

PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
S-E RAMP OVER WELLINGTON STREET/SHIRLEY AVENUE
HIGHWAY 7-NEW, KITCHENER TO GUELPH
G.W.P. 408-88-00

Geocres Number: 40P8-151

Report to

Ministry of Transportation Ontario
Southwestern Region

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a preliminary foundation investigation conducted at the site of the proposed S-E Ramp over Wellington Street/Shirley Avenue in the Regional Municipality of Waterloo. The proposed ramp is part of the Highway 7-New project.

The purpose of the 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, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions under the potential foundation footprint was developed from the data obtained in the course of the investigation.

The information collected in the course of the investigation and presented in this report is intended for preliminary design purposes only. Additional site investigation, field testing and engineering analysis will be required at the detail design stage. The extent of the additional investigation will depend, in part, on the final location and General Arrangement of the structure.

Thurber carried out the investigation for the Ministry of Transportation Ontario, Southwestern Region (MTO) under Purchase Order Number 3006-E-0123.

2 SITE DESCRIPTION

The site lies approximately 300 m to the east of existing Kitchener-Waterloo Expressway and Wellington Street interchange. At this location, the proposed S-E Ramp will cross over existing Wellington Street. The site lies within an area of industrial and commercial lands and is generally flat.

Based on the Ontario Geological Survey Special Volume 2, The Physiography of Southern Ontario, Third Edition by Chapman and Putnam, the site lies within the physiographic region known as the Waterloo Hills, characterized by ridges of sandy till and kames or kame moraines, with outwash sands occupying the intervening hollows.



3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing at this site was carried out from July 3 to 8, 2008. Two boreholes, numbered 08-026 and 08-029, were drilled approximately at the west and east abutments of a possible single-span structure arrangement. The depths of Boreholes 08-026 and 08-029 were 29.2 m and 26.0 m (Elevations 297.3 and 299.1), respectively. The Record of Borehole sheets for the boreholes are included in Appendix A. The approximate locations of the two boreholes are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix E.

Prior to commencing the site investigation, clearance was obtained from utility companies having plant in the area.

The boreholes were drilled using hollow stem auger equipment operated by a CME75 truck-mounted drill rig. Samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. In Borehole 08-029, drilled at the proposed east abutment, a standpipe piezometer consisting of 25 mm diameter PVC pipe with a slotted screen was installed and enclosed in filter sand to permit longer term groundwater level monitoring. The location and completion details of the piezometer are shown in Table 3.1. Borehole 08-026 was grouted with benseal upon completion. The borehole completion details are shown in Table 3.1.

The completion of the borehole and the standpipe piezometer were carried out in accordance with the requirements of O. Reg. 903 (as amended by O. Reg. 372/07).

Table 3.1 – Borehole Completion Details

Foundation Unit	Borehole Location	Piezometer Tip Depth/Elevation (m)	Completion Details
West Abutment	08-026	No Installation	Benseal to 0.6 m, then holeplug to surface.
East Abutment	08-029	25.8/299.3	Piezometer with 1.5 m slotted screen installed with sand filter to 23.9 m, holeplug from 23.9 m to 23.3 m, grout from 23.3 m to 0.6 m, holeplug from 0.6 m to surface.

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes and processed the recovered soil samples for transport to Thurber's laboratory for further examination and testing.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A. Selected samples were also subjected to gradation analysis (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 Appendix A. Details of the encountered soil stratigraphy along the proposed alignment are presented in this appendix 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.

In general, the site is underlain by topsoil and granular fill overlying native sand, silty clay till and sandy silt till. Layers of native silty clay and silt were also encountered in the boreholes.

5.1 Topsoil

Topsoil was identified at the ground surface in both boreholes. The topsoil thickness was 200 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 Fill

Fill was encountered below the topsoil. The fill consists of brown silty sand in Borehole 08-026 and sand and gravel in Borehole 08-029. The base of the fill extended to depths of 1.5 m and 1.4 m (Elevations 325.0 and 323.8) in Boreholes 08-026 and 08-029, respectively.

The fill is classified as loose to compact, based on SPT values ranging from 7 to 22 blows for 0.3 m of penetration. The natural moisture content ranged from 15 to 19%.

5.3 Sand

Native brown sand containing some silt, trace gravel and trace clay was encountered below the fill. Thickness of the sand layer was 4.1 m and 2.7 m in the proposed west and east abutments (Boreholes 08-026 and 08-029), respectively. The base of the sand layer extended to depths of 5.6 m and 4.1 m (Elevations 320.9 and 321.0) in the two boreholes.

In Borehole 08-026, a lower layer of sand was contacted at 10.2 m depth (Elevation 316.3). Thickness of this lower layer was 5.0 m. Occasional cobbles were encountered within the lower sand layer.

Both layers of sand are classified as compact to very dense, based on SPT values ranging from 18 to 80 blows for 0.3 m of penetration. SPT-N values higher than 100 blows per 0.275 m of penetration were measured in Borehole 08-026 at 3.0 m and 13.7 m depth (Elevations 323.5 and 312.8). The natural moisture content ranged from 3 to 19%.

Grain size distribution curves for four samples of sand 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 to 6
Sand	82 to 90
Silt & Clay	10 to 13

5.4 Silty Clay Till and Silty Clay

Native grey silty clay till and silty clay containing some sand to sandy, trace gravel and occasional sand seams were contacted below the native sand. An upper and a lower layer of till were contacted in both boreholes as indicated in Table 5.1.

Table 5.1 – Depths and Elevations of Native Silty Clay and Silty Clay Till

Foundation Unit	Borehole	Depth below existing ground surface (m)	Elevation (m)	Thickness (m)
West Abutment	08-026	Upper layer: 5.6 to 10.2 Lower layer: 15.2 to 29.2 (Borehole termination depth)	320.9 to 316.3 311.3 to 297.3	4.6 14.0+
East Abutment	08-029	Upper layer: 4.1 to 11.7 11.7 to 13.5* Lower layer: 16.3 to 22.3	321.0 to 313.4 313.4 to 311.6 308.8 to 302.9	7.6 1.8 6.0

* Silty clay

The cohesive layer is very stiff to hard in consistency, based on SPT 'N' values ranging from 20 blows per 0.3 m of penetration to greater than 100 blows per 0.15 m of penetration. Within the silty clay layer contacted in Borehole 08-029, SPT 'N' value was 14 blows per 0.3 m of penetration, indicating a stiff consistency. The moisture content varied from 10% to 21%.

Grain size distribution curves for selected silty clay and silty clay till samples are presented on the Record of Borehole sheets and on Figures B2 and B3 of Appendix B. Atterberg Limits test results are presented on Figure B6 of Appendix B.

The results of the laboratory tests are summarized as follows:

Soil Particles	(%)
Gravel	0 to 2
Sand	0 to 42
Silt	40 to 51
Clay	16 to 52

Liquid Limit	20 to 40
Plastic Limit	16 to 41

The above results show that the silty clay and silty clay till is of low to medium plasticity with group symbols of CL-CI.

It should be noted that glacial tills are known to contain cobbles and boulders.

5.5 Silt

A layer of grey silt was contacted in Borehole 08-029 (east abutment) at 13.5 m depth (Elevation 311.6). Thickness of the silt layer was 2.8 m.

SPT 'N' values measured in the silt were 75 blows per 0.3 m of penetration and 120 blows per 0.2 m of penetration, indicating a very dense relative density. The natural moisture content was approximately 19%.

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

Soil Particles	(%)
Gravel	0
Sand	8
Silt	83
Clay	9

5.6 Sandy Silt Till

In Borehole 08-029, grey sandy silt till containing trace gravel and some clay was encountered at 22.3 m depth (Elevation 302.9), extending to borehole termination depth.

SPT 'N' values measured in the sandy silt till were higher than 100 blows per 0.15 m of penetration, indicating a very dense relative density. The natural moisture contents generally lay in the range of 8 to 10%.

Grain size distribution curve for one sample of sandy silt till tested is presented on the Record of Borehole sheets and on Figure B5 of Appendix B. The results of the laboratory test are summarized as follows:

Soil Particles	(%)
Gravel	5
Sand	40
Silt	39
Clay	16

Although not encountered in the boreholes, this glacial till layer may contain cobbles and boulders which may account for some high SPT 'N' values and resistance to augering.

5.7 Groundwater Conditions

Water levels were observed in the boreholes during and upon completion of drilling. A standpipe piezometer was installed in Borehole 08-029 (east abutment) to monitor water levels after completion of drilling. The water level measured in the piezometer and the measurements in the open boreholes upon completion of drilling are summarized in Table 5.2.

Table 5.2 – Water Level Measurements

Foundation Unit	Borehole	Date (2008)	Water Level (m)		Comment
			Depth	Elevation	
West Abutment	08-026	July 4	4.5	322.0	During drilling
East Abutment	08-029	July 8	2.3	322.8	During drilling
		August 6	18.9	306.2	In piezometer
		August 20	19.2	305.9	In piezometer

The piezometric reading indicates that the groundwater level is near Elevation 305.9 m.

Perched water was also observed during drilling within the sand layer at 2.3 m and 4.5 m depths (Elevations 322.0 and 322.8).

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

All-Terrain Drilling of Waterloo, Ontario supplied a truck-mounted CME75 drill rig and conducted the drilling, sampling and in-situ testing operations.

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Stephane Loranger, C.E.T. of Thurber, under the direction of Mr. Alastair E. Gorman, P.Eng and Mr. Mark Farrant, P. Eng.

The coordinates for the boreholes and the ground surface elevations were obtained by Thurber Engineering Ltd. using GPS equipment.

Overall supervision of the field program was conducted by Mr. Alastair E. Gorman, P.Eng. and Mr. M. Farrant, 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.

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

Thurber Engineering Ltd.

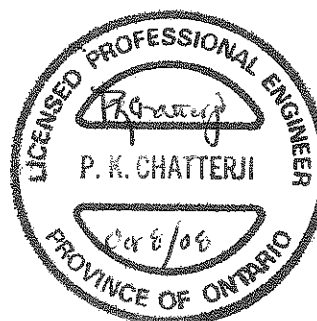


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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This report presents interpretation of the geotechnical data in the factual report and presents preliminary geotechnical design recommendations to assist the design team to select and design a suitable foundation system for the new ramp structure.

Based on the Plates 2A and 2B of the E.A:

- The new grade of Wellington Street will be in a cut of 4 m to 5 m deep. Wellington Street grade will decrease from west to east from approximate Elevations 321.9 to 320.8.
- The proposed grade of the S-E Entrance Ramp from Highway 7 will vary from west abutment to east abutment from Elevations 329.8 to 326.8. The existing ground surface within the proposed ramp structure is near Elevations 326.5 to 325.1. Hence, the S-E Ramp embankments will be about 3.3 m to 1.7 m high relative to the surrounding grade.
- At the ramp structure, the resulting west and east approach embankments relative to the new Wellington Street grade are approximately 3.0 m to 6.0 m above existing grade and Wellington Street grade will be in a cut 3.0 m to 4.0 m below existing grade.

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 this investigation.

8 STRUCTURE FOUNDATIONS

The stratigraphy identified in the preliminary investigation consisted primarily of topsoil and granular fill overlying native layers of compact to very dense sand, very stiff to hard silty clay till and very dense sandy silt till. Layers of native silty clay and silt were also encountered in the boreholes.

The groundwater level measured in the piezometer was 19.2 m (Elevation 305.9) below the ground surface. Perched water was also observed during drilling within the sand layer at 2.3 m and 4.5 m depths (Elevations 322.0 and 322.8).

In the preparation of the preliminary geotechnical design recommendations, consideration was given to the following foundation types:

- Spread footings bearing on native soil
- Spread footings on engineered fill
- Steel H-piles driven into the very dense or hard soil

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

8.1 Spread Footings on Native Soil

Spread footings bearing on native soil generally are the least expensive form of construction.

The existing fill is not considered to be suitable for the support of spread footings and the footings must be placed on the underlying native soils.

The design of spread footings bearing on native undisturbed compact to dense sand or hard silty clay till must be in accordance with the elevations and bearing resistances given in Table 8.1.

Table 8.1 – Bearing Resistances for Spread Footings

Element	Depth (m)	Elev.	ULS _r (kPa)	SLS (kPa)
West Abutment (BH 08-026)	1.7	324.8	450	300
	Below 2.5	Below 324.0	750	500
East Abutment (BH 08-029)	1.5	323.7	300	200
	Below 3.1	Below 322.0	450	350

The bearing resistances in Table 8.1 are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be adjusted as shown in the CHBDC (2006) Clause 6.7.3 and Clause 6.7.4.

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

Founding elevations presented in Table 8.1 are generally 16.0 m to 18.7 m above groundwater level measured in the piezometer. However, water was observed at 2.3 m and 4.5 m below ground surface during field investigation. If water is observed during footing excavation, groundwater control will be required to construct the footings in the dry, to prevent sloughing of the sides and to prevent disturbance of the footing bases due to the inflow of groundwater.

8.2 Spread Footings on Engineered Fill

Spread footings can also be founded on Granular “A” engineered fill pads. These would be most useful in the case of perched abutments on footings.

If an engineered fill pad is used, all topsoil, or other deleterious materials must be stripped from the footprint of the foundation to expose competent native subgrade material. The engineered fill must bear on native compact to dense sand and the highest permitted founding elevations at which engineered fill pads may be placed are given in Table 8.2.

Table 8.2 –Founding Elevations for Engineered Fill Pads

West Abutment (BH 08-026)	East Abutment (BH 08-029)
325.0	323.8

Typically, spread footings on pads of engineered granular fill at least 2 m thick may be designed for the following geotechnical resistances:

- Factored ULS 900 kPa
- SLS 350 kPa

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 settlement is not expected to exceed 20 mm across the width of the structure or between foundation elements.

The Granular A pad must be compacted to 100% of Standard proctor maximum dry density (SPMDD) at optimum moisture content $\pm 2\%$. The geometry of the fill pad must conform to the general requirements shown in Figure 1 in Appendix D.

8.3 Steel H-Piles

The soil stratigraphy encountered at this site is considered to be suitable for the support of foundations on driven steel piles.

It is recommended that the H-piles be driven to achieve resistance in the hard silty clay till or very dense sandy silt till encountered at this site. The depths and elevations at which the H-piles are expected to develop the required resistance are given in Table 8.3.

Table 8.3 – Estimated Pile Tip Elevation

Foundation Unit	Pile Tip Depth (m)	Highest Pile Tip Elevation	Soil
West Abutment (BH 08-026)	27.0	299.5	Hard silty clay till
East Abutment (BH 08-029)	24.1	301.0	Very dense sandy silt till

8.3.1 Axial Resistance

For preliminary design, the vertical, axial, factored geotechnical resistance at Ultimate Limit States (ULS) and geotechnical resistance at Serviceability Limit States (SLS) for two pile sections when driven into the hard silty clay till and very dense sandy silt till are presented in Tables 8.4.

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

Pile Section	Geotechnical Resistance (kN)	
	Factored ULS	SLS
HP 310 X 110	1,700	1,500
HP 360 X 132	1,900	1,700

The structural resistance of the pile must be checked by the structural designer.

Installation of the piles must be in accordance with SP 903S01 and must be controlled using the Hiley Formula and an ultimate resistance of 3,400 kN for an HP 310 X 110 pile and 3,800 kN for the HP 360 X 132 pile.

These are preliminary recommendations and may change during detail design based on the final alignment, final bridge arrangement and the results of the site investigation and field testing to be completed at that time.

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

8.3.2 Downdrag

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

8.4 Abutment Design Considerations

From a geotechnical perspective, the conditions at this site are considered to be suitable for the design of conventional, semi-integral or integral abutments.

8.5 Frost Cover

The design depth of frost penetration for this site is 1.4 m. All footing bases and undersides of pile caps/abutment stems must be provided with at least 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.

8.6 Recommended Foundation

From a geotechnical perspective, and based on current information, the recommended abutment foundation consists of steel H-piles driven into the very dense native sandy silt till and hard silty clay till, despite the higher cost noted in Appendix C.

9 BRIDGE APPROACHES AND EMBANKMENTS

Based on the two boreholes drilled at the site, the approach embankments will be constructed over compact to dense sand and may incorporate the sand and gravel fill of the existing embankment.

No long term settlement or global stability issues are anticipated for approach embankments built at this site. The 6.0 to 8.0 m high embankments likely to be constructed will be stable at side slopes of 2H:1V if constructed using SSM or granular fill.

Where earth fill embankments are higher than 8 m, mid-height berms should be incorporated in the design. 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.

The proposed cut (3.0 to 4.0 m) at Wellington Street shown on EA Plates 2A and 2B may be at approximately 15.0 m above the groundwater table. However, perched water was also observed during drilling at 2.3 m and 4.5 m (Elevations 322.0 and 322.8) within the sand layer.

During detail design, when the grade has been finalized, permanent drainage (if necessary) and slope protection requirements must be addressed. The cut slopes will be stable at slopes with a maximum inclination of 2H: 1V. MTO policy requires a mid-height bench in cut slopes higher than 6.0 m.

10 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 3 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 commence redriving 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. Destabilization of excavations

If excavation is carried out in cohesionless soil 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.

11 INVESTIGATION FOR DETAIL DESIGN

During the detail design phase of the project, additional site investigation and field testing will be required. The following minimum program is recommended:

1. Boreholes for structure foundations.

Additional boreholes may be required for the structure foundations, especially if the structure is built off the current S-E Ramp over Wellington Street alignment and thus removed from the alignment of the current investigation. Particular attention should be paid to groundwater levels in the various soil strata.

2. Pile Design

For piles extending below Elevation 297.0 and 299.0 (approximately) at the west and east abutment, respectively, a greater depth of exploration is required and must be addressed during the detail design phase.

3. Boreholes for approaches.

A minimum of one borehole is recommended in each approach fill on S-E Ramp.

4. Cut stability

At least one borehole is required in the mainline cut to either side of the structure. The boreholes in the cut must include piezometers for groundwater monitoring. Stability of cuts must be investigated during detail design phase.

12 CLOSURE

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

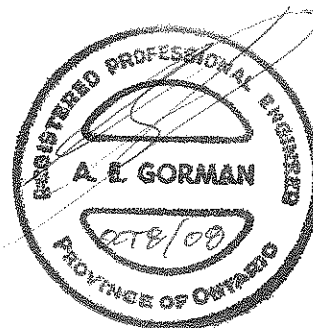
The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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

DISCONTINUITY SPACING		STRENGTH CLASSIFICATION			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m				
Very thinly bedded	20 to 60mm	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Laminated	6 to 20mm				
Thinly Laminated	Less than 6mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
		Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
		Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

TERMS	
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a 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.

RECORD OF BOREHOLE No 08-026

1 OF 4

METRIC

G.W.P. 408-88-00

LOCATION N 4 814 474.88 E 226 422.03

ORIGINATED BY SA

HWY 7

BOREHOLE TYPE Hollow Stem Augers

COMPILED BY SA

DATUM Geodetic

DATE 2008.07.03 - 2008.07.04

CHECKED BY RPR

[illegible]

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-026

2 OF 4

METRIC

G.W.P. 408-88-00 LOCATION N 4 814 474.88 E 226 422.03 ORIGINATED BY SA
HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
DATUM Geodetic DATE 2008.07.03 - 2008.07.04 CHECKED BY RPR

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

Continued Next Page

+³ . X³: Numbers refer to Sensitivity

20
15 10 5
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-026

3 OF 4

METRIC

G.W.P. 408-88-00 LOCATION N 4 814 474.88 E 226 422.03 ORIGINATED BY SA
HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
DATUM Geodetic DATE 2008.07.03 - 2008.07.04 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40					
	Continued From Previous Page													
	Silty CLAY, trace gravel, trace sand Hard Grey (TILL)		16	SS	53									0 6 51 43
							306							
							305							
							304							
			17	SS	68									
							303							
							302							
							301							
			18	SS	100/ .150		300							
			19	SS	100/ .025		299							
	occasional cobbles and boulders						298							
297.3			20	SS	114/ .225									
29.2	END OF BOREHOLE AT 29.2m. WATER LEVEL OBSERVED AT 4.5m DURING DRILLING. BOREHOLE BACKFILLED WITH BENSEAL TO 0.6m THEN													

Continued Next Page

+³ × 3: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-026

4 OF 4

METRIC

G.W.P. 408-88-00 LOCATION N 4 814 474.88 E 226 422.03 ORIGINATED BY SA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2008.07.03 - 2008.07.04 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
	Continued From Previous Page													
	HOLEPLUG TO SURFACE.													

METRIC

G.W.P.	408-88-00	LOCATION	N 4 814 529 54 E 226 497.29	ORIGINATED BY	SA
HWY	7	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	SA
DATUM	Geodetic	DATE	2208.07.08 - 2008.07.08	CHECKED BY	RPR

[illegible]

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-029

2 OF 3

METRIC

G.W.P. 408-88-00 LOCATION N 4 814 529.54 E 226 497.29 ORIGINATED BY SA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2208.07.08 - 2008.07.08 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
	Continued From Previous Page							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60			GR SA SI CL
313.4	Silty CLAY, trace sand Hard Grey (TILL)		10	SS	36		315					
11.7	Silty CLAY Stiff Grey Moist		11	SS	14		314					
311.6							313					0 3 45 52
13.5	SILT, trace sand, trace clay Very Dense Grey Wet		12	SS	75		312					
							311					
308.8			13	SS	120/ .200		310					0 8 83 9
16.3	Silty CLAY, trace gravel Hard Grey (TILL)		14	SS	39		309					
							308					
			15	SS	45		307					0 0 49 51
							306					

Continued Next Page

+ 3, X 3: Numbers refer to
Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-029

3 OF 3

METRIC

G.W.P. 408-88-00 LOCATION N 4 814 529.54 E 226 497.29 ORIGINATED BY SA
 HWY 7 BOREHOLE TYPE Hollow Stem Augers COMPILED BY SA
 DATUM Geodetic DATE 2208.07.08 - 2008.07.08 CHECKED BY RPR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)		
								○ UNCONFINED	+ FIELD VANE							● QUICK TRIAXIAL	× LAB VANE	
Continued From Previous Page																		
	Silty CLAY , trace gravel Hard Grey (TILL)		16	SS	41		305											
302.9							304											
22.3	Sandy SILT , trace gravel, some clay Very Dense Grey Moist (TILL)		17	SS	110/ 200		303											
							302								5 40 39 16			
			18	SS	110/ .150		301											
							300											
299.1			19	SS	100/ .125													
26.0	END OF BOREHOLE AT 26.0m. WATER LEVEL OBSERVED AT 2.3m DURING DRILLING. Piezometer installation consists of 25mm diameter schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) ELEV.(m) 2008.08.06 18.9 306.2 2008.08.20 19.2 305.9																	

+³, ×³: Numbers refer to
Sensitivity

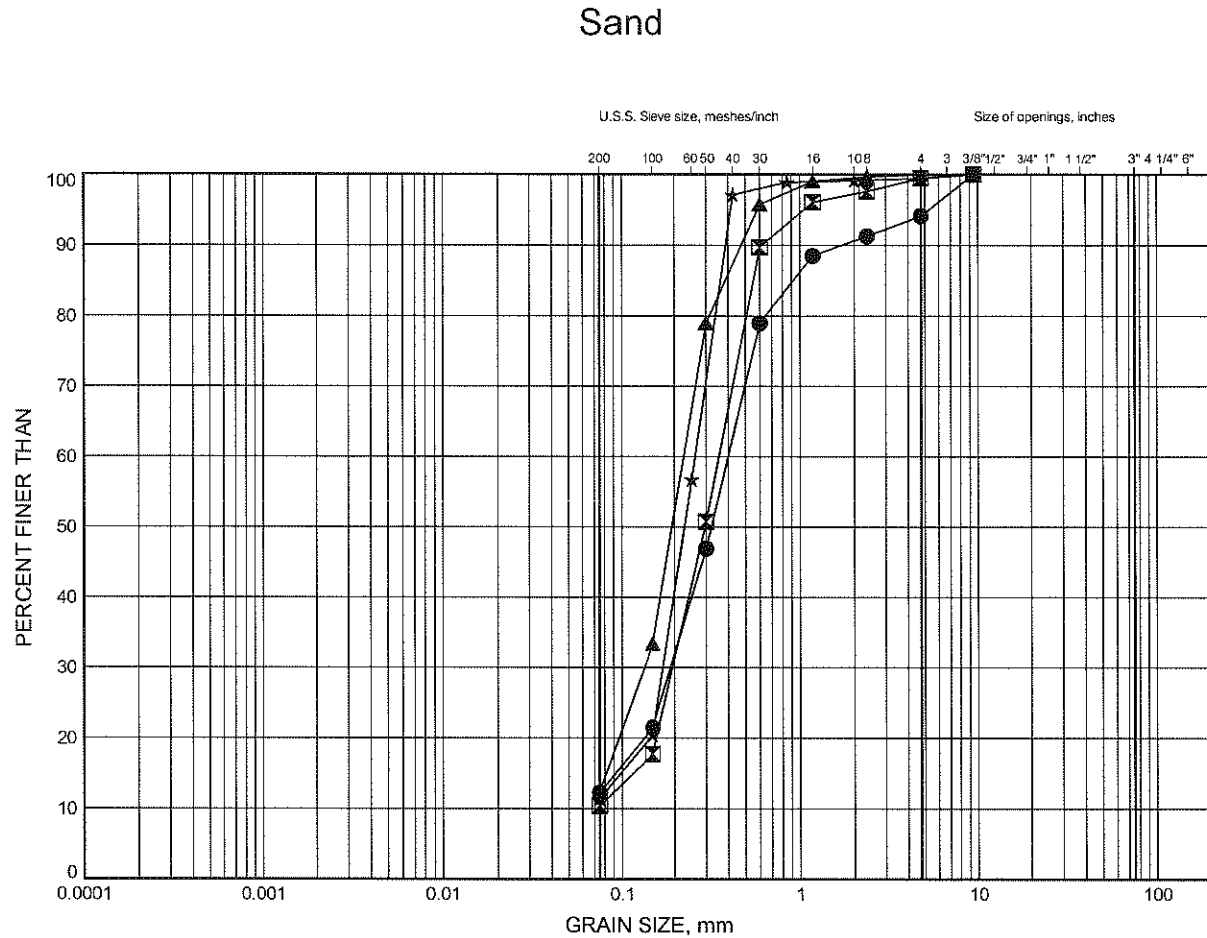
20
15 5
10 (%) STRAIN AT FAILURE

Appendix B

Laboratory Test Results

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B1



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-026	2.59	323.92
■	08-026	4.88	321.63
▲	08-026	12.50	314.01
★	08-029	2.59	322.54

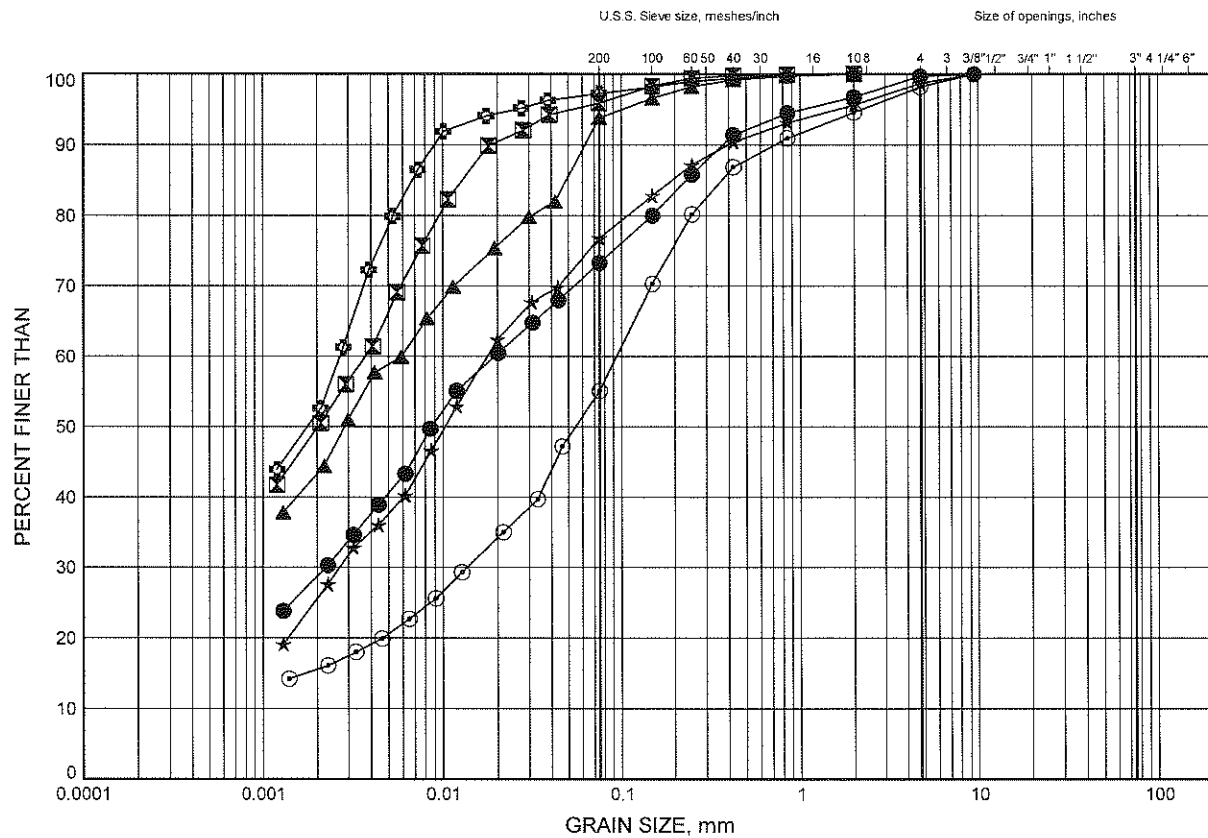


W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B2

Silty Clay / Silty Clay Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-026	7.92	318.59
⊠	08-026	15.46	311.05
▲	08-026	20.12	306.39
☆	08-029	6.40	318.73
⊙	08-029	9.45	315.68
⊕	08-029	12.50	312.63

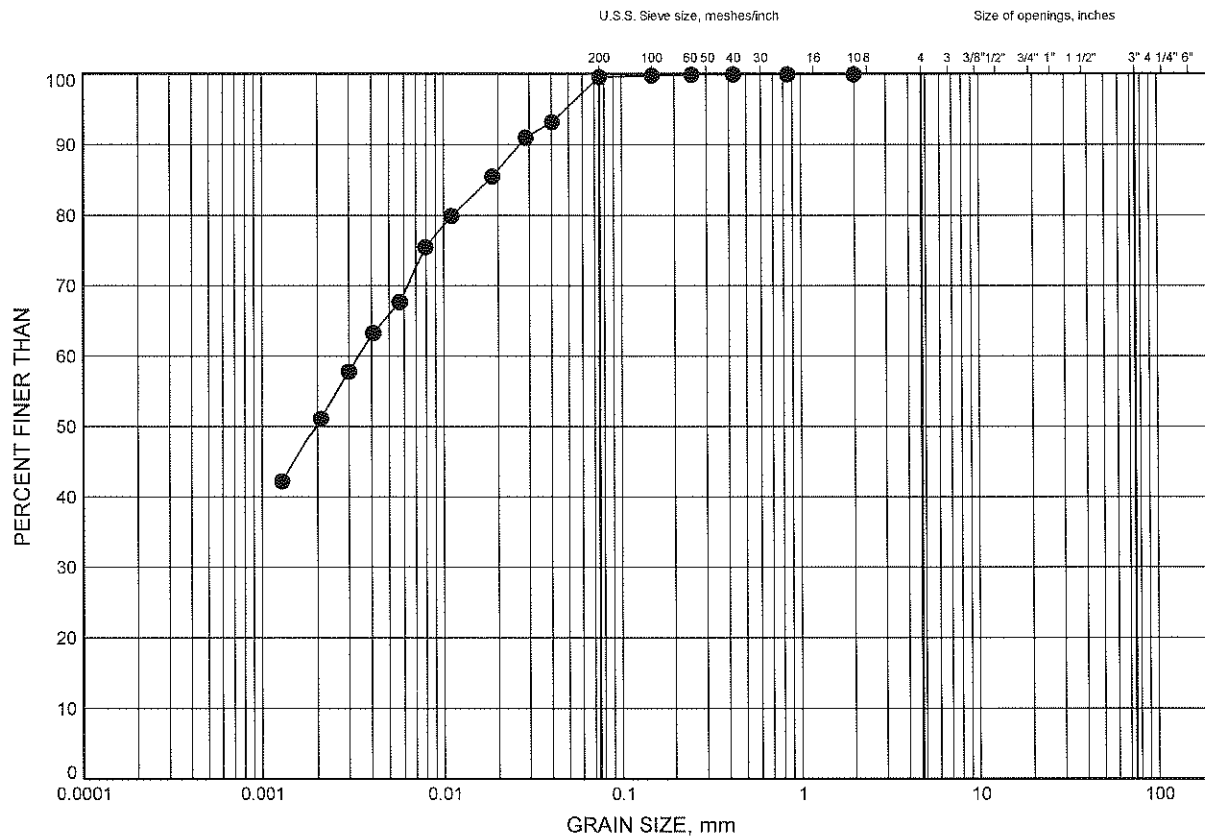


W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

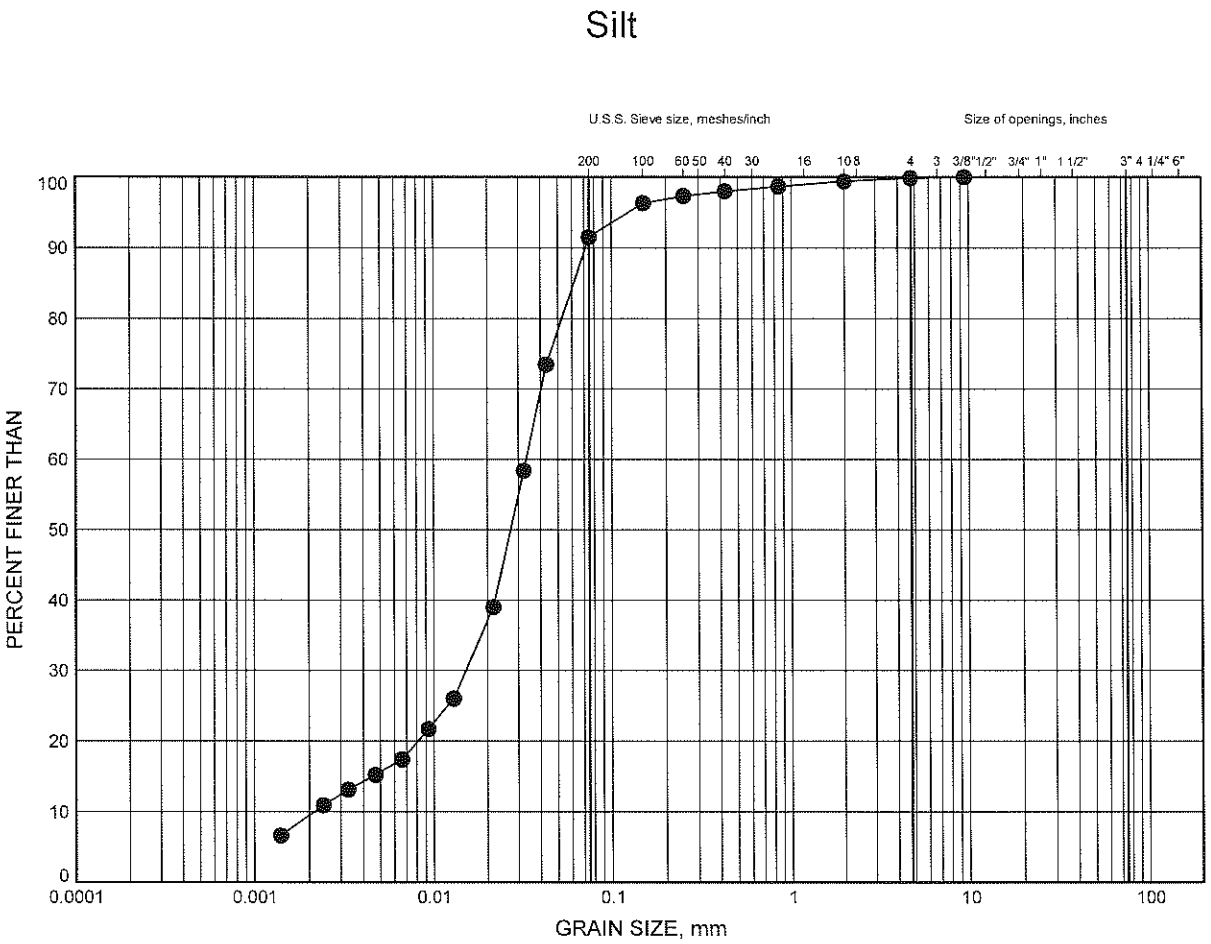
FIGURE B3

Silty Clay / Silty Clay Till



Highway 7 - New
GRAIN SIZE DISTRIBUTION

FIGURE B4



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-029	15.34	309.79

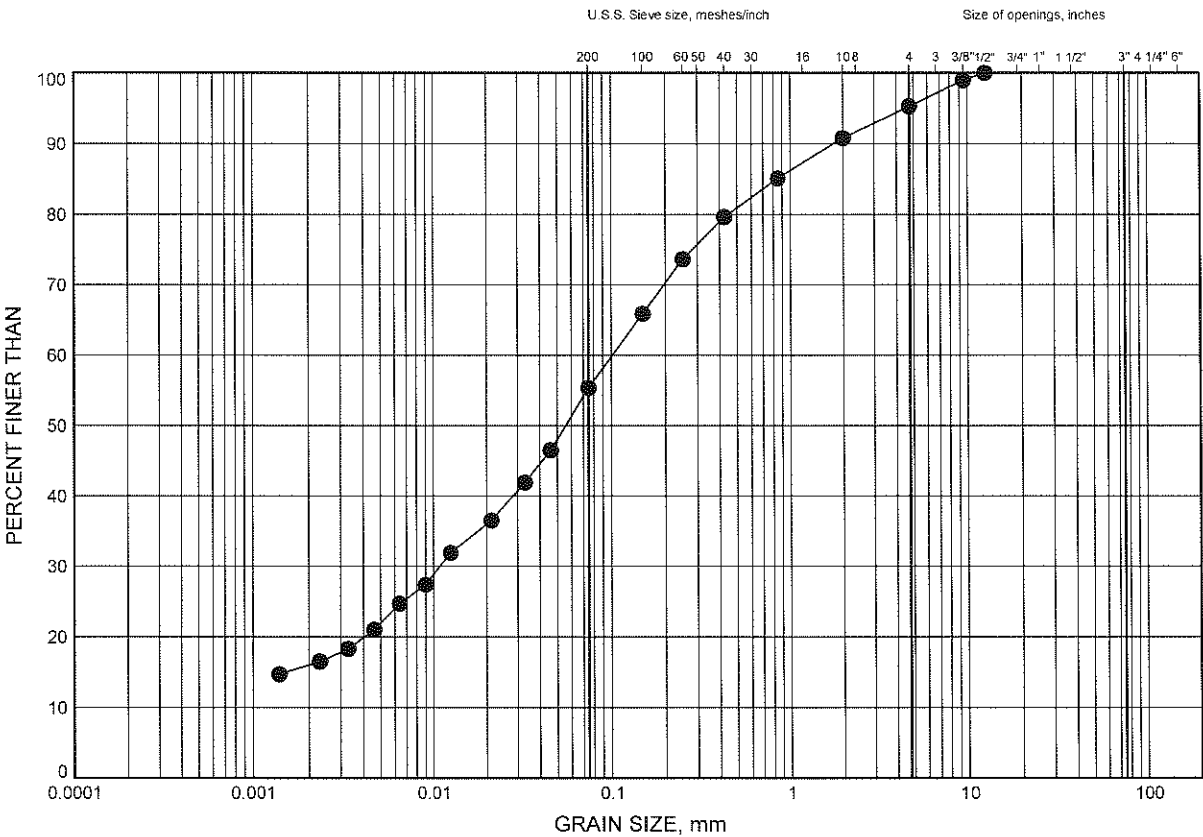


W.P.# 408-88-00
Prepared By MFA
Checked By RPR

Highway 7 - New GRAIN SIZE DISTRIBUTION

FIGURE B5

Sandy Silt Till



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-029	23.01	302.12



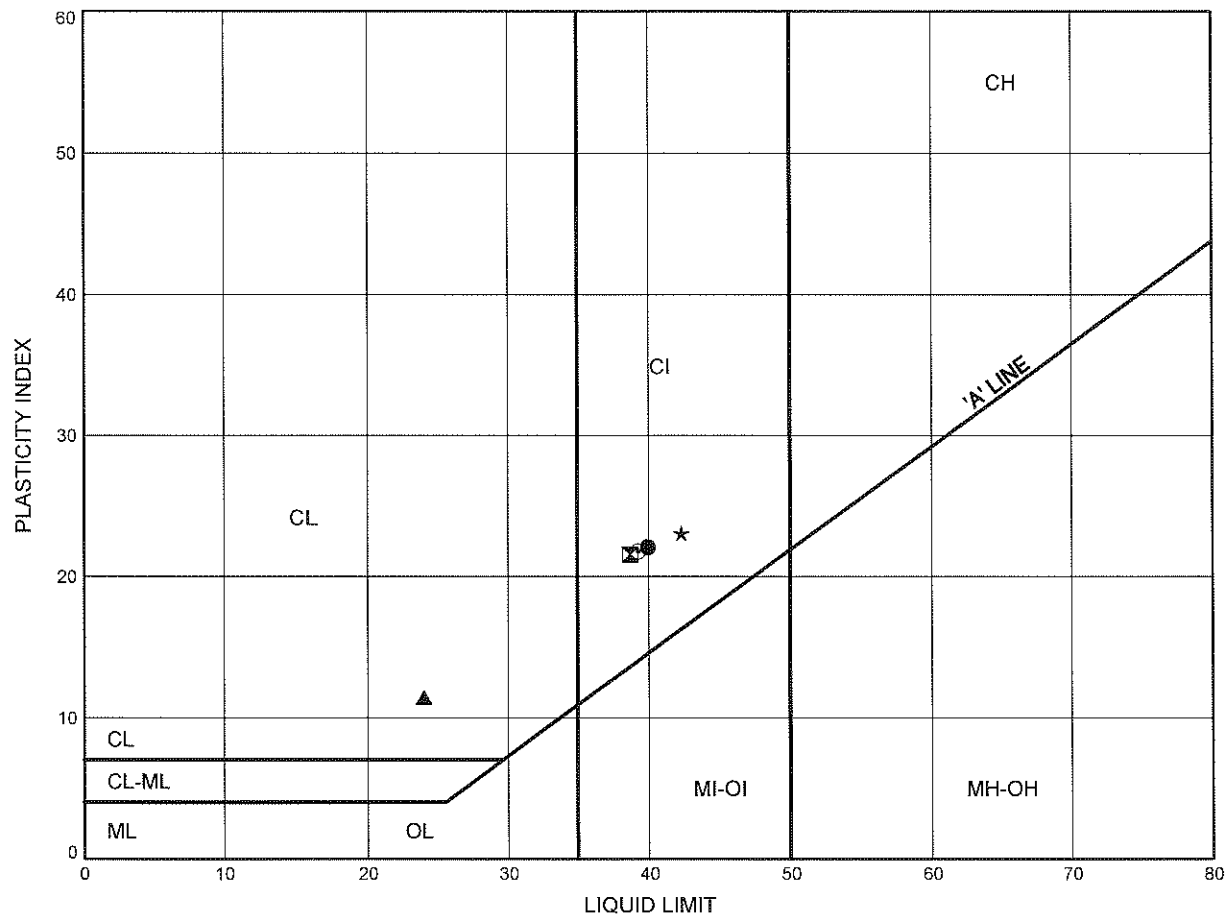
W.P.# 408-88-00
 Prepared By MFA
 Checked By RPR

Highway 7 - New

ATTERBERG LIMITS TEST RESULTS

FIGURE B6

Silty Clay / Silty Clay Till



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-026	15.46	311.05
⊗	08-026	20.12	306.39
▲	08-029	6.40	318.73
★	08-029	12.50	312.63
⊙	08-029	18.59	306.54

Date October 2008
 Project 408-88-00



Prep'd MFA
 Chkd. RPR

Appendix C

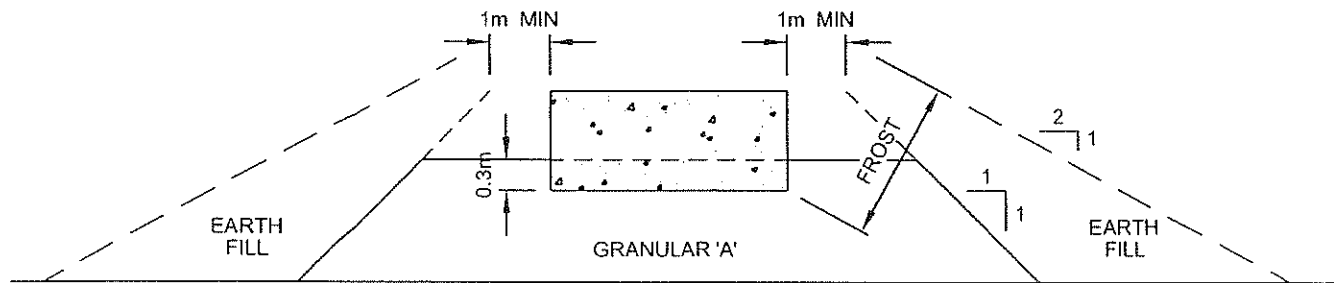
Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

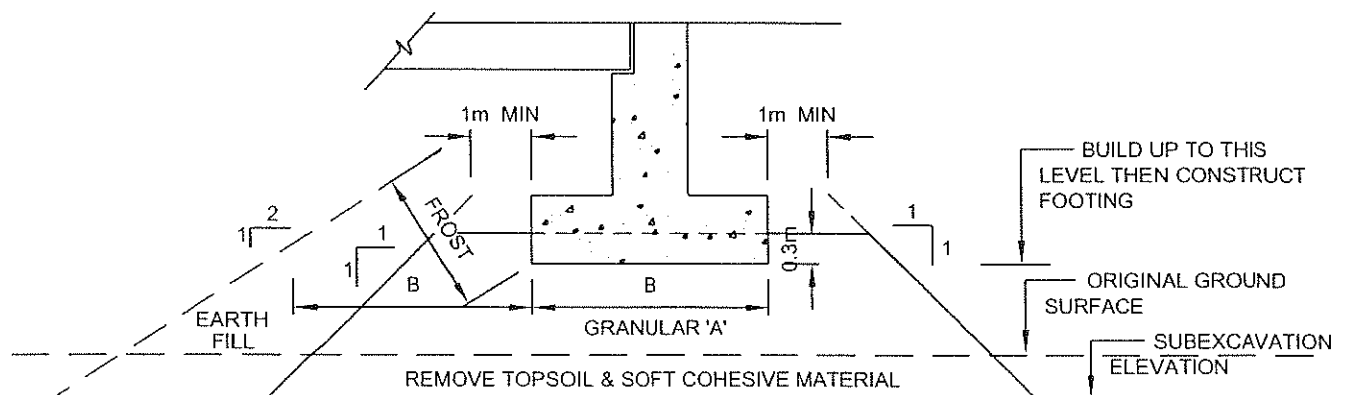
Foundation Element	Spread Footings	Spread Footings on Engineered Fill	Driven Piles
Abutments	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Lower geotechnical resistance available due to founding on compact soils near the surface. ii. Dewatering may be required, depending on depth of excavation. <p>NOT RECOMMENDED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. Generally less costly construction than deep foundation elements. <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Better geotechnical resistance than spread footings on native, but still influenced by the compact soils at the surface. ii. Dewatering may be required, depending on depth of excavation. <p>NOT RECOMMENDED</p>	<p>Advantages:</p> <ul style="list-style-type: none"> i. High geotechnical resistance may be developed by driving the piles into very dense/hard soils. ii. Comparatively short abutment stem possible iii. Permits integral abutment design <p>Disadvantages:</p> <ul style="list-style-type: none"> i. Higher unit cost compared to footings. ii. Very dense/hard soils at shallow depth will limit length of pile and geotechnical resistance that can be developed. iii. Possible presence of cobbles and boulders in the silty clay till and sandy silt till layers at the expected founding layer <p>RECOMMENDED</p>

Appendix D

Figure



CROSS-SECTION



LONGITUDINAL SECTION

NOT TO SCALE

NOTES:

1. REMOVE TOPSOIL AND SOFT SILTY CLAY SUBSOIL UNDER FOOTPRINT OF COMPACTED GRANULAR 'A'.
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
DRAWN	SS
DATE	April , 2004
APPROVED	PKC
SCALE	NTS

ABUTMENT ON COMPACTED FILL SHOWING
GRANULAR A CORE



DWG. NO.

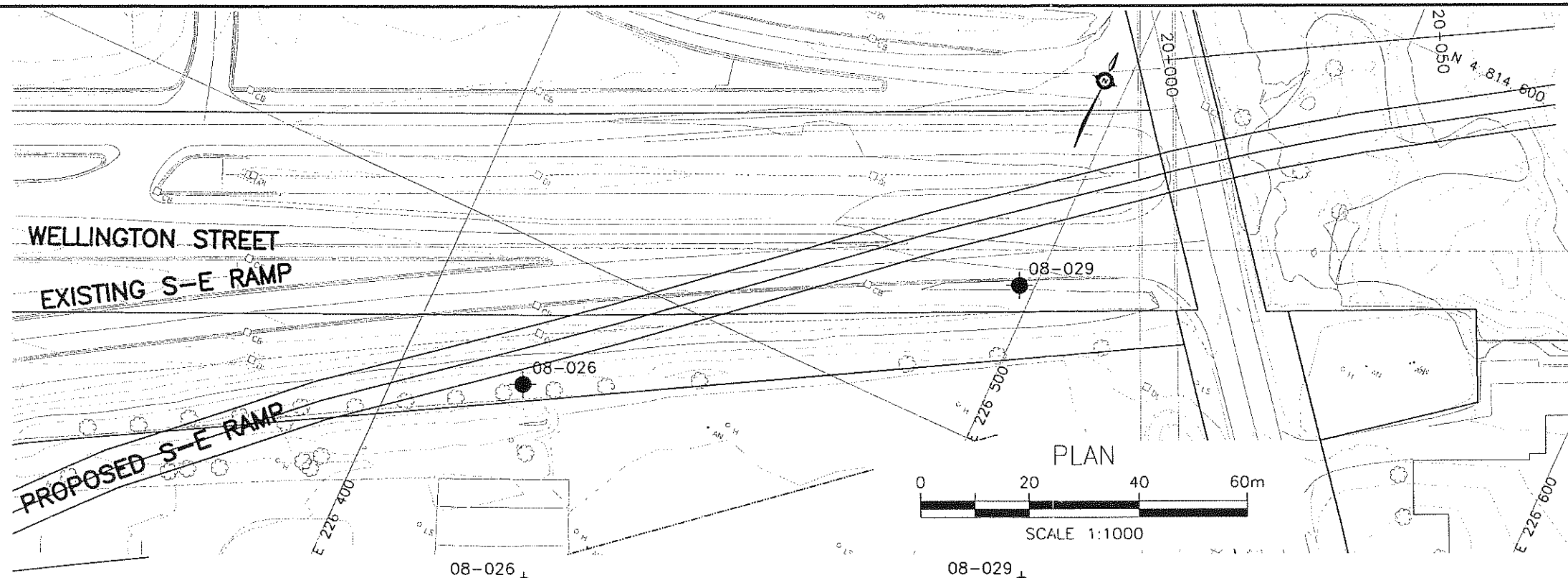
FIGURE 1

S-E Ramp over Wellington St./Shirley Ave.
Highway 7-New, Kitchener to Guelph

Appendix E

Drawing titled “Borehole Locations and Soil Strata”

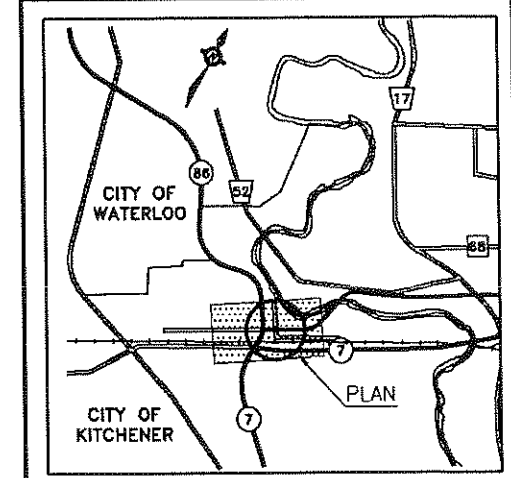
MINISTRY OF TRANSPORTATION, ONTARIO
PR-3-707 84-05
PLOT SCALE 1:1



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

CONT No GWP No 408-88-00	
HIGHWAY 7 RECOMMENDED ROUTE S-E RAMP OVER WELLINGTON/SHIRLEY BOREHOLE LOCATIONS AND SOIL STRATA	
SHEET	

THURBER ENGINEERING LTD.
GEOTECHNICAL • ENVIRONMENTAL • MATERIALS



KEYPLAN

LEGEND

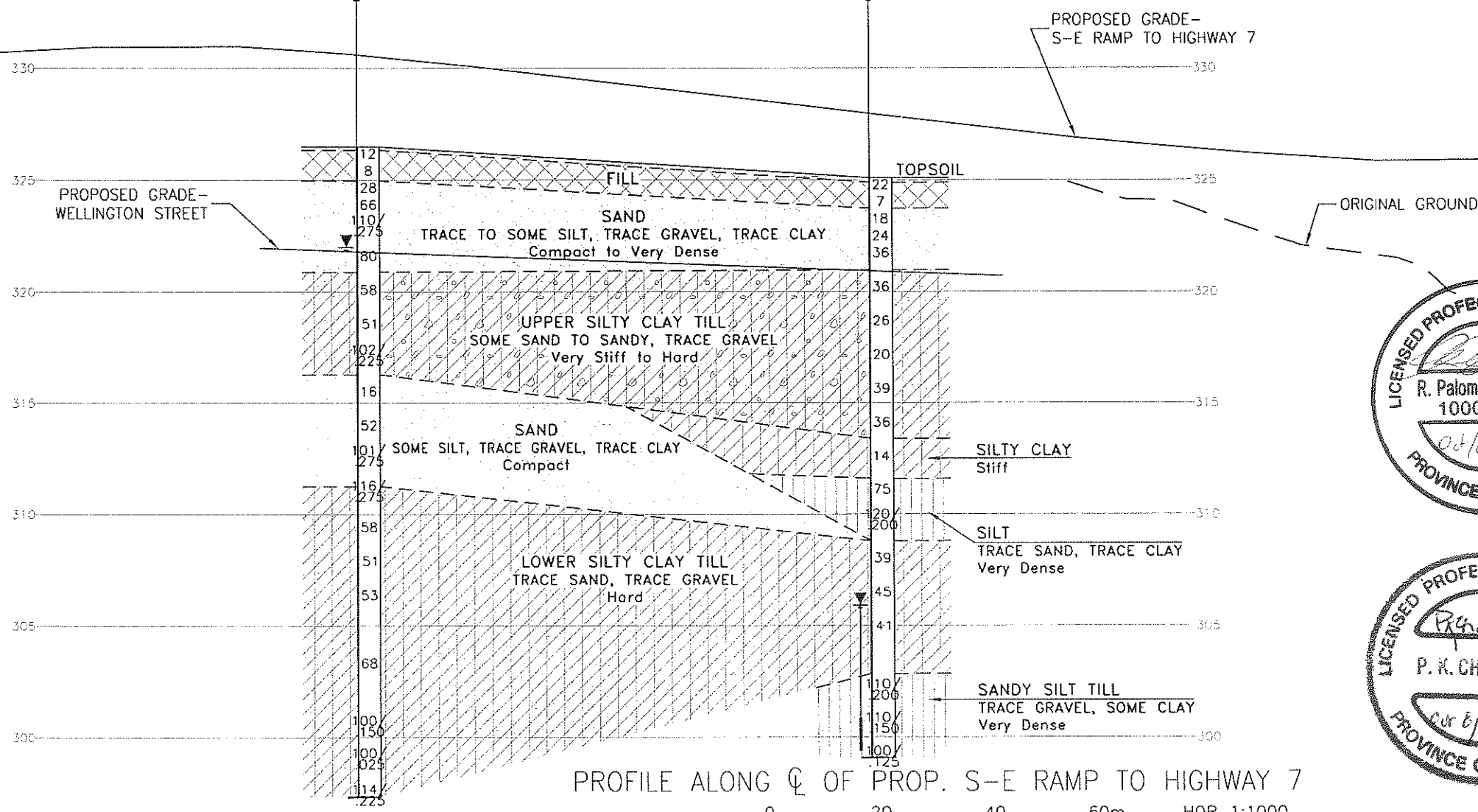
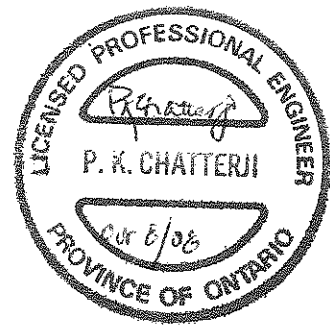
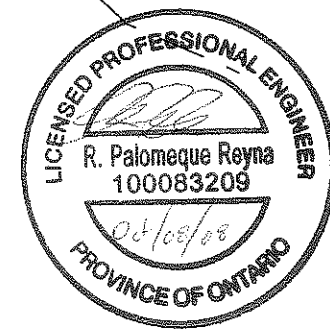
- Borehole
- Borehole and Cone
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60° Cone, 475J/blow)
- PH Pressure, Hydraulic
- Water Level
- Head Artesian Water
- Piezometer
- 90% Rock Quality Designation (RQD)
- A/R Auger Refusal

NO	ELEVATION	NORTHING	EASTING
08-026	326.5	4 814 474.9	226 422.0
08-029	325.1	4 814 529.5	226 497.3

NOTES

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Proposed grades are from Plate 2A of the E.A. Study.

GEOCREs No. 40P8-151



PROFILE ALONG CL OF PROP. S-E RAMP TO HIGHWAY 7

0 20 40 60m HOR 1:1000
0 5 10 15m VER 1:250

DRAWING NOT TO BE SCALED
100 mm ON ORIGINAL DRAWING

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	AEG	CHK	PKC
DRAWN	MFA	CHK	AEG
CODE	SITE	STRUCT	DWG
LOAD	DATE	AUG. 2008	

FILENAME: H:\Drafting\AUGUST\17\106417-Ramp1.dwg
PLOTDATE: Oct 06, 2008 - 3:00pm