Terraprobe

Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing

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FOUNDATION INVESTIGATION & DESIGN REPORT
KENNEDY ROAD UNDERPASS STRUCTURE
HIGHWAY 410 EXTENSION – PHASE III
FROM 300 m EAST OF HEART LAKE ROAD TO HIGHWAY 10
AGREEMENT No. 2005-A-000230, W.P. 106-00-01, SITE: 24-743

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TABLE OF CONTENTS

Appendices

FOUNDATION INVESTIGATION AND DESIGN REPORT
KENNEDY ROAD UNDERPASS STRUCTURE
HIGHWAY 410 EXTENSION – PHASE III
ONTARIO
AGREEMENT No. 2005-A-000230, W.P. 106-00-01, SITE: 24-743

PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the site of the Kennedy Road underpass structure on the proposed four-lane of Highway 410 in the Town of Caledon, Ontario. Previous, preliminary investigations were carried out by Golder Associates Ltd. (Golder) and the Ministry of Transportation (MTO) and the factual data from these investigations have been used as general reference for the preparation of this report.

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 description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained.

Terraprobe conducted the investigation as a sub-consultant to Giffels Associates Ltd. (Giffels), under the Ministry of Transportation Ontario (MTO) Agreement Number 2005-A-000230.

The following documents are referenced in the preparation of this report:

- Golder Associates Ltd., "Supplementary Foundation Feasibility Investigation, Proposed Highway 410 Extension, Bovaird Drive to Highway 10", W.P. 22-79-00, MTO District 6, Toronto, GEOCRES No. 30M12-208, dated April 1999.
- Ministry of Transportation, "Highway 410 Route Planning Study, Bovaird Drive Northerly to Highway 10", W.P. 22-79-00, MTO District 6, GEOCRES 30M12-208, dated January 24, 1989.

2 SITE DESCRIPTION

The site is located on Kennedy Road about 600± m north of the Kennedy Road/Mayfield Road intersection in the Town of Caledon. Kennedy Road is a two lane asphalt paved road with granular shoulders and ditches on both sides.

The site is located in a rural setting, surrounded generally by agricultural lands and the Etobicoke Creek valley further west. Vegetation is light consisting mainly of grass and occasional large trees.

The topography is generally flat on the east side of Kennedy Road. On the west side of Kennedy Road the ground surface falls to the Etobicoke Creek valley by about 20± m over a horizontal distance of 275± m.

The site is located in the physiographic region of Southern Ontario referred to as the Peel Plain whose topography slopes gradually and gently towards Lake Ontario. Etobicoke Creek and other rivers have cut deep valleys across the Peel Plain.

The Peel Plain is known to consist of generally clayey and silty soils that cover the central portion of the regions of York, Peel and Halton[1]. There are exceptions to be noted in these major soil groups. Trains of sandy alluvium can be found at various places in the stream valleys. These overburden soils are underlain by the Queenston Formation.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing for this project were carried out on November 11 and 12, 2002 when six boreholes numbered K1, K2, K3, K4, K5 and K6 were drilled. Further field investigations were undertaken on October 27 and November 06, 2005 and Boreholes K2A, K2B, K3A, K4A and K5A were drilled during this period. A total of eleven boreholes were drilled and sampled to depths ranging from 2.8 m to 31.9 m below ground surface. The approximate locations of the boreholes are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix C.

The coordinates, geodetic elevations and borehole locations of Boreholes K1, K2, K3, K4, K5 and K6 were established in the field by Giffels Associates Limited (Giffels). The borehole locations, coordinates and geodetic elevations of Boreholes K2A, K2B, K3A, K4A and K5A were established in the field by surveyors from Shiu Geomatics Limited based on drawings provided by Giffels. Terraprobe obtained utility clearances prior to drilling.

The drilling, sampling and in-situ testing operations were conducted with a truck mounted BOA 5M drill rig owned and operated by Groundworks Drilling Limited of Toronto, Ontario. Solid and hollow stem auger drilling techniques were used to advance the boreholes and samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils.

A Dynamic Cone Penetration test was also performed in Borehole K2B. In this test a 51 mm diameter, 60 degree apex cone point is driven into the ground using the same driving energy as in the SPT method. By recording the number of blows to drive the cone/rod assembly into the soil every 0.3 m, a qualitative record of relative density/consistency is obtained. Although the interpretation of the test results is difficult because no samples are obtained by the DCPT method and the penetration resistances are not necessarily equal to the N-values, useful information is gained by the continuity of the results and by the elimination of unbalanced hydrostatic effects which often affects the SPT 'N' values.

[1] Chapman and Putnam, "The Physiography of South Ontario", 3rd Edition, 1984.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. A standpipe piezometer consisting of 19 mm PVC pipe with a slotted screen enclosed in sand was installed in selected boreholes to permit longer term groundwater level monitoring. The locations and completion details of the piezometers are presented in Table 3.1.

Table 3.1 – Piezometer Installation Details

Piezometer Location	Piezometer Details	
	Tip Depth/ Elevation (m)	Completion Details
K2	12.2/253.2	Piezometer with 3 m slotted screen and a flush mounted piezometer cap installed with filter sand to 8.5 m, bentonite seal from 8.5 m to 7.9 m, drill cuttings from 7.9 m to 1.2 m, sand from 1.2 m to 0.6 m and concrete from 0.6 m to ground surface.
K5	12.2/253.8	Piezometer with 3 m slotted screen and a flush mounted piezometer cap installed with filter sand to 8.5 m, bentonite seal from 8.5 m to 7.9 m, drill cuttings from 7.9 m to 1.2 m, sand from 1.2 m to 0.6 m and concrete from 0.6 m to ground surface.

Members of Terraprobe's technical staff supervised the drilling and sampling operations on a full time basis. The supervisors logged the boreholes and processed the recovered soil samples for transport to Terraprobe's Brampton laboratory for further examination and testing.

4 LABORATORY TESTING

The recovered soil samples were subjected to Visual Identification (VI) and natural moisture content determination. Selected samples were subjected to gradation analysis and Atterberg Limits tests were also conducted on selected samples retrieved from the cohesive deposits. The results of this testing program are shown on the Record of Borehole sheets in Appendix A. The grain size distribution curves and a plasticity chart are illustrated 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 this appendix and on the "Borehole Locations and Soil Strata" drawing in Appendix C. 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 fill and overburden deposits of stiff to hard clayey silt till, very dense sand and silt and silt and sand till, very dense silt and hard clayey silt.

5.1 Sand and Gravel Fill

Sand and Gravel fill was encountered at the site. This fill is approximately 0.4 m to 0.7 m thick and extends to elevations ranging from 265.6 m to 264.3 m.

The grain size distribution curve of a sample of this fill material is illustrated in Figure B1. The results show a grain size distribution consisting of 34% gravel, 57% sand, 7% silt and 2% clay size particles.

Standard Penetration tests in this fill material yielded 'N' values ranging from 8 to 37 blows for 0.3 m penetration indicating a loose to dense relative density.

The moisture content of samples of this fill ranged from 6% to 13% by weight.

5.2 Clayey Silt Fill

Clayey silt fill was encountered at depths extending to 0.7 m to 1.4 m or to elevations ranging from 265.3 m to 263.6 m.

Refer to Figure B2 for the grain size distribution curve of a sample of this fill material. The results show a grain size distribution consisting of 1% gravel, 25% sand, 45% silt and 29% clay size particles.

Standard Penetration tests in this fill material yielded 'N' values ranging from 5 to 15 blows for 0.3 m penetration. Based on these results the clayey silt fill is considered to have a firm to stiff consistency.

The moisture content of samples of this fill ranged from 13% to 20% by weight.

5.3 Upper Clayey Silt Till

Across the site a major deposit of clayey silt till was encountered. This deposit was fully penetrated in Boreholes K2, K3, K4 and K5 where it extends to depths ranging from 8.0 m to 8.5 m below ground surface or to elevations ranging from 257.5 m to 257.2 m. Two shallow boreholes (K1 and K6) were terminated in this deposit at depths of 3.5 m (Elev. 261.5 m) and 2.8 m (Elev. 263.5 m) below ground surface.

The grain size distribution curves of samples of this clayey silt till are presented in Figure B3 and B4. These results show a grain size distribution consisting of 0-10% gravel, 5-50% sand, 30-75% silt and 12-20% clay size particles. Till soils are also known to contain cobbles and boulders due to their mode of deposition.

Six samples of the clayey silt till were also subjected to Atterberg Limits tests and the results are illustrated in Figure B5. The index values from these tests are summarized below:

Liquid Limit:	21-25%
Plastic Limit:	14-18%
Plasticity Index:	4-11%
Natural Moisture Content:	13-24%

These values are characteristic of clayey soils of low plasticity.

Standard Penetration tests in this clayey silt till layer yielded 'N' values ranging from 10 to more than 100 blows for 0.3 m penetration indicating a stiff to hard consistency.

The moisture content of samples from this deposit ranged from 8% to 26% by weight.

5.4 Sand and Silt Till

A deposit of sand and silt till was encountered in some of the boreholes. This deposit was fully penetrated in Boreholes K2A, K3A, K4A and K5A where it extends to depths ranging from 13.0 m to 14.6 m below ground surface or elevations ranging between 252.2 m and 251.2 m.

Refer to Figure B6 where the grain size distribution curves of five samples of the sand and silt till are illustrated. The results show a grain size distribution consisting of 3-8% gravel, 41-62% sand, 35-48% silt and 8-9% clay size particles. Cobbles and boulders can also be expected within the matrix of till soils.

Blow counts of more than 100 blows for 0.3 m penetration were obtained from Standard Penetration tests in this stratum indicating a very dense relative density.

The moisture contents of samples from this deposit ranged from 4% to 11% by weight.

5.5 Lower Clayey Silt Till

A lower layer of clayey silt till was encountered across the site extending to depths ranging from 14.7 m (Elev. 250.5 m) to 20.0 m (Elev. 246.0 m) below ground surface.

A sample from this clayey silt till deposit was subjected to a grain size analysis and the results are presented in Figure B7. These results show a grain size distribution consisting of 10% gravel, 25% sand, 52% silt and 13% clay size particles. Cobbles and boulders can also be expected to occur in till soils.

Standard Penetration tests conducted in this clayey silt till gave 'N' values ranging from 41 to more than 100 blows for 0.3 m penetration. Based on these results the clayey silt till is considered to have a hard consistency.

The moisture contents of samples retrieved from this stratum ranged from 8% to 22% by weight.

5.6 Silt and Sand Till

A granular stratum of silt and sand till was encountered across the site. This deposit was fully penetrated in some of the boreholes where it was found to extend to depths ranging from 22.1 m (Elev. 243.2 m) to 22.2 m (Elev. 243.8 m) below ground surface.

Refer to Figure B8 for the grain size distribution curves of tested samples from this deposit. The results show a grain size distribution consisting of 6-21% gravel, 35-52% sand, 23-50% silt and 4-9% clay size particles.

Standard Penetration tests in this stratum gave 'N' values ranging from 54 to more than 100 blows for 0.3 m penetration. Based on these results the silt and sand till is considered to have a very dense relative density.

The moisture contents of samples from this silt and sand till ranged from 7% to 13% by weight.

5.7 Silt

Boreholes K2A, K2B and K5A encountered a layer of silt. This silt layer was fully penetrated in Borehole K2B where it extends to a depth of 26.9 m (Elev. 238.4 m) below ground surface.

Two samples from this stratum were subjected to grain size analysis and the grain size distribution curves are presented in Figure B9. The results show a grain size distribution consisting of 0% gravel, 1-7% sand, 83-91% silt and 8-10% clay sized particles.

The blow counts from Standard Penetration tests conducted in this stratum ranged from 34 to more than 100 blows for 0.3 m penetration. Based on these results the silt is considered to have a dense to very dense relative density.

The moisture contents of samples of this silt ranged from 15% to 19% by weight.

5.8 Clayey Silt

A layer of clayey silt was encountered in Borehole K2B at a depth of 26.9 m (Elev. 238.4 m) below ground surface. This layer extends to the borehole termination depth of 31 m (Elev. 234.3 m) and possibly beyond.

The grain size distribution curve of a tested sample of this clayey silt is presented in Figure B10. These results show a grain size distribution consisting of 0% gravel, 0% sand, 73% silt and 27% clay size particles.

Standard Penetration tests in this stratum gave 'N' values more than 100 blows for 0.3 m penetration indicating a hard consistency.

The moisture content of samples from this stratum ranged from 16% to 20% by weight.

5.9 Water Levels

A flush mounted piezometer was installed in Boreholes K2, and K5. The water level readings measured on a separate visit made after the completion of drilling are presented in Table 5.1.

Table 5.1 – Water Level Measurements

Borehole	Date	Water Levels	
		Depth (m)	Elevation (m)
K2	Nov. 25, 2002	9.6	255.8
K5	Nov. 25, 2002	11.2	254.8

These observations suggest that the local groundwater level at the site is likely to exist at elevations ranging between 254.8 m and 255.8 m. All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

6 GENERAL

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

A two span underpass structure is required to carry Kennedy Road over the proposed four lanes of Highway 410. The span lengths between the abutments and pier will be 22.5± m and the structure will be about 13.7± m wide. The proposed finished grades will be about Elev. 265.5± m and Elev. 266.2± m at the north and south abutments respectively. RSS walls are proposed for the abutment (false abutment) and wing walls.

Based on the proposed geometry and the vertical alignment of Highway 410 relative to the existing ground surface, about 12± m of existing overburden will be excavated at this site.

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.

7 STRUCTURE FOUNDATIONS

The proposed bridge is a two span structure with two abutments and a pier as foundation elements.

The stratigraphy encountered at the abutment and pier locations consists of surficial layers of sand and gravel and clayey silt fill material underlain by stiff to hard clayey silt till, very dense sand and silt and silt and sand till, very dense silt and hard clayey silt. The groundwater level exists at elevations ranging between 254.8 m and 255.8 m.

Consideration was given to the following foundation types:

- Spread footings
- Augered Caissons (drilled shafts)
- Driven piles

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

7.1 Spread Footings

Based on the subsurface stratigraphy encountered at this site and the vertical alignment of Kennedy Road, spread footings are feasible for supporting the pier and abutments.

A conventional cantilever type abutment may be impractical because of the relatively high cut (up to 12± m). However, an alternative scheme such as pedestals supported by a spread footing may be practical in which case it is likely that the highest founding elevation for spread footings will be about Elev. 254± m.

The recommended founding depths and geotechnical resistances for footings (minimum footing width of 2 m) founded on undisturbed competent natural soils are tabulated below.

Table 7.1 – Geotechnical Resistances at Abutment & Pier Locations

Borehole Location	Existing Ground Surface Elev. (m)	Recommended Bottom of Footing Level Below Existing Ground Surface (m)	Founding Elevation (m)	Factored Geotech. Resistance at ULS (kPa)	Geotech. Resistance at SLS (kPa)	Subgrade Material
North Abutment K2 & K2A	265.4± (K2) 265.3± (K2A)	Below 11.4± (K2) Below 11.3±(K2A)	Below 254.0	475	325	Sand & Silt Till
South Abutment K5 & K5A	266.0±	Below 12.0±	Below 254.0	475	325	Sand & Silt Till
Pier K3 & K3A	265.7± (K3) 265.2± (K3A)	Below 11.7± (K3) Below 11.2±(K3A)	Below 254.0	475	325	Sand & Silt Till
Pier K4 & K4A	265.8±	Below 11.8±	Below 254.0	475	325	Sand & Silt Till

These values are for vertical, concentric loads only. Effects of load inclination and eccentricity should be taken into account as illustrated in CHBDC 2000, Clause 6.7.3 and Clause 6.7.4.

The SLS values quoted above corresponds to a settlement of up to 25 mm, a significant portion of which will be complete by the end of construction.

The sand and silt till is susceptible to disturbance below the groundwater table. It is therefore recommended that allowance be made to pour a 150 mm thick layer of lean concrete (mud mat) on the foundation bearing surfaces as soon as possible after excavation and approval.

Resistance to lateral forces/sliding resistance between the concrete footing and the subgrade soils should be evaluated in accordance with the CHBDC 2000. Assume an ultimate coefficient of friction of 0.7 for the very dense sand and silt till.

7.2 Augered Caissons (Drilled Shafts)

Competent soils were encountered at relatively shallow depths at this site and more economical foundation schemes such as spread footings are feasible. Therefore, augered caissons are not considered to be a feasible option that warrants further consideration.

7.3 Driven Piles

It is recognised than an integral abutment bridge (which requires pile foundations) offers significant long term advantages. The subsurface conditions at the site are considered suitable for the design of foundations supported on steel H-piles.

7.3.1 Axial Resistance

Two steel pile sections believed to be currently available have been considered for use in the proposed foundations.

Piles driven at the abutment locations and encountering effective refusal in the hard clayey silt or the very dense silt should be designed on the basis of the concentric, axial geotechnical resistances given in Table 7.2. The actual pile tip elevations will be controlled as described in Section 7.3.6 Pile Installation.

Table 7.2 – Axial Resistance of Various Pile Sections

Location	PILE TYPE - HP 310x110				
	Reference Boreholes	Estimated Pile Tip Elevation (m)	Founding Stratum	Factored Axial Resistance U.L.S (kN)	SLS (25 mm Settlement) (kN)
North Abutment	K2, K2A, K2B	236.0±	Clayey Silt	1600	1200
South Abutment	K5, K5A	239.5±	Silt		
Location	**PILE TYPE – HP 360X132**				
	Reference Boreholes	**Estimated Pile Tip Elevation (m)**	**Founding Stratum**	**Factored Axial Resistance U.L.S (kN)**	**SLS (25 mm Settlement) (kN)**
North Abutment	K2, K2A, K2B	235.0±	Clayey Silt	2100	1600
South Abutment	K5, K5A	238.5±	Silt		

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

The H-piles for the recommended foundation scheme will be driven to effective refusal. Piles will penetrate through till layers that are likely to contain cobbles and boulders. It is therefore recommended that the pile tips be fitted with driving shoes to provide reinforcement to the pile section.

The contract documents should contain a NSSP alerting the contractor to the fact that cobbles and boulders may be encountered in the soil. The NSSP should require the QVE to terminate driving before the pile is damaged by overdriving. If the required resistance according to the Hiley Formula is not achieved and further driving is likely to cause damage to the pile, pile driving should cease and the contract administrator should be notified. Suggested wording for the NSSP is included in Appendix E.

7.3.2 Downdrag

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

7.3.3 Integral Abutment Considerations

The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. At the abutment locations the upper 9 m to 10 m of pile will lie in the RSS core. In order to provide the upper 3 m of the pile with the required flexibility, and to ensure that superstructure movement does not damage the RSS wall a 2-CSP system is recommended as per MTO SO-96-01. An outer CSP is placed around an inner sand filled CSP (about 600 mm in diameter).

The space between the pile and the inner CSP should be filled with sand. An NSSP should be included in the contract drawings specifying the gradation of the sand according to Table 7.3.

Table 7.3 – 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%

7.3.4 Lateral Resistance

The lateral resistance of the piles 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 [cohesionless soils] (kN/m^3)
k_s = 67 S_u/D [cohesive soils] (kN/m^3)
p_{ult} = 3 γ z K_p [cohesionless soils] (kPa)
p_{ult} = 9 S_u [cohesive soils] (kPa)

where z = depth of embedment of pile (m)
D = pile width (m)
S_u = undrained shear strength (Table 7.4) (kPa)
n_h = coefficient of horizontal subgrade reaction (Table 7.4) (kN/m^3)
γ = unit weight (Table 7.4) (kN/m^3)
K_p = passive earth pressure coefficient (1+Sin ϕ)/(1-Sin ϕ)
ϕ = angle of internal friction (Table 7.4) (degrees)

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 must not exceed the ultimate lateral resistance or the factored structural flexural resistance of the pile. For design purposes a maximum horizontal passive resistance of 120 kN (ULS) is recommended.

The spring constant, K, for analysis may be obtained by the expression, $K = k_s \times L \times D$ (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, P_{ult}, may be obtained from the expression, $P_{ult} = p_{ult} \times L \times D$.

Table 7.4 – Recommended Soil Parameters

Area Reference Borehole No.	*Applicable Elevation (m)	Soil Type	Bulk Unit Weight (kN/m^3)	Angle of Internal Friction (ϕ) Degrees	Undrained Shear Strength (S_u) (kPa)	Recommended n_h Value (kN/m^3)**
North Abutment K2, K2A, K2B	265.5 – 253.5	Granular Fill	21	32	-	6000
	253.5 – 252.1	Sand & Silt Till	21	35	-	10000
	252.1 – 248.9	Clayey Silt Till	21	0	200	-
	248.9 – 243.2	Silt & Sand Till	21	35	-	10000
	243.2 – 238.4	Silt	21	32	-	9000
	238.4 – 234.3	Clayey Silt	21	0	200	-
South Abutment K5, K5A	266.2 – 253.7	Granular Fill	21	32	-	6000
	253.7 – 251.5	Sand & Silt Till	21	35	-	10000
	251.5 – 246.0	Clayey Silt Till	21	0	200	-
	246.0 – 243.8	Silt & Sand Till	21	35	-	10000
	243.8 – 238.3	Silt	21	32	-	9000

* Assumes that the native soils will be excavated to Elev. 253.5 m and Elev. 253.7 m at the north and south abutments respectively and the piles will lie within compacted granular fill comprising the RSS Core.
** Values estimated based on Table 20.3 data, Canadian Foundation Engineering Manual, 3rd edition, 1992.

Since the H-piles are end bearing, the vertical resistance will not be significantly affected by the pile spacing. Pile interaction should be considered with reference to CHBDC Clause 6.8.9.2.

For lateral soil/pile group interaction analysis, the equation for k_s quoted above may be used in conjunction with appropriate reduction factors.

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

* 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.

7.3.5 Pile Tips

Due to the possible presence of cobbles and boulders in the till layers; the tips of all piles should be fitted with driving shoes to protect the pile tip from damage.

7.3.6 Pile Installation

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

The Contract Documents should contain a NSSP alerting the Contractor to the presence of cobbles and boulders in the till soils.

7.3.7 Pile Driving

Pile driving should 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 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". Piles should be driven with a suitable hammer capable of delivering a rated energy of at least 55 kJ/blow, but not more than 70 kJ/blow. "R" must have the minimum values shown in Table 7.5.

Table 7.5 – Ultimate geotechnical Resistance of Piles

Pile	Ultimate Resistance (R) (kN)
HP 310X110	3,600 kN
HP 360X132	4,800 kN

Hiley formula calculations need not be carried out until the pile has been driven below Elev. 236.5 m at the north abutment and Elev. 240 m at the south abutment.

7.4 Recommended Foundation

It is recognised than an integral abutment bridge (which requires pile foundations) offers significant long-term advantages. The use of H-piles at the abutments allows for the design of an integral abutment structure. From a geotechnical point of view, it is recommended that the abutments for the main bridge structure be supported on steel H-piles. A spread footing is recommended for supporting the pier.

7.5 Frost Cover

Pile caps and footings should be provided with a minimum of 1.2 m of earth cover or equivalent protection.

8 EXCAVATION AND BACKFILL

8.1 General

All excavations must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the native soils at this site may be classified as Type 2 soils above the water table and Type 4 soils below the water table. Excavation below the groundwater level is not recommended without prior dewatering. Provided unwatering is carried out as described below, excavations may be sloped at 2H:1V

8.2 Foundations

The excavation and backfilling for foundations must be carried out in accordance with SP 902S01.

9 GROUNDWATER CONTROL

The groundwater level at this site is estimated to range between Elev. 254.8 m and Elev. 255.8 m and groundwater is likely to be encountered in the excavations.

The design of the unwatering system should be the responsibility of the Contractor. However, a suitable system that might be employed is a system of interceptor trenches and pumping from strategically located filtered sumps.

Any accumulation of water from the base of the excavation should be removed prior to placing concrete or compacting granular fill. Placement of concrete or compacting engineered fill must be done in the dry.

10 APPROACH FILL

It is envisaged that the approach fill will be retained by RSS walls. Non-cohesive earth fill or SSM would be feasible for use provided the approaches are constructed on the underlying stiff to hard clayey silt glacial till or the very dense sand and silt till.

The original ground will be excavated at both abutments to facilitate the construction of an integral abutment structure. It is envisaged that the retained height of fill will be about 12 ± m and 12.5 ± m at the north and south abutments respectively.

The total post construction settlement due to loads imposed by the 12± m to 12.5± m high fill will be negligible.

The fill will however experience settlement resulting from its consolidation. This settlement is expected to be about 125 mm for 12.5± m high fill. The settlement within the non-cohesive fill should be immediate in nature and essentially be complete shortly after construction has been completed.

For the purpose of stability analyses, the commercially available slope stability program Slope W developed by Geo-Slope International Ltd. was used. The Bishop's simplified method for stability analysis was employed.

Global stability analyses were conducted for earth fill or SSM material retained by RSS walls. The retained fill at the bridge abutments were also analysed for global stability. Factors of safety against global failure of 1.3 and greater were obtained for both long term and short term conditions.

Embankment construction should be in accordance with OPSS 206, as amended by Special Provision "Amendment to OPSS 206, December 1993", dated November 2002.

11 CUT SLOPES

Permanent earth cuts inclined at 2H:1V and up to 12± m high will be required at the north and south abutments.

A temporary detour of Kennedy Road will be required during construction requiring a temporary earth cut approximately 11± m high and inclined at 1.5H:1V.

Global stability analyses were conducted on the permanent earth cuts assuming excavations will be made to Elev. 253.5± m and Elev. 253.8± m at the north and south abutments respectively. The temporary earth cut was also analysed for global stability assuming that excavation will be made to Elev. 254± m at the pier location.

Factors of safety against global failure of 1.4 and greater were obtained for both long term and short term conditions for permanent earth cuts inclined at 2H:1V and temporary earth cuts inclined at 1.5H:1V.

Where permanent and temporary earth cuts are higher than 6 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the cut height exceeds 6 m
- be at least 2 m wide
- have 2% positive drainage to shed run-off water.

The following requirements must be met for open cuts:

- No traffic, construction equipment, stockpiles (including snow) or other construction supplies is permitted at the top of the cut slope within a distance of at least 1.5 m from the top of the cut.
- Exposed soil along the slope must be protected from surface erosion.
- Construction activities should be scheduled so that the length of time any temporary cut slope is left open is reduced to the extent practical.
- Surface water must be diverted away from the excavation and from the top of the slope and runoff from the site should be reduced to the extent practical.

Proper erosion control measures should be implemented both during construction and permanently. Temporary erosion and sediment control must be provided in accordance with OPSS 577. Cut slopes must be provided with permanent erosion protection in accordance with OPSS 571 and/or OPSS 572.

12 RETAINED SOIL SYSTEMS

Retained soil system (RSS) walls may be used subject to the requirements presented in this section. It is understood that an RSS (false) abutment is proposed. RSS could also be used for wing walls and other retaining structures.

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.

12.1 Foundation

The performance of an RSS is dependent, among other factors, on 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.

The levelling pad for the RSS wall may be formed directly on the native very dense sand and silt till or the very stiff to hard clayey silt till. In addition to the requirements for the levelling pad, the RSS can also be founded on the native very dense sand and silt till or very stiff to hard clayey silt till. All founding subgrades should be inspected and evaluated by the Quality Verification Engineer (QVE), at the time of construction.

The recommended geotechnical resistances and construction details for the proposed RSS walls are tabulated below.

RSS Location	RSS Wall Base Elev. (m)	Max. Wall Height (m)	Required SLS Bearing Resistance (kPa)	Recommended Geotechnical Resistances (kPa)		Relevant Borehole & Subgrade Soil	Additional Requirements
				ULS	SLS		
NE & NW Wall	*253.5 for 6.4 m	12.0	312	475	325	K2/K2A Sand & Silt Till	
	**253.5 for 6.7 m	12.0	312	475	325	K2/K2A Sand & Silt Till	
	258.5 for 6.0 m	7.0	182	300	200	K2 Clayey Silt Till	
	261.0 for 6.0 m	4.5	117	225	150	K2 Clayey Silt Till	
North Abutment Face	253.5	12.0	312	475	325	K2/K2A Sand & Silt Till	
SE & SW Wall	!253.8 for 8.6 m	12.4	323	475	325	K5/K5A Sand & Silt Till	
	!!253.8 for 6.5 m	12.4	323	475	325	K5/K5A Sand & Silt Till	
	259.0 for 8.0 m	7.2	187	300	200	K5 Clayey Silt Till	
	262.0 for 8.0 m	4.2	109	225	150	K5 Clayey Silt Till	
South Abutment Face	253.8	12.4	323	475	325	K5/K5A Sand & Silt Till	

* Applies to NE Wall Only; ** Applies to NW Wall Only
! Applies to SE Wall Only; !! Applies to SW Wall Only

The settlement of RSS walls founded on native soils at this site will depend on the material used, the foundation soils and the quality of construction. However, settlements are expected to be less than 25 mm and to occur essentially as the RSS is constructed.

The following parameters may be used for the design of the RSS

- Ultimate coefficient of friction of sliding resistance of cast in-situ concrete levelling pad on very stiff to hard clayey silt till = 0.60; very dense sand and silt till = 0.7
- Ultimate coefficient of sliding resistance of RSS mass on native clayey silt till or very dense sand and silt till = 0.6

All topsoil, organics and soft soils should be removed from the subgrade of the RSS wall prior to placement of the fill.

The entire block of reinforced earth must also be designed against various modes of failure including sliding and overturning.

12.2 Global Stability

The global stability of the RSS wall is dependent on the characteristics of the approach fill and the foundation soils, the geometry of the approach and location of the RSS.

RSS walls are likely to be used for the abutment and its wing walls. It is envisaged that the RSS will be founded on native clayey silt till and sand and silt till.

Stability analyses of RSS walls were carried out considering the following variables:

- RSS founded at the base of the approach on sand and silt till.
- RSS founded up slope on clayey silt till – outer slope horizontal.
- Fill behind the RSS is horizontal.

Analysis carried out on the RSS walls located at the bridge abutments and up the slope yielded a factor of safety greater than 1.3 using a conventional anchor length of 60% of the height of the wall.

Consequently, it may be assumed that RSS walls located at the bride abutments will be stable against global failure. For an RSS wall founded up the slope, the specific geometry and soil conditions must be analyzed to determine the requirements for global stability. The actual design configuration must be checked for global stability prior to finalization.

The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for this site.

13 BACKFILL TO ABUTMENTS

In the case of integral or semi-integral abutments, backfill to the abutment should be granular material. In the case of a conventional abutment, granular backfill is recommended but rock backfill can be permitted. Granular material is recommended as backfill.

The backfill to the abutment walls should be in accordance with OPSS 902 as amended by Special Provision 902S01. Granular backfill should be placed to the extents shown in OPSD 3501.000.

All granular material should meet the specifications of Special Provision 110F13 "Amendment to OPSS 1010, March 1993".

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

The design of the abutment should incorporate a subdrain as shown in OPSD 3501.000 or OPSD 3505.000, as applicable.

14 EARTH PRESSURE

For cases where backfill to the abutment is placed in accordance with OPSD 3501.000 or OPSD 3505.000, as recommended, the lateral earth pressure will be governed by the properties of the material within the backfill limits shown in the respective OPSD, i.e. a line projected up at 1.5H:1V for granular backfill.

If the support system allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the geotechnical design of the structure. If the support system does not allow yielding (restrained system), at-rest horizontal earth pressures should be used. The amount of wall movement required for the development of active, passive and at-rest earth pressures may be interpreted using Figure C6.9.1(a) in the Commentary to the CHBDC.

Earth pressures acting on the structure should be computed in accordance with Clause 6.9 of the CHBDC but generally are given by the expression:

$P_h = K(\gamma h + q)$
P_h = horizontal pressure on the wall (kPa)
K = earth pressure coefficient (see table 13.1)
γ = unit weight of retained soil (see table 13.1)
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 at a depth of 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 given in Table 14.1.

Table 14.1 – Earth Pressure Coefficients

Wall Condition	Earth Pressure Coefficient (K)			
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°$; $\gamma = 22.8$ 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)	3.70	-	3.30	-

* For wing walls.

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 or semi-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 the table 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 CHBDC, 2000.

15 SEISMIC CONSIDERATIONS

15.1 Seismic Design Parameters

The site is treated as lying in Seismic Zone 0. The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 0
- 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 I. Therefore, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient "S" (ground motion amplification factor) of 1.0 should be used in seismic design.

15.2 Liquefaction Potential

There is no potential for liquefaction of the foundation soils below the abutments and pier.

The immediate approach fill will bear on stiff to hard clayey silt till and very dense sand and silt till and therefore there is negligible potential for soil liquefaction below the approaches.

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.

In calculating the active, passive and at rest earth pressure coefficients the angle of friction between the wall and backfill material is assumed to be 0.5 ϕ. 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 for Earthquake Loading

<table>
<tr><th colspan="5">Earth Pressure Coefficient (K) for Earthquake Loading</th></tr>
<tr><th rowspan="2">Wall Condition</th><th colspan="2">OPSS Granular A or
OPSS Granular B Type II
$\phi = 35°$; $\delta = 17.5°$
$\gamma = 22.8$ kN/m^3</th><th colspan="2">OPSS Granular B Type I
$\phi = 32°$; $\delta = 16°$
$\gamma = 21.2$ kN/m^3</th></tr>
<tr><th>Horizontal Surface Behind Wall</th><th>Sloping Surface Behind Wall (2H:1V)</th><th>Horizontal Surface Behind Wall</th><th>Sloping Surface Behind Wall (2H:1V)</th></tr>
<tr><td>Active (K_{AE})*</td><td>0.28</td><td>0.45</td><td>0.31</td><td>0.55</td></tr>
<tr><td>Passive (K_{PE})</td><td>3.69</td><td>-</td><td>3.26</td><td>-</td></tr>
<tr><td>At Rest (K_{OE})**</td><td>0.53</td><td>-</td><td>0.58</td><td>-</td></tr>
</table>

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

16 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction.

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

- the possibility of boulders and hard driving conditions being encountered while driving the pile through the till soils.
- the nature and geotechnical properties of non-cohesive earth fill used in the approach fills.

LICENSED PROFESSIONAL ENGINEER
R.A. ABDUL
Jan 26/2007
PROVINCE OF ONTARIO

Engineering Analysis and Report Preparation by:
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MICHAEL TANOS
26·01·2007
PROVINCE OF ONTARIO

Report Reviewed by:
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Review Principal

APPENDICES

Terraprobe Limited

LIMITATIONS AND RISK

Procedures

The soil conditions were confirmed at the borehole locations only and conditions may vary between and beyond the boreholes. The boundaries between the various strata as shown on the logs are based on non-continuous sampling. These boundaries represent an inferred transition between the various strata, rather than a precise plane of stratigraphic change.

This investigation has been carried out using investigation techniques and engineering analysis methods consistent with those ordinarily exercised by Terraprobe and other engineering practitioners, working under similar conditions and subject to the time, financial and physical constraints applicable to this project. The discussions and recommendations that have been presented are based on the factual data obtained.

It must be recognized that there are special risks whenever engineering or related disciplines are applied to identify subsurface conditions. Even a comprehensive sampling and testing programme implemented in accordance with the most stringent level of care may fail to detect certain conditions. Terraprobe has assumed for the purposes of providing design parameters and advice, that the conditions that exist between sampling points are similar to those found at the sample locations. The conditions that Terraprobe has interpreted to exist between sampling points can differ from those that actually exist.

It may not be possible to drill a sufficient number of boreholes or sample and report them in a way that would provide all the subsurface information that could affect construction costs, techniques, equipment and scheduling. Contractors bidding on or undertaking work on the project should be directed to draw their own conclusions as to how the subsurface conditions may affect them, based on their own investigations and their own interpretations of the factual investigation results, cognizant of the risks implicit in the subsurface investigation activities.

Changes In Site And Scope

It must be recognized that the passage of time, natural occurrences, and direct or indirect human intervention at or near the site have the potential to alter subsurface conditions. Groundwater levels are particularly susceptible to seasonal fluctuations.

The design advice is based on the factual data obtained from this investigation made at the site by Terraprobe and are intended for use by the owner and its retained designers in the design phase of the project. If there are changes to the project scope and development features, or there is any additional information relevant to the interpretations made of the subsurface information, the geotechnical design parameters and comments relating to constructibility issues and quality control may not be relevant or complete for the revised project. Terraprobe should be retained to review the implications of such changes with respect to the contents of this report

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS $\bar{N}$.

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 – 12	12 – 25	25 – 50	50 – 100	100 – 200	>200
	VERY SOFT	*SOFT*	*FIRM*	*STIFF*	*VERY STIFF*	*HARD*

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 – 5	5 – 10	10 – 30	30 – 50	>50
	VERY LOOSE	*LOOSE*	*COMPACT*	*DENSE*	*VERY DENSE*

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND/OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY IS:

RQD (%)	0 – 25	25 – 50	50 – 75	75 – 90	90 – 100
	VERY POOR	*POOR*	*FAIR*	*GOOD*	*EXCELLENT*

JOINTING AND BEDDING:

SPACING	50mm	50 – 300mm	0.3m – 1m	1m – 3m	>3m
JOINTING	*VERY CLOSE*	*CLOSE*	*MOD. CLOSE*	*WIDE*	*VERY WIDE*
BEDDING	*VERY THIN*	*THIN*	*MEDIUM*	*THICK*	*VERY THICK*

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ε	%	LINEAR STRAIN
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa^{-1}	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
C_v	m^2/s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{vo}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	- °	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	- °	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = c_u / τ_r

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES
γ_s	kN/m^3	UNIT WEIGHT OF SOLID PARTICLES
ρ_w	kg/m^3	DENSITY OF WATER
γ_w	kN/m^3	UNIT WEIGHT OF WATER
ρ	kg/m^3	DENSITY OF SOIL
γ	kN/m^3	UNIT WEIGHT OF SOIL
ρ_d	kg/m^3	DENSITY OF DRY SOIL
γ_d	kN/m^3	UNIT WEIGHT OF DRY SOIL
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL
γ_{sat}	kN/m^3	UNIT WEIGHT OF SATURATED SOIL
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL

e	1,%	VOID RATIO
n	1,%	POROSITY
w	1,%	WATER CONTENT
S_r	%	DEGREE OF SATURATION
w_L	%	LIQUID LIMIT
w_P	%	PLASTIC LIMIT
w_S	%	SHRINKAGE LIMIT
I_P	%	PLASTICITY INDEX = $(w_L - w_P)$
I_L	1	LIQUIDITY INDEX = $(w - w_P)/I_P$
I_C	1	CONSISTENCY INDEX = $(w_L - w)/I_P$
e_{max}	1,%	VOID RATIO IN LOOSEST STATE

e_{min}	1,%	VOID RATIO IN DENSEST STATE
I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
D	mm	GRAIN DIAMETER
D_n	mm	n PERCENT - DIAMETER
C_u	1	UNIFORMITY COEFFICIENT
h	m	HYDRAULIC HEAD OR POTENTIAL
q	m^3/s	RATE OF DISCHARGE
v	m/s	DISCHARGE VELOCITY
i	1	HYDRAULIC GRADIENT
k	m/s	HYDRAULIC CONDUCTIVITY
j	kN/m^3	SEEPAGE FORCE

APPENDIX A

Record of Borehole Sheets

Terraprobe Limited

RECORD OF BOREHOLE No K1

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,376.5 N; 279,003.5 E. ORIGINATED BY A.S.

DIST ___ HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY J.B.

DATUM Geodetic DATE 11.12.02 CHECKED BY J.N.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
265.0	Ground Surface						
0.0 / 264.3	**Fill** - Sand And Gravel, damp to moist, loose, brown	1	SS	9	*		
0.7 / 263.6	**FILL** - Clayey Silt, sandy, trace gravel, trace rootlets, moist, stiff, brown	2	SS	15		264	1 25 45 29
1.4	**CLAYEY SILT** sandy, trace to some gravel, damp to moist, very stiff to hard, brown (GLACIAL TILL)	3	SS	28		263	
		4	SS	25		262	10 29 42 19
261.5		5	SS	31			
3.5	End of Borehole * Borehole dry (unstabilized) and hole open to full depth upon completion of drilling						

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 (%) 10 20 30

UNIT WEIGHT γ kN/m³

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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No K2

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,371.3 N; 279,022.3 E. ORIGINATED BY A.S.

DIST ____ HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY J.B.

DATUM Geodetic DATE 11.11.02 CHECKED BY J.N.

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
265.4	Ground Surface				
0.0	Fill - Sand, some gravel, damp, compact, brown	1	SS	10	
264.9					
264.7	FILL - Clayey Silt, some sand, trace gravel, moist, stiff, brown				
0.7	CLAYEY SILT sandy, trace gravel, damp to moist, very stiff to hard, brown (GLACIAL TILL)	2	SS	25	
		3	SS	34	
		4	SS	47	
		5	SS	41	
		6	SS	54	
	stiff, grey	7	SS	11	0 31 57 12
	hard	8	SS	100/ 23cm	
257.4 / 8.0	SAND AND SILT trace clay, trace gravel, damp, very dense, brown (GLACIAL TILL)	9	SS	100/ 13cm	3 62 (35)
	grey	10	SS	100/ 8cm	8 44 40 8
253.2 / 12.2	End of Borehole	11	SS	100/ 14cm	

Elevation scale: 265, 264, 263, 262, 261, 260, 259, 258, 257, 256, 255, 254

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 (%) 10 20 30

UNIT WEIGHT γ kN/m³

Piezometer Installation consists of 19mm diameter, schedule 40 PVC pipe with a 3.0m slotted screen.

Water Level Readings:

Date	Height(m)	Elevation(m)
Nov.25.02	9.6	255.8

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No K2A

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,371.3 N; 279,022.3 E. ORIGINATED BY H.A.

DIST ____ HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY D.B.

DATUM Geodetic DATE 27.10.05 CHECKED BY R.A.

ELEV / DEPTH	SOIL PROFILE 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, × LAB VANE; 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
265.3 / 0.0	Augered to 12.1m, refer to BH K2 for inferred soil stratigraphy						265 – 254				
253.2 / 12.1	**SAND AND SILT** trace clay, trace gravel, damp, very dense, grey (GLACIAL TILL)		1	SS	194	∇ **	253		o		** Sampler Wet
252.1 / 13.2	**CLAYEY SILT** trace sand, trace to some gravel, damp, hard, grey (GLACIAL TILL)		2	SS	63		252, 251		o		

Continued Next Page

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

RECORD OF BOREHOLE No K2A

 METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,371.3 N; 279,022.3 E. ORIGINATED BY H.A.

DIST HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY D.B.

DATUM Geodetic DATE 27.10.05 CHECKED BY R.A.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
	CLAYEY SILT trace sand, trace to some gravel, damp, hard, grey (GLACIAL TILL) *(continued)*	3	SS	53		250
248.9 / 16.4	**SILT AND SAND** trace to some gravel, trace clay, damp to moist, very dense, grey (GLACIAL TILL)	4	SS	71		249, 248
		5	SS	54		247, 246
		6	SS	100/10cm		245
		7	SS	170		244
243.2 / 22.1	**SILT** trace clay, trace sand, moist to wet, very dense, grey	8	SS	73		243, 242
		9	SS	100/15cm		241, 240
		10	SS	70		239
238.9 / 26.4	End of Borehole					

* Water level at 12.2m (unstabilized) and hole open to 13.1m upon completion of drilling.

Column headings also printed: SOIL PROFILE; SAMPLES; STRAT PLOT; 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 (%) (10 20 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

RECORD OF BOREHOLE No K2B

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,369.2 N; 279,621.3 E. ORIGINATED BY H.A.

DIST ______ HWY 410 Extension BOREHOLE TYPE Solid & Hollow Stem Augers & DCPT COMPILED BY D.B.

DATUM Geodetic DATE 06.11.05 CHECKED BY R.A.

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 (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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
265.3 0.0	Augering to 22.9m, refer to BH K2 and K2A for inferred soil stratigraphy						265 264 263 262 261 260 259 258 257 256 255 254 253 252 251				

Continued Next Page

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No K2B

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,369.2 N; 279,621.3 E. ORIGINATED BY H.A.

DIST ____ HWY 410 Extension BOREHOLE TYPE Solid & Hollow Stem Augers & DCPT COMPILED BY D.B.

DATUM Geodetic DATE 06.11.05 CHECKED BY R.A.

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Augering to 22.9m, refer to BH K2 and K2A for inferred soil stratigraphy					∇ (248)	250–243	
242.4 / 22.9	SILT trace clay, trace sand, moist to wet, dense to very dense, grey		1	SS	34		242	0 7 83 10
			2	SS	69		241	
			3	SS	64		239	
238.4 / 26.9	CLAYEY SILT damp to moist, hard, grey		4	SS	131/ 28cm		238	0 0 73 27
			5	SS	161/ 23cm		236	

Plot headings: 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 (%) 10 20 30; UNIT WEIGHT γ kN/m³

Continued Next Page

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

RECORD OF BOREHOLE No K2B

METRIC

W.P. 106-00-01	LOCATION Co-ords. 4,845,369.2 N; 279,621.3 E.		ORIGINATED BY H.A.
DIST	HWY 410 Extension	BOREHOLE TYPE Solid & Hollow Stem Augers & DCPT	COMPILED BY D.B.
DATUM Geodetic		DATE 06.11.05	CHECKED BY R.A.

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, × LAB VANE; 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
	CLAYEY SILT damp to moist, hard, grey *(continued)*						235				
			6	SS	102				o		
234.3 / 31.0	End of Borehole						234				
233.5 / 31.8	End of DCPT										

* Wet cave at 17.4m upon completion of drilling.

Dynamic Cone Penetration Test (D.C.P.T.) performed from 31.0m to 31.8m.

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

RECORD OF BOREHOLE No K3

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,349.7 N; 279,029.2 E. ORIGINATED BY A.S.

DIST HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY J.B.

DATUM Geodetic DATE 11.12.02 CHECKED BY J.N.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
265.7	Ground Surface						
0.0	**FILL** - Sand and Gravel, damp, loose, brown	1	SS	8	*		34 57 7 2
265.2 / 265.0 / 0.7	**FILL** - Clayey Silt, some sand, trace gravel, moist, firm, brown					265	
	CLAYEY SILT trace sand to sandy, trace gravel, damp to moist, stiff to 1.4m, very stiff to hard below, brown (GLACIAL TILL)	2	SS	14			
		3	SS	24		264	
		4	SS	33		263	4 32 46 18
		5	SS	49		262	
		6	SS	72		261	
	grey					260	
		7	SS	23		259	1 5 75 19
		8	SS	86		258	
257.2 / 8.5	**SAND AND SILT** trace gravel, damp, very dense, grey (GLACIAL TILL)					257	
		9	SS	100/ 8cm		256	
		10	SS	100/ 13cm		255	7 45 (48)
					∇	254	
253.5 / 12.2	End of Borehole	11	SS	100/ 14cm			
	* Wet cave at 11.7m upon completion of drilling						

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 (%) 10 20 30

UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No K3A

METRIC

W.P. 106-00-01
LOCATION Co-ords. 4,845,349.6 N; 279,029.2 E.
ORIGINATED BY M.K.
DIST ____ HWY 410 Extension
BOREHOLE TYPE Solid Stem Augers
COMPILED BY D.B.
DATUM Geodetic
DATE 27.10.05
CHECKED BY R.A.

ELEV DEPTH	SOIL PROFILE: 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, × LAB VANE) 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
265.2 0.0							265				
							264				
							263				
							262				
	Augered to 12.1m, refer to BH K3 for inferred soil stratigraphy.						261				
							260				
							259				
							258				
							257				
							256				
	Increased resistance to augering at 9.7m (Elev. 255.5m), inferred cobbles.						255				
							254				
253.1 12.1	**SAND AND SILT** trace gravel, trace clay, damp, very dense, grey (GLACIAL TILL)		1	SS	100/ 13CM		253		o		
252.2 13.0	**CLAYEY SILT** trace to some sand, trace gravel, damp, hard, grey (GLACIAL TILL)					* ∇	252				
			2	SS	61	**	251		o		** Sampler Wet
250.5 14.7											

Continued Next Page

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No K3A

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,349.6 N; 279,029.2 E. ORIGINATED BY M.K.

DIST ____ HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY D.B.

DATUM Geodetic DATE 27.10.05 CHECKED BY R.A.

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
	SILT AND SAND trace gravel, trace clay, damp, very dense, grey, **(GLACIAL TILL)** *(continued)*	3	SS	59	250	6	35	50	9
					249				
	becoming sandy and gravelly	4	SS	134	248	21	52	23	4
					247				
246.4 18.8		5	SS	66					
	End of Borehole * Water level at 13.4m (unstabilized) and hole open to 16.7m upon completion of drilling.								

Column headings: 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 (%) (10, 20, 30); STRAT PLOT; GROUND WATER CONDITIONS; UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No K4

METRIC

W.P. 106-00-01	LOCATION Co-ords. 4,845,354.9 N; 279,038.2 E.		ORIGINATED BY A.S.
DIST	HWY 410 Extension	BOREHOLE TYPE Solid Stem Augers	COMPILED BY J.B.
DATUM Geodetic	DATE 11.12.02		CHECKED BY J.N.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
265.8	Ground Surface					
0.0	**FILL** - Sand and Gravel, damp, dense, brown	1	SS	37		
265.1 / 0.7	**CLAYEY SILT** sandy, trace gravel, damp to moist, stiff to 1.4m, very stiff to hard below, brown (GLACIAL TILL)	2	SS	10	265	
		3	SS	30	264	
		4	SS	35		9 29 42 20
		5	SS	59	263	
		6	SS	50	262 / 261	
	---- grey				260	
		7	SS	21		
		8	SS	64	259 / 258	
257.3 / 8.5	**SAND AND SILT** trace clay, trace gravel, dry to damp, very dense, grey (GLACIAL TILL)	9	SS	100/ 8cm	257	
		10	SS	100/ 13cm	256 / 255	
253.6 / 12.2	End of Borehole	11	SS	100/ 13cm	254	8 41 42 9

* Borehole dry (unstabilized) and hole open to full depth upon completion of drilling.

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, × LAB VANE, 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   O 3% STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No K4A

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,354.9 N; 279,038.2 E. ORIGINATED BY M.K.

DIST HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY D.B.

DATUM Geodetic DATE 27.10.05 CHECKED BY R.A.

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	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, × LAB VANE; 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
265.8 0.0	Augering to 12.1m, refer to BH K4 for inferred soil straligraphy.						265 … 254				
253.7 12.1	**SAND AND SILT** trace clay, trace gravel, damp, very dense, grey (GLACIAL TILL)		1	SS	155	**	253		O		** Sampler Wet
			2	SS	162		252		O		
251.2 14.6							251				

Continued Next Page

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

RECORD OF BOREHOLE No K4A

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,354.9 N; 279,038.2 E. ORIGINATED BY M.K.

DIST ____ HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY D.B.

DATUM Geodetic DATE 27.10.05 CHECKED BY R.A.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE
	CLAYEY SILT some sand, trace gravel, damp to moist, hard, grey (GLACIAL TILL) *(continued)*	3	SS	72		250
248.9 / 16.9	**SILT AND SAND** trace to some gravel, damp, very dense, grey (GLACIAL TILL)	4	SS	100/ 8CM	* ∇	249
		5	SS	91		248
247.0 / 18.8	End of Borehole * Water level at 17.2m (unstablilized) and hole open to 18.1m upon completion of drilling.					

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; 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 (%) (10 20 30); UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

RECORD OF BOREHOLE No K5

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,333.1 N; 279,045.1 E. ORIGINATED BY A.S.

DIST HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY J.B.

DATUM Geodetic DATE 11.11.02 CHECKED BY J.N.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	WATER CONTENT	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
266.0	Ground Surface					
0.0	FILL - Sand and Gravel, damp, compact, brown	1	SS	11		
265.6 / 0.4	FILL - Clayey Silt, some sand, trace gravel, occasional topsoil inclusions, damp to moist, stiff, brown					
265.3 / 0.7	CLAYEY SILT sandy, trace gravel, damp, very stiff to hard, brown (GLACIAL TILL)	2	SS	17		
		3	SS	34		
		4	SS	35		
		5	SS	45		5 30 46 19
		6	SS	47		
	grey	7	SS	26		
		8	SS	55		
257.5 / 8.5	SAND AND SILT trace gravel, trace clay, dry to damp, very dense, grey (GLACIAL TILL)	9	SS	100/8cm		5 47 40 8
		10	SS	100/5cm		
253.8 / 12.2	End of Borehole	11	SS	100/10cm		

Elevation scale: 265, 264, 263, 262, 261, 260, 259, 258, 257, 256, 255, 254

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 (%) 10 20 30

UNIT WEIGHT γ kN/m³

Piezometer Installation consists of 19mm diameter, schedule 40 PVC pipe with a 3.0m slotted screen.

Water Level Readings:

Date	Height(m)	Elevation(m)
Nov.25.02	11.2	254.8

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No K5A

METRIC

W.P. 106-00-01 LOCATION Co-ords. 4,845,333.1 N; 279,045.1 E. ORIGINATED BY H.A.

DIST ___ HWY 410 Extension BOREHOLE TYPE Solid Stem Augers COMPILED BY D.B.

DATUM Geodetic DATE 27.10.05 CHECKED BY R.A.

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 ○ 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 (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
266.0 0.0	Augering to 12.1m, refer to BH K5 for inferred soil stratigraphy.						265 … 255				
						∇	256				
253.9 12.1	**SAND AND SILT** trace clay, trace gravel, damp, very dense, grey (GLACIAL TILL)		1	SS	100/15cm	**	254		○		** Sampler Wet
			2	SS	100/15cm		252		○		
251.5 14.5											

Continued Next Page

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

Ministry of Transportation
Ontario

Foundation Design

RECORD OF BOREHOLE No K5A

 METRIC

W.P. 106-00-01	LOCATION Co-ords. 4,845,333.1 N; 279,045.1 E.		ORIGINATED BY H.A.
DIST	HWY 410 Extension	BOREHOLE TYPE Solid Stem Augers	COMPILED BY D.B.
DATUM Geodetic		DATE 27.10.05	CHECKED BY R.A.

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	CLAYEY SILT sandy, trace gravel, damp to moist, hard, grey (GLACIAL TILL) *(continued)*	3	SS	115			10 25 52 13
						250	
		4	SS	85		249	
						248	
		5	SS	41			
						247	
246.0 / 20.0	**SILT AND SAND** trace clay, trace gravel, damp to moist, very dense, grey (GLACIAL TILL)	6	SS	100/ 15cm		246	
						245	
		7	SS	100/ 15cm			6 41 45 8
243.8 / 22.2	**SILT** trace clay, trace sand, moist to wet, very dense, grey					244	
		8	SS	74		243	
						242	
		9	SS	100/ 15cm			0 1 91 8
						241	
						240	
		10	SS	156			
						239	
		11	SS	100/ 15cm			
238.3 / 27.7	End of Borehole * Water level at 10.0m (unstabilized) and hole open to 14.9m upon completion of drilling.						

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 (%): 10 20 30

UNIT WEIGHT γ kN/m³

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

RECORD OF BOREHOLE No K6

METRIC

W.P. 106-00-01
LOCATION Co-ords. 4,845,326.4 N; 279,067.0 E.
ORIGINATED BY A.S.
DIST
HWY 410 Extension
BOREHOLE TYPE Solid Stem Augers
COMPILED BY J.B.
DATUM Geodetic
DATE 11.12.02
CHECKED BY J.N.

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 (%): 10 20 30
UNIT WEIGHT γ kN/m³
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
266.3	Ground Surface									
0.0	**FILL** - Sand and Gravel, damp to moist, compact, brown	1	SS	17	*	266				
265.6 / 0.7	**FILL** - Clayey Silt, some sand, trace gravel, damp to moist, firm, brown	2	SS	5		265				
264.9 / 1.4	**CLAYEY SILT** and sand, trace gravel, damp to moist, stiff to 2.1m, hard below, brown (GLACIAL TILL)	3	SS	13						
		4	SS	44		264	3	50	30	17
263.5 / 2.8	End of Borehole									

* Borehole dry (unstabilized) and hole open to full depth upon completion of drilling.

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

APPENDIX B

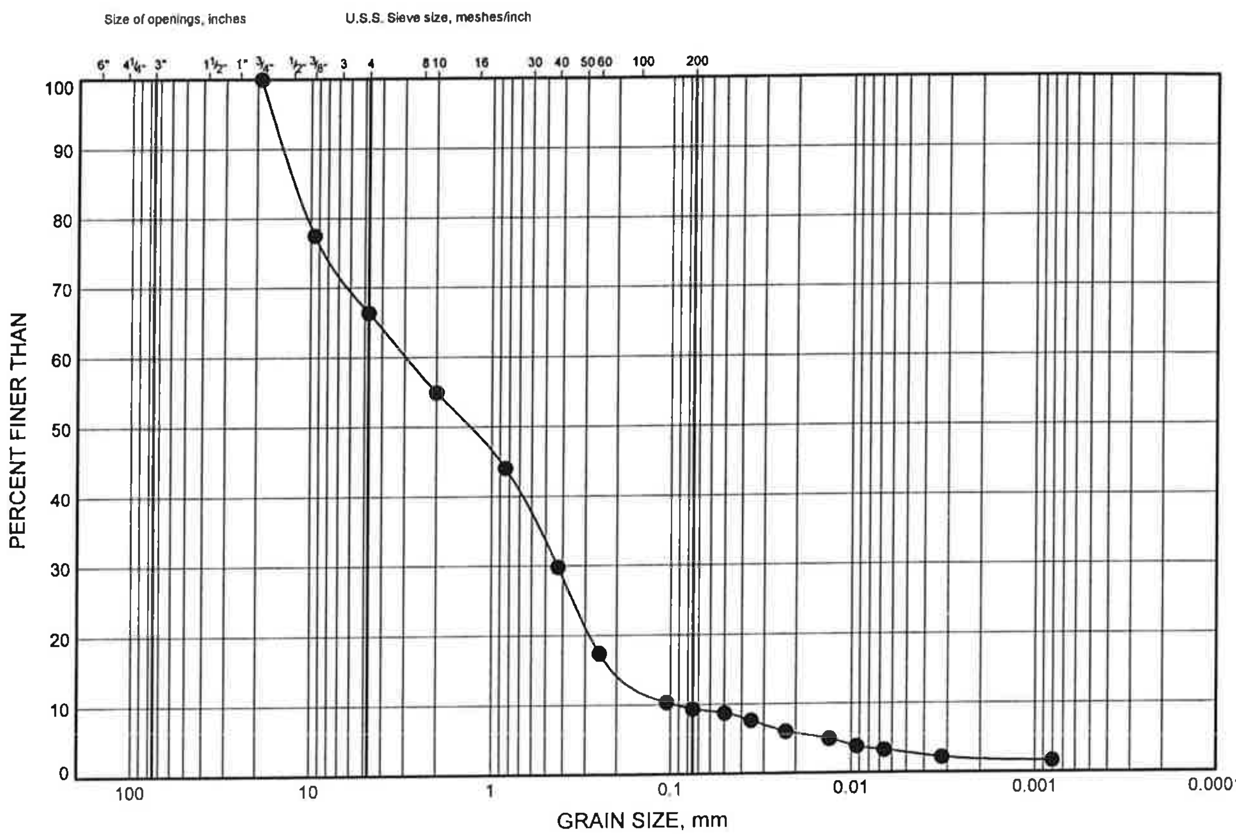
Laboratory Test Results

Terraprobe Limited

GRAIN SIZE DISTRIBUTION

FIGURE B1

Sand and Gravel (FILL)



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K3	0.3	265.4

GSD 1-00-0350 HWY 410 K.GPJ 15/12/05

Date December 2005

Project 106-00-01

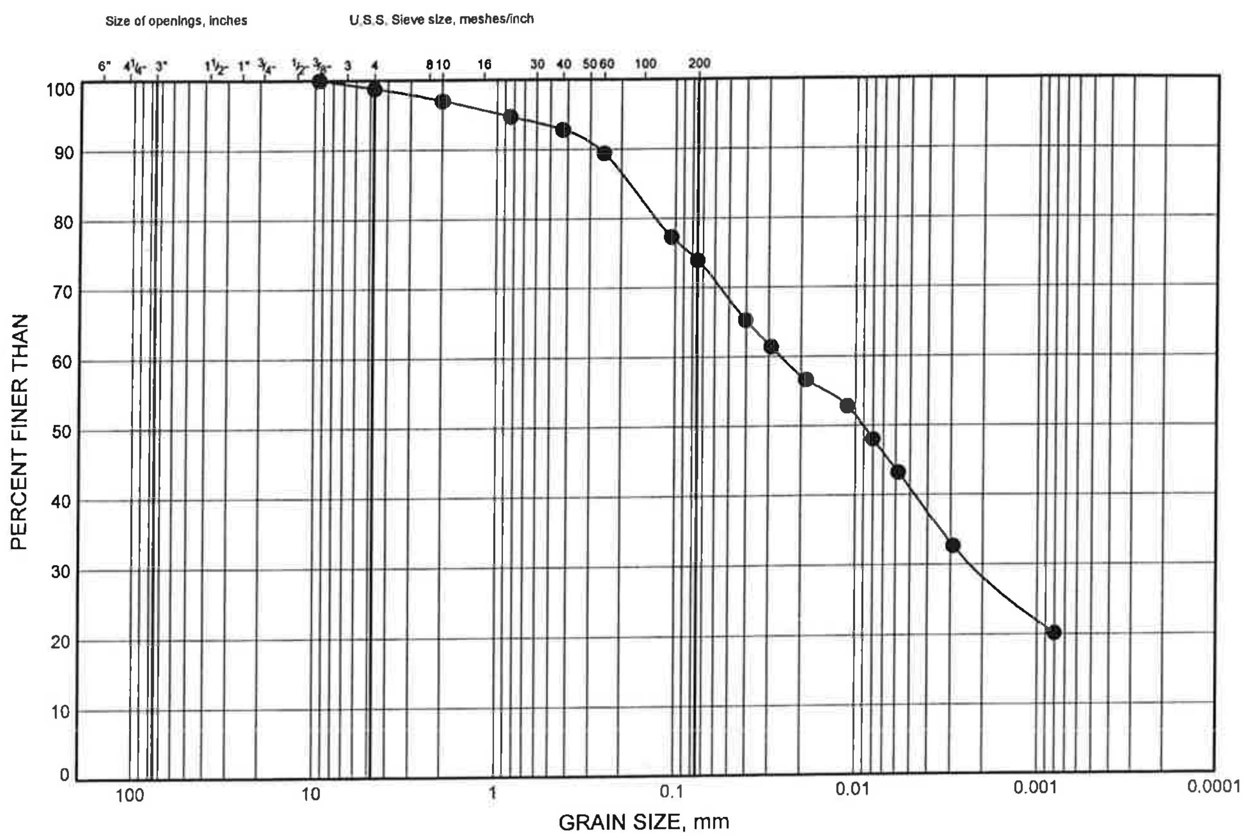
Prep'd DB

Chkd. RA

GRAIN SIZE DISTRIBUTION

FIGURE B2

Clayey Silt (FILL)



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K1	1.0	264.0

Date December 2005

Project 106-00-01

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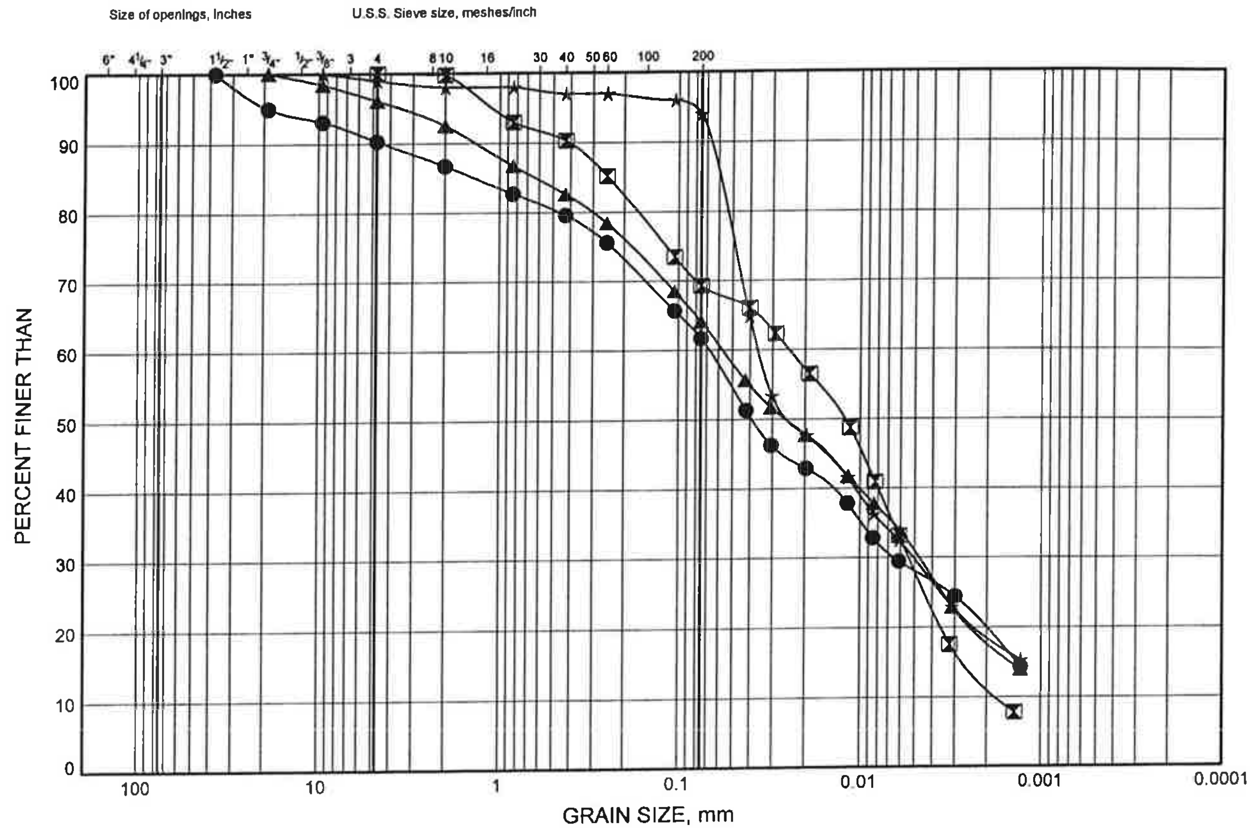
GSD 1-00-0350 HWY 410 K.GPJ 15/12/05

GRAIN SIZE DISTRIBUTION

FIGURE B3

Upper Clayey Silt Till



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K1	2.5	262.5
⊠	K2	6.3	259.1
▲	K3	2.5	263.2
★	K3	6.3	259.4

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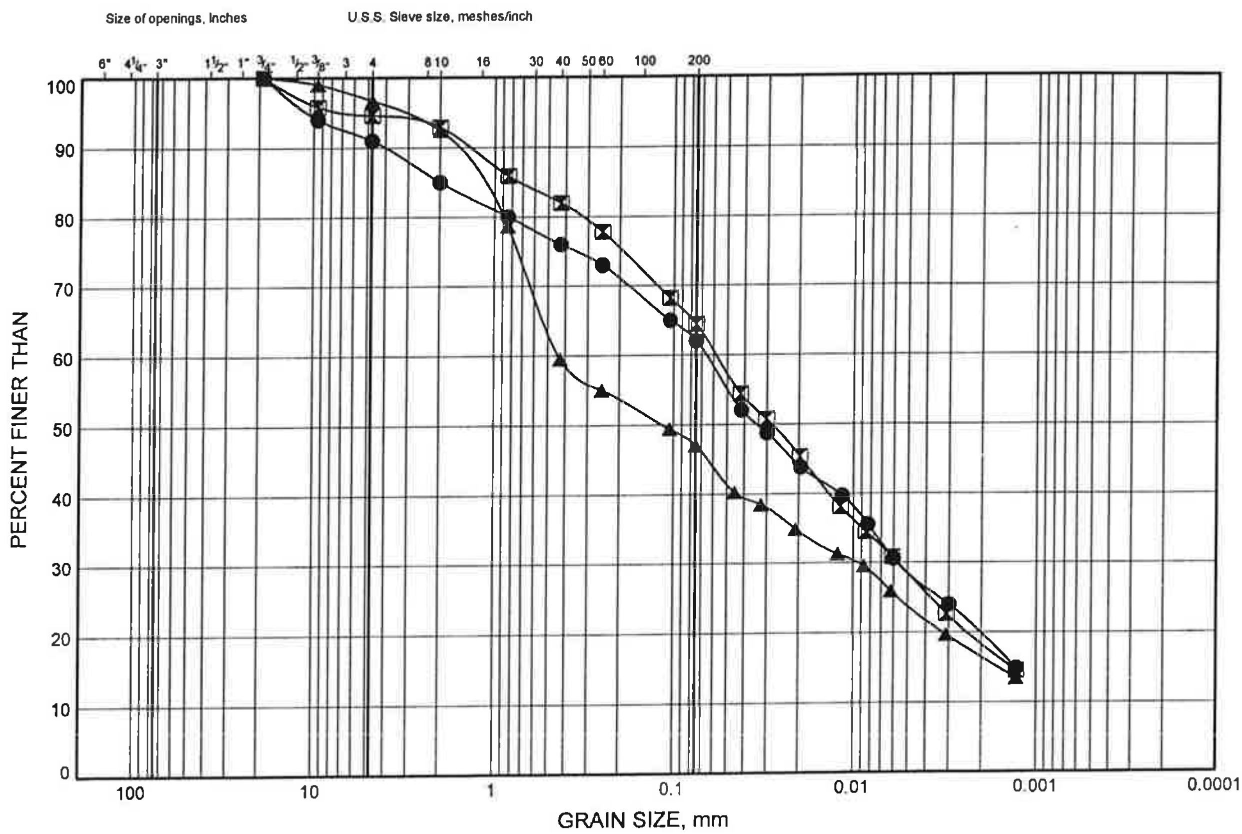
GRAIN SIZE DISTRIBUTION

FIGURE B4

Upper Clayey Silt Till



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K4	2.5	263.3
⊠	K5	3.2	262.8
▲	K6	2.5	263.8

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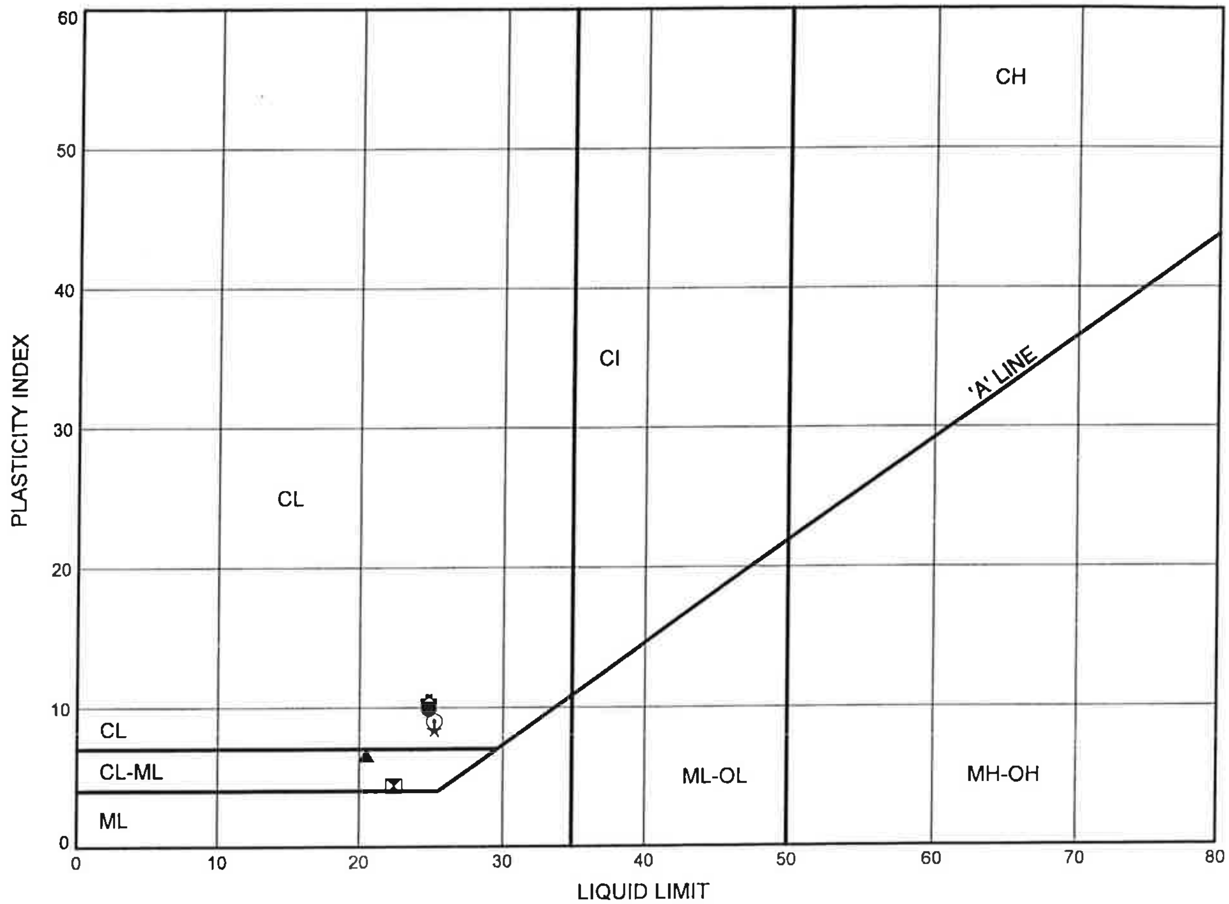
ATTERBERG LIMITS TEST RESULTS

FIGURE B5

Upper Clayey Silt Till



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K1	2.5	262.5
⊠	K2	6.3	259.1
▲	K3	6.3	259.4
★	K4	2.5	263.3
⊙	K5	3.2	262.8
✪	K6	2.5	263.8

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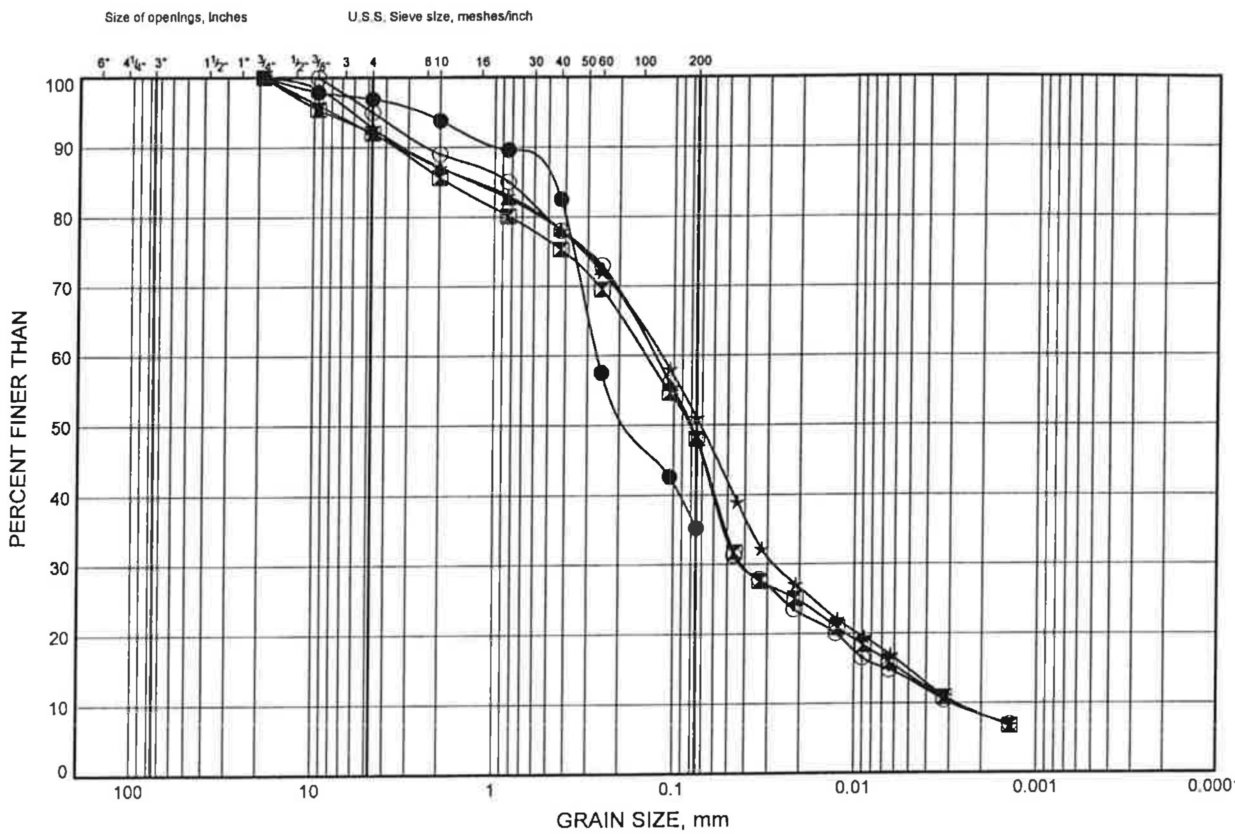
ALTR 1-00-0350 HWY 410 K.GPJ 15/12/05

GRAIN SIZE DISTRIBUTION	FIGURE B6

Sand and Silt Till



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K2	9.2	256.2
⊠	K2	10.7	254.7
▲	K3	10.8	254.9
★	K4	12.1	253.7
⊙	K5	9.1	256.9

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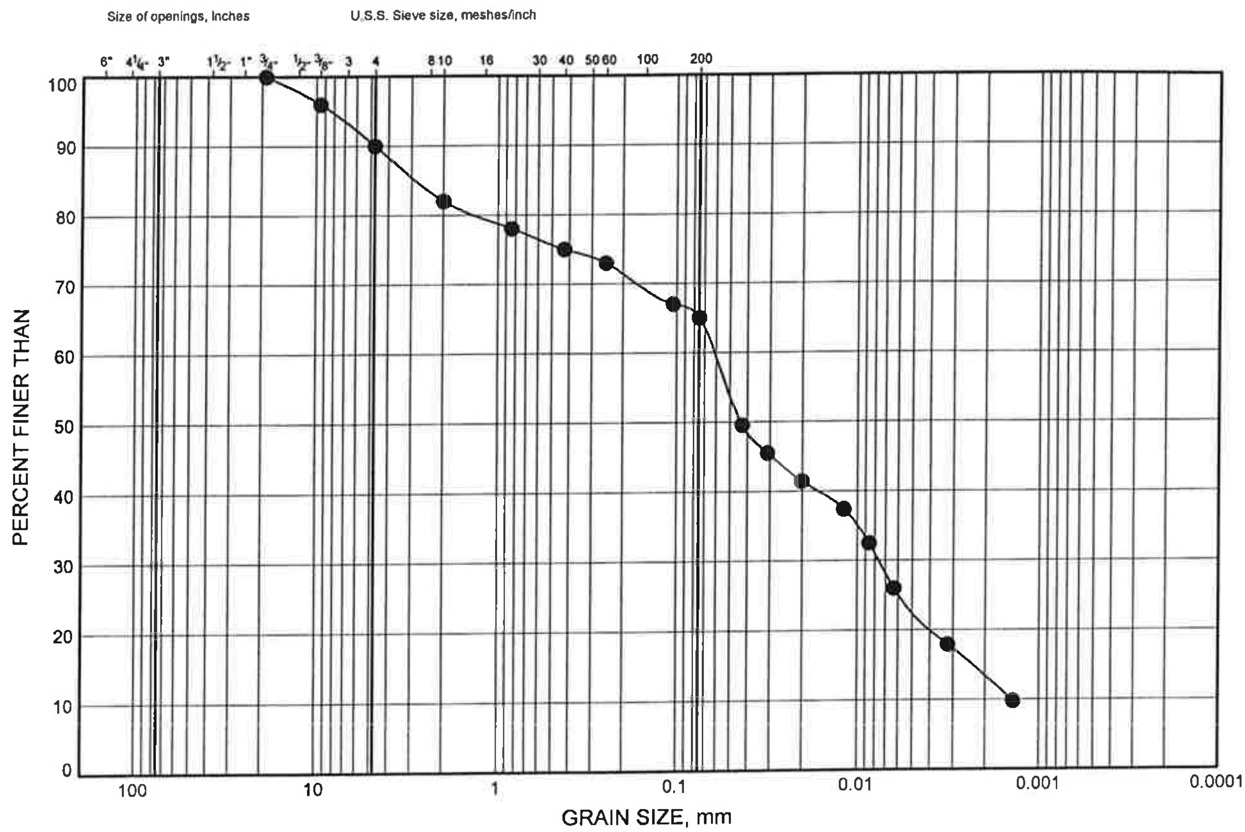
GRAIN SIZE DISTRIBUTION	FIGURE B7

Lower Clayey Silt Till



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K5A	15.4	250.6

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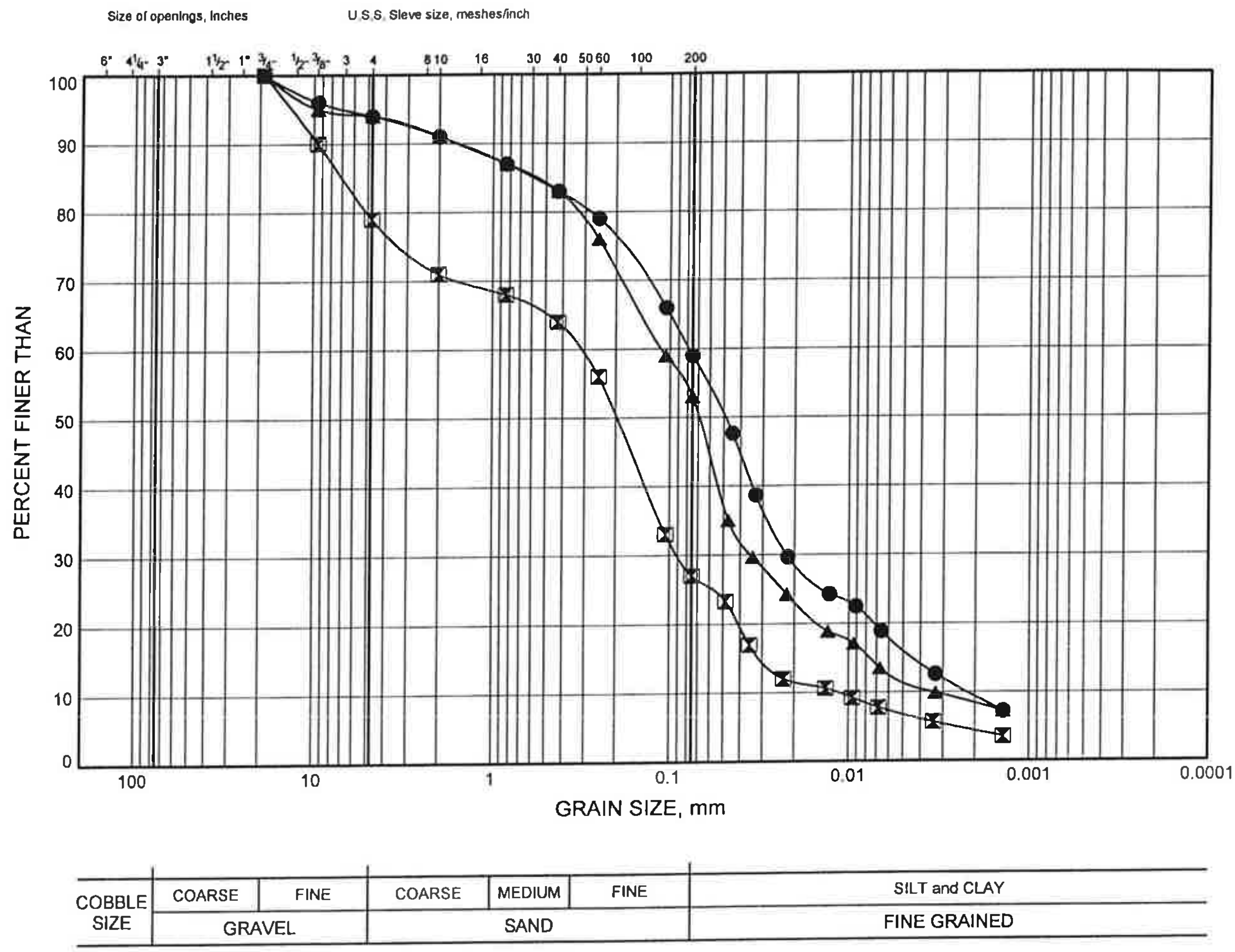
GRAIN SIZE DISTRIBUTION

FIGURE B8

Silt and Sand Till



SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K3A	15.4	249.8
⊠	K3A	17.0	248.2
▲	K5A	21.5	244.5

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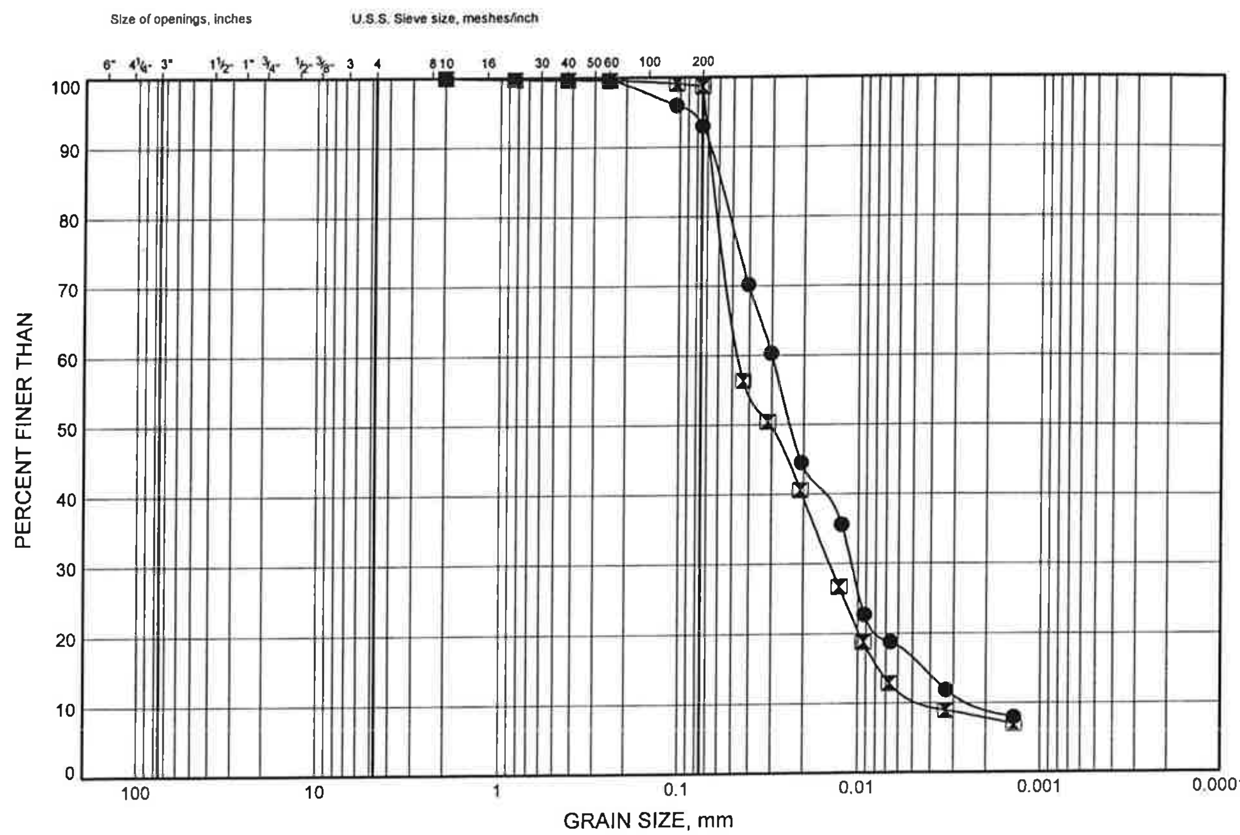
GRAIN SIZE DISTRIBUTION

FIGURE B9

Silt



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K2B	23.1	242.2
⊠	K5A	24.6	241.4

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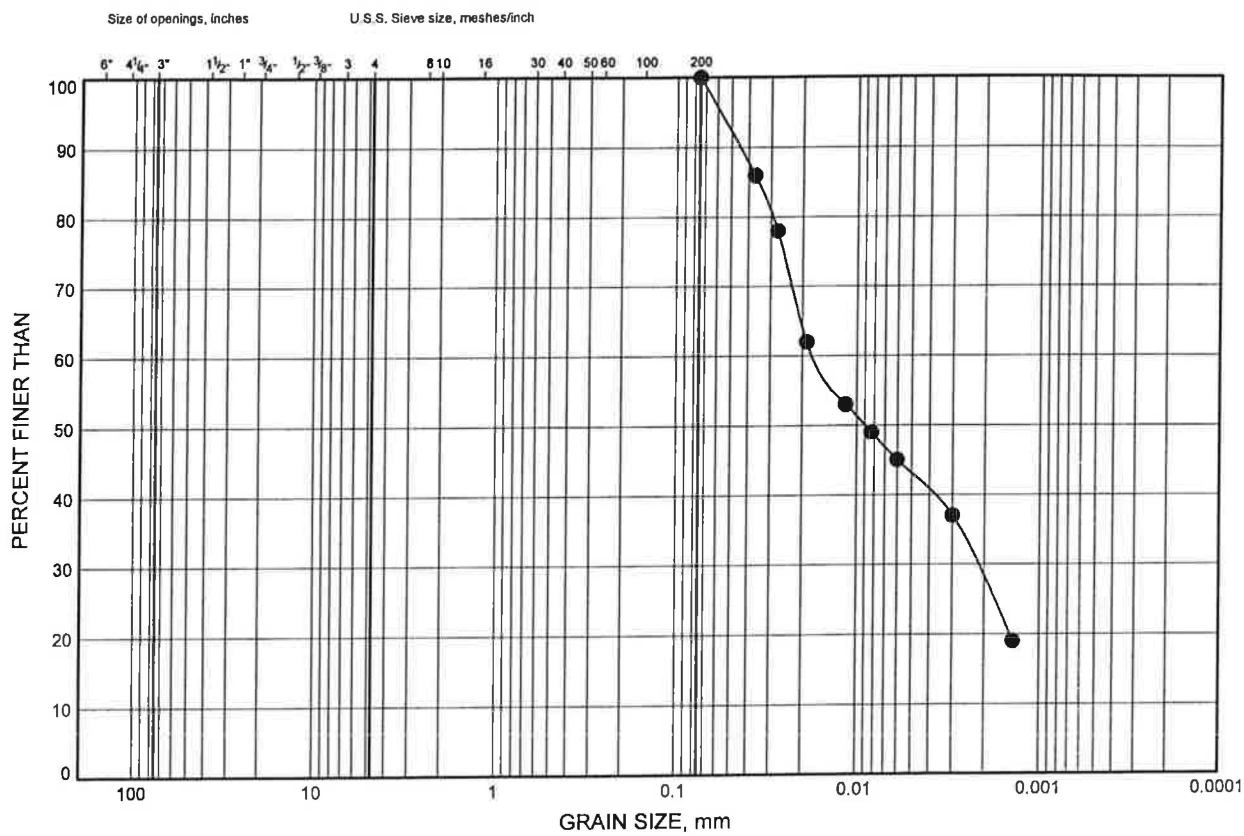
GRAIN SIZE DISTRIBUTION

FIGURE B10

Clayey Silt



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

SYMBOL	BOREHOLE	DEPTH (m)	ELEVATION (m)
●	K2B	27.6	237.7

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APPENDIX C

Drawing

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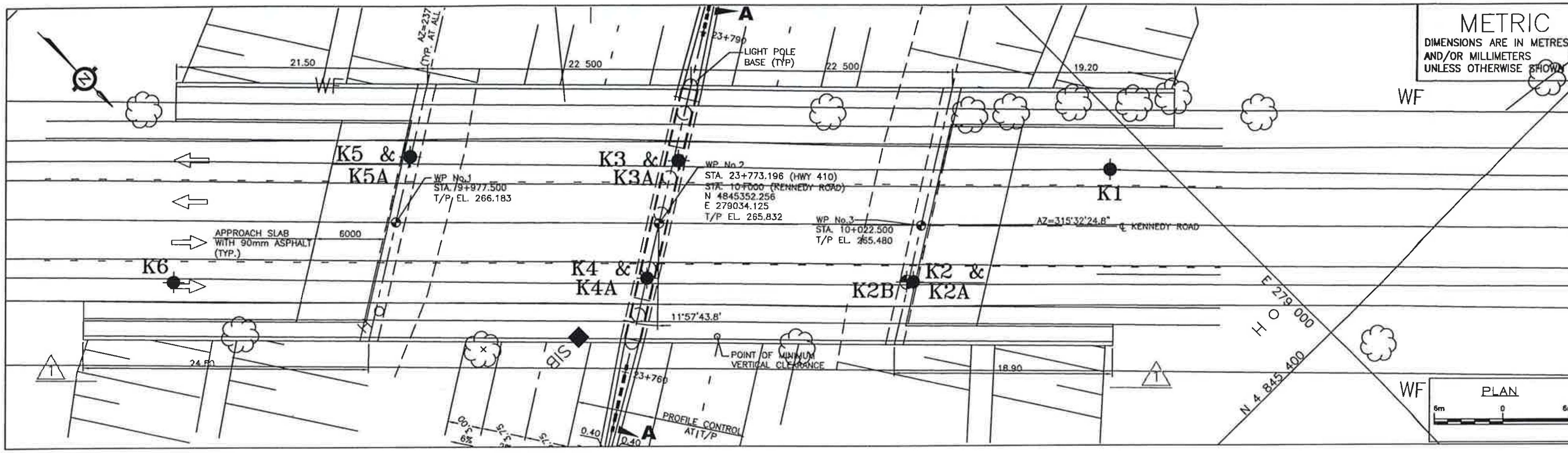
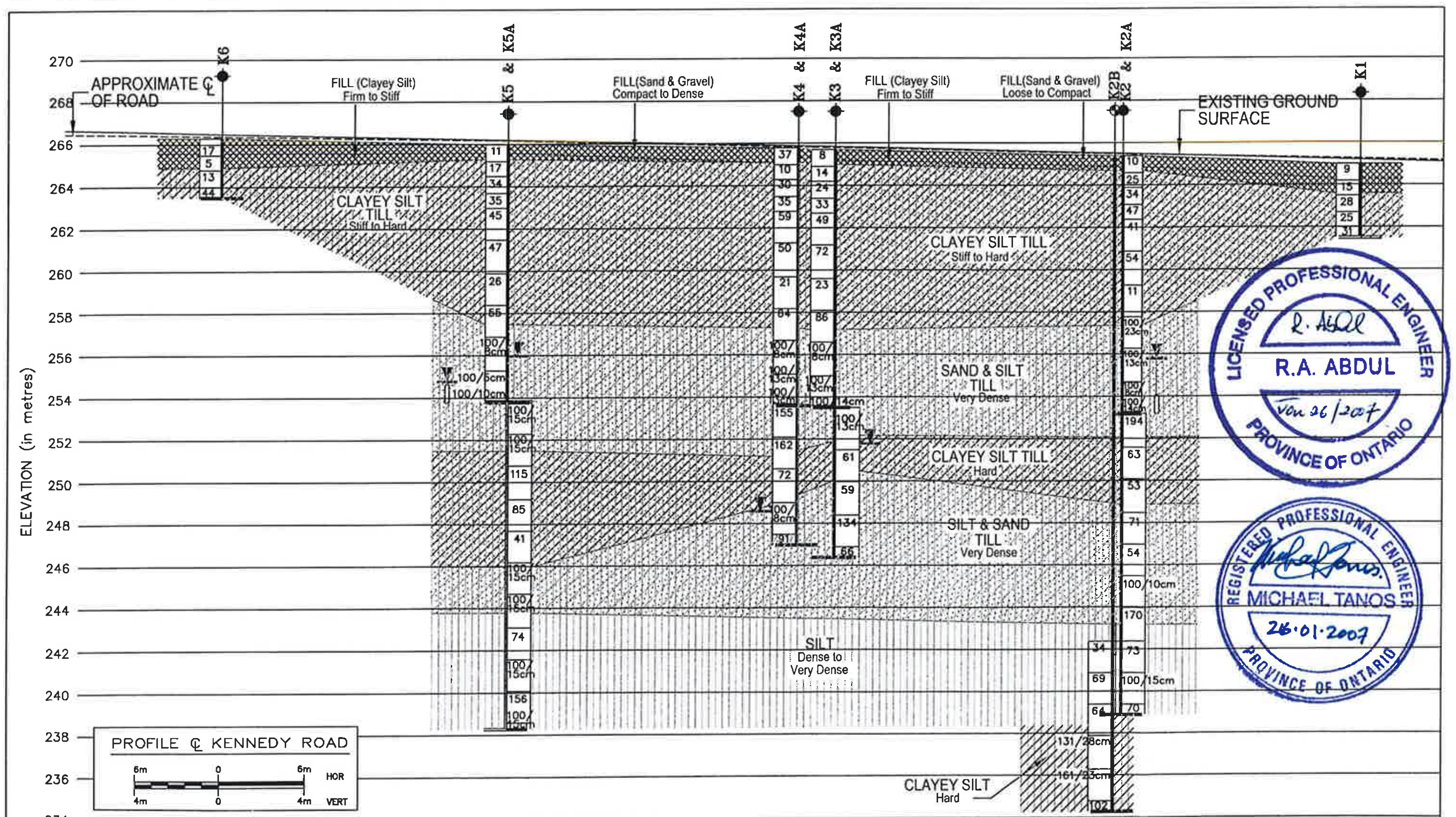
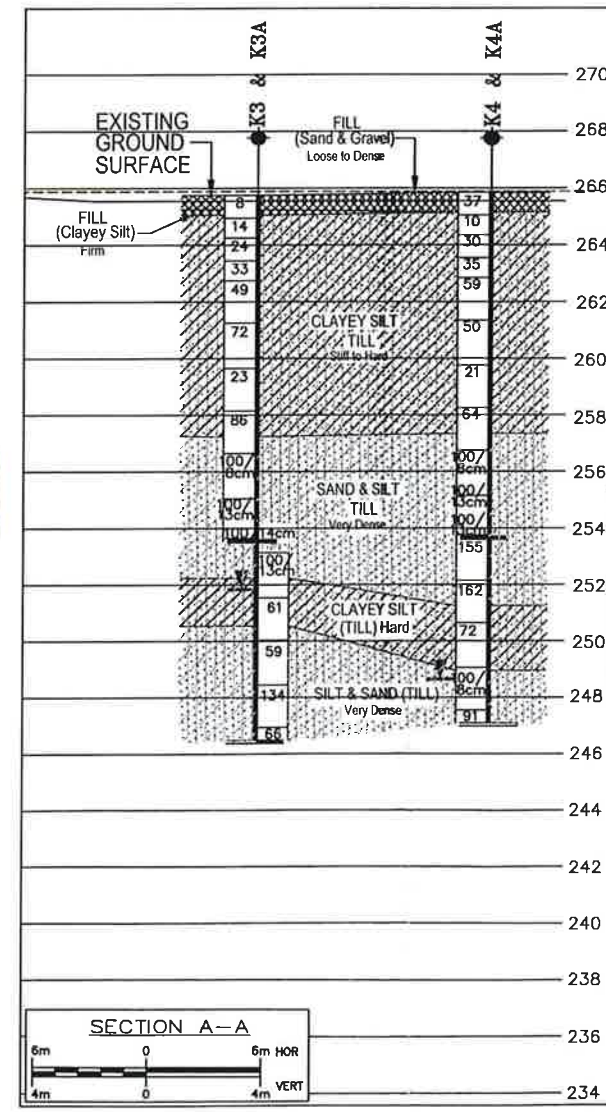
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETERS UNLESS OTHERWISE SHOWN







DRAWING NOT TO BE SCALED

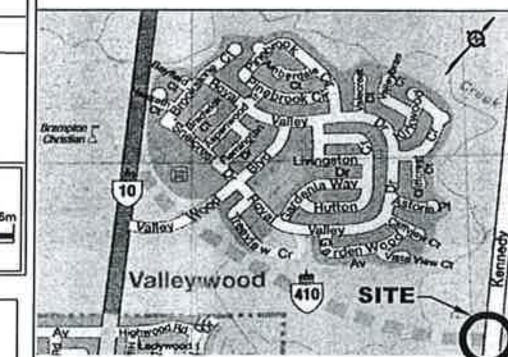
CONT. W.P. 106–00–01

HIGHWAY 410 – PHASE III
KENNEDY ROAD UNDERPASS
BOREHOLE LOCATIONS
AND SOIL STRATA

SHEET 324

Giffels
An Ingenium Group Company

Terraprobe
Consulting Geotechnical & Environmental Engineering
Construction Materials Engineering, Inspection & Testing



KEY PLAN

LEGEND

	Bore Hole
	Dynamic Cone Penetration Test
	Bore Hole And Cone
'N'	Blows/0.3m (Std Pen Test, 475 J/blow)
CONE	Blows/0.3m (60° Cone, 475 J/blow)
	WL at Time of Investigation
	WL in Piezometer 99 02
	Piezometer
90%	Rock Quality Designation
A/R	Auger Refusal

No	ELEVATION	COORDINATES	
		NORTHING	EASTING
BH–K1	265.0	4845376.5	279003.5
BH–K2	265.4	4845371.3	279022.3
BH–K2A	265.3	4845371.3	279022.3
BH–K2B	265.3	4845369.2	279621.3
BH–K3	265.7	4845349.7	279029.2
BH–K3A	265.2	4845349.6	279029.2
BH–K4	265.8	4845354.9	279038.2
BH–K4A	265.8	4845354.9	279038.2
BH–K5	266.0	4845333.1	279045.1
BH–K5A	266.0	4845333.1	279045.1
BH–K6	266.3	4845326.4	279067.0

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore holes the boundaries are assumed from geological evidence.

REVISIONS	DATE	BY	DESCRIPTION

DESIGN R.A	CODE CHBDC2000	LOAD	DATE APRIL 2006
DRAWN P.S	CHK R.A	SITE: 24–743	STRUCT / DWG 2

APPENDIX D

Foundation Comparison

Terraprobe Limited

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

Foundation Element	Driven Piles	Augered Caissons	Footing on Native Soil
North & South Abutments	***Advantages:*** i. High geotechnical resistances available. ii. Allows choice of integral or semi-integral abutment design. iii. Readily installed. ***Disadvantages:*** i. Higher unit cost compared to footings. ii. Construction concerns related to the possibility of piles being obstructed by a boulder during driving.	***Advantages:*** i. High geotechnical resistances available. ***Disadvantages:*** i. Precludes consideration of an integral abutment structure. ii. Higher unit cost compared to other options.	***Advantages:*** i. High geotechnical resistances available. ii. Less costly compared to other options. ***Disadvantages:*** i. Precludes consideration of an integral abutment structure. ii. Conventional abutments may be impractical due to height.
Pier	***Advantages:*** i. High geotechnical resistances available. ii. Readily installed. ***Disadvantages:*** i. Higher unit cost compared to spread footings. ii. Construction concerns related to the possibility of piles being obstructed by a boulder during driving.	***Advantages:*** i. High geotechnical resistances available. ***Disadvantages:*** i. Higher unit cost compared to other options.	***Advantages:*** i. High geotechnical resistances available. ii. Less costly compared to other options. ***Disadvantages:*** i. N/A

APPENDIX E

Suggested NSSP Wording

Terraprobe Limited

In this report reference is made to the following Provincial Standard:

- SP 903S01

The contract documents should contain a NSSP containing the following wording:

Cobbles and Boulders

"The Contractor is informed that the soils at this site may contain cobbles and boulders that could impede the progress of pile driving operations. The soil conditions are described in the Foundation Investigation Report prepared for this site".

If a pile encounters refusal on cobbles and boulders the QVE should terminate driving before the pile is damaged by overdriving. If the required resistance according to the Hiley Formula is not achieved and further driving is likely to cause damage to the pile, pile driving should cease and the contract administrator should be notified.