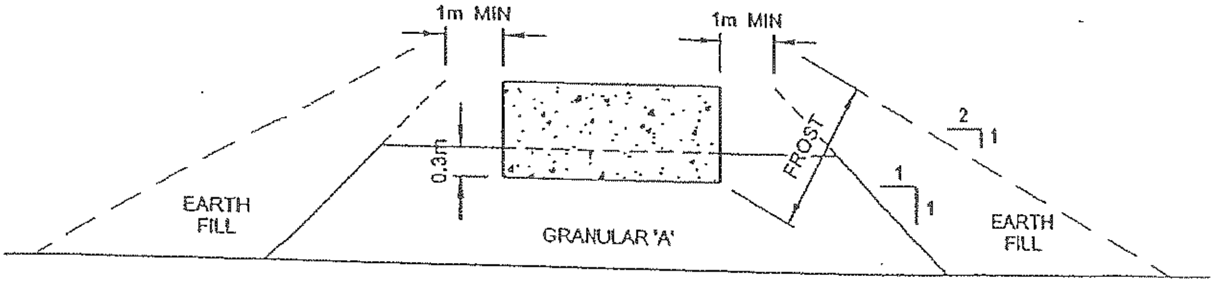
COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

Driven Piles	Augered Caissons	Footing on Native Soil	Footing on Engineered Fill
Advantages:	*Advantages:*	*Advantages:*	*Advantages:*
i. High geotechnical resistance available by driving piles to achieve resistance in the very dense soil. ii. Allows choice of conventional, integral or semi-integral abutment design. iii. Readily installed.	i. High geotechnical resistance available for units founded in very dense soil. ii. Construction of caissons could continue in freezing weather.	i. Economical to install.	i. Possibility of shortening the abutment height. ii. Higher geotechnical resistance than is available on native soil. iii. Lower cost compared to deep foundations. iv. Allows use of perched abutments. v. Allows choice of semi-integral abutment.
Disadvantages:	*Disadvantages:*	*Disadvantages:*	*Disadvantages:*
i. Higher unit cost compared to footings. ii. Construction concerns related to the possibility of piles being obstructed by a boulder during driving.	i. Higher unit cost compared to other foundation options such as footings or driven piles. ii. High risks associated with inflow of groundwater and soil fines. iii. Soil conditions encountered at this site are considered to be unsuitable.	i. Comparatively longer abutment stem. ii. Deep excavation and dewatering required. iii. Potential for settlements.	i. Lower geotechnical resistance than piles. ii. High cost of constructing engineered fill. iii. Potential settlements.
RECOMMENDED	**NOT RECOMMENDED**	**FEASIBLE BUT NOT RECOMMENDED**	**FEASIBLE**

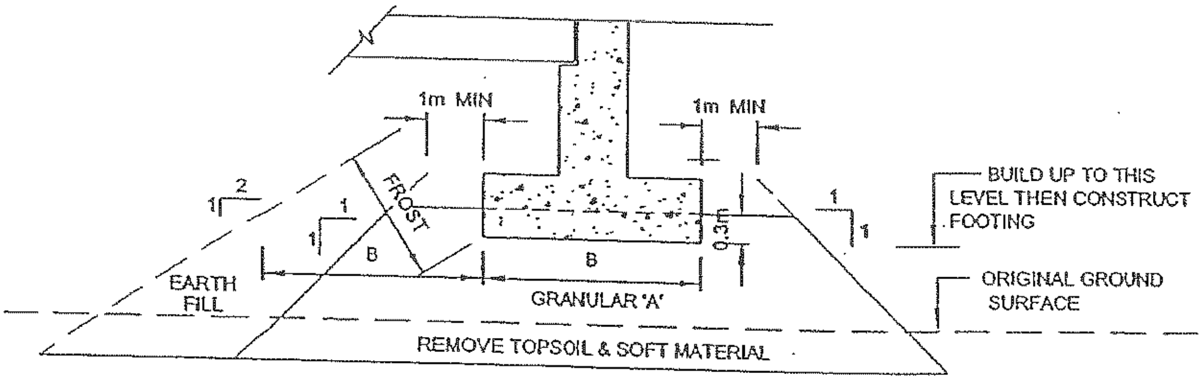
Appendix E

Figure

March , 2004



CROSS-SECTION



LONGITUDINAL SECTION

NOT TO SCALE

NOTES:

1. REMOVE TOPSOIL AND OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' AND EARTH FILL.
2. PLACE GRANULAR 'A' AND EARTH FILL TO BOTTOM OF FOOTING LEVEL, COMPACTED ACCORDING TO O.P.S.S. 501.
3. CONSTRUCT CONCRETE FOOTING.
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. SOURCE M.T.C. 1982.

ENGINEER AEG	ABUTMENT ON COMPACTED FILL SHOWING GRANULAR A CORE	THURBER
DRAWN SS		
DATE		
APPROVED PKC		DWG. NO. FIGURE 1
SCALE NTS		

TED35146.DWG

Appendix F

List of SPs and OPSS, and Suggested Text for Selected NSSP

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

- OPSS 572
- OPSS 902 as amended by Special Provision 902S01.
- SP 110F13 Amendment to OPSS 1010, March 1993
- SSP 105S10
- OPSD 3501.000
- OPSD 3505.000
- OPSD 3501.000
- OPSD 3505.000

OPSS 206, as amended by Special Provision "Amendment to OPSS 206, December 1993", dated November 2002.

2. Suggested text for a NSSP on Pile Installation

The till may contain cobbles and boulders, particularly below Elevation 250.0 at the west abutment and elevation 240.0 m at the pier and east abutment. The presence of cobbles and boulders will potentially have an impact on the installation of piles at the site. Some possible impacts that must be taken into consideration include, but are not necessarily limited to:

- The cobbles and boulders may impede the driving of the piles resulting in more arduous driving in the very dense soils.
- Some piles may meet refusal on boulders that are large enough not to be dislodged or broken by the pile driving.
- As a result of the presence of boulders, piles may meet refusal at varying depths.
- Pile driving must be controlled according to the criteria specified for the site.

CSP FOR INTEGRAL ABUTMENT - Item No.

Special Provision

Scope

This specification covers the requirements for the installation of the CSP's, including sand fill and polystyrene sheets, at the integral abutments.

References

This specification refers to the following standards, specifications or publications:

Ontario Provincial Standard Specifications, Construction:

OPSS 906 Structural Steel
OPSS 909 Prestressed Concrete - Precast Members

Ontario Provincial Standard Specifications, General:

OPSS 180 Management and Disposal of Excess Materials

Ontario Provincial Standard Specifications, Material:

OPSS 1605 Expanded Extruded Polystyrene
OPSS 1801 Corrugated Steel Pipe Products

Canadian Standards Association Standards:

CSA G164-M Galvanizing of Irregularly-Shaped Articles

Ministry of Transportation Publications

MTO Manual of Designated Sources of Materials

Definitions

For the purposes of this specification, the following definitions apply:

Abutment Stem: means the cast-in-place concrete component of the abutment placed over the top of the piles and forming the bearing seat for the girders.

CSP: means helical corrugated steel pipe.

Design Engineer: means the Engineer who produces the design and/or working drawings, and who has a minimum of five (5) years in the design and/or construction of bridges.

Submission and Design Requirements

Submissions

All submissions shall bear the seal and signature of the Design Engineer.

At least two weeks prior to commencement of installation of the abutment, the Contractor shall submit to the Contract Administrator, for information purposes only, three (3) sets of the working drawings.

The Contractor shall have a copy of the submitted working drawings on site at all times.

Working Drawing Requirements

Working drawings shall include at least the following:

1. Layout and Elevations of the CSP's;
2. Source of the sand fill, and description of placing method and equipment;
3. Location and details of all temporary bracing, including permanent and temporary spacers, for the piles, CSP's and abutment stems;
4. Detailed construction sequence for the work, including installation and removal of the temporary bracing.

Design Requirements

The Contractor shall be responsible for the complete detailed design of the construction sequence for the work, including the installation and removal of all temporary bracing. The general sequence of construction shall be as shown on the Contract drawings.

The Contractor shall be responsible for the complete detailed design of all temporary bracing, including temporary and permanent spacers, required to maintain the piles, CSP's, abutment stems and girders in their specified positions through all stages of construction until concrete in deck has reached a compressive strength of 25 MPa. All temporary bracing, except spacers identified as permanent on the Contract drawings, shall be removed.

Temporary bracing for prestressed, precast girders shall meet the requirements of OPSS 909. Temporary bracing for structural steel girders shall meet the requirements of OPSS 906.

Material

Corrugated Steel Pipe

CSP shall be in accordance with OPSS 1801, and shall be from a supplier listed under DSM # 4.60.80. The CSP shall be of the diameter and wall thickness specified on the Contract drawings, and shall be galvanized in accordance with CSA G164-M.

Permanent Spacers and Associated Hardware

Permanent spacers and associated hardware left in place shall not consist of wood and corrodible material.

Sand Fill

The sand fill for backfilling the inner CSP shall meet the gradation requirements of Table 1 below:

Table 1 - Sand Fill Gradation Requirements

MTO Sieve Designation		Percentage Passing by Mass
2 mm	# 10	100 %
600 μm	# 30	80 % to 100 %
425 μm	# 40	40 % to 80 %
250 μm	# 60	5 % to 25 %
150 μm	# 100	0 % to 6 %

Expanded Extruded Polystyrene

Expanded extruded polystyrene shall be in accordance with OPSS 1605, and shall be from a supplier listed under DSM # 3.30.30.

Construction

General

The sequence of construction for installing the concrete pads, CSP's, sand fill and abutment stems, including the installation and removal of the temporary bracing, shall be in accordance with the working drawings.

The Contractor shall not proceed with the abutment backfill above the level of the bottom of the CSP's without written permission from the Contract Administrator.

Corrugated Steel Pipe

CSP's shall be supplied in the lengths and with the end treatments, either square or skew, as specified on the Contract drawings; field cutting and splicing of CSP's will not be permitted. Cut ends shall be neat and free of burrs. The planes defined by the end treatments of each CSP shall be parallel to each other.

Handling and storage of CSP's shall be in accordance with the manufacturer's recommendations. Damaged CSP's shall be rejected. Localized areas of damaged galvanizing on otherwise acceptable CSP's shall be repaired by two coats of zinc-rich paint.

The Contractor shall set the inner and outer CSP over each pile in the abutment into the concrete pad, following the batter of the pile, while the concrete in the concrete pad is still plastic. The CSP's shall extend at least 150 mm into the concrete pad.

The Contractor shall ensure the full perimeter of the tops of all CSP's at each abutment are at the Elevation shown on the working drawings.

After the CSP's have been set, the Contractor shall take all measures necessary to prevent the ingress of water, backfill and debris into the CSP's.

Sand Fill

The sand fill shall be placed dry of optimum and free-flowing, completely filling the volume between the inner CSP and pile. No additional compaction effort other than the action of placing the sand fill itself shall be applied to the sand fill.

The placing of the sand fill shall be carried out in a manner such as to not damage and displace the CSP's.

After the sand fill has been placed to the top of each inner CSP, the Contractor shall take all measures necessary to prevent the ingress of water and other liquids into the sand fill until after the concrete in the abutment stem has been placed and cured.

Expanded Extruded Polystyrene

The expanded extruded polystyrene sheets shall completely cover the area under the abutment stem as shown on the Contract drawings. The sheets shall be placed in one piece for the width of the abutment stem, with butt joints perpendicular to the centre-line of abutment bearings. The minimum length of sheet shall be 500 mm.

Joints between sheets within 500 mm of a pile centre-line will not be permitted. At each pile location, a minimum 1000 mm long sheet shall be centred on the pile and a 500 mm diameter hole neatly cut in the sheet so as to fit over the pile in one piece, fully spanning the annular space between the double CSP's.

The Contractor shall adjust the backfill to ensure full and uniform contact of the sheets with the backfill and the full perimeter of the tops of the CSP's. The vertical step at joints between sheets shall not exceed 5 mm.

The Contractor shall protect the sheets from damage during installation of the reinforcing for the abutment stem, and shall secure the sheets from "floating" during placing of the concrete in the abutment stem. Only hardware approved by the Owner shall be used to secure the sheets. All hardware used to secure the sheets shall be installed so as not to project above the top surface of the sheets into the abutment stem.

Temporary Bracing

Temporary bracing shall be installed and removed in accordance with the working drawings.

The temporary bracing shall not distort, nor pierce the walls of, the CSP's. Welding to the CSP's will not be permitted.

Concrete anchors shall be removed and the holes filled with non-shrink grout.

Tolerances

The CSP's at each pile shall be constructed to the following tolerances:

Criteria	Tolerance
Maximum deviation of inner and outer CSP from pile centroid.	± 25 mm
Maximum deviation from specified spacing between inner and outer CSP's.	± 25 mm
Maximum deviation of any point on the top perimeter of the CSP's from the specified Elevation.	± 10 mm

Quality Assurance

Prior to placing the CSP's, the Contractor shall establish reference points at each abutment and determine the location of the centroid of each pile in the abutment with respect to these reference points. The Contractor shall maintain the reference points until written permission to proceed with the backfill above the level of the bottom of the CSP's has been given by the Contract Administrator.

Measurement for Payment

There will be no measurement for this item.

Basis of Payment

Payment at the contract price for the above items shall be full compensation for all labour, equipment and material required to do the work.

Appendix G

Slope Stability Output

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Earth Fill	21	0	30	1
Sand & Silt Till	22	0	30	1

Thurber Engineering Ltd. - Toronto
19-1605-69 Hwy404 Extension Green Lane to Queensville Road
Queensville Road
August 27, 2009
East and West Approaches - Earth Fill
Embankment height: 15 m

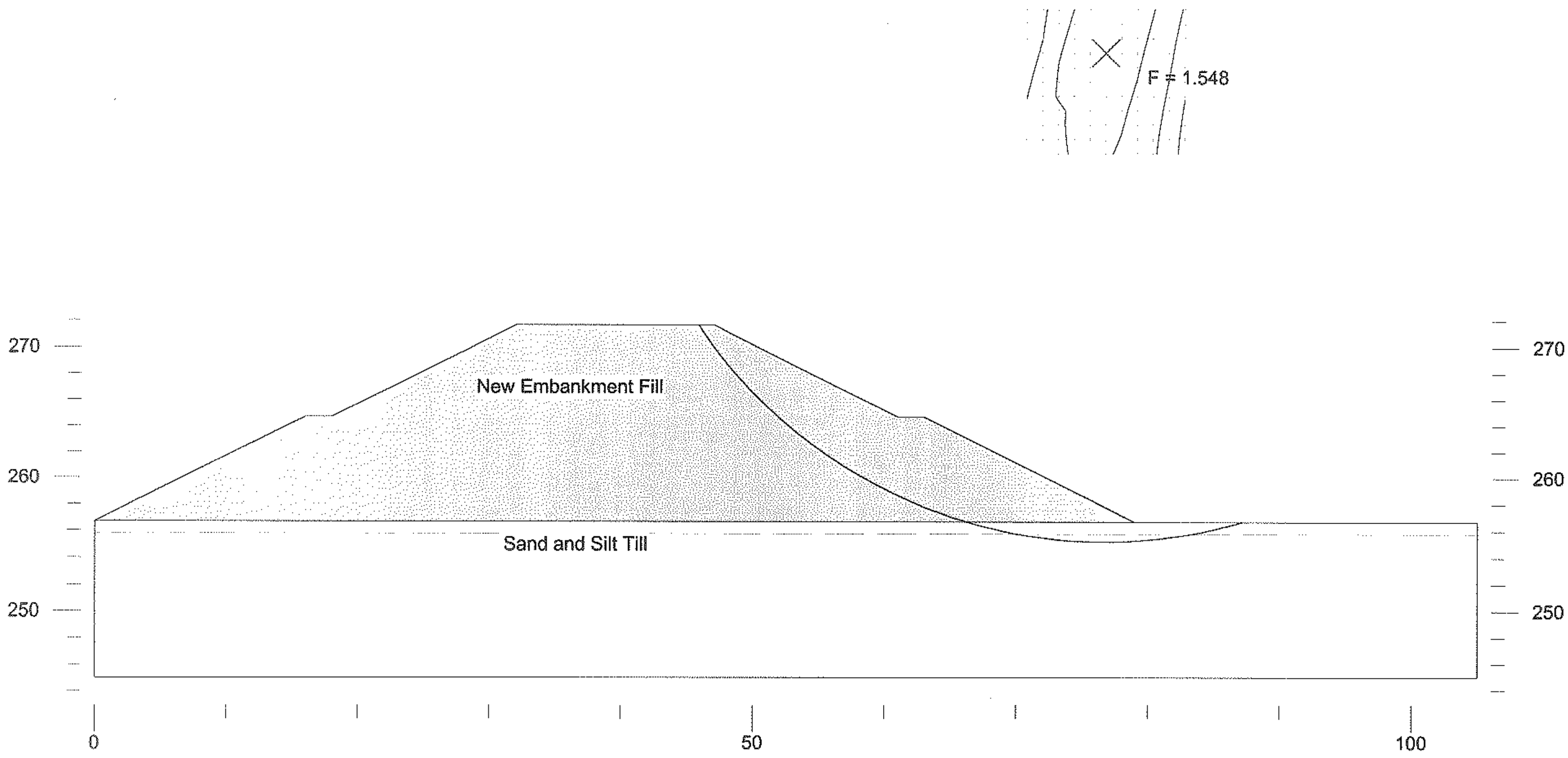


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FIGURE 1

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Earth Fill	21	0	30	1
Sand & Silt Till	22	0	30	1

Seismic coefficient = 0.08

Thurber Engineering Ltd. - Toronto
19-1605-69 Hwy404 Extension Green Lane to Queensville Road
Queensville Road
August 27, 2009
East and West Approaches - Earth Fill
Embankment height: 15 m - SEISMIC

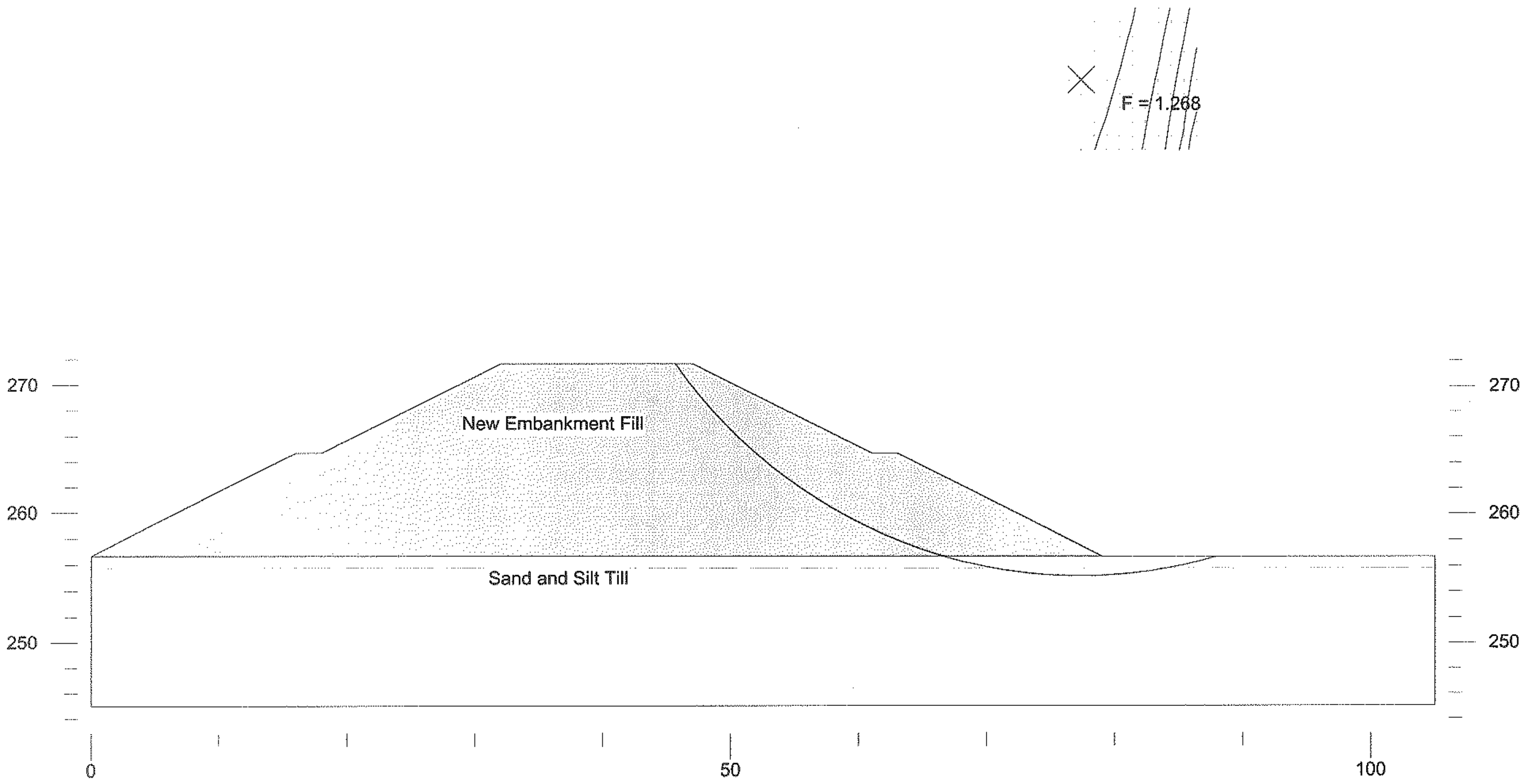

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FIGURE 2

Appendix H

Site Photographs

Photograph 1 – View of the site looking north of Queensville Sideroad

Photograph 2 – View of the site looking northwest of Queensville Sideroad

Photograph 3 –Looking south of Queensville Sideroad

Photograph 4 – Looking west along Queensville Sideroad

Appendix I

Drawing
Borehole Locations and Soil Strata

METRIC

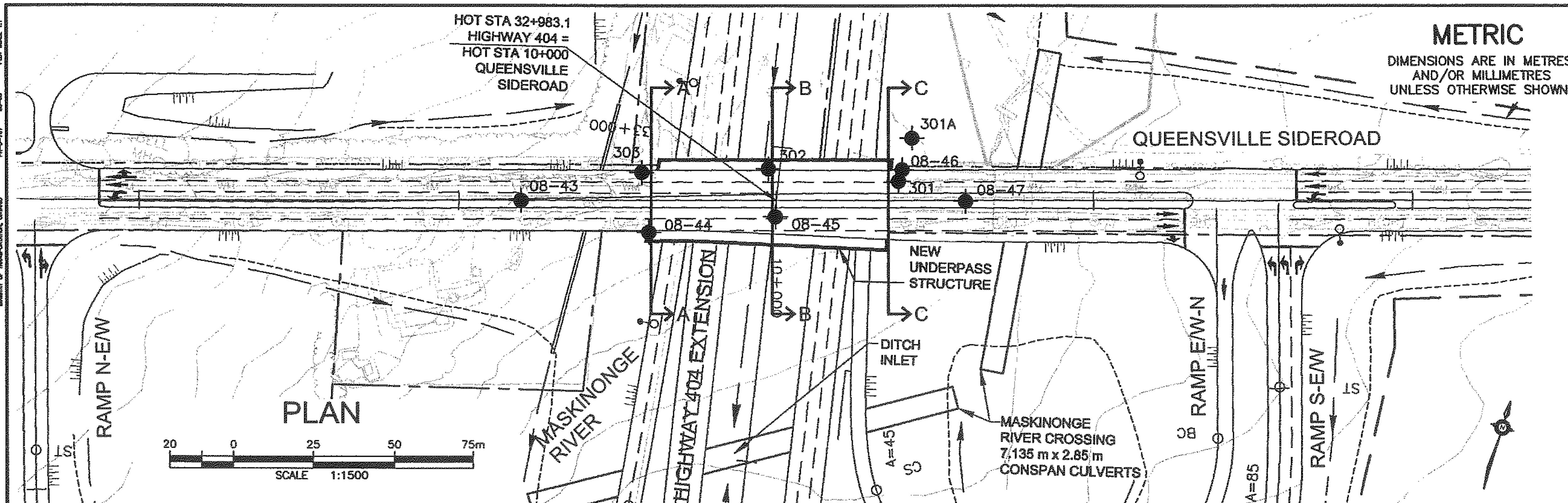
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

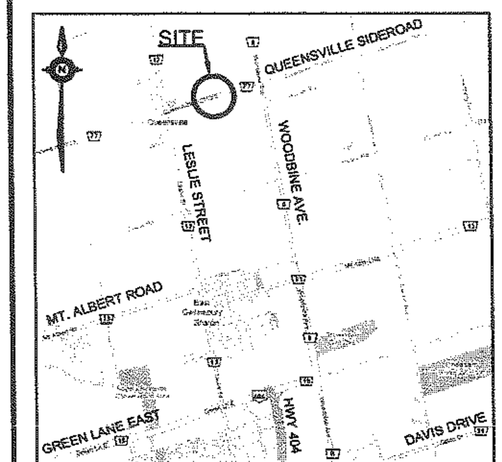
CONT No
GWP No

HIGHWAY 404 EXTENSION
FOUNDATIONS
QUEENSVILLE UNDERPASS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



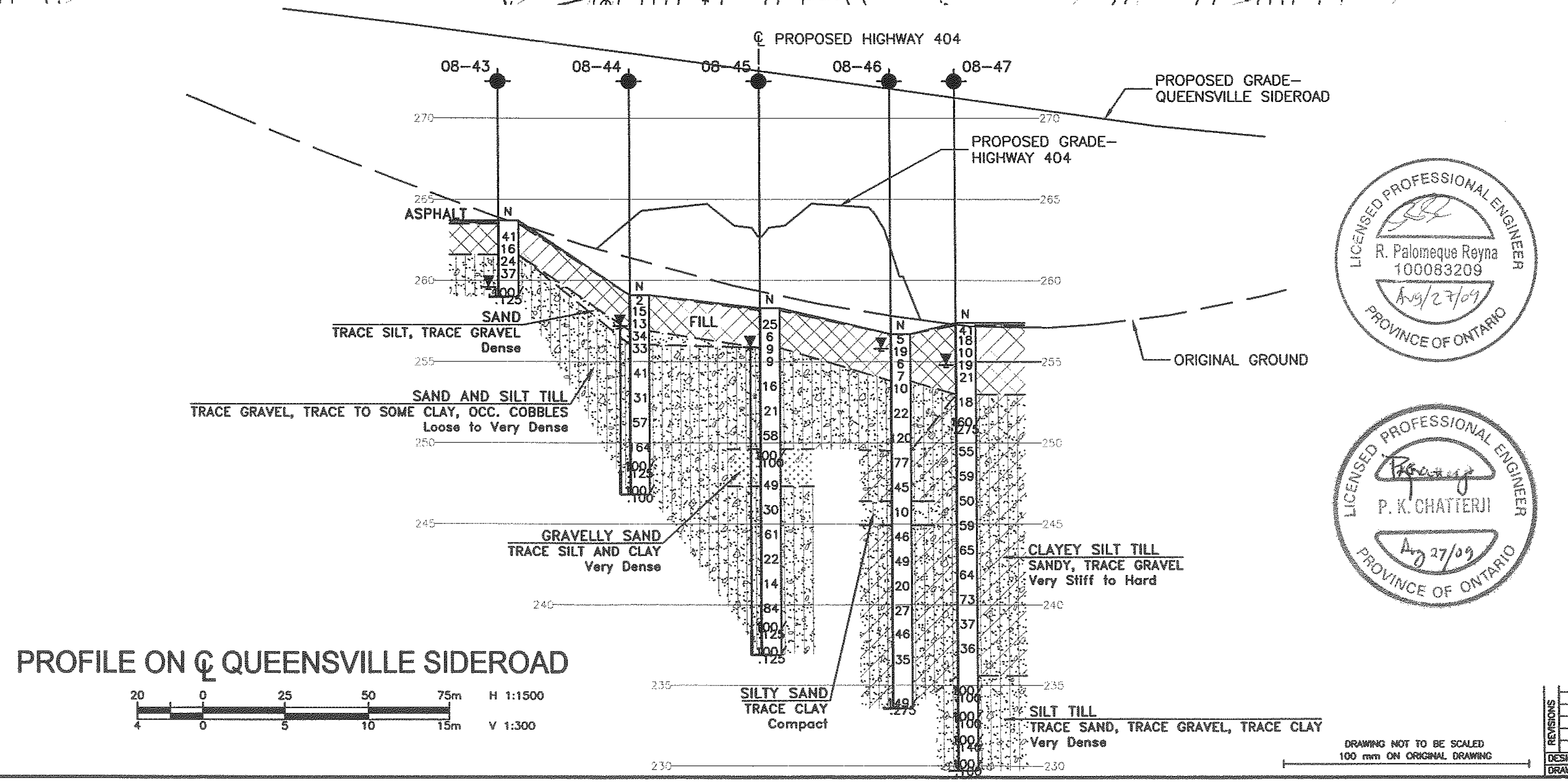


KEYPLAN

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
- Head Artesian Water
- Piezometer
- 90% — Rock Quality Designation (RQD)
- A/R — Auger Refusal

NO	ELEVATION	NORTHING	EASTING
08-43	263.9	4 889 051.2	309 710.3
08-44	259.1	4 889 053.5	309 751.4
08-45	258.3	4 889 070.2	309 788.1
08-46	256.7	4 889 096.4	309 821.8
08-47	257.4	4 889 092.8	309 843.9
301	257.5	4 889 092.6	309 821.8
301A	256.0	4 889 107.0	309 821.9
302	259.0	4 889 084.1	309 781.5
303	261.0	4 889 071.0	309 743.7



PROFILE ON ℄ QUEENSVILLE SIDEROAD

H 1:1500
V 1:300

LICENSED PROFESSIONAL ENGINEER
R. Palomeque Reyna
100083209
Aug/27/09
PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
Aug 27/09
PROVINCE OF ONTARIO

-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.

GEOCRES No. 31D-449

DRAWING NOT TO BE SCALED
100 mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	DESCRIPTION
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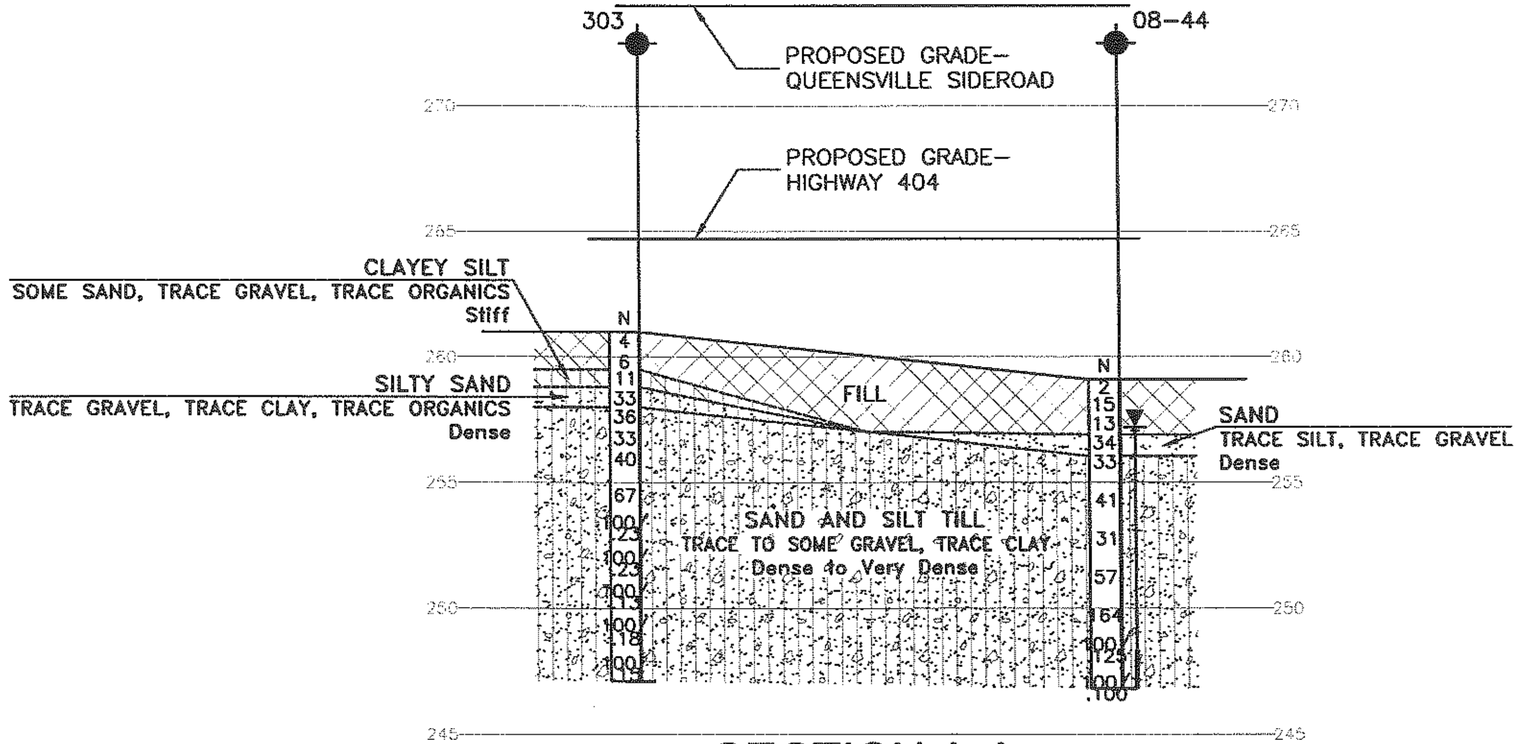
METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN



SECTION A-A

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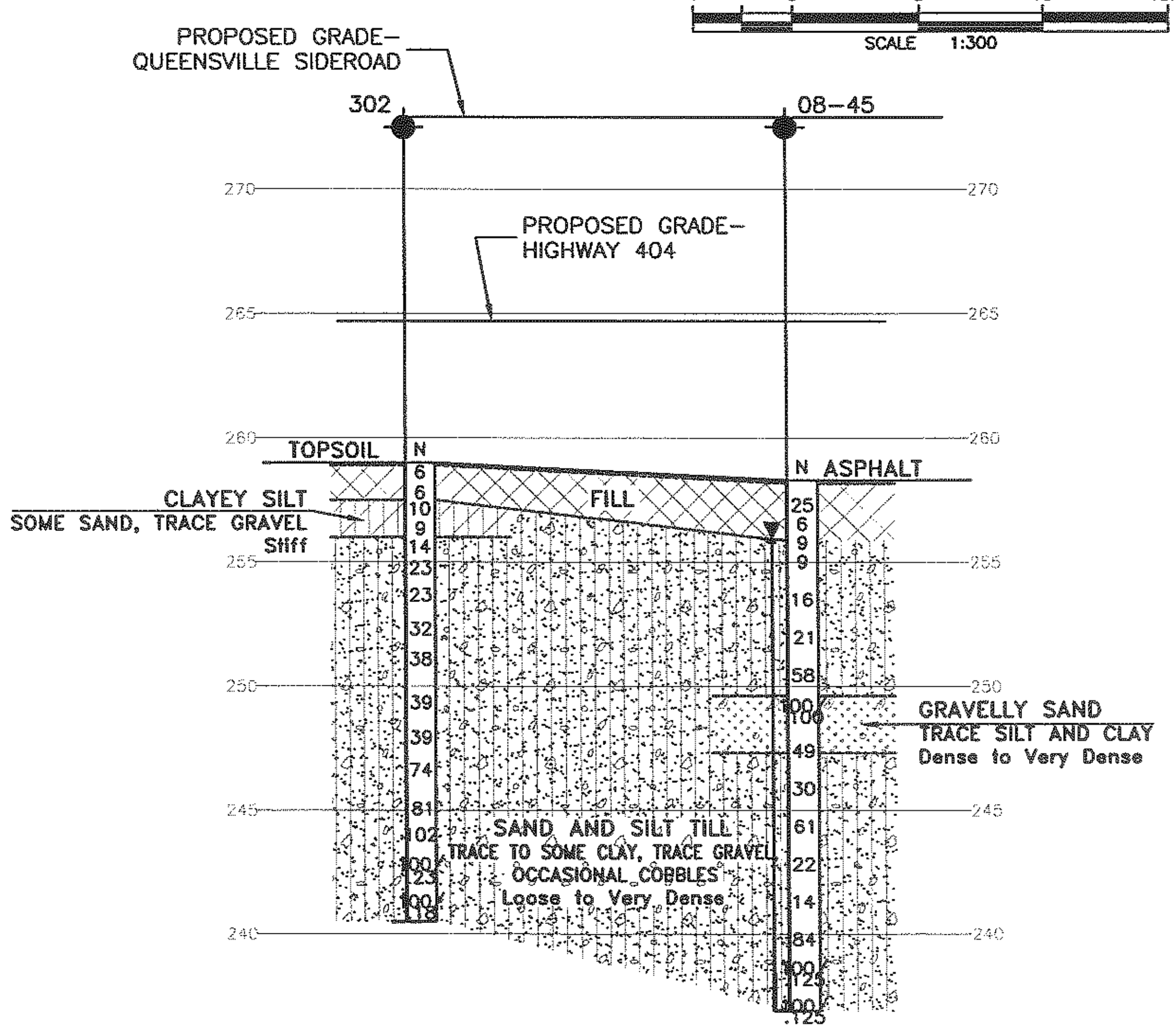

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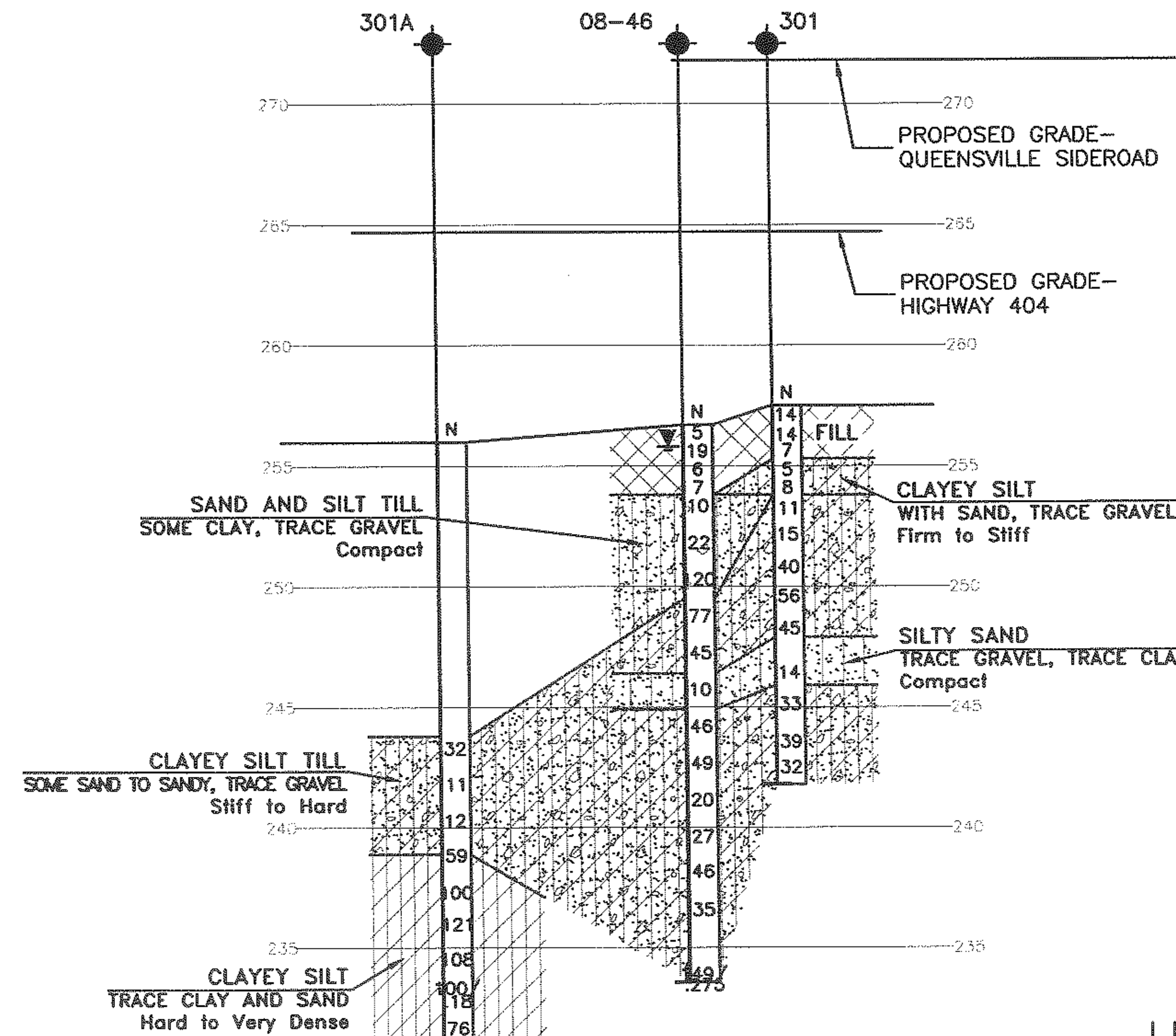


SECTION C-C

LICENSED PROFESSIONAL ENGINEER R. Palomeque Reyna 100083209 Aug/27/09 PROVINCE OF ONTARIO

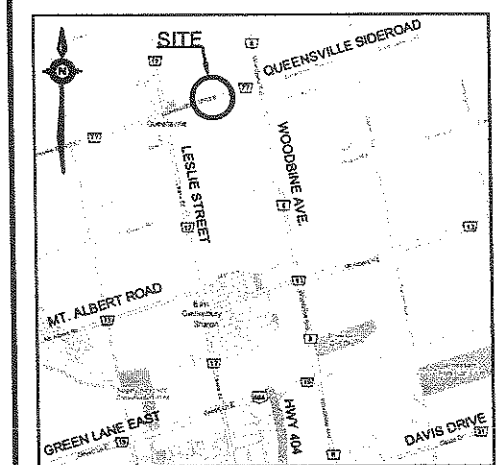
LICENSED PROFESSIONAL ENGINEER P. K. CHATTERJI Aug 27/09 PROVINCE OF ONTARIO

CONT No
GWP No

HIGHWAY 404 EXTENSION
QUEENSVILLE UNDERPASS
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



KEYPLAN

LEGEND

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

NO	ELEVATION	NORTHING	EASTING
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301A	256.0	4 889 107.0	309 821.9
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-NOTES-

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GEOCRES No. 31D-449

DRAWING NOT TO BE SCALED
100 mm ON ORIGINAL DRAWING

REVISIONS | DATE | BY | DESCRIPTION

DESIGN | CHK AEG | CODE | LOAD | DATE AUG. 2009
DRAWN MFA | CHK RPR | SITE | STRUCT | DWG