FOUNDATION INVESTIGATION AND DESIGN REPORT
RETAINING WALL – NORTH OF GREEN LANE
HIGHWAY 404 EXTENSION
FROM GREEN LANE TO QUEENSVILLE SIDEROAD
ONTARIO
G.W.P. 2109-05-00

Geocres Number: 31D-455

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 retaining wall to be constructed in connection with the proposed Highway 404 extension project 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 and stratigraphic profile, 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.

2 SITE DESCRIPTION

The proposed retaining wall will be located in the northeast quadrant of the Hwy 404 and Green Lane interchange, approximately 900.0 m west of Woodbine Avenue (York Regional Road 8), in the Town of East Gwillimbury, Regional Municipality of York.

The ground surface within the proposed structure varies, from south to north, from Elevation 290.0 to Elevation 287.0.

The site lies in a cultivated field at the edge of a wooded area. The lands around the site are generally agricultural. Vegetation beyond the cultivated area consists mainly of tall grass, shrubs and a few mature trees. There are farmsteads to the north and south of Green Lane.

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 D show:

1. View of the site looking at Borehole RW09-1 drilled near the south end of the proposed retaining wall.
2. View of the site looking at Borehole RW09-2 drilled near the proposed retaining wall.
3. View of the site looking at Borehole RW09-3 drilled near the north end of the proposed retaining wall.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out on January 14, 2009 and consisted of drilling and sampling three boreholes (numbered RW09-1 to RW09-3) along the alignment of the proposed retaining wall.

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

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

Drilling was carried out using a track mounted B-57 drill rig. Solid 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. A standpipe piezometer consisting of 19 mm diameter PVC pipe with slotted screens was installed and enclosed in filter sand in one borehole (RW09-1) to permit longer term groundwater level monitoring. The location and completion details of the piezometer are shown in Table 3.1.

Table 3.1 – Borehole Completion Details

Location Relative to Retaining Wall	Borehole	Piezometer Tip Depth/ Elevation (m)	Completion Details
North end	RW09-1	7.6/282.4	Sand from 7.6 m to 5.5 m, holeplug from 5.5 m to 0.3m, cuttings from 0.3 m to surface.
Centre	RW09-2	None installed	Borehole backfilled with holeplug to 0.6 m, then auger cuttings to surface.
South end	RW09-3	None installed	Borehole backfilled with holeplug to 2.4 m, then auger cuttings 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). 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 Appendix A. Details of the encountered soil stratigraphy are presented in these sheets and on the "Borehole Locations and Soil Strata Drawing" in Appendix E. An overall description of the stratigraphy is given in the following paragraphs. However, the factual data presented in the Record of Borehole Sheets governs any interpretation of the site conditions.

The soil stratigraphy encountered at the borehole locations typically consists of topsoil overlying native deposits of sand, sandy silt till and sand and silt till. More detailed descriptions of the individual strata are presented below.

5.1 Topsoil

Topsoil was identified at ground surface in the three boreholes drilled along the proposed alignment of the retaining wall. The topsoil thickness ranged from 400 mm to 500 mm.

The topsoil thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities.

5.2 Sand

Native brown sand was contacted below the topsoil in Boreholes RW09-1 and RW09-2. Thickness of the sand layer ranged from 300 mm to 400 mm. The depth to the base of the sand layer was 0.8 m in both boreholes (Elevations 289.3 and 287.6 in Boreholes RW09-1 and RW09-2, respectively).

SPT 'N' values were 6 and 9 blows per 0.3 m of penetration, indicating a loose relative density. The moisture contents of samples from the sand layer were 22% and 32%.

5.3 Sandy Silt Till

Layers of native brown sandy silt till containing some clay were observed in all the boreholes at depths and elevations as indicated in Table 5.1.

Table 5.1 – Locations of Native Sand and Silt Till

Location Relative to Retaining Wall	Borehole	Depth below existing ground surface (m)	Elevation (m)	Thickness (m)
North end	RW09-1	0.8 to 1.4	289.3 to 288.6	0.7
Centre	RW09-2	0.8 to 2.1	287.6 to 286.2	1.4
South end	RW09-3	0.5 to 2.6	286.6 to 284.4	2.2

Standard Penetration tests in the sandy silt till deposit gave SPT 'N' values ranging from 6 to 43 blows per 0.3 m of penetration, indicating a loose to dense relative density. The moisture content of samples from the sandy silt till deposit varies between 18% and 32%.

Grain size distributions for sandy silt till samples tested are presented on the Record of Borehole sheets and on Figure B1 of Appendix B.

The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Gravel	0
Sand	18 to 21
Silt	62 to 68
Clay	11 to 17

Glacial tills inherently contain cobbles and boulders.

5.4 Sand and Silt Till

Layers of native grey sand and silt till containing some clay, trace gravel and occasional sand seams were observed below the sandy silt till at 1.4 m, 2.1 m and 2.6 m depths (Elevations 288.6, 286.2 and 284.4) in Boreholes RW09-1, RW09-2 and RW09-3, respectively. Boreholes were terminated within the sand and silt till deposit at depths ranging from 7.7 m to 7.9 m (Elevations 282.1 to 279.3).

Standard Penetration tests in this sand and silt till deposit gave SPT 'N' values ranging from 104 blows per 0.3 m of penetration to higher than 100 blows per 0.1 m of penetration, indicating a very dense relative density. The moisture content of samples from the sand and silt till deposit varies between 6% and 18%.

Grain size distributions for sand and silt till samples tested are presented on the Record of Borehole sheets and on Figure B2 of Appendix B.

The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Gravel	0 to 7
Sand	36 to 52
Silt	34 to 44
Clay	11 to 16

Glacial tills inherently contain cobbles and boulders which may account for some high SPT 'N' values.

5.5 Water Levels

Water levels were observed in the boreholes during and upon completion of drilling. A standpipe piezometer was installed in Borehole RW09-1 to monitor water levels after completion of drilling. The water levels measured in the piezometer are summarized in Table 5.1, along with the measurements in the boreholes upon completion of drilling.

Table 5.1 – Water Level Measurements

Location Relative to Retaining Wall	Borehole	Date (2009)	Water Level (m)		Comment
			Depth	Elevation	
North end	RW09-1	January 14	2.9	287.1	Open borehole
		February 6	4.5	285.5	In piezometer
		February 10	4.1	285.9	In piezometer
Centre	RW09-2	January 14	1.8	286.5	Open borehole

The piezometric readings indicate that the water level is near Elevation 285.9.

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 a track mounted B-57 drill rig 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 Ms. R. Palomeque Reyna, 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 for the proposed retaining wall.

The proposed length of the retaining wall is approximately 127 m (approximate Stations 26+679 to 28+806). Details of the proposed retaining wall were not provided at the time of preparation of this report.

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 investigation.

8 STRUCTURE FOUNDATIONS

Based on the results of the boreholes drilled along the proposed retaining wall alignment, the stratigraphy at the site generally consists of topsoil overlying native loose sand, loose to dense sandy silt till and very dense sand and silt till deposit.

The piezometric readings indicate that water level at this site is generally 4.0 m below ground surface, near Elevation 285.9.

In preparation of geotechnical design recommendations, consideration was given to the following wall designs:

- A conventional cantilever wall with granular backfill on spread footings founded on native dense soils
- Retained Soil System (RSS) wall
- A concrete toe wall

Foundation recommendations for each type of wall are presented below.

8.1 Cantiliver Wall on Spread Footings

Construction of a new retaining wall supported on spread footings on native ground is considered feasible.

The retaining wall footings must be founded on native undisturbed dense sandy silt till or very dense sand and silt till. The highest permitted founding elevations for spread footings on native dense sandy silt till or very dense sand and silt till are given in Table 8.1.

Table 8.1 – Highest Permitted Founding Elevations

Location Relative to Retaining Wall	Borehole	Depth below existing ground surface (m)	Founding Elevation (m)	Soil Conditions
North end	RW09-1	1.6	288.4	Very dense sand and silt till
Centre	RW09-2	2.3	286.0	Very dense sand and silt till
South end	RW09-3	1.6	285.4	Dense sandy silt till

Provided a minimum footing width of 2 m is maintained, the design of spread footings bearing on native undisturbed dense sandy silt till or very dense sand and silt till at or below elevations indicated in Table 8.1 should be designed using a factored geotechnical resistance of 600 kPa at ULS. The recommended geotechnical resistance at SLS is 400 kPa for a settlement not exceeding 25 mm.

The geotechnical resistances quoted above are for concentric, vertical loads only. The retaining wall will impose eccentric or inclined loading and the geotechnical resistance must be modified as illustrated in the CHBDC Clause 6.7.3 and Clause 6.7.4.

Based on the recommended founding elevations, excavations for the wall foundations may penetrate approximately 0.5 m below the groundwater table. The design of the temporary works required to control the groundwater and permit construction in the dry is the responsibility of the Contractor. However, one system that may be adequate consists of perimeter ditching, filtered sumps and pumps.

The sliding resistance of mass concrete poured on the native sandy silt till and sand and 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 must 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 of concrete as used in 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.

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.

8.2 Retained Soil Systems

RSS walls used on this project must be specified to be "High Performance" and "High Appearance". Therefore it is important that the RSS walls be founded on soil capable of supporting the imposed loading and limiting settlements under the RSS wall to acceptable magnitudes.

Provided the RSS design takes into account the subsurface conditions at this site and proper foundation preparation is carried out prior to construction of the walls, RSS systems are expected to meet the aesthetic and structural requirements.

To provide an acceptable foundation performance, the RSS must be founded on compact to very dense sandy silt till or sand and silt till and extended below the level of any topsoil or disturbed material.

The highest permitted base levels for the underside of the RSS system are as presented in Table 8.2.

Table 8.2 – Highest Permitted Elevations for RSS

Location Relative to Retaining Wall	Borehole	Depth below existing ground surface (m)	Founding Elevation (m)	Soil Conditions
North end	RW09-1	1.6	288.4	Very dense sand and silt till
Centre	RW09-2	1.8	286.5	Very dense sand and silt till
South end	RW09-3	1.6	285.4	Dense sandy silt till

Alternatively, the RSS may be founded on engineered fill founded on the native, compact to very dense sand and silt till or dense sandy silt till. Engineered fill placed under the RSS mass to achieve the design founding level must consist 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 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 or engineered granular fill in contact with the sandy silt or sand and silt till may be estimated using an ultimate friction coefficient of 0.55.

The contract drawings must 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 must reference the NSSP for RSS walls.

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. RSS walls founded on the compact to very dense soils at this site and having a maximum height of 8.0 m are considered to be safe against global instability.

8.3 Concrete Toe Wall

In low fill situations, a toe wall may be appropriate. The toe wall design should be in accordance with OPSD 3120.100.

The highest permitted founding elevations foe toe walls on native soils to achieve a factored geotechnical resistance of 300 kPa at ULS are as presented for spread footings in Table 8.1.

If the toe wall is required to be founded at higher elevations, it may be placed on an engineered fill pad founded at the elevations given in Table 8.2. The engineered fill must consist of OPSS Granular "A" compacted to 100% of the SPMDD at within 2% of the optimum moisture content.

The sliding resistance of mass concrete poured on the native sandy silt till and sand and silt till or on engineered fill may be computed on the basis of an ultimate coefficient of friction of 0.55.

9 EXCAVATION

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA and due to the loose to compact conditions, the native soils in the upper 2 m at this site are classed as Type 3 soils. The underlying dense to very dense native sand and silt till above the water table are classified as Type 2 soils.

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 require dislodging and removal of cobbles and boulders.

10 UNWATERING

Piezometers installed in boreholes revealed that the groundwater level is near elevation 285.9. However, water was observed near elevation 286.5 in Borehole RW09-1 upon completion of drilling. Water table may be higher during spring or after a period of heavy rain fall. Perched water may be encountered locally within the upper cohesionless materials.

If footings are selected for foundations, it is anticipated that at some locations (near Borehole RW09-2) footing excavation will be close to or extend below the groundwater table and dewatering to lower the groundwater level below the footing excavation base will be required. 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.

11 BACKFILL

The wall backfill should consist of Granular A or Granular B material. The backfill must be in accordance with OPSS 902 as amended by Special Provision 902S01, and placed to the extents shown in OPSD 3121.150 where applicable. Backfill to the toe walls should be in accordance with OPSD 3120.100.

The design of the retaining walls must incorporate a subdrain as shown in OPSD 3121.150 and 3190.100. For RSS walls, supplier specifications should be followed.

Compaction equipment to be used adjacent to retaining structures must be restricted in accordance with OPSS 501.07.

12 EARTH PRESSURE

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

$$P_h = K*(\gamma h + q)$$

Where:

P_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 12.1 below)

γ = unit weight of retained soil (see Table 12.1 below)

h = depth below top of fill where pressure is computed (m)

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the retaining wall are dependent on the material used as backfill. Typical values for granular backfill are shown in Table 12.1.

Table 12.1 – 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	-

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

The factors in Table 13.1 above 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.

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.

Compaction equipment to be used adjacent to the retaining structure must be restricted in accordance with OPSS 501.07.

The design of the retaining wall must incorporate a subdrain as shown in OPSD 3121.150 and 3190.100. For RSS walls, supplier specifications should be followed.

13 SEISMIC CONSIDERATIONS

13.1 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.

13.2 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 under the existing conditions the foundation soils at the retaining wall are not prone to liquefaction.

[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.

13.3 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 13.1 may be used.

Table 13.1 – Earth Pressure Coefficient (K) for Earthquake Loading

Wall Condition	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	
	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

14 CONSTRUCTION CONCERNS

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

1. **Destabilization of excavations**

   If footing 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.

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

15 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 RW09-1

METRIC

G.W.P. 2109-05-00 LOCATION N 4 883 107.1 E 310 943.6 ORIGINATED BY ES

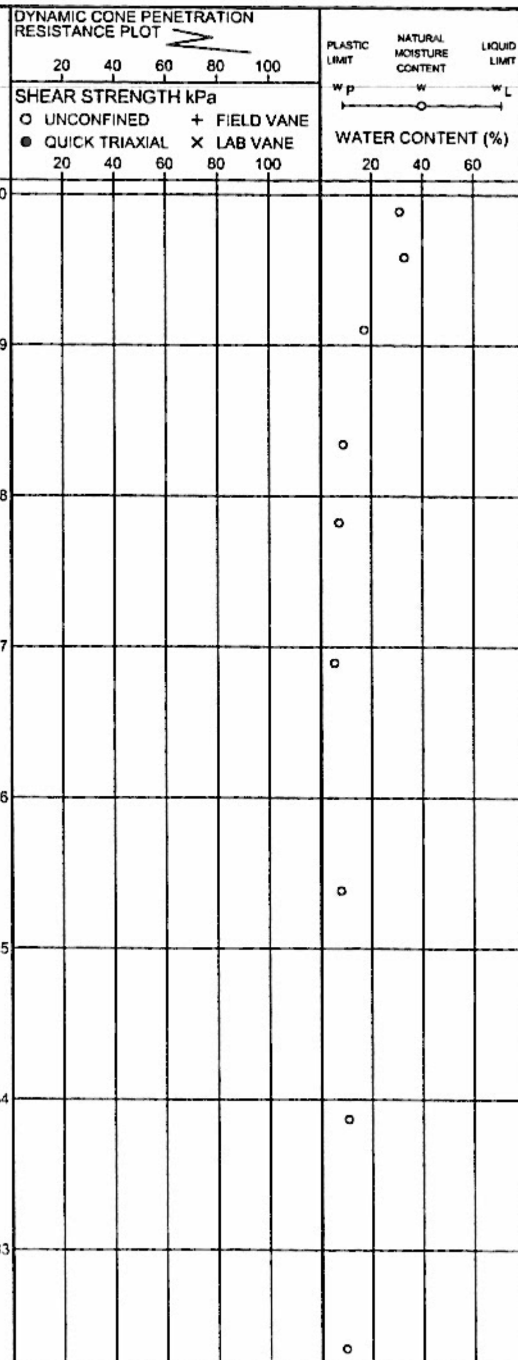
HWY 404 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN

DATUM Geodetic DATE 2009.01.14 - 2009.01.14 CHECKED BY RPR

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
290.0						
0.0	TOPSOIL, occasional organics, occasional roots, Loose, Dark Brown (400mm)	1	SS	9	290	
289.6 / 0.4						
289.3 / 0.8	SAND, trace silt, Loose, Brown, Moist	2	SS	6	289	0 21 68 11
288.6 / 1.4	Sandy SILT, some clay, Loose, Brown, Moist (TILL)	3	SS	105	288	
	SAND and SILT, some clay, trace gravel, occasional oxide staining, Very Dense, Grey, Damp (TILL)	4	SS	105/0.275		0 44 44 12
		5	SS	105	287	
					286	
		6	SS	105/0.275	285	4 45 37 14
		7	SS	108/0.250	284	
					283	
282.1		8	SS	118/0.250		
7.9	END OF BOREHOLE AT 7.9m. BOREHOLE OPEN AND WATER LEVEL AT 2.9m UPON COMPLETION OF DRILLING. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.					

WATER LEVEL READINGS:

DATE	DEPTH (m)	ELEV. (m)
2009.02.06	4.5	285.5
2009.02.10	4.1	285.9



UNIT WEIGHT γ kN/m³

$+^3, \times^3$: Numbers refer to Sensitivity   (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No RW09-2

METRIC

G.W.P.	2109-05-00	LOCATION	N 4 883 168.4 E 310 929.7
HWY	404	BOREHOLE TYPE	Solid Stem Augers
DATUM	Geodetic	DATE	2009.01.14 - 2009.01.14

ORIGINATED BY ES
COMPILED BY AN
CHECKED BY RPR

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
288.3 / 0.0	TOPSOIL, occasional organics, trace sand, Loose, Dark Brown (500mm)	1	SS	6		
287.8 / 0.5; 287.6 / 0.8	SAND, trace silt, Compact, Brown, Moist	2	SS	20		
	Sandy SILT, some clay, occasional oxidized staining, Compact, Brown, Wet (TILL)	3	SS	10	▽	0 21 62 17
286.2 / 2.1	SAND and SILT, some clay, trace gravel, Grey, Very Dense, Moist (TILL)	4	SS	104		
		5	SS	100/ 0.150		2 53 34 11
		6	SS	100/ 0.125		
		7	SS	100/ 0.100		
280.5 / 7.8		8	SS	132/ 0.225		

END OF BOREHOLE AT 7.8m.
BOREHOLE OPEN AND WATER LEVEL AT 1.8m UPON COMPLETION OF DRILLING.
BOREHOLE BACKFILLED WITH HOLEPLUG TO 0.6m, THEN AUGER CUTTINGS TO SURFACE.

Elevation scale: 288, 287, 286, 285, 284, 283, 282, 281

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m³

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

ONTMT4S 0596.GPJ 12/23/09

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No RW09-3

METRIC

G.W.P. 2109-05-00
LOCATION N 4 883 230.1 E 310 917.8
ORIGINATED BY ES

HWY 404
BOREHOLE TYPE Solid Stem Augers
COMPILED BY AN

DATUM Geodetic
DATE 2009.01.14 - 2009.01.14
CHECKED BY RPR

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION
287.0	
0.0	**TOPSOIL**, occasional organics, occasional roots Loose Dark Brown (500mm)
286.6 / 0.5	Sandy **SILT**, some clay, occasional oxidized staining Loose to Dense Brown Moist (TILL) Layer of firm silty clay (400mm)
284.4 / 2.6	**SAND** and **SILT**, trace gravel, some clay, occasional sand seams, occasional oxide staining Very Dense Grey Damp (TILL)
279.3 / 7.7	END OF BOREHOLE AT 7.7m. BOREHOLE OPEN AND DRY UPON COMPLETION OF DRILLING. BOREHOLE BACKFILLED WITH HOLEPLUG TO 2.4m, THEN CUTTINGS TO SURFACE.

SAMPLE NUMBER	TYPE	"N" VALUES	GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	6				
2	SS	6				
3	SS	43				
4	SS	36	0	18	65	17
5	SS	102/ 0.225				
6	SS	100/ 0.150				
7	SS	100/ 0.150	7	36	41	16
8	SS	100/ 0.100				

Column headings: STRAT PLOT; GROUND WATER CONDITIONS; ELEVATION SCALE (287, 286, 285, 284, 283, 282, 281, 280); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

ONTMT4S 0596.GPJ 3/17/09

Appendix B

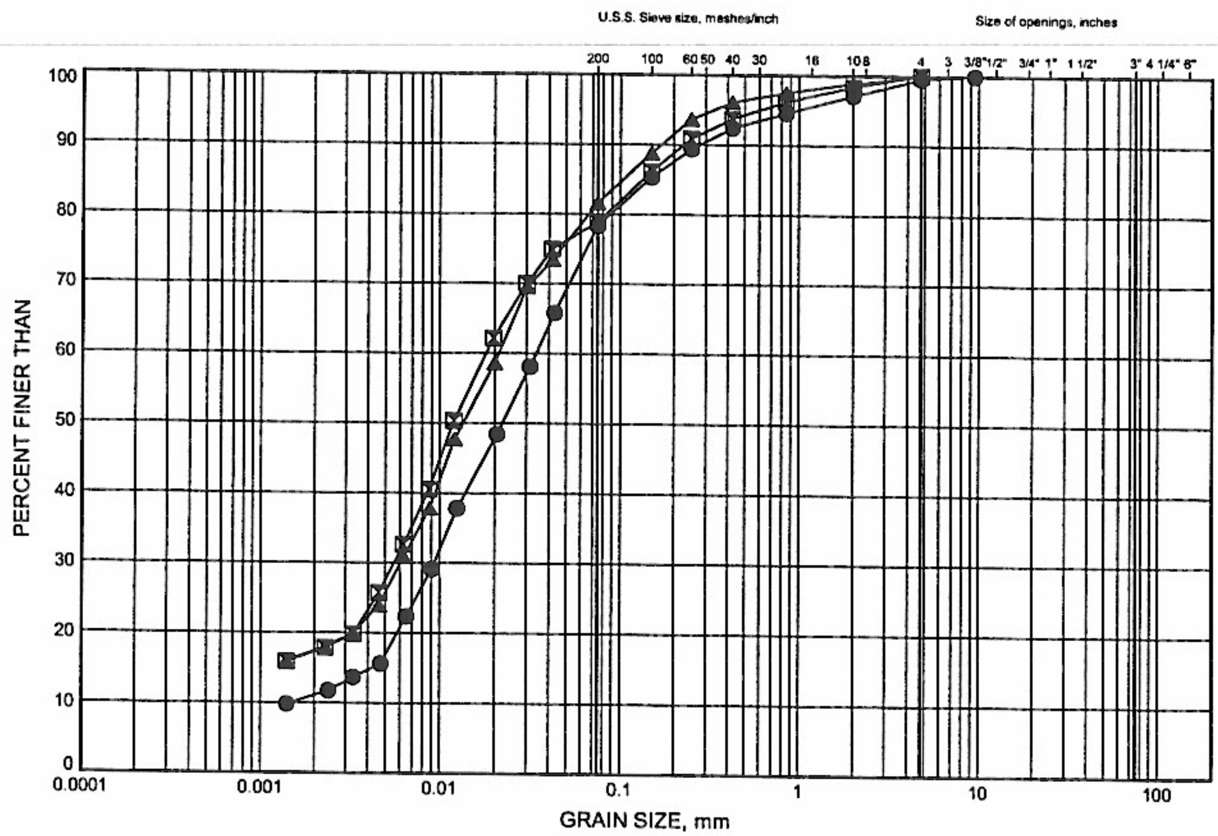
Laboratory Test Results

Hwy 404 Extension

GRAIN SIZE DISTRIBUTION

FIGURE B1

Sandy Silt TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RW09-1	0.99	289.03
⊠	RW09-2	1.75	286.57
▲	RW09-3	2.51	284.53

W.P.# 2109-05-00

Prepared By AN

Checked By RPR

THURBER

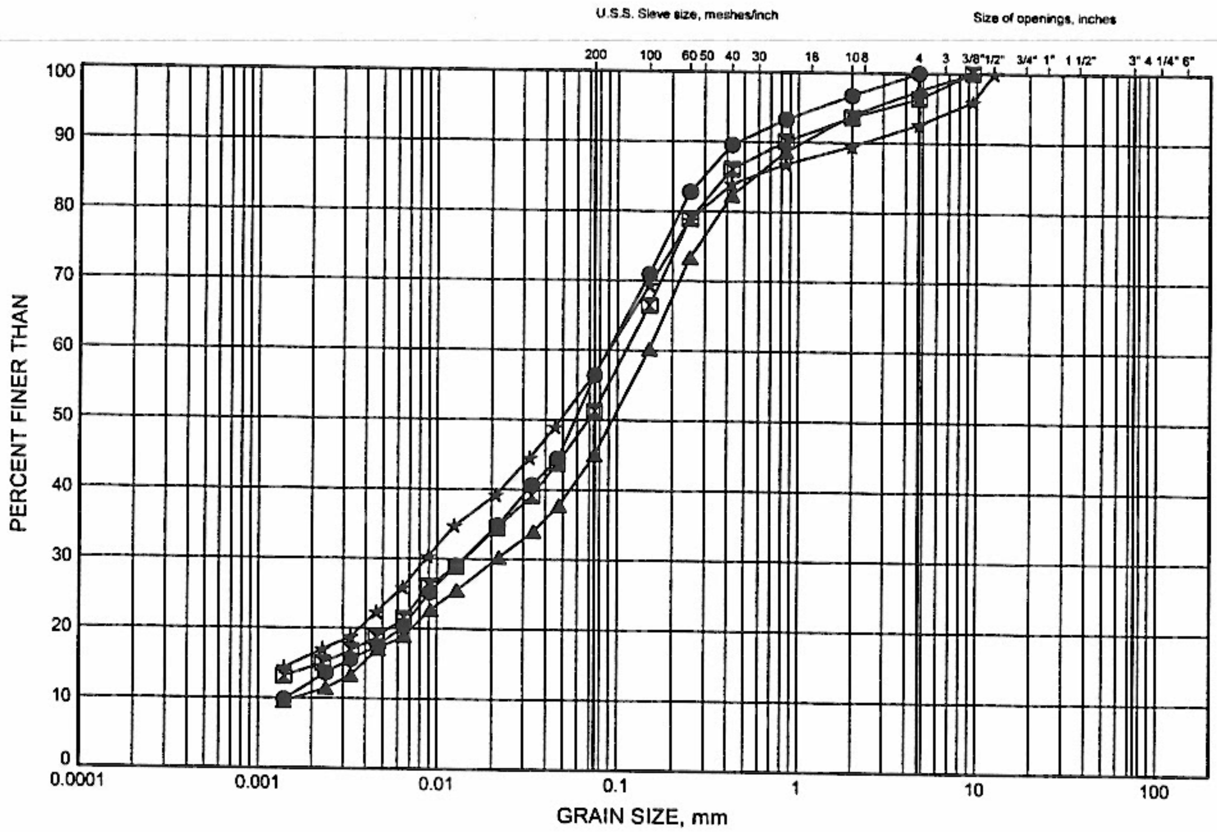
GRAIN SIZE DISTRIBUTION - THURBER 0596.GPJ 12/18/09

Hwy 404 Extension

GRAIN SIZE DISTRIBUTION

FIGURE B2

Sand & Silt TILL



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	RW09-1	2.58	287.44
⊠	RW09-1	4.71	285.31
▲	RW09-2	3.12	285.20
★	RW09-3	6.17	280.87

THURBER

W.P.# 2109-05-00

Prepared By AN

Checked By RPR

GRAIN SIZE DISTRIBUTION - THURBER 0596.GPJ 12/18/09

Appendix C

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

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

- SP 902S01
- OPSS 902
- OPSD 3121.150
- OPSD 3121.150
- OPSD 3190.100
- OPSS 501.07
- OPSD 3120.100
- OPSS 501

Appendix D

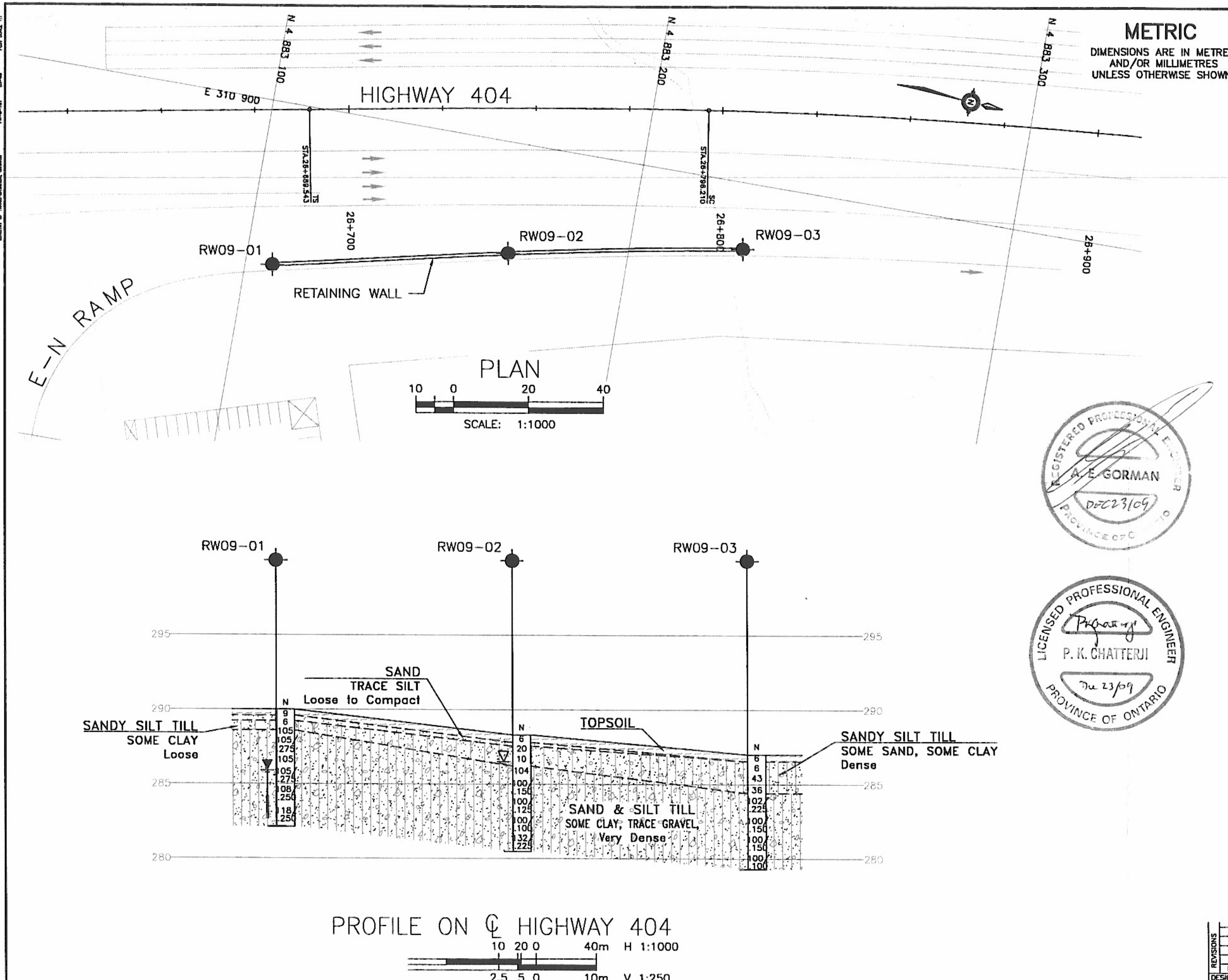
Site Photographs

Photograph 1

View of the site looking at Borehole RW09-1 drilled on the south end of the proposed retaining wall.

Photograph 2
View of the site looking at Borehole RW09-2 drilled at the proposed retaining wall.

Photograph 3
View of the site looking at Borehole RW09-3 drilled on the north end of the proposed retaining wall.



METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN

CONT No
GWP No 2109-05-00

HIGHWAY 404 EXTENSION
GREEN LANE
RETAINING WALL
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET

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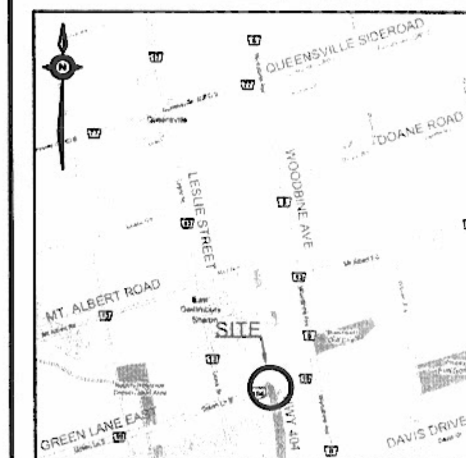
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



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
RW09-01	290.0	4 883 107.1	310 943.5
RW09-02	288.3	4 883 168.4	310 929.7
RW09-03	287.0	4 883 230.1	310 917.8

-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-455

REVISIONS DATE	BY	DESCRIPTION		
DESIGN RPR	CHK PKC	CODE	LOAD	DATE DEC. 2009
DRAWN AN	CHK AEG	SITE	STRUCT	DWG