FOUNDATION INVESTIGATION AND DESIGN REPORT
MUNICIPAL SERVICE ROAD
OVER MAGNETAWAN RIVER SOUTH CROSSING
HIGHWAY 11, HIGHWAY 518 WEST TO HIGHWAY 520
G.W.P. 480-93-00, W.P. 5403-04-01, SITE 44-426

Geocres Number: 31E-224

Report to

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PART 1: FACTUAL INFORMATION

1 INTRODUCTION

This report presents the factual findings obtained from a foundation investigation conducted at the site of a proposed bridge to carry Municipal Service Road over the south crossing of Magnetawan River, south of the village of Katrine, Ontario. A previous, preliminary investigation had been carried out at the structure location by Shaheen & Peaker Limited (S&P) and the factual data from that investigation has been incorporated in the current assignment.

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, borehole logs, stratigraphic profile and cross-sections, and a written description of the subsurface conditions. A model of the subsurface conditions was developed through considering a combination of the data from the previous S&P investigation and the data obtained in the course of the present investigation. This model describes the geotechnical conditions influencing design and construction of the foundations and approach embankments for the underpass structure.

Thurber carried out the investigation as a sub-consultant to Marshall Macklin Monaghan, under the Ministry of Transportation Ontario (MTO) Agreement Number 5005-A-000285.

2 SITE DESCRIPTION

The site is located approximately 45 m west of the existing Highway 11 alignment at the south crossing of Magnetawan River, approximately 800 m south of Three Mile Lake Road/Doe Lake Road in Katrine. Municipal Service Road will run essentially parallel to the four-laned Highway 11 at this location. The bridge will be constructed near Municipal Service Road Station 8+400, and Highway 11 Station 11+240, Armour Township.

The general site area is located within the physiographic region known as the Canadian Shield, characterized by Pre-Cambrian bedrock typically occurring as rounded knobs and ridges where exposed. Locally however, the site lies in the valley of the Magnetawan River, which is underlain by relatively deep deposits of ice-contact and glacio-fluvial sands and gravels.

The Magnetawan River channel is approximately 24 m wide at the site and the maximum channel depth, based on contour data, is approximately 5 m. The water level in the river in May 2003 was near elevation 294, about 1 m below the top of riverbank. The ground surface is relatively flat adjacent to the channel, and begins to slope upward a distance of some 150 m south and 75 m north of the river. No global stability problems were observed along the riverbanks.

The bridge area typically comprises grassed pasture and woodland. The surrounding uplands adjacent to the river valley are heavily forested.

3 SITE INVESTIGATION AND FIELD TESTING

Thurber carried out site investigation and field testing at the proposed location of the bridge between September 23 and October 21, 2004. Preliminary investigation was carried out by S&P between May 22 and 31, 2001.

The current site investigation consisted of drilling and sampling six boreholes (boreholes 426-1, 426-3, 426-4, 426-7, 426-8 and 426-10) to depths of 35.9 to 46.9 m at the abutments and piers, and to depths of 9.8 and 10.1 m at the approaches. All boreholes except borehole 426-1 were supplemented by dynamic cone penetration testing. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing in Appendix G.

Prior to the start of drilling, the borehole locations were staked in the field and utility clearances were obtained.

Hollow stem augers and rotary wash boring techniques with casing were used to advance the boreholes. Samples were obtained using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Where soft to firm cohesive soils were encountered, the undrained shear strength was evaluated by in situ vane testing.

The positions of the principal boreholes considered in the preparation of this report, relative to the structure site are as shown in Table 3.1.

Table 3.1 – Borehole Locations Relative to Structure

Location on Structure	Boreholes Considered in Design
South Approach	426-1, RT1/1A*
South Abutment	426-3, RT2*
South Pier	426-4
North Pier	426-7, RT3*
North Abutment	426-8, RT4*
North Approach	426-10

* Boreholes drilled by S&P in 2001

The coordinates and elevations of the boreholes are given on the Borehole Locations and Soil Strata Drawing and on the individual Record of Borehole Sheets in Appendix A.

A standpipe piezometer, consisting of 19 mm PVC pipe with slotted tip, was installed in each borehole to monitor groundwater levels. A shallow piezometer was installed at the north pier in the course of the preliminary investigation.

The completion details for the piezometers are shown in Table 3.2.

Table 3.2 – Piezometer Details

Piezometer Location	Piezometer Details	
	Tip Depth/ Elevation	**Completion Details**
BH 426-1	9.1/286.0	Piezometer with 1.5 m tip installed at bottom of borehole. Sand filter to 7.0, bentonite seal to 6.4, grout to 0.6 and bentonite seal to surface.
BH 426-3	34.3/260.8	Piezometer with 1.5 m tip installed at bottom of borehole. Sand filter to 32.8, bentonite grout to 2.1 and bentonite seal to the surface.
BH 426-4	39.6/255.6	Piezometer with 1.5 m tip installed at bottom of borehole. Sand filter to 37.0, bentonite grout to 1.2 and bentonite seal to the surface.
BH 426-7	37.6/257.9	Piezometer with 1.5 m tip installed at bottom of borehole. Sand filter to 34.7, bentonite grout to 3.7 and bentonite seal to the surface.
BH 426-8	44.2/251.1	Piezometer with 1.5 m tip installed at bottom of borehole. Sand filter to 42.4, bentonite grout to 3.7 and bentonite seal to the surface.
BH 426-10	9.8/285.6	Piezometer with 1.5 m tip installed at bottom of borehole. Sand filter to 6.1, bentonite grout to 0.6 and bentonite seal to the surface.

A member of Thurber's engineering staff supervised the drilling and sampling operations on a full time basis. The inspector logged the boreholes and the recovered samples and processed them for transport to Thurber's Oakville office.

4 LABORATORY TESTING

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

Selected samples were subjected to gradation analysis (sieve and hydrometer) and Atterberg Limits testing. The results are shown on the Record of Borehole sheets in Appendix A and on the charts in Appendix B. A total of 27 samples were selected for this testing.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

5.1 General

Reference is made to the Record of Borehole sheets in Appendix A and to the Record of Borehole sheets prepared by S&P included in Appendix C. Details of the encountered soil stratigraphy are presented in these appendices and on the attached Borehole Locations and Soil Strata Drawing. An overall description of the stratigraphy is given in the following paragraphs however the factual data presented in the borehole logs governs any interpretation of the site conditions.

The soil stratigraphy encountered at this site is consistent with that encountered in much of the Highway 11 corridor between Huntsville and North Bay. Typically, this comprises bedrock mantled by sand and gravel containing cobbles and boulders, which is overlain by glacial outwash soils deposited in glacio-fluvial and glacio-lacustrine environments. Locally, the surface soils have been reworked and re-deposited by the Magnetawan River.

In general terms, the site was found to be underlain by a thin veneer of topsoil underlain by a thick deposit of silty sand to sandy silt, interrupted by discontinuous layers of silt, clayey silt and silty clay in the upper 10 m, and by layers of sand and gravel with cobbles and boulders at greater depth. The boreholes were terminated in very dense sand/sand and gravel deposits; the bedrock surface was not contacted within the exploration depth.

More detailed descriptions of the individual strata are presented below.

5.2 Topsoil

Topsoil was identified surficially in all boreholes except borehole RT2 drilled near the south abutment and borehole 04-8 drilled at the north abutment. The topsoil thickness was established only at the borehole locations and ranged from 50 to 400 mm. The topsoil thickness may vary between and beyond the borehole locations and the data is not intended for the purpose of estimating quantities.

5.3 Silty Sand to Sandy Silt

Non-cohesive silty sand to sandy silt was encountered below the topsoil in all boreholes and formed the predominant soil type at the site. Material grading to sandy silt was generally restricted to the upper 10 m of the boreholes, and within this depth, the sand deposit was interrupted by discontinuous layers of silt, clayey silt and silty clay. At greater depth, sand and gravel layers were encountered within the silty sand to sand deposit. Cobbles and boulders were also encountered occasionally.

Standard Penetration Test (SPT) N-values in the silty sand to sandy silt were typically less than 10 blows/0.3 m penetration to depths of 10 to 15 m, with occasional values of up to 21 blows/0.3 m. These values indicate a loose to very loose condition with compact zones. Below these depths, the sand became typically compact to dense with N-values ranging from 3 to 65 blows/0.3 m, generally 11 to 34 blows/0.3 m penetration. Very dense sand with N-values exceeding 50 blows/0.15 m penetration was contacted below an interbedded sand and gravel layer at depths of about 29.6 to 36.6 m (elevation 265.7 to 258.6 m).

Grain size distribution results for the silty sand to sandy silt are reported on the Record of Borehole sheets and plotted in Figures B1 to B3 of Appendix B. Grain size results from the preliminary investigation are included in Appendix C.

Moisture contents ranged from 10 to 38%, with the higher values recorded in the upper zone potentially containing organic material. Typically, the moisture contents ranged from 15 to 25%.

Boreholes 426-4 and 426-7 drilled at the piers and borehole 426-8 drilled at the north abutment were terminated in very dense sand at depths of 37.6 to 46.9 m (elevation 257.9 to 248.4 m). Approach borehole 426-10 was terminated in silt and sand at 9.8 m depth.

5.4 Clayey Silt to Silty Clay

A discontinuous layer of cohesive clayey silt was encountered within the sand deposit in boreholes RT1A, RT3 and RT4. In borehole RT1A on the south side of the river, the clayey silt layer was 0.7 m thick and encountered at 5.3 m depth (elevation 290.3 m). In boreholes RT3 and RT4 on the north side of the river, the clayey silt was 1.5 and 2.5 m thick, with an upper boundary at depths of 2.2 and 0.7 m (elevation 292.7 and 294.4 m). A very soft to very stiff consistency is indicated by SPT values of 1 to 22 blows/0.3 m penetration. Grain size results and Atterberg Limits plots for this material, from the preliminary study, are included in Appendix C.

In approach borehole 426-1 drilled at the south limit of the study area, silty clay was encountered below a sand layer at 2.2 m depth (elevation 292.9 m). SPT N-values in this material generally increased with depth from 1 to 9 blows/0.3 m penetration. The undrained shear strength of the clay determined by in situ vane testing also increased with depth, from 80 to 150 kPa, indicating a stiff to very stiff consistency. The sensitivity ranged from 3.2 to 3.5.

Grain size distribution results for the clay in borehole 426-1 are provided on the Record of Borehole sheet and in Figure B4 of Appendix B. The results of Atterberg Limits testing (Figure B7 of Appendix B) classify the soil as medium plastic (CI). Moisture contents ranged between 32 and 42%.

5.5 Silt

Non-cohesive silt strata were encountered within the silty sand/sandy silt in the upper 3.0 to 10.1 m of all boreholes except boreholes 426-1 and RT2. The silt layers ranged from 0.8 to 4.9 m in thickness and were contacted at depths of 0.3 to 7.3 m (elevation 295.0 to 287.9 m). In borehole RT1/1A, drilling was terminated at 9.6 m depth, 3.6 m into the silt, and the full thickness of this layer was not determined.

SPT N-values obtained in the silt generally ranged from 3 to 18 blows/0.3 m penetration, indicating a very loose to compact condition. In borehole 426-10, the N-values ranged from 6 to 46 blows/0.3 m, indicating a loose to dense condition. The measured natural moisture contents ranged from 16 to 34%, typically 16 to 24%. The soil is generally described as brown or grey in colour.

Grain size distributions for this silt are reported on the Record of Borehole sheets and are plotted in Figure B5 in Appendix B. Grain size results from the preliminary study are included in Appendix C as well.

5.6 Sand and Gravel

A layer of sand and gravel to gravelly sand was encountered within the sand deposit in all boreholes advanced at the abutment and pier locations. The upper boundary of the primary, possibly continuous layer of sand/gravel was contacted at depths of 20.4 to 28.7 m (elevation 274.9 to 266.4 m). Two additional layers were encountered at depths of 16.8 and 35.1 m (elevation 278.3 and 260.0 m) in borehole 426-3, and an isolated upper layer was also encountered in borehole 426-8 at 4.0 m depth (elevation 291.3 m). The thickness of the sand and gravel layer ranged from 1.8 to 6.1 m where fully penetrated. Boreholes 426-3, RT2 and RT3 were terminated in sand/gravel after penetrating 0.8 to 6.2 m into this layer.

The sand and gravel layer contained cobbles and boulders which may have influenced the results of SPT testing. N-values obtained in these layers ranged from 9 blows/0.3 m to greater than 50 blows/.075 m of penetration, indicating a typically compact to very dense condition. However, it is possible that the sampler was driving on the cobbles and boulders in many cases, and the resulting high SPT values may be unrepresentative. The isolated layer of sand and gravel at 4.0 m depth in borehole 426-8 was very loose with a N-value of 2 blows/0.3 m obtained.

The results of grain size distribution analyses conducted on samples of the sand and gravel deposit, including the gravelly sand zones, are presented on Figure B6 of Appendix B and in Appendix C. The samples excluded particle sizes greater than about 30 mm. Moisture contents ranged from 5 to 19%.

5.7 Bedrock

Bedrock was not contacted within the exploration depths of 9.6 to 46.9 m during the investigation.

5.8 Depths to Refusal

The depths at which effective refusal was encountered, defined as an SPT value exceeding 100 blows for 0.3 m of penetration or bedrock, are shown in Table 5.1.

Table 5.1 – Refusal Depths (Elevations)

Location	Borehole	Refusal Depth (Elevation), m	Material
South Abutment	426-3	32.6 (262.5)	Gravelly Sand
South Pier	426-4	36.6 (258.6)	Sand
North Pier	426-7	27.0 (268.5)	Gravelly Sand
North Abutment	426-8	29.6 (265.7)	Sand

5.9 Water Levels

The initial and final groundwater depths and elevations measured in the piezometers installed in the boreholes are shown in Table 5.2.

Table 5.2 – Groundwater Depths and Elevations

Location	Borehole	Date	Water Level (m)	
			Depth	Elevation
South Approach	426-1	November 11, 2004	0.1	295.0
South Abutment	426-3	October 21, 2004	0.1	295.0
		November 11, 2004	0.0	295.1
		December 8, 2004	0.2	294.9
South Pier	426-4	October 21, 2004	0.0	295.2
		November 11, 2004	0.0	295.2
		December 8, 2004	0.2	295.0
North Pier	RT3	June 1, 2001	0.5	294.4
	426-7	November 11, 2004	0.2	295.3
		December 8, 2004	0.3	295.2
North Abutment	426-8	September 30, 2004	0.2	295.1
		November 11, 2004	0.0	295.3
		December 8, 2004	0.1	295.2
North Approach	426-10	September 30, 2004	1.4	294.0
		November 11, 2004	0.7	294.7
		December 8, 2004	0.7	294.7

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, and will be influenced by the water level in the Magnetawan River.

6 MISCELLANEOUS

Marshall Macklin Monaghan completed field layout for the site investigation and provided borehole coordinates and ground surface elevations.

All-Terrain Drilling Limited supplied and operated the drilling and sampling equipment used for the current investigation. Full time supervision of the field activities, including obtaining utility clearances, was carried out by Mr. Stephane Loranger of Thurber.

Interpretation of the field data and preparation of the investigation report was conducted by Mr. Murray Anderson, P.Eng. Overall supervision of the field program and review of the report was performed by Mr. Alastair E. Gorman, P.Eng. The report was also reviewed by Dr. P.K. Chatterji, Ph.D., a Designated Principal Contact for MTO Foundations Projects.

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PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

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

A three-span, 99.0 m long prestressed concrete girder structure is proposed at this site and integral abutments are under consideration. The preliminary General Arrangement drawing indicates that the centre span will be 45 m long and the two outside spans will each be 27 m in length. This configuration has been selected based on structural and hydraulic considerations, among others.

Both approaches will lie on comparatively flat, low-lying land of the river flood plain. The undersides of the abutment stems will lie approximately 0.4 to 1.2 m above the river level.

At the north abutment, the finished road grade will be about Elevation 301.1 and the original ground lies at Elevation 295.3±, resulting in an approach fill approximately 5.8 m high.

At the south abutment, the finished grade will be about Elevation 300.3 and the original ground lies at Elevation 295.1 ±, resulting in an approach fill approximately 5.2 m high.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigation, together with the factual data from the previous investigation by S&P.

8 STRUCTURE FOUNDATIONS

Foundation alternatives are presented in the following sections together with the corresponding geotechnical design parameters. A preferred foundation scheme is recommended.

Based on the results of the exploratory boreholes drilled at the proposed abutment locations, the stratigraphy consists of a thin veneer of topsoil underlain by a thick deposit of very loose to dense silty sand to sandy silt, interrupted by discontinuous layers of silt, clayey silt and silty clay in the upper 10 m, and by layers of sand and gravel with cobbles and boulders at greater depth. The sand deposit and sand and gravel layers become very dense below depths of about 27 to 37 m. The boreholes were terminated in the very dense deposits; the bedrock surface was not contacted within the maximum exploration depth of 46.9 m.

Initial consideration was given to the following foundation types:

- Spread footings on native soil
- Spread footings on engineered fill
- Driven steel H-piles
- Caissons (drilled shaft piles)

Appendix D contains a table presenting a comparison of the technical advantages and disadvantages of the different foundation schemes at this site.

8.1 Spread Footings

8.1.1 Footings on Native Soil

The near surface soils at the abutment locations are considered too loose to provide adequate support to spread footings due to the low bearing resistance available and the potential for comparatively large settlements. In addition, the risk of scour undermining spread footings at this site is considered to be high.

Accordingly spread footings founded on native soil were eliminated from further consideration.

8.1.2 Footings on Engineered Fill

Very loose to loose soils were encountered to depths of about 10 to 15 m at both the south and north abutments. These soil conditions are considered unsuitable for the support of an engineered fill pad due to the low bearing resistance available and the potential for comparatively large settlements. In addition, the risk of scour undermining spread footings at this site is considered to be high.

Accordingly spread footings founded on engineered fill pads were eliminated from further consideration.

8.2 Driven Steel Piles

The geotechnical conditions encountered at this site are considered suitable for driven steel H-pile foundations.

The piles are expected to encounter refusal in the very dense sand, silty sand, and sand and gravel deposits at depths greater than 27 m. The piles should be designed on the basis of the axial geotechnical resistances given in Table 8.1.

Table 8.1 – Pile Geotechnical Resistance

Pile Section	Piles Driven Into Sand with Cobbles and Boulders					
	ULS (Factored)	SLS (25 mm Settlement)	Estimated Pile Tip Elevation			
			South Abutment	South Pier	North Pier	North Abutment
HP 310 X 110	1,800 kN	1,600 kN	262.5	258.6	268.5	265.7
HP 310 X 125	1,800 kN	1,600 kN	262.5	258.6	268.5	265.7
HP 360 X 132	2,100 kN	1,800 kN	262.5	258.6	268.5	265.7

The estimated pile tip elevations are also provided in Table 8.1. The elevation at which the design capacity is achieved is expected to vary and in some cases a pile may encounter refusal on cobbles and boulders. The pile tip elevations shown in Table 8.1 should be used for cost estimating purposes only. The actual pile tip elevations will be controlled as described in Section 8.2.2 Pile Installation.

8.2.1 Pile Tips

Due to the presence of cobbles and boulders in the expected founding layer, the tips of all piles should be fitted with cast steel, H-section rock points from an approved manufacturer such as Titus Steel (Standard H-point) or APF hard Bite or approved equivalent.

The use of rock points is recommended for the following reasons:

- The piles will be driven into soil containing cobbles and boulders, which requires a higher level of protection than driving into soils containing only smaller particle sizes
- Some piles may achieve refusal on large boulders, which will require the same pile tip protection and reinforcement as founding on bedrock

8.2.2 Pile Installation

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

The Contract Documents should contain a NSSP (as shown in Appendix E) alerting the Bidders to:

- The presence of cobbles and boulders in the sand, silty sand, and sand and gravel.
- The possibility of piles within a group achieving the specified resistance at different elevations.
- The possibility of some piles meeting refusal on a large boulder.

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

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

8.2.3 Pile Constructability at Piers

The pile groups required to support the piers may be driven partially or wholly in the river. The depth to the underside of the pile cap will be dictated by other studies (e.g. scour protection), but from preliminary information the underside of the pile cap is expected to lie near elevation 292.5 m.

Based on the subsurface information gathered during the investigation, excavation for the pier pile caps will penetrate through topsoil and into very loose to compact sands and silts. Since the base of the pile cap will lie some 2.5 m below the river/groundwater level, instability in the form of boiling (quicksand condition) may occur if dewatering within a conventional cofferdam is attempted.

One possible method which may be considered to construct the pier pile caps within a stable excavation is as follows:

1. Drive an outer steel liner of sufficient diameter to accommodate driving the H-piles. The tip of the liner must be at least 1.0 m below the underside of the pile cap.
2. Excavate inside of the outer liner to a level 0.5 m above the tip of the liner, keeping the liner flooded to approximately river level to avoid base instability.
3. Drive the H-piles for the foundation.
4. Place an appropriate sized Sonotube (e.g. 1.5 m diameter) to a level of at least 0.5 m below the underside of the pile cap.
5. Place a minimum 0.5 m thick slab of concrete in the bottom of the Sonotube using tremie methods.
6. Allow the tremie concrete to harden, then unwater the Sonotube.
7. Construct the pile cap and pier inside the unwatered Sonotube.
8. Remove the outer steel liner.

The foregoing procedure is illustrated schematically in the attached Sketch SK1, based on the preliminary GA for the structure. It is intended primarily for design and estimating purposes. The Contractor should design the liner and dewatering scheme and may elect to implement a variation of the procedure that better suits his equipment, schedule and experience, provided it achieves the objective of constructing the pile cap and pier without destabilizing the riverbank or creating unacceptable impacts on the river environment.

The design must take account of probable river levels during construction. In particular, the top of the liner must be set to be above the highest expected river level during construction.

8.2.4 Pile Driving

Pile driving within 3 m of the estimated pile tip elevation (Table 8.1) 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". "R" must have the minimum values shown in Table 8.2.

Table 8.2 – Ultimate Geotechnical Resistance of Piles

Pile	Ultimate Resistance, R (kN)
HP 310 X 110	3,600 kN
HP 310 X 125	3,600 kN
HP360 X 132	4,200 kN

The Contractor should be alerted to the fact that the piles may meet refusal on a large boulder in the sand and gravel deposit. If this happens, the Hiley formula is not applicable, and a site decision must be made that refusal has been encountered and that further pile driving must be controlled to adequately seat the pile on the boulder. To avoid overdriving and damaging the tip, a limiting criterion of 10 blows at full energy for 12 mm penetration for two consecutive sets of 10 blows should be established to control pile driving on a boulder. The geotechnical resistances given in Table 8.1 remain valid in this situation.

8.2.5 Downdrag

The soils at the abutments are predominantly non-cohesive and settlements induced in the native soils around the piles by construction of the approach embankments will be substantially complete as construction of the embankment is completed. Post-construction downdrag on the piles is therefore not considered to be an issue at this site. However, it is recommended that the approach embankments be constructed three months in advance of pile driving. The embankment should be constructed up to the level of the abutment from the forward slope to a distance back sufficiently far to allow access and operation of construction equipment. Beyond that distance, the embankment should be constructed to full height.

8.2.6 Lateral Resistance of Piles

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:

$$k_s = n_h\, z / D \qquad (\mathrm{kN/m^3})$$

$$p_{ult} = 3 \,.\, \gamma \,.\, z \,.\, K_p \qquad (\mathrm{kPa})$$

where z = depth of embedment of pile in metres

D = pile width in metres

n_h = coefficient of horizontal subgrade reaction (Table 8.3)

γ = unit weight (Table 8.3)

K_p = passive earth pressure coefficient (Table 8.3)

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

The spring constant, K, for analysis may be obtained by the expression, $K = k_s \times L \times D$ (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 8.3 – Parameters for Lateral Pile Resistance

Location	Elevation	n_h (kN/m^3)	K_p	Unit Weight* (kN/m^3)
South Abutment	OGL to 284	1,500	3.0	10
	284 to 266	3,000	3.3	10
	266 to 260	8,000	3.7	11
South Pier	OGL to 278	1,500	3.0	10
	278 to 262	3,000	3.3	10
	262 to 257	8,000	3.7	11
North Pier	OGL to 284	1,500	3.0	10
	284 to 270	3,000	3.3	10
	270 to 262	8,000	3.7	11
North Abutment	OGL to 284	1,500	3.0	10
	284 to 267	3,000	3.3	10
	267 to 262	8,000	3.7	11

* Buoyant unit weight for water table near ground surface.

The total horizontal passive resistance of a single pile used in design should not exceed the following values:

Table 8.4 – Maximum Horizontal Passive Resistance of Piles

Pile	Maximum Passive Resistance	
	Factored ULS	SLS
HP 310 X 110	110 kN	40 kN
HP 310 X 125	110 kN	40 kN
HP360 X 132	150 kN	50 kN

The modulus of subgrade reaction may have to be reduced, based on the pile spacing. The reduction factors to be used for a pile group oriented perpendicular or parallel to the direction of loading are provided in Table 8.5. Intermediate values may be obtained by linear interpolation.

Table 8.5 – Subgrade Reaction Reduction Factors for Pile Spacing

Condition	Pile Spacing, Centre to Centre*	Reduction Factor
Pile group oriented ***perpendicular*** to direction of loading	4D	1.0
	1D	0.5
Pile group oriented ***parallel*** to direction of loading	8D	1.0
	6D	0.7
	4D	0.4
	3D	0.25

* where D is the breadth of pile

In the case of conventional abutments, i.e. not integral, horizontal loads may be resisted by means of battered piles.

8.3 Caissons

The soil and groundwater conditions at this site are not considered to be suitable for caisson foundations. To achieve the high resistance necessary to justify the construction costs, the caissons would have to be founded in the very dense non-cohesive deposits near elevation 257 to 262. This level is over 30 m below the water level on site. It would be impossible to achieve a liner seal at the caisson base to allow unwatering of the caisson, and slurry excavation with tremie concreting would be necessary.

Further, caisson excavation would be relatively slow and problematic due to the cobbles and boulders encountered in the sand and sand/gravel deposits.

Caissons are also not considered to be suitable for construction on a batter to resist horizontal loads.

On the basis of the installation difficulties and risks assessed for this site, caissons are not recommended.

8.4 Recommended Foundation

The preferred foundation system for all foundation elements at this site is steel H-piles driven to refusal as controlled by application of the Hiley formula.

8.5 Abutment Type

From a geotechnical perspective, the subsurface conditions at this site are considered to be suitable for the construction of conventional, semi-integral or integral abutments. However, the recommended foundation system of H-piles makes integral abutments a feasible option.

The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. At this site, the upper 3 m of the pile length will typically lie in very loose to compact silt and sand, which in its original state should provide sufficient flexibility.

However, if these soils become compacted by the construction process, the required flexibility may be compromised. Accordingly, to provide the required flexibility in the piles, the upper 3 m of the piles should be surrounded by a 600 mm diameter CSP filled with sand (for a "true abutment" supported on piles) or by concentric CSPs in accordance with standard integral abutment design procedures (for a "false abutment").

Backfill sand placed in the CSP should meet the gradation shown in Table 8.6 and must be placed after pile driving to minimize the potential for densification.

Table 8.6 – Integral Abutment Sand Grading

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

8.6 Frost Protection

The depth of earth cover required to provide frost protection for footings and pile caps at this site is 1.8 m.

It is possible to reduce the thickness of earth cover by the substitution of synthetic insulation. A 25 mm thickness of rigid, extruded polystyrene insulation is equivalent to 600 mm of earth cover. Synthetic insulation must be covered to provide protection where it is used.

Rock fill is not equivalent to earth fill in terms of thermal resistance. Frost may penetrate deeper through rock fill than earth fill and the possibility exists for freezing conditions to develop below the pile cap. Therefore, non-frost susceptible free-draining granular fill with less than 5% particles by mass finer than 75 μm should be specified for the pile driving pad within the rock fill.

9 EXCAVATION

All excavation 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 classed as Type 3 soils above the water table. This classification is based on the lack of cohesion in the soils and the resulting possibility that excavation slopes will slough if excavated vertically for the lower 1.2 m. Excavation slopes should not exceed 1V:1H above the groundwater level.

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

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

Due to the proximity of the river, control of groundwater in an open excavation will be difficult and methods such as excavation within a cofferdam may be required. Selection and design of the appropriate excavation and dewatering system is the responsibility of the Contractor. The Contract Documents should alert him to the requirement to maintain a stable excavation and that any shoring system should be designed by a shoring specialist, taking account of the need to control groundwater and prevent basal instability within the excavation.

10 UNWATERING

Based on the preliminary GA for the bridge structure, it is expected that work at the piers and possibly the abutments will require excavation some 2 m below the groundwater level. The Contractor should be prepared to provide appropriate methodology to dewater the excavations as necessary.

The design of any dewatering system that may be required is the responsibility of the Contractor and the Contract Documents should alert him to this responsibility and the need to engage a dewatering specialist. While the responsibility for dewatering should remain with the Contractor, suitable systems that might be employed include pumping from filtered sumps for penetration of no more than 0.5 m below the groundwater level and the use of vacuum wellpoints for deeper penetration below the groundwater level. Cofferdam construction or other means may be required for pier installation in/adjacent to the river.

The design of the dewatering system should be coordinated with the design of the excavation shoring system, where required.

11 APPROACH EMBANKMENTS

The global and internal stability of the approach embankments was analyzed for both earth fill and rock fill. The computer output for the stability analyses of the approach embankments is presented in Appendix F.

The stability analysis has been based on the existing configuration of the river banks. It is necessary that adequate erosion protection be provided to ensure that the river does not erode material in front of the abutments. Design of this erosion protection is not included in the foundations design and must be completed by others.

11.1 South Approach Stability

The soil conditions governing stability of the south approach embankment consist of loose to compact sands and silts interrupted by a discontinuous silty clay stratum. The groundwater level is near the ground surface. Stability analysis was carried out for the proposed embankment height of approximately 5 m, for side slopes inclined at 1.25H:1V for rock fill and 2H:1V for earth fill. Total and effective stress analyses were conducted.

The analysis showed that a rock fill embankment will have a factor of safety against slope failure of 1.4 under normal circumstances. Under a "worst case scenario" assuming the combined occurrence of a 100 year flood (water level at elevation 296.2 m) and an earthquake (seismic acceleration factor of 0.08), a factor of safety of 1.1 was obtained. The analysis was repeated for an earth fill embankment and similar factors of safety were obtained. The factors of safety obtained from the analyses are summarized in Table 11.1

The worst-case results indicate a state of incipient failure under the combined flood and earthquake conditions. However, the risk of both conditions occurring simultaneously is considered to be low, and either condition occurring separately yielded a factor of safety greater than 1.0.

It should be noted that the analyses assumed that the foundation soils would not be subject to liquefaction. This topic is dealt with more completely in Section 15: Seismic Considerations.

11.2 North Approach Stability

The soil conditions governing stability of the north approach embankment consist of loose silt, very loose sand and gravel, and loose to compact silty sand. The groundwater level is near the ground surface. Stability analysis was carried out for the proposed embankment height of approximately 6 m, for side slopes inclined at 1.25H:1V for rock fill and 2H:1V for earth fill.

The analysis showed that a rock fill embankment will have a factor of safety against slope failure of 1.4 under normal circumstances. Under a "worst case scenario" assuming the combined occurrence of a 100 year flood (water level at elevation 296.2 m) and an earthquake (seismic acceleration factor of 0.08), a factor of safety of 1.1 was obtained. The analysis was repeated for an earth fill embankment and factors of safety of 1.3 and 1.0 were obtained for the respective scenarios. The factors of safety obtained from the analyses are summarized in Table 11.1

The worst-case results indicate a state of incipient failure under the combined flood and earthquake conditions. However, the risk of both conditions occurring simultaneously is considered to be low, and either condition occurring separately yielded a factor of safety greater than 1.0.

It should be noted that the analyses assumed that the foundation soils would not be subject to liquefaction. This topic is dealt with more completely in Section 15: Seismic Considerations.

Table 11.1 – Approach Embankment Factors of Safety

Location	Fill Type	Condition	Factor of Safety	Figure No.
South Approach	Rock Fill	Normal GWL, No Seismic	1.42	F1
	Rock Fill	100 yr Flood, 0.08 Seismic	1.12	F2
	Earth Fill	Normal GWL, No Seismic	1.41	F3
	Earth Fill	100 yr Flood, 0.08 Seismic	1.05	F4
North Approach	Rock Fill	Normal GWL, No Seismic	1.37	F5
	Rock Fill	100 yr Flood, 0.08 Seismic	1.09	F6
	Earth Fill	Normal GWL, No Seismic	1.34	F7
	Earth Fill	100 yr Flood, 0.08 Seismic	1.00	F8

11.3 Settlement

In general, the native subsoils under the immediate approach embankments are regarded as behaving as cohesionless materials and settlements are expected to be immediate in nature. It is estimated that the settlement under the embankment loading will be in the order of 75 mm. This value was computed by calculating the stress increase under a rockfill embankment with a height of 5.8 m, platform width of 13 m, and sideslopes of 1.25H:1V.

Locally at the south approach (borehole 426-1), a relatively thick layer of cohesive silty clay was encountered within the non-cohesive soils. Settlement at this location will have an immediate elastic component as well as a time-dependent consolidation component due to the clay. The elastic and consolidation settlements under the embankment loading are estimated to be in the order of 30 and 100 mm respectively. It is anticipated that the majority (90%) of the consolidation settlement will be complete within three months of embankment construction. It is therefore recommended that the approach embankment be in place at least 3 months prior to road construction to reduce the post-construction settlement experienced by the road surface. Since the north approach will lie on very loose to loose silt, it is considered worthwhile to pre-load the north approach embankment as well.

Settlement within the 5.2 to 5.8 m high embankment of rockfill itself is expected to be in the order of 10 mm after 3 months, 20 mm after 1 year, and 60 mm after 10 years.

11.4 Seismic Considerations

The embankments discussed above are considered to be stable under earthquake loading on the assumption of a stable foundation. This topic is dealt with more completely in Section 15: Seismic Considerations.

11.5 Forward Slope Protection

It is recommended that the forward slopes be constructed at the same inclination as the side slopes, i.e. 1.25H:1V for rock fill and 2H:1V for earth fill. Rock fill is the preferred option.

In the case of earth fill slopes, rip rap protection should be provided and advice should be provided by a river hydrologist regarding potential scour forces to be resisted. This protection must be designed to prevent the river eroding beyond its existing channel or eroding the approach embankments.

11.6 Recommended Approach Fill

In view of the location in the river flood plain, it is recommended that it be constructed using rock fill as this will be more resistant to the impact of flood water and does not require separate rip rap protection.

11.7 General Embankment Requirements

All topsoil and organic soils should be stripped from the footprint of the immediate approach fills.

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

Where embankments are higher than 6 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the embankment height exceeds 6 m
- be 2 m wide
- have 2% positive drainage to shed run-off water (earth fill embankments).

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

12 RETAINED SOIL SYSTEMS

RSS walls used in conjunction with bridge abutments must be "High Performance" and, typically, "High Appearance". The geotechnical parameters that can be used for the design of RSS walls at this site are presented in Table 12.1.

Table 12.1 – RSS Design Parameters

Parameter	South Abutment	North Abutment
Bearing resistance on native soil	ULS_f = 330 kPa SLS = 220 kPa	ULS_f = 330 kPa SLS = 220 kPa
Coefficient of sliding resistance	0.5	0.5
Estimated settlement	130 mm	130 mm

The near surface foundation soils, particularly at the north abutment, consist of very loose to compact sandy silts. It is considered that the predicted magnitude of settlement is unacceptable for "High Performance, High Appearance".

The consequence of these settlements could include, though not necessarily be limited to:

- Opening of spaces between the precast panels
- Separation of the RSS wall from the structure where they meet, horizontally or vertically
- Loss of backfill through the spaces described above
- Localized crushing of the concrete panels
- In extreme cases, possible failure of components of the wall
- Distortion of the plane of the wall and degradation of its appearance

However, if other design requirements warrant over-riding this recommendation then the following ground preparation is required under the RSS mass:

1. The RSS mass must be founded on an engineered fill pad at least 2 m thick. The engineered fill must consist of OPSS Granular "A" compacted to 100% of its SPMDD at a moisture content within 2% of optimum.
2. The engineered fill pad must extend at least 500 mm beyond the limits of the RSS mass and levelling strip.
3. The highest permitted founding levels for the underside of the engineered fill are Elevation 294.0 at the south abutment and Elevation 293.0 at the north abutment. Lower founding elevation may be required to accommodate the required thickness of engineered fill.

Construction of the RSS mass as described in (1) through (3) above is expected to induce settlement in the underlying very loose to loose soils, especially at the north abutment. Any design of a RSS wall must take account of the possible settlement of the top of the wall. The magnitude of the settlement is difficult to predict accurately, but is estimated to be in the range of 20 to 40 mm.

This settlement is not expected to affect the performance of the RSS wall but it may have an impact on the appearance.

The RSS supplier/designer may specify more stringent criteria or other requirements related to the particular design. The RSS must conform to the requirements of SP599S22.

Preliminary stability analysis of an RSS wall with a maximum height of 5.8 m and reinforcement extending a distance back from the wall face a distance of two-thirds of the wall height was carried out. The analyses indicate a minimum factor of safety of 1.7 against global instability.

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. A NSSP is required to specify grading limits for the rock fill. The rock fill used as backfill to the abutment should be limited to fragments no greater than 75 mm and including adequate spalls to fill voids in the rock fill.

In all cases where the approach embankment consists of rock fill and granular backfill to the abutment wall is used, the granular backfill must consist of OPSS Granular "B" Type II.

The backfill to the abutment walls must be in accordance with OPSS 902 as amended by Special Provision 902S01. Granular backfill must be placed to the extents shown in OPSD 3501.000, and rock backfill must be placed to the extents shown in OPSD 3505.000.

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

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

14 EARTH PRESSURE COEFFICIENTS (ABUTMENTS)

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

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

where: p_h = horizontal pressure on the wall at depth h (kPa)

K = earth pressure coefficient (see Table 14.1)

γ = unit weight of retained soil (see Table 14.1)

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

q = value of any surcharge (kPa)

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 14.1.

Table 14.1 – Earth Pressure Coefficients (K)

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \gamma = 22.8$ kN/m^3		OPSS Granular B Type I $\phi = 32°, \gamma = 21.2$ kN/m^3		Rock Fill (Limited to 300 mm size) $\phi = 42°, \gamma = 19$ kN/m^3	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	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	0.43*	0.2	.30*
At rest (Restrained Wall)	0.43	-	0.47	-	.33	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	5.0	-

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

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

In accordance with Clause 6.9.3 of the CHBDC, a compaction surcharge should be added. The magnitude should be 12 kPa at the top of fill and decreasing to 0 kPa at a depth of 2.0 m for Granular B Type I or 1.7 m for Granular A or Granular B Type II.

For integral abutment design, the following values of modulus of horizontal subgrade reaction, k_s, may be used to calculate spring constants for the backfill:

$k_s = 4{,}500\ z/h$ (kN/m^3) for Granular B Type I

$k_s = 5{,}600\ z/h$ (kN/m^3) for Granular A

where: z = depth from top of abutment wall to point of interest (m)

h = full height of abutment wall (m)

15 SEISMIC CONSIDERATIONS

For design purposes, the site is treated as lying in Seismic Zone 1.

15.1 Seismic Design Parameters

The following seismic parameters should be used for design:

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

The Soil Profile Type at this site has been classified as Type I. Thus, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient "S" of 1.0 should be used in seismic design.

15.2 Liquefaction Potential

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

Using this method, it was determined that the foundation soils at the abutments are not in danger of liquefaction under earthquake loading.

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. The seismic earth pressure coefficients to be used in design at this site are shown in Table 15.1.

In Table 15.1, the angle of friction between the wall and the backfill, δ, is taken as 50% of the angle of internal friction of the backfill, ϕ.

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

Table 15.1 – Earth Pressure Coefficients (K) for Seismic Design

Condition	Earth Pressure Coefficient (K) for Earthquake Loading					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35°, \delta = 17°$		OPSS Granular B Type I $\phi = 32°, \delta = 16°$		Rock Fill (Limited to 300 mm size) $\phi = 42°, \delta = 21°$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active*, K_{AE} (Unrestrained Wall)	0.28	0.46	0.31	0.58	0.21	.30
At rest**, K_{OE} (Restrained Wall)	0.53	-	0.58	-	.44	-
Passive*, K_{PE} (Movement Towards Soil Mass)	7.0	-	5.5	-	14.1	-

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

15.4 Slope Stability Considerations

Seismic effects were taken into account in the slope stability analyses conducted for this site using pseudo-static methods and assuming that the foundation soils would not be subject to liquefaction. Under these conditions, satisfactory factors of safety were obtained from the analysis, i.e. all values exceeded 1.0.

16 CONSTRUCTION CONCERNS

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

- The possibility of piles reaching refusal on large boulders. In this case, the Hiley formula is not appropriate and site staff must make a decision regarding pile resistance and the appropriateness of continued driving.
- The potential variability of pile lengths at refusal or set.
- Problems associated with installation of piles for piers that may be totally or partially in the river. The Contractor must exercise care in constructing the cofferdam or alternative system to achieve an unwatered condition in which to construct the pile cap and pier.
- Excavation and unwatering close to the river.

17 CLOSURE

Engineering analysis and preparation of the foundation design report was conducted by Mr. Murray Anderson, P.Eng. The report was reviewed by Mr. Alastair E. Gorman, P.Eng. The report was also reviewed by Dr. P.K. Chatterji, Ph.D., a Designated Principal Contact for MTO Foundations Projects.

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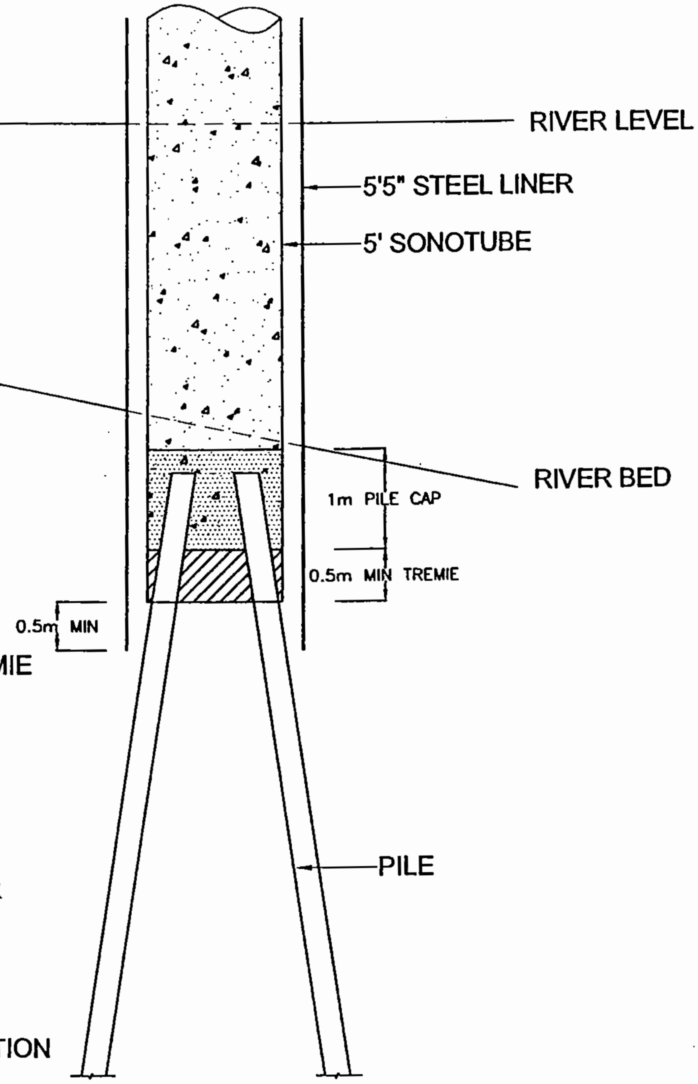
P.K. Chatterji, P.Eng., Ph.D.
Review Principal

DEC , 2004

N.B.

WEIGHT AND SHEAR RESISTANCE OF TREMIE PLUG MUST RESIST FULL HYDROSTATIC UPLIFT.



NOTES:

1)* DRIVE STEEL LINER AT LEAST 0.5m BEYOND PROPOSED TIP OF SONOTUBE AND AT LEAST 2m INTO RIVER BED

2) MUCK OUT TO REQUIRED BASE OF TREMIE PLUG

3) DRIVE PILES

4)* INSTALL SONOTUBE

5) PLACE TREMIE CONCRETE PLUG UNDER WATER AND LET HARDEN

6) DEWATER INSIDE SONOTUBE

7) CUT TOP OF PILES TO REQUIRED ELEVATION

8) INSTALL REINFORCING AND CONCRETE PILE CAP

9) INSTALL REINFORCING AND CONCRETE PIER TO ABOVE RIVER LEVEL

10) REMOVE TEMPORARY STEEL LINER

* LINER TO BE ABOVE RIVER LEVEL AND SONOTUBE ALSO TO EXTEND ABOVE RIVER LEVEL

RISKS:

A) BOILING OF BASE IF LINER MUCKED OUT TOO FAST

B) DANGER OF LINER GRABBING SONOTUBE/ PILE CAP ON REMOVAL

ENGINEER AEG		
DRAWN HS	INSTALLATION OF PIER FOUNDATION IN RIVER (FOR ILLUSTRATION ONLY)	THURBER
DATE DEC , 2004		
APPROVED		DWG. NO. SK1
SCALE NTS		

SK_DWG

Appendix A

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

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

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

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

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

NOTE: Hierarchy of Soil Strength Prediction

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

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

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

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE

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

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

▼ Water Level

C_{pen} Shear Strength Determination by Pocket Penetrometer

(1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.

(2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

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

EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

SYMBOLS

- CLAYSTONE
- SILTSTONE
- SANDSTONE
- COAL
- Bedrock (general)

DISCONTINUITY SPACING

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

TERMS

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

STRENGTH CLASSIFICATION

Rock Strength	**Approximate Uniaxial Compressive Strength** (MPa)	(psi)	**Field Estimation of Hardness***
Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

THURBER

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-1

METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-1 N 5 047 512.3 E 316 636.4 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY WM

DATUM Geodetic | DATE 01.10.04 - 01.10.04 | CHECKED BY MA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	DYNAMIC CONE PENETRATION / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.1									
0.0	**TOPSOIL**				295				
294.8 / 0.3	**SAND**, trace silt, Very Loose, Brown, Moist	1	SS	3	294				
293.7 / 1.4	Silty **SAND**, Very Loose, Grey, Wet	2	SS	3					
292.9 / 2.2	Silty **CLAY**, trace sand, Firm to Very Stiff, Grey, Moist	3	SS	1	293				
		4	SS	2	292				0 2 53 45
					291	+ 3.2			
		5	SS	6	290	+ 3.4			
		6	SS	7	289				
					288	+ 3.4			
		7	SS	9	287				0 0 63 36
					286	>> + 3.5			
		8	SS	6					

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

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

SHEAR STRENGTH legend: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-1

METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-1 N 5 047 512.3 E 316 636.4 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY WM

DATUM Geodetic | DATE 01.10.04 - 01.10.04 | CHECKED BY MA

SOIL PROFILE			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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
285.0											
10.1	END OF BOREHOLE AT 10.13 m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) 11.11.04 0.05						285				

+3, ×3: Numbers refer to Sensitivity

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

ONTMT4S 2316(426).GPJ 07/01/05

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-3

METRIC

W.P. 5403-04-01 LOCATION Municipal Service Road, 426-3 N 5 047 531.5 E 316 633.0 ORIGINATED BY SL

HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY WM

DATUM Geodetic DATE 04.10.04 - 07.10.04 CHECKED BY MA

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.1 / 0.0	**TOPSOIL**, sandy, some rootlets, Dark Brown				
294.7 / 0.4	**SAND**, fine grained, trace silt, Compact, Brown, Moist	1	SS	10	
293.7 / 1.4	**SILT**, some sand to sandy, Loose to Compact, Grey, Wet	2	SS	5	0 13 79 8
		3	SS	15	
292.1 / 3.0	**SAND**, fine grained, trace silt to silty, Compact to Loose, Grey, Wet	4	SS	13	
		5	SS	7	
		6	SS	6	0 57 43 (SI+CL)
		7	SS	7	
		8	SS	7	

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION SCALE (295, 294, 293, 292, 291, 290, 289, 288, 287, 286); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60); UNIT WEIGHT γ kN/m³.

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

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

ONTMT4S 2316(426).GPJ 07/01/05

RECORD OF BOREHOLE No 426-3

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-3 N 5 047 531.5 E 316 633.0	ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Hollow Stem Augers/NW Casing	COMPILED BY WM
DATUM Geodetic	DATE 04.10.04 - 07.10.04	CHECKED BY MA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		9	SS	8	285	0 94 6 (SI+CL)
					284	
	becoming compact	10	SS	21		
282.9 / 12.2	**SAND,** trace silt, trace to some gravel Compact Grey Wet				283	
		11	SS	11	282	
					281	
		12	SS	17		
					280	
	occasional cobbles	13	SS	11	279	
278.3 / 16.8	**SAND and GRAVEL,** trace silt, occasional cobbles Dense to Compact Grey Wet				278	
		14	SS	45		36 61 3 (SI+CL)
					277	
		15	SS	18	276	

Dynamic cone penetration resistance plot scale: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)
PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60
UNIT WEIGHT γ kN/m³

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 426-3

METRIC

W.P. 5403-04-01 LOCATION Municipal Service Road, 426-3 N 5 047 531.5 E 316 633.0 ORIGINATED BY SL

HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY WM

DATUM Geodetic DATE 04.10.04 - 07.10.04 CHECKED BY MA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS
274.8	200 mm cobble encountered				275		
20.3	**SAND**, trace silt, trace gravel Compact to Loose Grey Wet	16	SS	15			
					274		
					273		
					272		
		17	SS	3		o (~20)	
					271		
	occasional cobbles and boulders						
					270		
					269		
	170 mm boulder encountered						
		18	SS	26	268	o (~25)	
	becoming compact						
					267		
266.4 28.7	Gravelly **SAND**, trace silt, occasional cobbles and boulders Very Dense Grey Wet				266		

Continued Next Page

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

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

RECORD OF BOREHOLE No 426-3

METRIC

W.P.	5403-04-01	LOCATION	Municipal Service Road, 426-3 N 5 047 531.5 E 316 633.0	ORIGINATED BY	SL
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NW Casing	COMPILED BY	WM
DATUM	Geodetic	DATE	04.10.04 - 07.10.04	CHECKED BY	MA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		19	SS	86	265	15 77 8 (SI+CL)
					264	
					263	
262.1		20	SS	101	262	
33.0	Silty **SAND**, some gravel Very Dense Grey Wet	21	SS	100/ .100	261	12 49 39 (SI+CL)
260.0 35.1	**SAND and GRAVEL**, some silt Very Dense Grey Wet				260	
259.2		22	SS	100/ .050		
35.9	END OF BOREHOLE AT 35.86 m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen.					

WATER LEVEL READINGS:

DATE	DEPTH (m)
21.10.04	0.08
11.11.04	0.00
08.12.04	0.16

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

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-3A

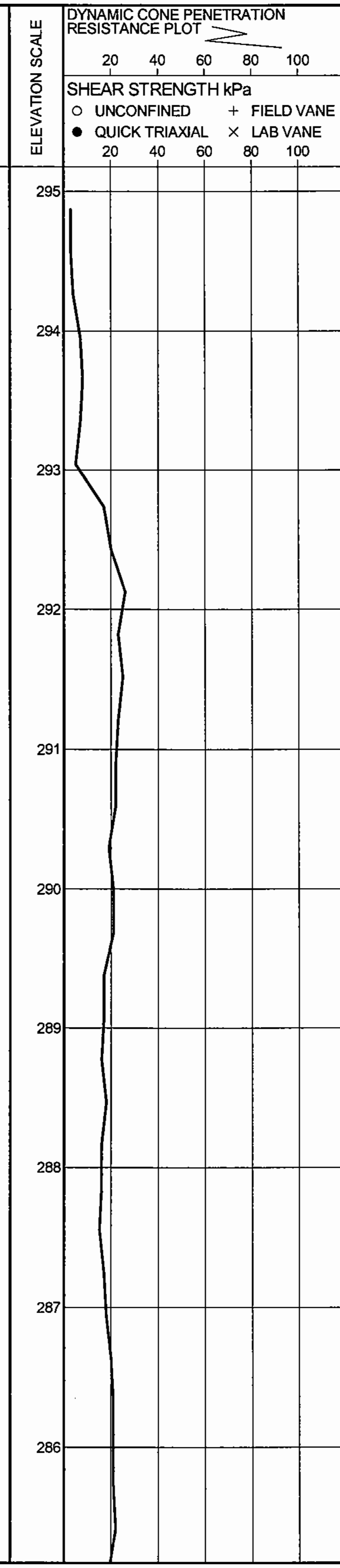
METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-3A N 5 047 532.5 E 316 633.5 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT) | COMPILED BY WM

DATUM Geodetic | DATE 08.10.04 - 08.10.04 | CHECKED BY MA

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.1											
0.0	DCPT from surface.						295–286				



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+ 3, × 3: Numbers refer to Sensitivity

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

ONTMT4S 2316(426).GPJ 07/01/05

Ministry of Transportation
Ontario

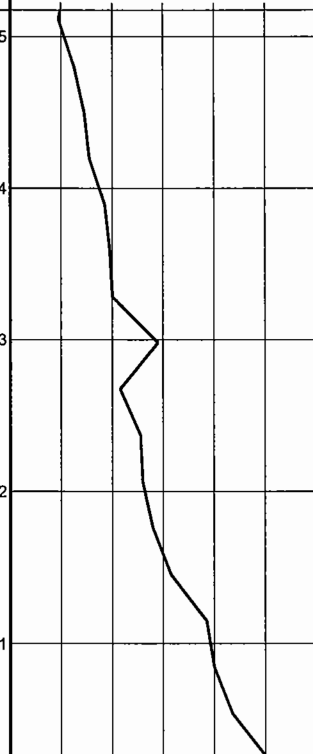
THURBER

RECORD OF BOREHOLE No 426-3A

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-3A N 5 047 532.5 E 316 633.5		ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT)		COMPILED BY WM
DATUM Geodetic	DATE 08.10.04 - 08.10.04		CHECKED BY MA

SOIL PROFILE: ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
							285				
							284				
							283				
							282				
							281				
280.2 14.9	END OF DCPT AT 14.91 m.										



+ ³, × ³: Numbers refer to Sensitivity

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

ONTMT4S 2316(426).GPJ 07/01/05

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-4

METRIC

W.P. 5403-04-01 LOCATION Municipal Service Road, 426-4 N 5 047 548.4 E 316 607.9 ORIGINATED BY SL

HWY 11 BOREHOLE TYPE Hollow Stem Augers/HW Casing, NW Casing COMPILED BY WM

DATUM Geodetic DATE 18.10.04 - 20.10.04 CHECKED BY MA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
295.2										
0.0	**TOPSOIL**				295					
0.2	**SAND and SILT**, trace clay Loose to Very Loose Brown Wet	1	SS	6	294	~38	0	50	47	3
		2	SS	2		~21				
293.0 2.2	**SILT**, some sand Compact Brown to Grey Wet	3	SS	11	293	~21	0	18	76	6
292.2 3.0	Silty **SAND**, fine grained Compact to Loose Grey Wet	4	SS	14	292	~29				
		5	SS	7	291, 290	~19	0	76	24 (SI+CL)	
		6	SS	7	289	~21				
287.9 7.3	**SILT**, some sand Very Loose to Loose Grey Wet	7	SS	3	288, 287	~21	0	16	79	5
		8	SS	7	286	~21				

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m^3; REMARKS & GRAIN SIZE DISTRIBUTION (%); STRAT PLOT; GROUND WATER CONDITIONS.

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-4

METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-4 N 5 047 548.4 E 316 607.9 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Hollow Stem Augers/HW Casing, NW Casing | COMPILED BY WM

DATUM Geodetic | DATE 18.10.04 - 20.10.04 | CHECKED BY MA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE
285.1 / 10.1	**SAND**, fine grained, trace to some silt Compact to Loose Grey Wet				285
		9	SS	16	284
		10	SS	4	283
					282
		11	SS	7	281
					280
		12	SS	4	279
	Becoming Compact	13	SS	10	278
					277
276.9 / 18.3	**SAND**, trace silt, trace to some gravel, occasional cobbles and boulders Very Dense to Compact Grey Wet	14	SS	65	276

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: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Continued Next Page

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-4

METRIC

W.P.	5403-04-01	LOCATION	Municipal Service Road, 426-4 N 5 047 548.4 E 316 607.9	ORIGINATED BY	SL
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/HW Casing, NW Casing	COMPILED BY	WM
DATUM	Geodetic	DATE	18.10.04 - 20.10.04	CHECKED BY	MA

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
					275	
					274	
		15	SS	27		
					273	
					272	
					271	
		16	SS	33		
					270	
					269	
268.7 / 26.5	Gravelly **SAND**, with cobbles and boulders Compact Grey Wet					
					268	
		17	SS	13		
					267	
					266	

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

Continued Next Page

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

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-4

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-4 N 5 047 548.4 E 316 607.9	ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Hollow Stem Augers/HW Casing, NW Casing	COMPILED BY WM
DATUM Geodetic	DATE 18.10.04 - 20.10.04	CHECKED BY MA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
					265		
		18	SS	100/ .125		o	19 72 9 (SI+CL)
					264		
263.5 31.7	**SAND**, some silt, occasional cobbles and boulders Compact to Very Dense Grey Wet						
		19	SS	17	263	o	
					262		
		20	SS	77		o	0 87 13 (SI+CL)
					261		
					260		
					259		
		21	SS	50/ .075		o	
					258		
		22	SS	100/ .100	257	o	
					256		
255.5		23	SS	100/ .075		o	
39.7	END OF BOREHOLE AT 39.70 m. Piezometer installation consists of 19						

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 426-4

METRIC

W.P.	5403-04-01	LOCATION	Municipal Service Road, 426-4 N 5 047 548.4 E 316 607.9	ORIGINATED BY	SL
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/HW Casing, NW Casing	COMPILED BY	WM
DATUM	Geodetic	DATE	18.10.04 - 20.10.04	CHECKED BY	MA

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
	mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) 21.10.04 0.03 11.11.04 0.0 08.12.04 0.21										

+ ³, × ³: Numbers refer to Sensitivity

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

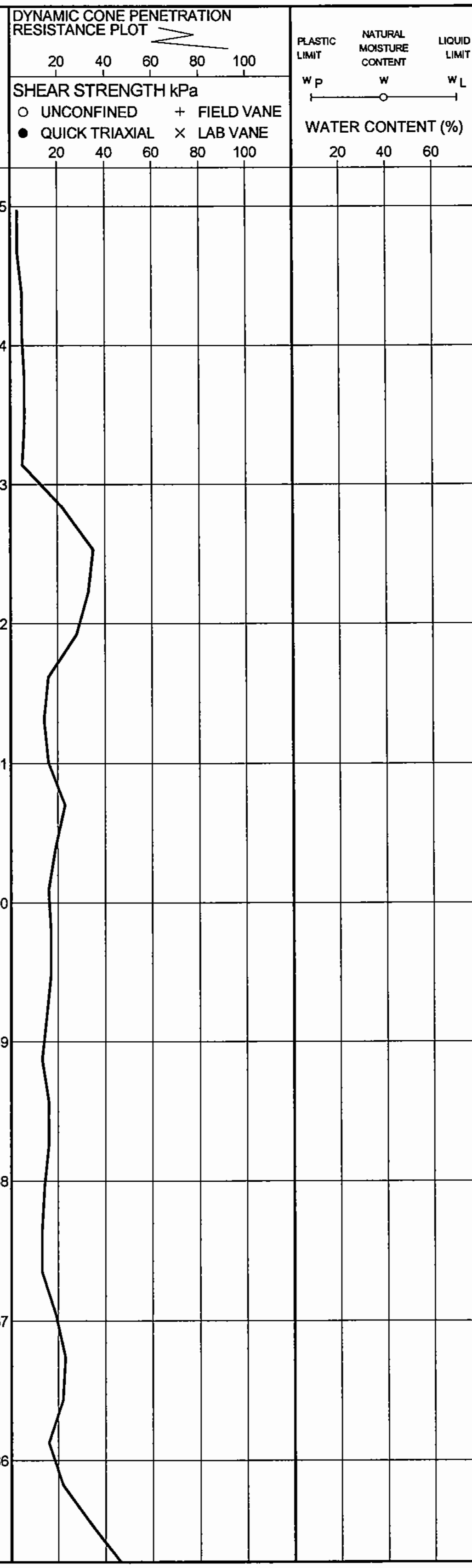
THURBER

RECORD OF BOREHOLE No 426-4A

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-4A N 5 047 549.9 E 316 607.9		ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT)		COMPILED BY WM
DATUM Geodetic	DATE 21.10.04 - 21.10.04		CHECKED BY MA

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.2 / 0.0	DCPT started from surface.						295, 294, 293, 292, 291, 290, 289, 288, 287, 286				



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

Ministry of Transportation
Ontario

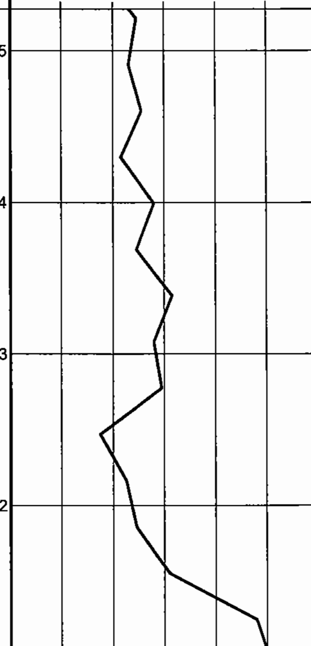
THURBER

RECORD OF BOREHOLE No 426-4A

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-4A N 5 047 549.9 E 316 607.9		ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT)		COMPILED BY WM
DATUM Geodetic	DATE 21.10.04 - 21.10.04		CHECKED BY MA

SOIL PROFILE: ELEV DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
							285				
							284				
							283				
							282				
281.0											
14.2	END OF DCPT AT 14.12 m.										



+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-7

METRIC

W.P.	5403-04-01	LOCATION	Municipal Service Road, 426-7 N 5 047 594.1 E 316 598.0	ORIGINATED BY	SL
HWY	11	BOREHOLE TYPE	Hollow Stem Augers/NW Casing	COMPILED BY	WM
DATUM	Geodetic	DATE	29.09.04 - 30.09.04	CHECKED BY	MA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.5 / 0.0	**TOPSOIL**, sandy, some rootlets						
0.2	Sandy **SILT**, trace rootlets, occasional topsoil staining Loose Brown Moist				295		
		1	SS	6			
		2	SS	6	294	○	
293.3 / 2.2	**SAND and SILT**, fine grained, trace clay Loose Grey Wet	3	SS	8	293		
		4	SS	6	292	○	0 55 43 3
291.5 / 4.0	**SILT**, trace sand, trace clay Very Loose Grey Wet				291		
		5	SS	3	290	○	0 4 90 6
289.7 / 5.8	Silty **SAND**, fine grained Loose to Compact Grey Wet	6	SS	4	289	○	
		7	SS	9	288	○	
		8	SS	5	287 / 286		

Column headings: SOIL PROFILE; STRAT PLOT; SAMPLES; GROUND WATER CONDITIONS; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

Continued Next Page

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-7

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-7 N 5 047 594.1 E 316 598.0		ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Hollow Stem Augers/NW Casing		COMPILED BY WM
DATUM Geodetic	DATE 29.09.04 - 30.09.04		CHECKED BY MA

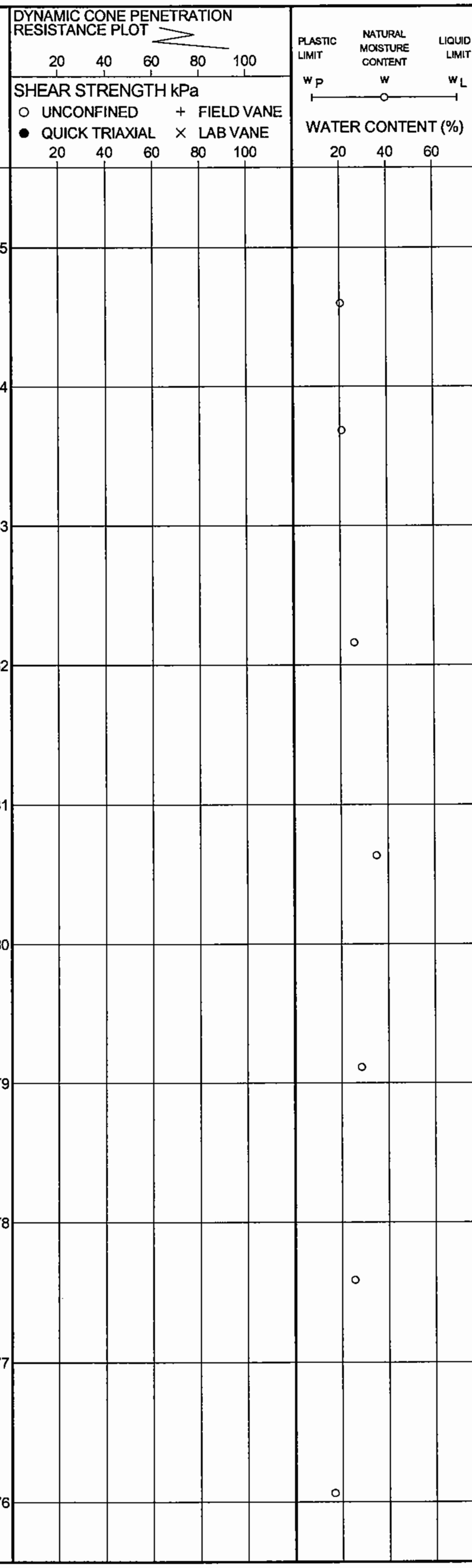
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
283.0 / 12.5	**SAND and SILT**, occasional clay pockets Compact Grey Wet
280.0 / 15.5	**SAND**, some silt, trace gravel Grey Compact Wet

SAMPLES

NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
9	SS	11	
10	SS	11	0 81 19 (SI+CL)
11	SS	16	
12	SS	12	0 48 42 10
13	SS	21	
14	SS	20	
15	SS	17	

ELEVATION SCALE: 285, 284, 283, 282, 281, 280, 279, 278, 277, 276



UNIT WEIGHT γ kN/m³

GROUND WATER CONDITIONS

STRAT PLOT

Continued Next Page

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-7

METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-7 N 5 047 594.1 E 316 598.0 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Hollow Stem Augers/NW Casing | COMPILED BY WM

DATUM Geodetic | DATE 29.09.04 - 30.09.04 | CHECKED BY MA

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L
WATER CONTENT (%): 20 40 60
UNIT WEIGHT γ kN/m^3
REMARKS & GRAIN SIZE DISTRIBUTION (%): GR SA SI CL

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
					275		
		16	SS	21		o (approx. 21)	
					274		
					273		
					272		
		17	SS	14		o (approx. 20)	0 89 10 (SI+CL)
					271		
					270		
269.6 / 25.9	Gravelly **SAND**, occasional cobbles Very Dense Grey Wet						
					269		
		18	SS	50/ .150		o (approx. 18)	
					268		
					267		
					266		

Continued Next Page

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

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-7

METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-7 N 5 047 594.1 E 316 598.0 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Hollow Stem Augers/NW Casing | COMPILED BY WM

DATUM Geodetic | DATE 29.09.04 - 30.09.04 | CHECKED BY MA

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		19	SS	50/ .100			
					265		
					264		
263.5 / 32.0	**SAND**, some silt, trace gravel, occasional cobbles Very Dense Grey Wet						
					263		
		20	SS	50/ .150		o	
					262		
					261		
					260		
		21	SS	100/ .200		o	6 78 16 (SI+CL)
					259		
257.9		22	SS	100/ .150	258	o	
37.6	END OF BOREHOLE AT 37.64 m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen.						

WATER LEVEL READINGS:

DATE	DEPTH (m)
11.11.04	0.22
08.12.04	0.32

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

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

ONTMT4S 2316(426).GPJ 07/01/05

Ministry of Transportation Ontario

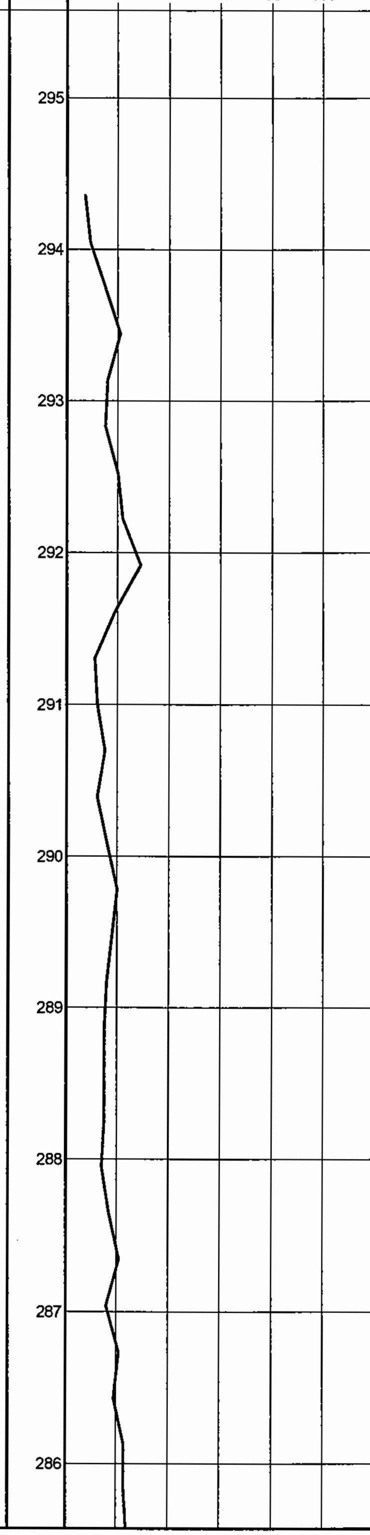
THURBER

RECORD OF BOREHOLE No 426-7A

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-7A N 5 047 595.6 E 316 598.0	ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT)	COMPILED BY WM
DATUM Geodetic	DATE 30.09.04 - 30.09.04	CHECKED BY MA

SOIL PROFILE: ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.5 / 0.0	DCPT from 1.22 m.										



Continued Next Page

+ ³, × ³ : Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-7A

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-7A N 5 047 595.6 E 316 598.0		ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT)		COMPILED BY WM
DATUM Geodetic	DATE 30.09.04 - 30.09.04		CHECKED BY MA

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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
							285				
							284				
							283				
							282				
							281				
280.3 / 15.2	END OF DCPT AT 15.21 m.										

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-8

METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-8 N 5 047 611.4 E 316 573.1 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Hollow Stem Augers/NW Casing | COMPILED BY WM

DATUM Geodetic | DATE 23.09.04 - 28.09.04 | CHECKED BY MA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.3 / 0.0	**SAND**, trace gravel, trace silt, Brown, Moist (FILL)					
295.0 / 0.3	**SILT**, some sand, trace clay, Loose, Brown, Wet				295	
		1	SS	3		
					294	
		2	SS	3		
					293	
		3	SS	6		
		4	SS	6	292	1 18 73 8
291.3 / 4.0	**SAND and GRAVEL**, trace silt, Very Loose, Brown, Wet				291	
		5	SS	2		
					290	
289.5 / 5.8	Silty **SAND**, fine grained, Loose to Compact, Grey, Wet				289	
		6	SS	6		
					288	
		7	SS	6	287	
					286	

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

Continued Next Page

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-8

METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-8 N 5 047 611.4 E 316 573.1 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Hollow Stem Augers/NW Casing | COMPILED BY WM

DATUM Geodetic | DATE 23.09.04 - 28.09.04 | CHECKED BY MA

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
		8	SS	10		~20	0 71 29 (SI+CL)
					285		
					284		
		9	SS	14		~20	
					283		
		10	SS	9		~20	
					282		
					281		
	occasional silt layers	11	SS	15		~20	
					280		
		12	SS	13		~20	0 72 28 (SI+CL)
					279		
					278		
		13	SS	11		~20	
					277		
		14	SS	23		~20	
					276		

Continued Next Page

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

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

RECORD OF BOREHOLE No 426-8

METRIC

W.P. 5403-04-01 LOCATION Municipal Service Road, 426-8 N 5 047 611.4 E 316 573.1 ORIGINATED BY SL

HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY WM

DATUM Geodetic DATE 23.09.04 - 28.09.04 CHECKED BY MA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
274.9 / 20.4	Gravelly **SAND**, occasional cobbles, Very Dense, Grey, Wet	15	SS	67	275	○	25 64 11 (SI+CL)
					274		
					273		
					272		
		16	SS	50/ .075		○	
					271		
270.6 / 24.7	**SAND**, trace gravel, trace silt, occasional silty sand layers, Compact to Very Dense, Grey, Wet				270		
					269		
		17	SS	11		○	8 82 10 (SI+CL)
					268		
					267		
					266		
		18	SS	60/ .125			

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

15-⊕-5 (20, 10) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-8

METRIC

W.P. 5403-04-01 LOCATION Municipal Service Road, 426-8 N 5 047 611.4 E 316 573.1 ORIGINATED BY SL

HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY WM

DATUM Geodetic DATE 23.09.04 - 28.09.04 CHECKED BY MA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)
					265	
					264	
					263	
		19	SS	50/ .125		o
					262	
					261	
					260	
		20	SS	50/ .100		o
					259	
257.8					258	
37.5	Silty **SAND**, some gravel, occasional cobbles Very Dense Grey Wet					
					257	
		21	SS	50/ .150		o
					256	

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

Continued Next Page

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

20 15 5 10 (%) STRAIN AT FAILURE

ONTMT4S 2316(426).GPJ 07/01/05

Ministry of Transportation Ontario

THURBER

RECORD OF BOREHOLE No 426-8

METRIC

W.P. 5403-04-01 LOCATION Municipal Service Road, 426-8 N 5 047 611.4 E 316 573.1 ORIGINATED BY SL

HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY WM

DATUM Geodetic DATE 23.09.04 - 28.09.04 CHECKED BY MA

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
					255		
					254		
		22	SS	50/ .075		o	4 55 40 1
					253		
					252		
					251		
		23	SS	50/ .100		o	
					250		
					249		
248.4 46.9	END OF BOREHOLE AT 46.94 m. Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen.						

WATER LEVEL READINGS:

DATE	DEPTH (m)
29.09.04	0.62
30.09.04	0.18
11.11.04	0.00
08.12.04	0.11

ONTMT4S 2316(426).GPJ 07/01/05

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

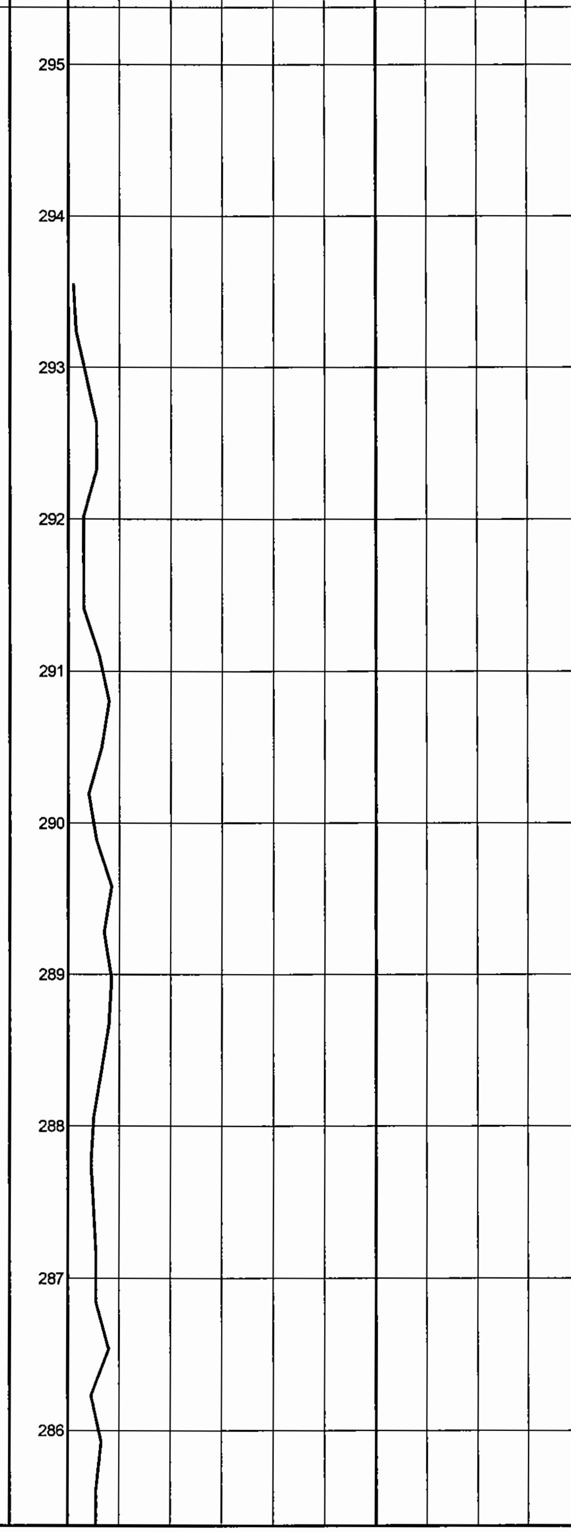
THURBER

RECORD OF BOREHOLE No 426-8A

METRIC

W.P.	5403-04-01	LOCATION	Municipal Service Road, 426-8A N 5 047 612.9 E 316 573.1	ORIGINATED BY	SL
HWY	11	BOREHOLE TYPE	Dynamic Cone Penetration Test (DCPT)	COMPILED BY	WM
DATUM	Geodetic	DATE	28.09.04 - 28.09.04	CHECKED BY	MA

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 (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
295.3 0.0	DCPT from 1.52 m.										



Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

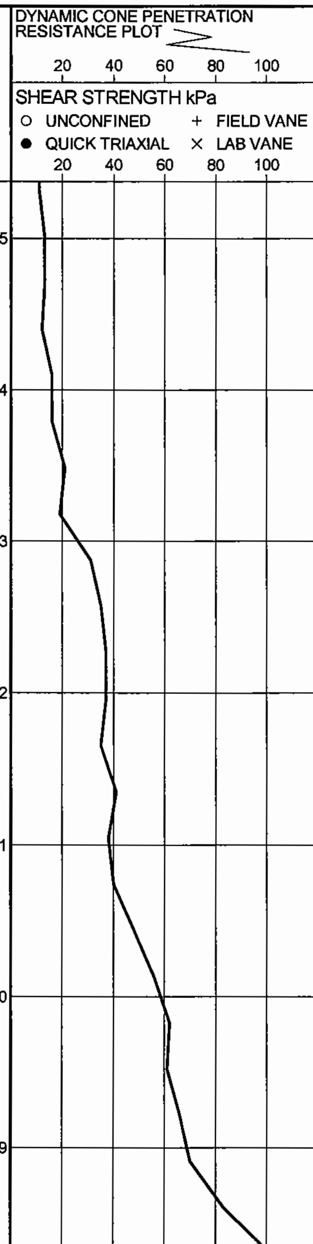
THURBER

RECORD OF BOREHOLE No 426-8A

METRIC

W.P. 5403-04-01	LOCATION Municipal Service Road, 426-8A N 5 047 612.9 E 316 573.1		ORIGINATED BY SL
HWY 11	BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT)		COMPILED BY WM
DATUM Geodetic	DATE 28.09.04 - 28.09.04		CHECKED BY MA

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
							285				
							284				
							283				
							282				
							281				
							280				
							279				
278.3 17.0	END OF DCPT AT 17.04 m.										



+ 3, × 3: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 426-10

METRIC

W.P. 5403-04-01 | LOCATION Municipal Service Road, 426-10 N 5 047 630.7 E 316 569.1 | ORIGINATED BY SL

HWY 11 | BOREHOLE TYPE Hollow Stem Augers | COMPILED BY WM

DATUM Geodetic | DATE 29.09.04 - 29.09.04 | CHECKED BY MA

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	"N" VALUES	WATER CONTENT (%)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.4						
0.0	**TOPSOIL**					
0.1	**SAND**, trace silt, Brown, Moist					
294.8 / 0.6	**SILT**, trace clay, trace sand, occasional iron oxide staining, Compact to Dence, Grey, Wet	1	SS	11	~20	
		2	SS	46	~18	
		3	SS	21	~20	
		4	SS	14	~20	0 4 91 6
291.1 / 4.3	**SILT**, some sand, Loose, Grey, Wet	5	SS	6	~20	
289.9 / 5.5	**SILT and SAND**, Loose, Grey, Wet	6	SS	5	~25	
		7	SS	6	~25	0 41 57 2
		8	SS	WH		
285.6 / 9.8	END OF BOREHOLE AT 9.75 m.					

Continued Next Page

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

RECORD OF BOREHOLE No 426-10

METRIC

W.P.	5403-04-01	LOCATION	Municipal Service Road, 426-10 N 5 047 630.7 E 316 569.1	ORIGINATED BY	SL
HWY	11	BOREHOLE TYPE	Hollow Stem Augers	COMPILED BY	WM
DATUM	Geodetic	DATE	29.09.04 - 29.09.04	CHECKED BY	MA

SOIL PROFILE			SAMPLES						DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE					
	Piezometer installation consists of 19 mm diameter Schedule 40 PVC pipe with a 1.52 m slotted screen. WATER LEVEL READINGS: DATE DEPTH (m) 29.09.04 2.34 30.09.04 1.37 11.11.04 0.74 08.12.04 0.71											

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

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-10A

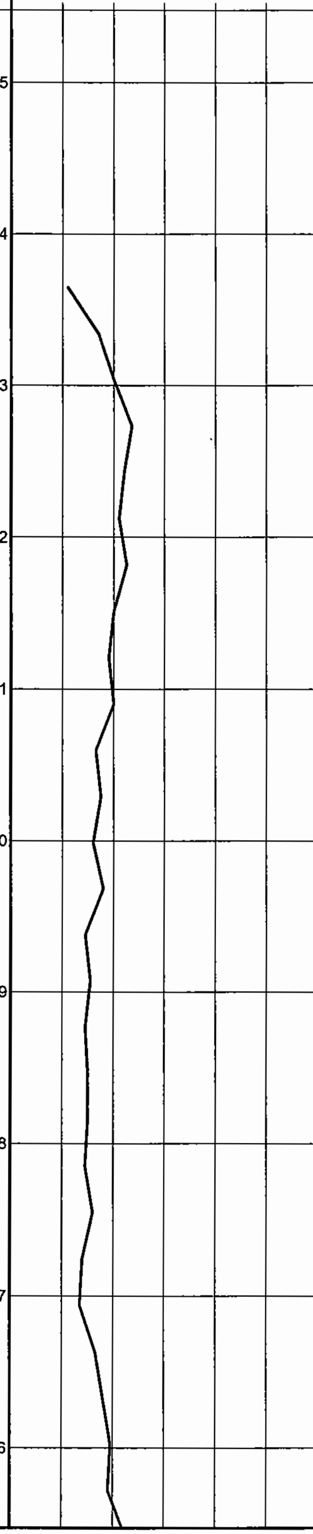
METRIC

W.P. 5403-04-01 — LOCATION Municipal Service Road, 426-10A N 5 047 630.7 E 316 569.1 — ORIGINATED BY SL

HWY 11 — BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT) — COMPILED BY WM

DATUM Geodetic — DATE 29.09.04 - 29.09.04 — CHECKED BY MA

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.4 / 0.0	DCPT from 1.52 m.						295, 294, 293, 292, 291, 290, 289, 288, 287, 286				



Continued Next Page

+³, ×³ : Numbers refer to Sensitivity

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

SHEAR STRENGTH kPa legend: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE

PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L

ONTMT4S 2316(426).GPJ 07/01/05

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 426-10A

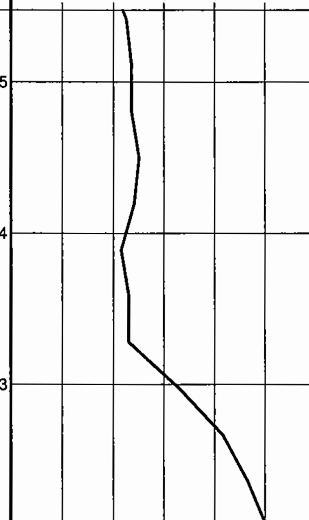
METRIC

W.P. 5403-04-01 LOCATION Municipal Service Road, 426-10A N 5 047 630.7 E 316 569.1 ORIGINATED BY SL

HWY 11 BOREHOLE TYPE Dynamic Cone Penetration Test (DCPT) COMPILED BY WM

DATUM Geodetic DATE 29.09.04 - 29.09.04 CHECKED BY MA

SOIL PROFILE: ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
							285				
							284				
							283				
282.0 / 13.4	END OF DCPT AT 13.39 m.										



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

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

ONTMT4S 2316(426).GPJ 07/01/05

Appendix B

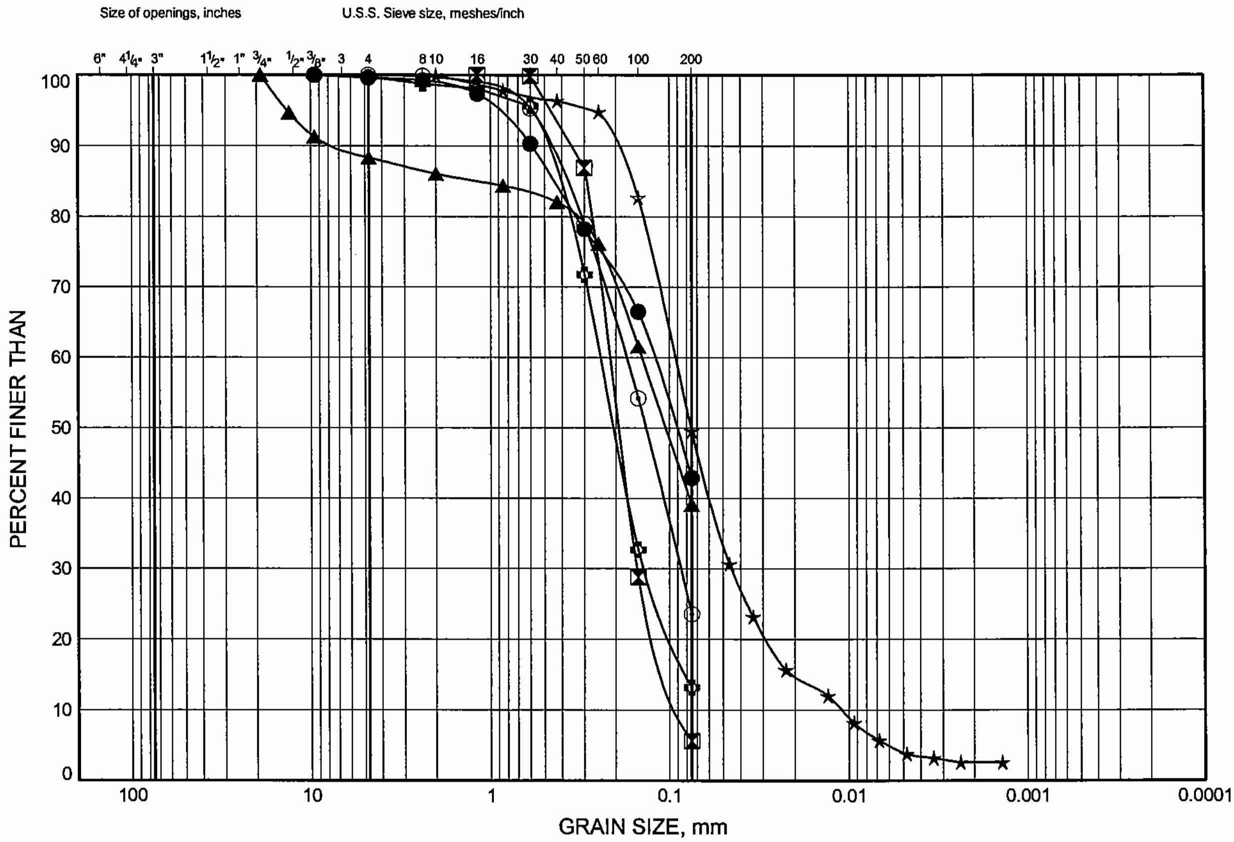
Laboratory Test Results

Hwy 11 Katrine

GRAIN SIZE DISTRIBUTION

FIGURE B1

Sand to Sandy Silt



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	426-3	6.40	288.70
⊠	426-3	10.21	284.89
▲	426-3	34.27	260.83
★	426-4	1.07	294.13
⊙	426-4	4.88	290.32
✿	426-4	33.83	261.37

Date January 2005

Project 5403-04-01

THURBER

Prep'd HS

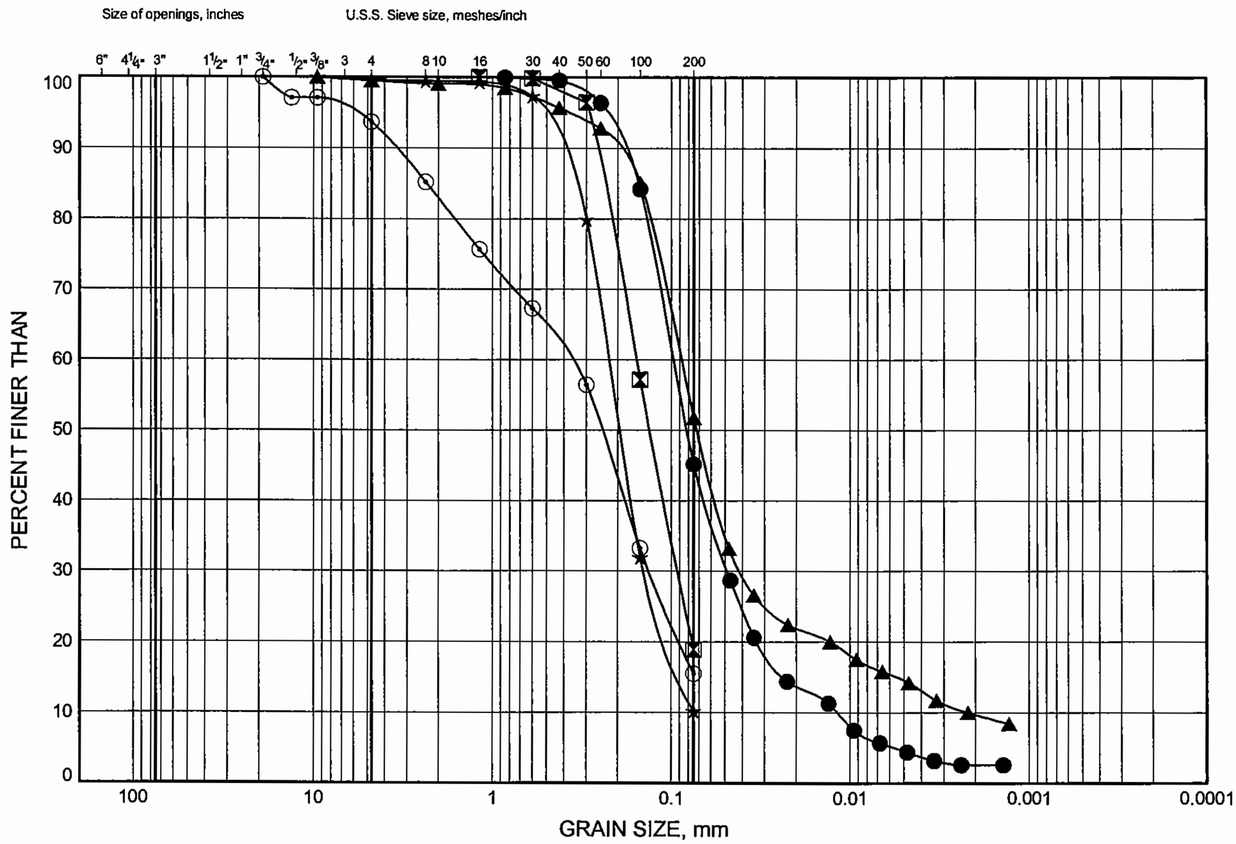
Chkd. MA

THURBGSD 2316(426).GPJ 07/01/05

GRAIN SIZE DISTRIBUTION

FIGURE B2

Sand to Sandy Silt



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	426-7	3.35	292.15
⊠	426-7	11.89	283.61
▲	426-7	14.94	280.56
★	426-7	24.08	271.42
⊙	426-7	36.12	259.38

Date January 2005

Project 5403-04-01

THURBER

Prep'd HS

Chkd. MA

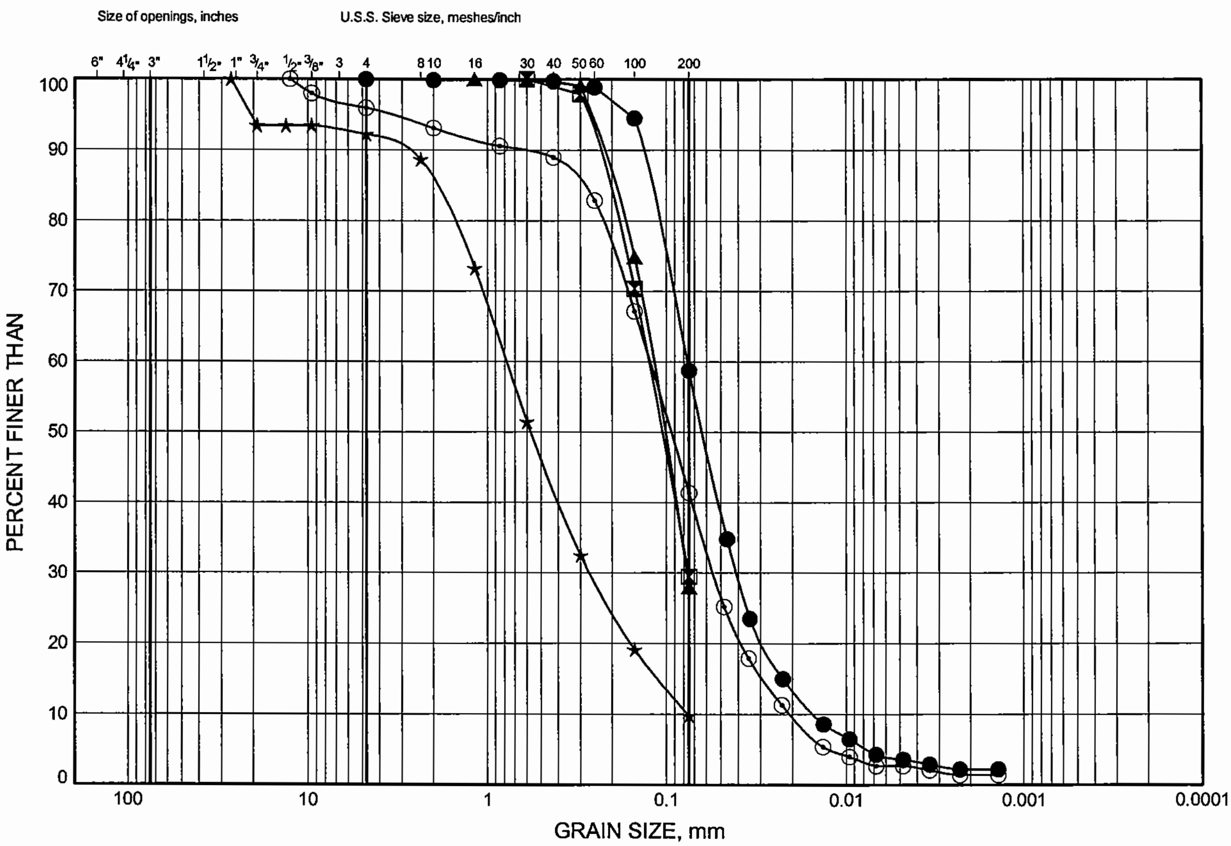
THURBGSD 2316(426).GPJ 07/01/05

Hwy 11 Katrine

GRAIN SIZE DISTRIBUTION

FIGURE B3

Sand to Sandy Silt



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	426-10	7.92	287.48
⊠	426-8	10.06	285.24
▲	426-8	16.15	279.15
★	426-8	26.82	268.48
⊙	426-8	41.86	253.44

Date January 2005

Project 5403-04-01

THURBER

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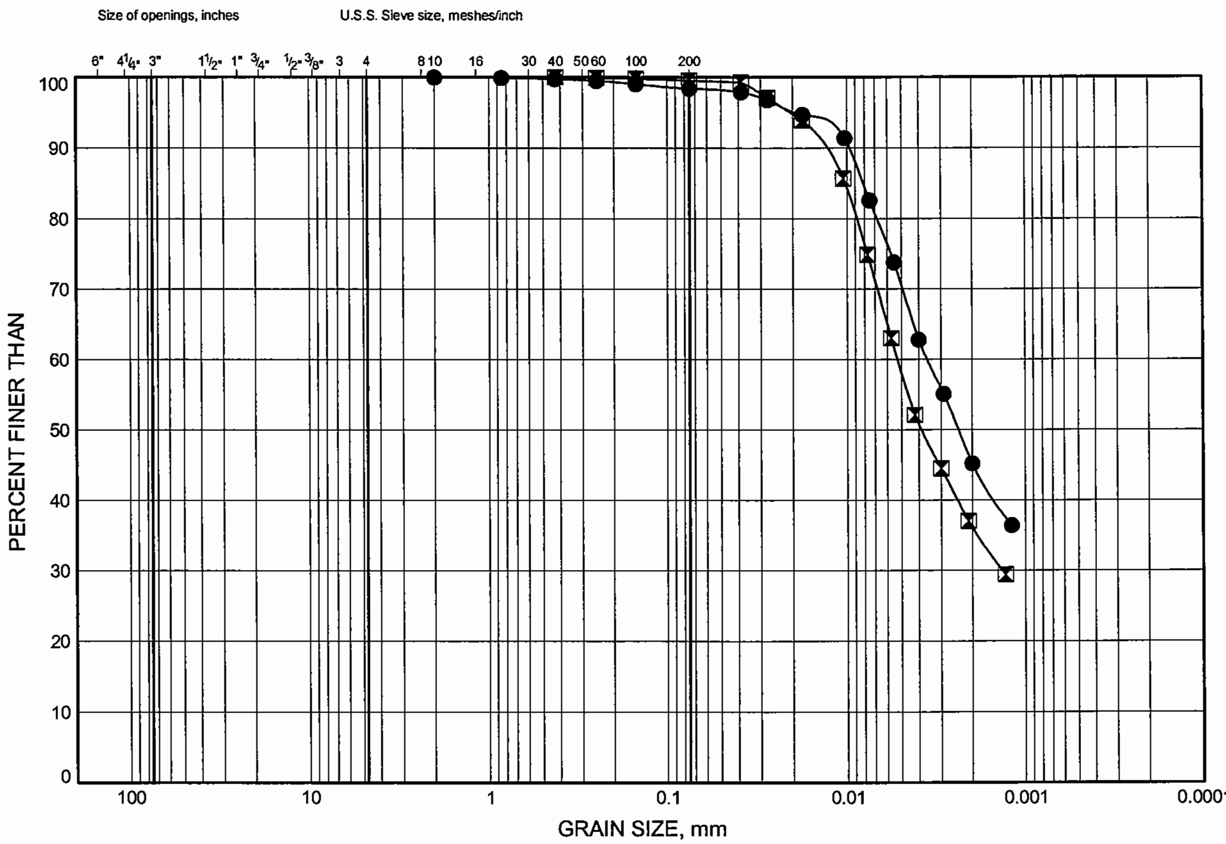
Chkd. MA

Hwy 11 Katrine

GRAIN SIZE DISTRIBUTION

FIGURE B4

Clay



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	426-1	3.35	291.75
⊠	426-1	7.92	287.18

Date January 2005

Project 5403-04-01

THURBER

Prep'd HS

Chkd. MA

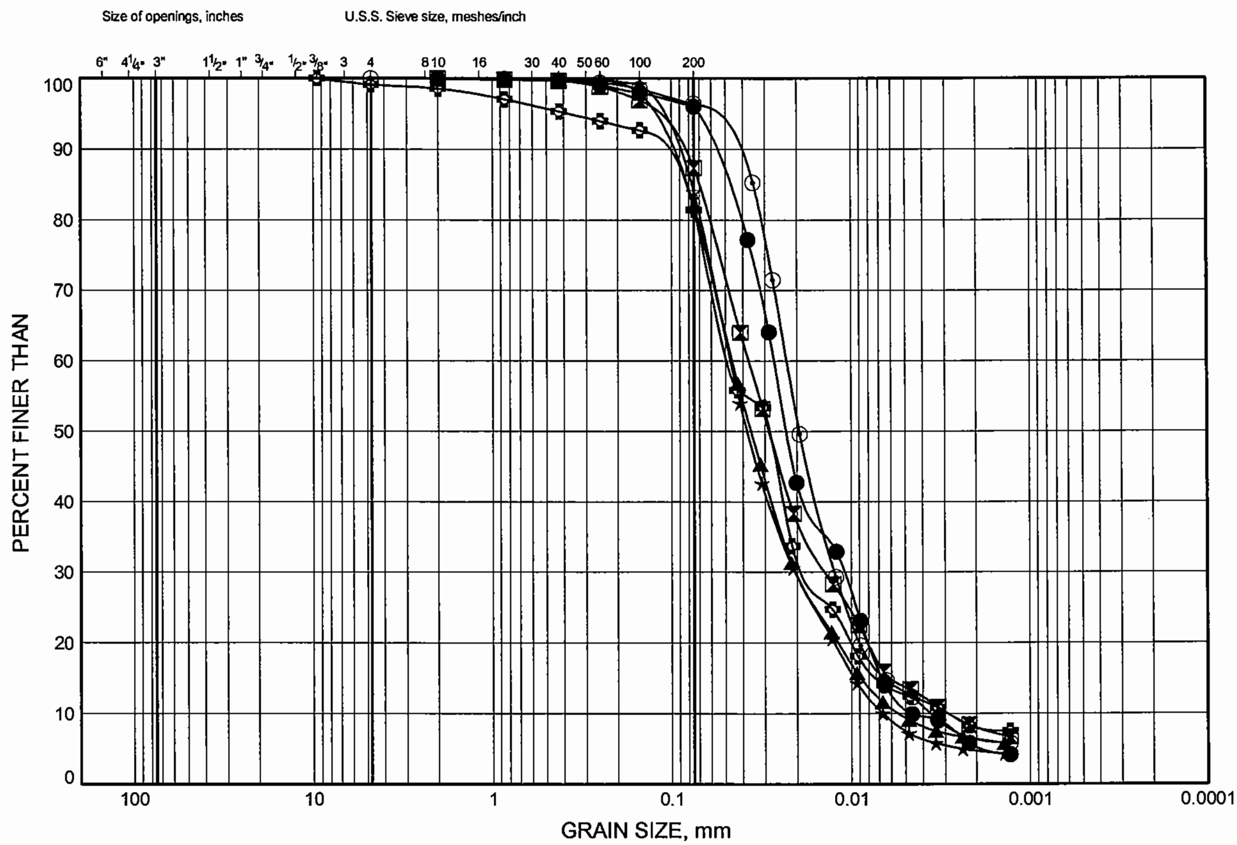
THURBGSD 2316(426).GPJ 07/01/05

Hwy 11 Katrine

GRAIN SIZE DISTRIBUTION

FIGURE B5

Silt



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	426-10	3.35	292.05
⊠	426-3	1.83	293.27
▲	426-4	2.59	292.61
★	426-4	7.92	287.28
⊙	426-7	4.88	290.62
✪	426-8	3.35	291.95

Date January 2005

Project 5403-04-01

THURBER

Prep'd HS

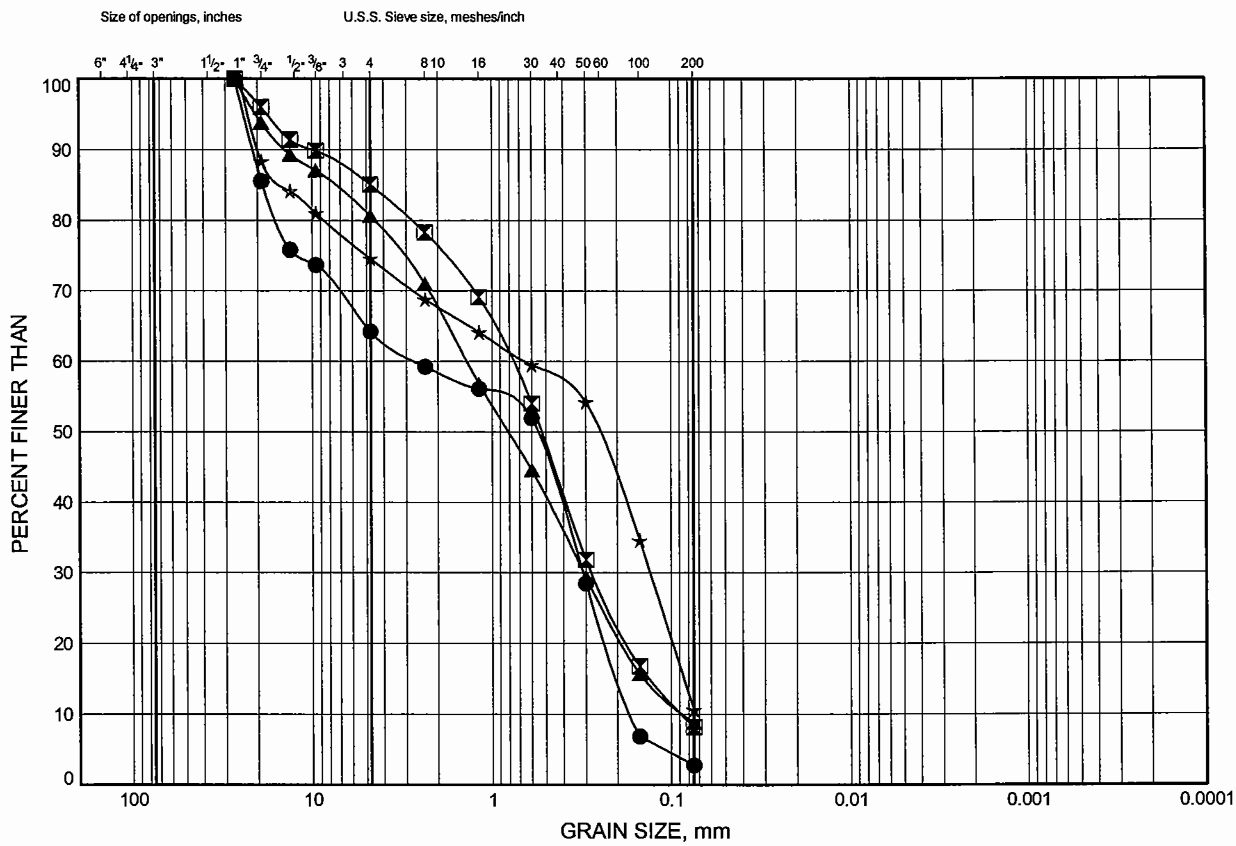
Chkd. MA

Hwy 11 Katrine

GRAIN SIZE DISTRIBUTION

FIGURE B6

Sand and Gravel to Gravelly Sand



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	426-3	17.83	277.27
⊠	426-3	30.02	265.08
▲	426-4	30.63	264.57
★	426-8	20.73	274.57

THURBGSD 2316(426).GPJ 07/01/05

Date January 2005

Project 5403-04-01

THURBER

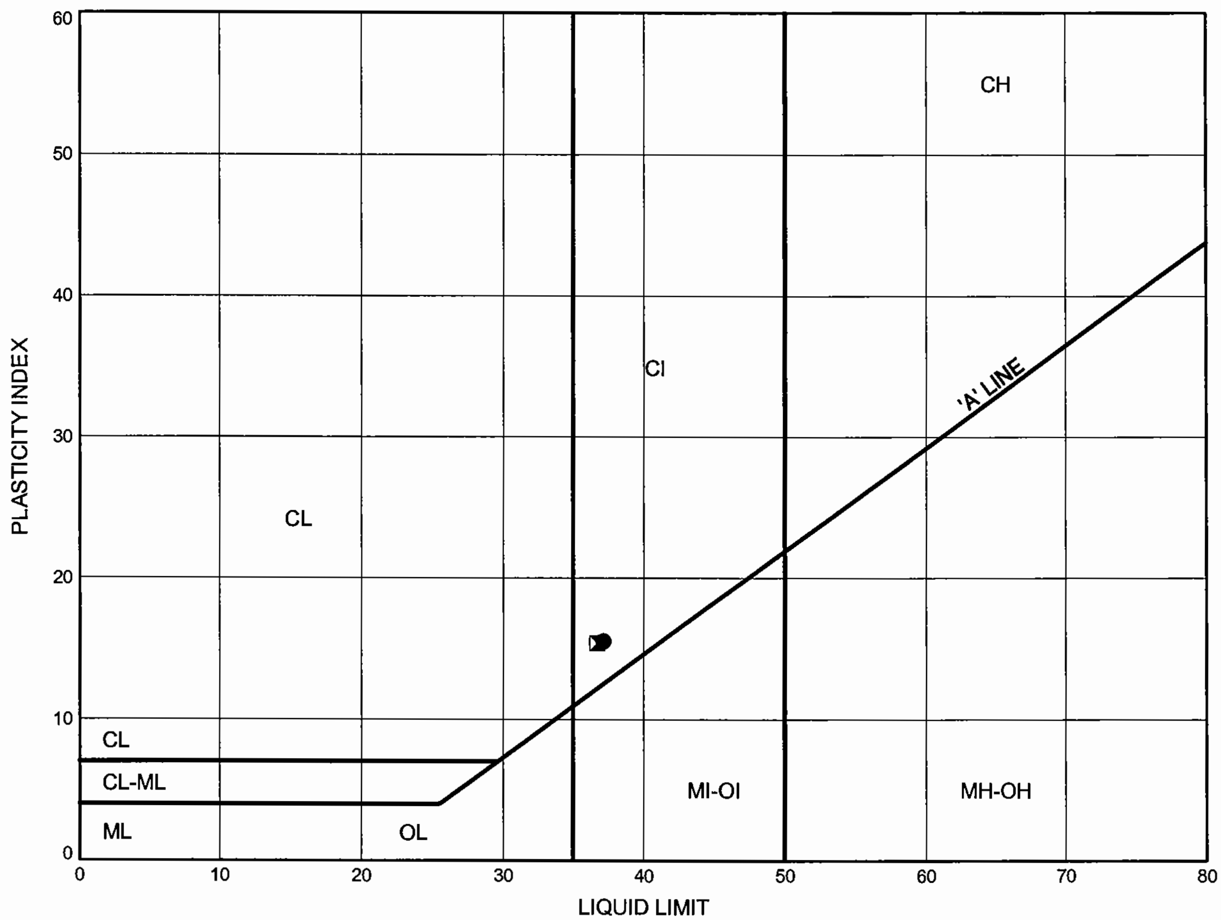
Prep'd HS

Chkd. MA

Hwy 11 Katrine

ATTERBERG LIMITS TEST RESULTS

FIGURE B7



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	426-1	3.35	291.75
⊠	426-1	7.92	287.18

THURBALT 2316(426).GPJ 07/01/05

Date January 2005

Project 5403-04-01

THURBER

Prep'd HS

Chkd. MA

Appendix C

Data From Shaheen & Peaker Report

RECORD OF BOREHOLE No RT1

METRIC

W.P. 314-99-00 LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 521.2; E 316 637.1 ORIGINATED BY R.A
DIST 52 HWY 11 BOREHOLE TYPE Hollow Stem Augering COMPILED BY G.T
DATUM Geodetic DATE 25.05.01 CHECKED BY LSR

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
295.6	Ground Surface						
0.0	100 mm Topsoil	1	SS	4			
						295	
	SILTY FINE SAND with organic matter to 2.2 m, layered; loose to very loose moist	2	SS	5			
						294	
		3	SS	4	▼*		
	----- wet loose to compact	4	SS	11		293	0 60 (40)
		5	SS	8			
						292	
	brown	6	SS	8			
	-----					291	**SS7:
	grey	7	SS	1**			Low N-value probably due to hydrostatic uplift
290.3 5.3	End of borehole						

End of borehole
Borehole abandoned because of sand backup in hollow stem augers
For continuation of BH RT1 see BH RT1A
Ground water not stabilized on completion of boring
*Ground water level estimated from moisture condition of soil samples

Column headings also include: STRAT PLOT; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE, 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³.

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No RT1A

METRIC

W.P. 314-99-00 | LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 519.9; E 316 637.9 | ORIGINATED BY R.A

DIST 52 HWY 11 | BOREHOLE TYPE Hollow Stem Augering | COMPILED BY G.T

DATUM Geodetic | DATE 31.05.01 | CHECKED BY LSR

ELEV DEPTH	DESCRIPTION (SOIL PROFILE)	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR SA SI CL
295.6 / 0.0	Ground Surface								
	Augered to 4.6 m without sampling. For soil profile see Borehole RT1 SS1 through SS7				295, 294, 293, 292				
291.0 / 4.6	SILTY FINE SAND ; with dark grey organic layers, loose, brown, wet	1	SS	9	291		o		
290.3 / 5.3	CLAYEY SILT firm, grey, wet	2	SS	6	290	+4	o		0 18 62 20
289.6 / 6.0	SILT some fine sand, loose to compact, grey, wet; clayey laminations	3	TW	PH	289		o	19.0	
		4	SS	9			o		0 16 84 0
		5	SS	18	288, 287		o		
		6	SS	7			o		
286.0 / 9.6	End of borehole. Water used for washboring and drilling mud used for counter-balancing hydrostatic uplift. Ground Water level not stabilized upon completion of boring. BH RT1A drilled 1.3 m S and 0.8 m E of BH RT1				286				

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

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

RECORD OF BOREHOLE No RT2

METRIC

W.P. 314-99-00 | LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 540.6; E 316 630.7 | ORIGINATED BY R.A

DIST 52 HWY 11 | BOREHOLE TYPE Hollow Stem Augering, Washboring, NQ Rock Coring & D.C.P.T. | COMPILED BY G.T

DATUM Geodetic | DATE 28.05.01 to 30.05.01 | CHECKED BY LSR

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

295.1 Ground Surface
0.0

SILTY FINE SAND with silt layers, very loose to loose
- rootlets
- damp / ---- / wet
- brown
- grey organic silt layers
- grey

NUMBER	TYPE	"N" VALUES	REMARKS / GRAIN SIZE (GR SA SI CL)
1	SS	5	
2	SS	4	
3	SS	3	0 70 30 0
4	SS	1	
5	SS	2	
6	SS	6	
7	SS	6	
8	SS	7	
9	SS	6	
10	SS	4	
11	SS	8	
12	SS	5	0 45 (55)
13	SS	7	
14	SS	10	

Elevation scale: 295, 294, 293, 292, 291, 290, 289, 288, 287, 286, 285, 284, 283, 282, 281

Remarks: HST Augering / Washboring

280.1
15.0

Continued Next Page

+³, ×³: Numbers refer to Sensitivity

15 20 5 10 (%) STRAIN AT FAILURE

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RECORD OF BOREHOLE No RT2

METRIC

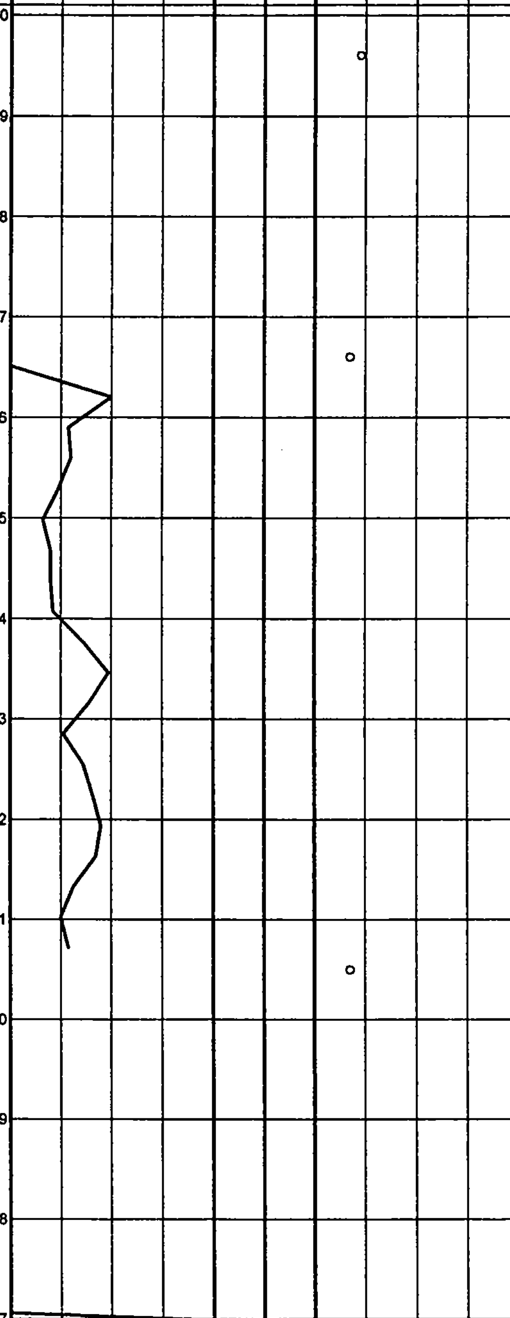
W.P. 314-99-00 LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 540.6; E 316 630.7 ORIGINATED BY R.A

DIST 52 HWY 11 BOREHOLE TYPE Hollow Stem Augering, Washboring, NQ Rock Coring & D.C.P.T. COMPILED BY G.T

DATUM Geodetic DATE 28.05.01 to 30.05.01 CHECKED BY LSR

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

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	REMARKS	GR	SA	SI	CL
280.1										
15.0	**SILTY FINE SAND** compact, grey; wet	15	SS	16	280		0	89	11	0
					279					
					278					
	gravelly	16	SS	58	277					
					276, 275, 274, 273, 272, 271					
270.3		17	SS	10						
24.8	**GRAVELLY SAND** with silt, cobbles and boulders very dense, grey, wet	18	NQ		270	May 28				
		19	NQ			May 29				
		20	SS	17	269	May 29				
		21	NQ			May 30				
		22	NQ		268					
	D.C.P.T. from 28.0 m to 28.2 m (150 blows)	23	SS	9						
266.9		24	SS	66/20	267		27	71	2	0
28.2	End of borehole. Water used for washboring and drilling mud used for counter-balancing hydrostatic uplift. Ground water level not stabilized upon completion									



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

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RECORD OF BOREHOLE No RT2

METRIC

W.P. 314-99-00	LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 540.6; E 316 630.7	ORIGINATED BY R.A
DIST 52 HWY 11	BOREHOLE TYPE Hollow Stem Augering, Washboring, NQ Rock Coring & D.C.P.T.	COMPILED BY G.T
DATUM Geodetic	DATE 28.05.01 to 30.05.01	CHECKED BY LSR

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 (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
	*Ground water level estimated from moisture condition of SS sampler and soil samples Dynamic Cone Penetration Test performed from 18.6 m to 24.4 m and Soil stratigraphy inferred only										

+³, ×³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No RT3

 METRIC

W.P. 314-99-00	LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 598.9; E 316 591.2	ORIGINATED BY R.A
DIST 52 HWY 11	BOREHOLE TYPE Hollow Stem Augering, Washboring, NQ Rock Coring & D.C.P.T.	COMPILED BY G.T
DATUM Geodetic	DATE 22.05.01 to 24.05.01	CHECKED BY LSR

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
294.9	Ground Surface
0.0	80 mm Topsoil; cobbles
	SILTY FINE SAND, layered, very loose to loose; brown, moist ---- wet, grey; traces of organic matter
292.7 / 2.2	CLAYEY SILT, some sand, traces of organic matter, very soft to stiff, grey, wet
291.2 / 3.7	SILT, some fine sand, laminated, loose to very loose, grey, wet
289.7 / 5.2	SILTY FINE SAND with silt layers, grey, wet; very loose to loose ---- compact
279.9 / 15.0	Continued Next Page

SAMPLES

NUMBER	TYPE	"N" VALUES
1	SS	24
2	SS	4
3	SS	8
4	SS	9
5	SS	3
6	SS	5
7	SS	4
6	SS	4
9	SS	3
10	SS	6
11	SS	4
12	SS	1*
13	SS	13
14	SS	15
15	SS	28

Elevation scale: 294, 293, 292, 291, 290, 289, 288, 287, 286, 285, 284, 283, 282, 281, 280

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Sample	GR	SA	SI	CL
4	0	13	74	13
7	0	13	87	0
15	0	83	17	0

Hollow Stem Augering

Washboring

* SS12: Low N-value probably due to hydrostatic uplift

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

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

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RECORD OF BOREHOLE No RT3

METRIC

W.P. 314-99-00
LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 598.9; E 316 591.2
ORIGINATED BY R.A

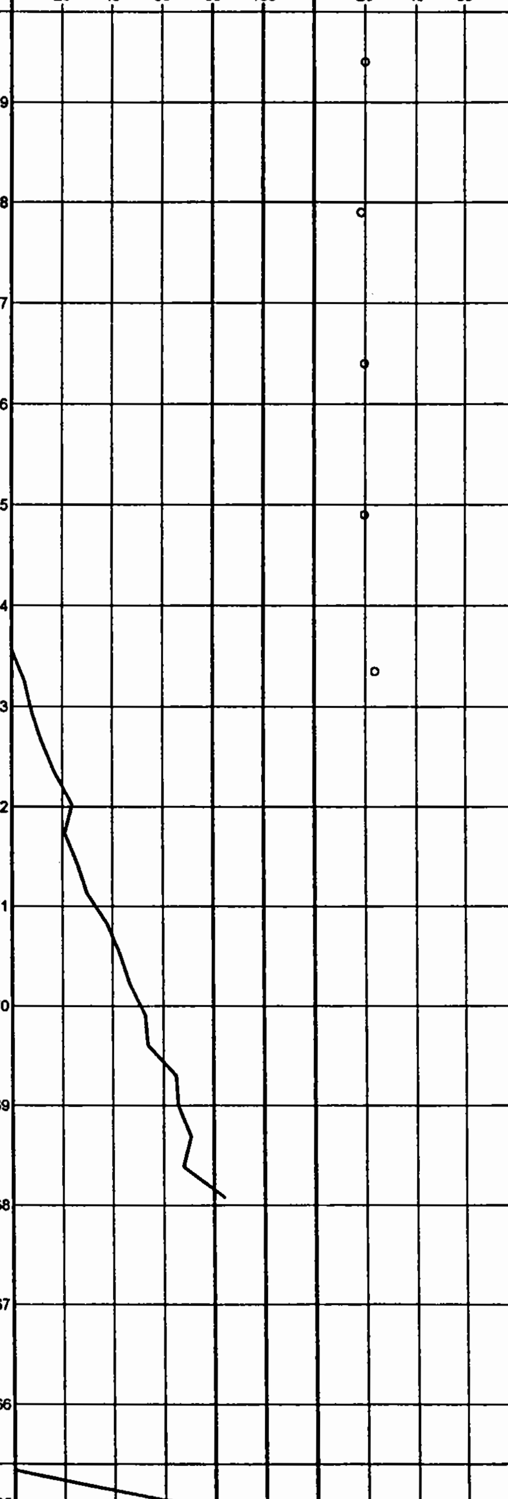
DIST 52 HWY 11
BOREHOLE TYPE Hollow Stem Augering, Washboring, NQ Rock Coring & D.C.P.T.
COMPILED BY G.T

DATUM Geodetic
DATE 22.05.01 to 24.05.01
CHECKED BY LSR

ELEV DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	"N" VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
279.9 15.0	SILTY FINE SAND with silt layers compact to dense grey wet	16	SS	11	
		17	SS	23	
		18	SS	34	0 67 33 0; May 22 ------ May 23
		19	SS	30	
		20	SS	7*	*SS20: Low N-value probably due to hydrostatic uplift
271.6	probable lower boundary of silty sand deposit				
23.3	GRAVELLY SAND with cobbles and boulders, dense to very dense, grey, wet				May 23 ----- May 24
		21	SS	60/13	
		22	NQ		
265.4		23	SS	33	
29.5 264.9	End of borehole				
30.0					

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X LAB VANE (20 40 60 80 100); ELEVATION SCALE 279 to 265



PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; GROUND WATER CONDITIONS; STRAT PLOT

+ ³, × ³: Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No RT3

METRIC

W.P. 314-99-00 LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 598.9; E 316 591.2 ORIGINATED BY R.A

DIST 52 HWY 11 BOREHOLE TYPE Hollow Stem Augering, Washboring, NQ Rock Coring & D.C.P.T. COMPILED BY G.T

DATUM Geodetic DATE 22.05.01 to 24.05.01 CHECKED BY LSR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa O UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						
264.9											
264.7											
30.2	End of Dynamic Cone Penetration Test Dynamic Cone Penetration Test performed from 21.3 m to 26.8 m, Soil stratigraphy inferred only Dynamic Cone Penetration Test performed from 29.6 m to 30.2 m Piezometer installed to 6.7 m Stabilized ground water level in piezometer at 0.5 m (May 29, 30 and June 01/2001)										

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

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

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RECORD OF BOREHOLE No RT4

METRIC

W.P. 314-99-00 | LOCATION Municipal Service Rd. Crossing over Magnetawan River-Coords N 5 047 616.9; E 316 583.3 | ORIGINATED BY R.A

DIST 52 HWY 11 | BOREHOLE TYPE Hollow Stem Augering | COMPILED BY G.T

DATUM Geodetic | DATE 24.05.01 | CHECKED BY LSR

Soil Profile

ELEV / DEPTH	DESCRIPTION
295.1	Ground Surface
0.0	50 mm Topsoil; SILTY FINE SAND, compact, brown, damp
294.4 / 0.7	CLAYEY SILT, trace sand and gravel, grey, wet; very soft / stiff; with organic matter; very stiff
291.9 / 3.2	SILT, trace fine sand, loose, grey, wet; with sand
289.2 / 5.9	SILTY FINE SAND, very loose to loose, grey, wet
285.5 / 9.6	End of borehole

Samples

NUMBER	TYPE	"N" VALUES	UNIT WEIGHT γ (kN/m³)	GR	SA	SI	CL
1	SS	10					
2	SS	1					
3	SS	12		0	17	73	10
4	SS	22					
5	TW	PH	19.6				
6	SS	6		0	5	95	0
7	SS	3**					
8	SS	5		0	43	56	1
9	SS	5					
10	SS	4					
11	SS	6					
12	SS	2**					
13	SS	3**					

Elevation scale: 295, 294, 293, 292, 291, 290, 289, 288, 287, 286

Ground water conditions: ▼* (at approx. elev. 294)

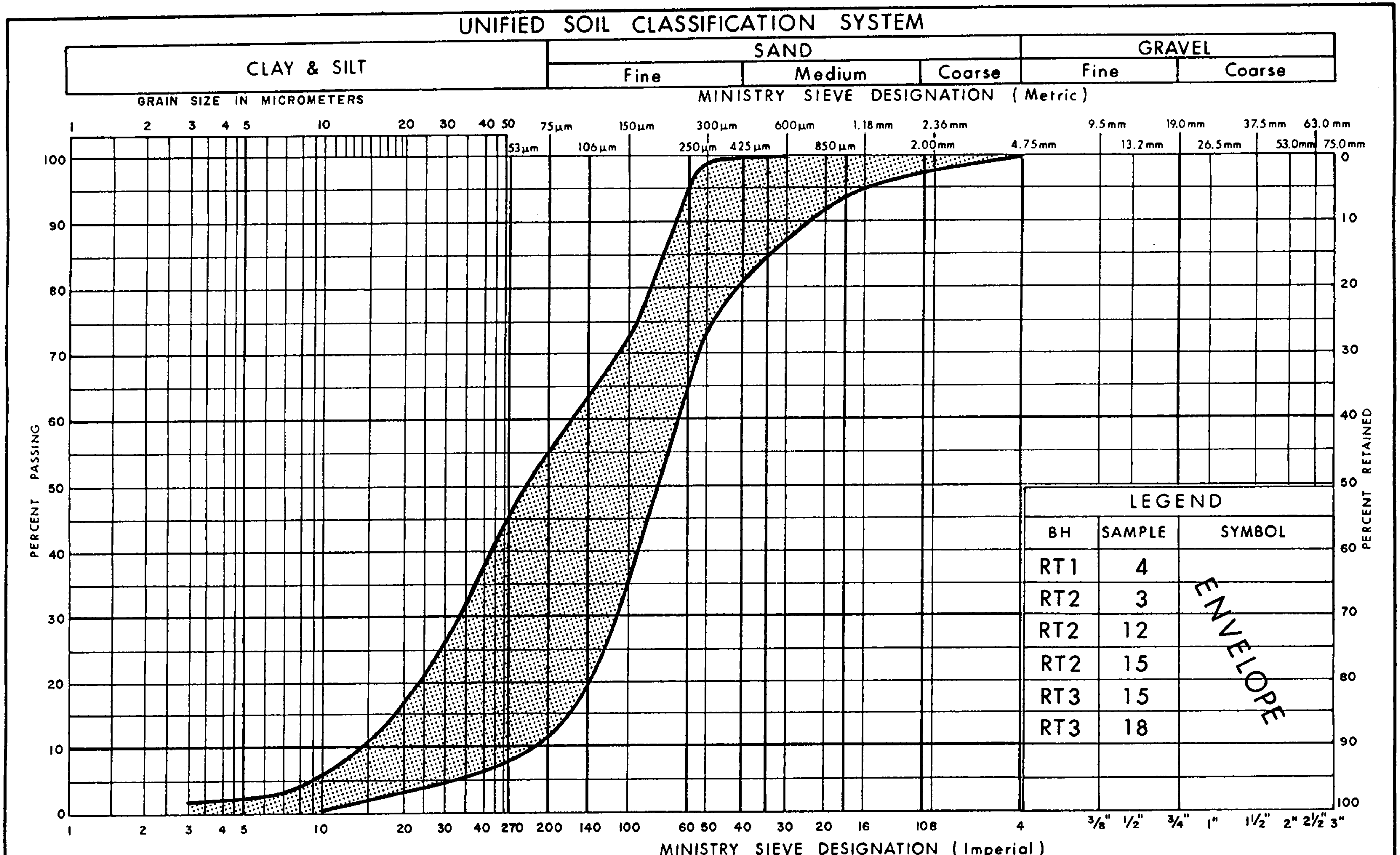
REMARKS: ** SS7, SS12 and SS13 Low N-value probably due to hydrostatic uplift

Plot headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (20, 40, 60)

End of borehole
Ground water level not stabilized on completion of boring
*Ground water level estimated from moisture condition of SS sampler and soil samples

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

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



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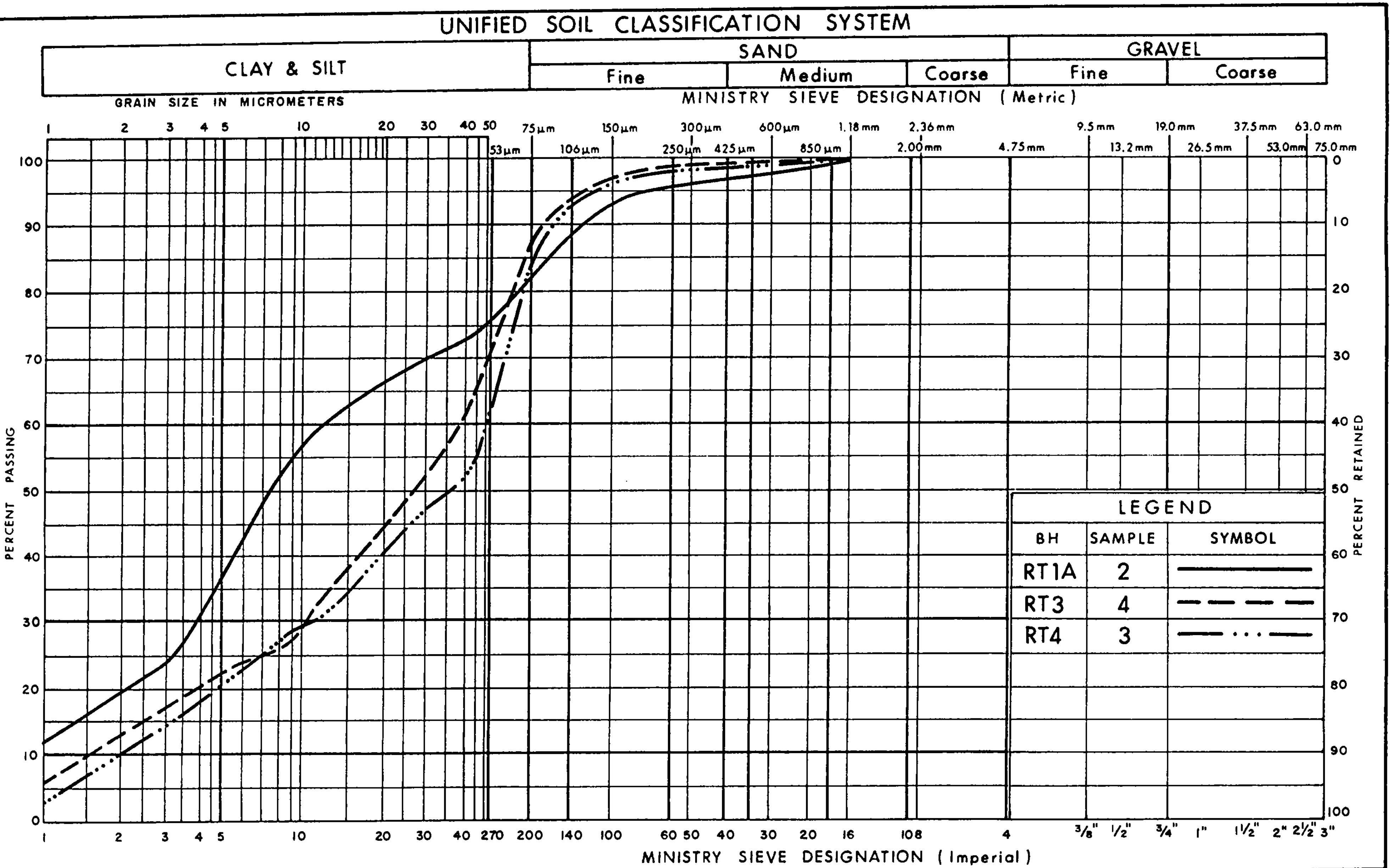
GRAIN SIZE DISTRIBUTION
SILTY FINE SAND

FIG No 1

W P 314-99-00

SPT 1010A

78 12 M



LEGEND

BH	SAMPLE	SYMBOL
RT1A	2	————
RT3	4	— — —
RT4	3	—·· —

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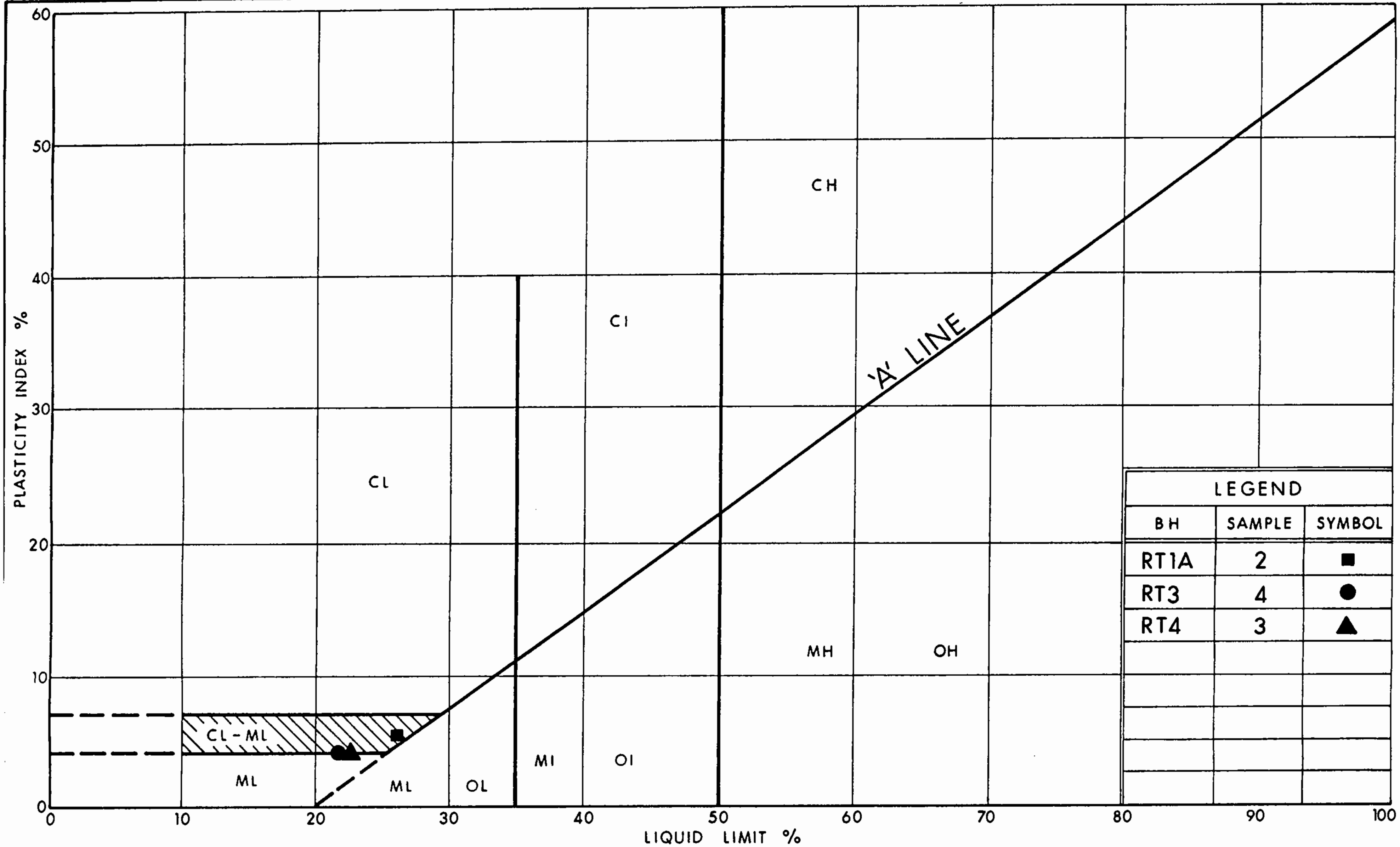
GRAIN SIZE DISTRIBUTION

CLAYEY SILT, TRACE FINE SAND

FIG No 2

W P 314-99-00

SPT 1010A



LEGEND		
BH	SAMPLE	SYMBOL
RT1A	2	■
RT3	4	●
RT4	3	▲

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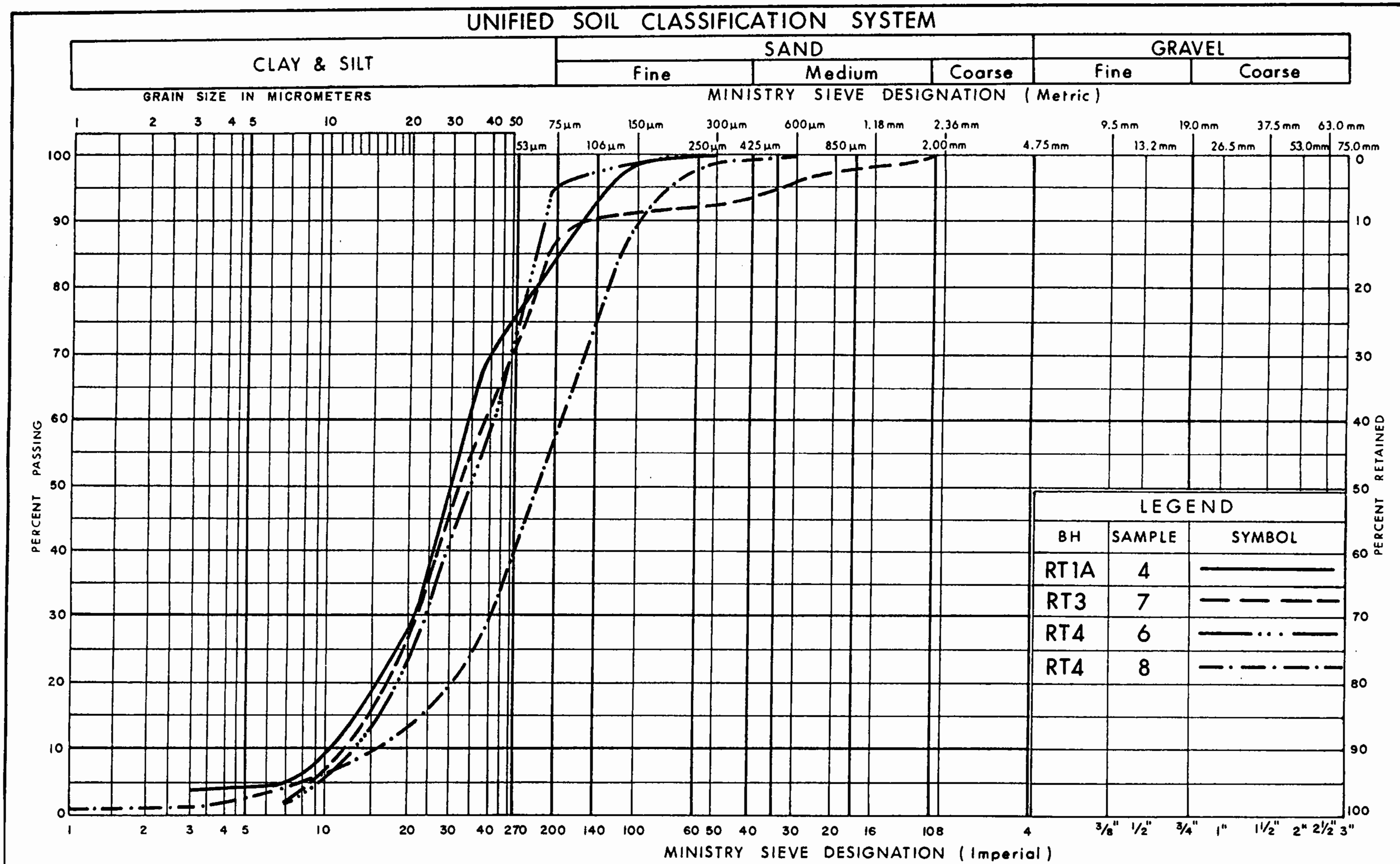
PLASTICITY CHART
CLAYEY SILT, TRACE FINE SAND

FIG No 3
W P 314-99-00
SPT 1010A

78 12 M



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GRAIN SIZE DISTRIBUTION

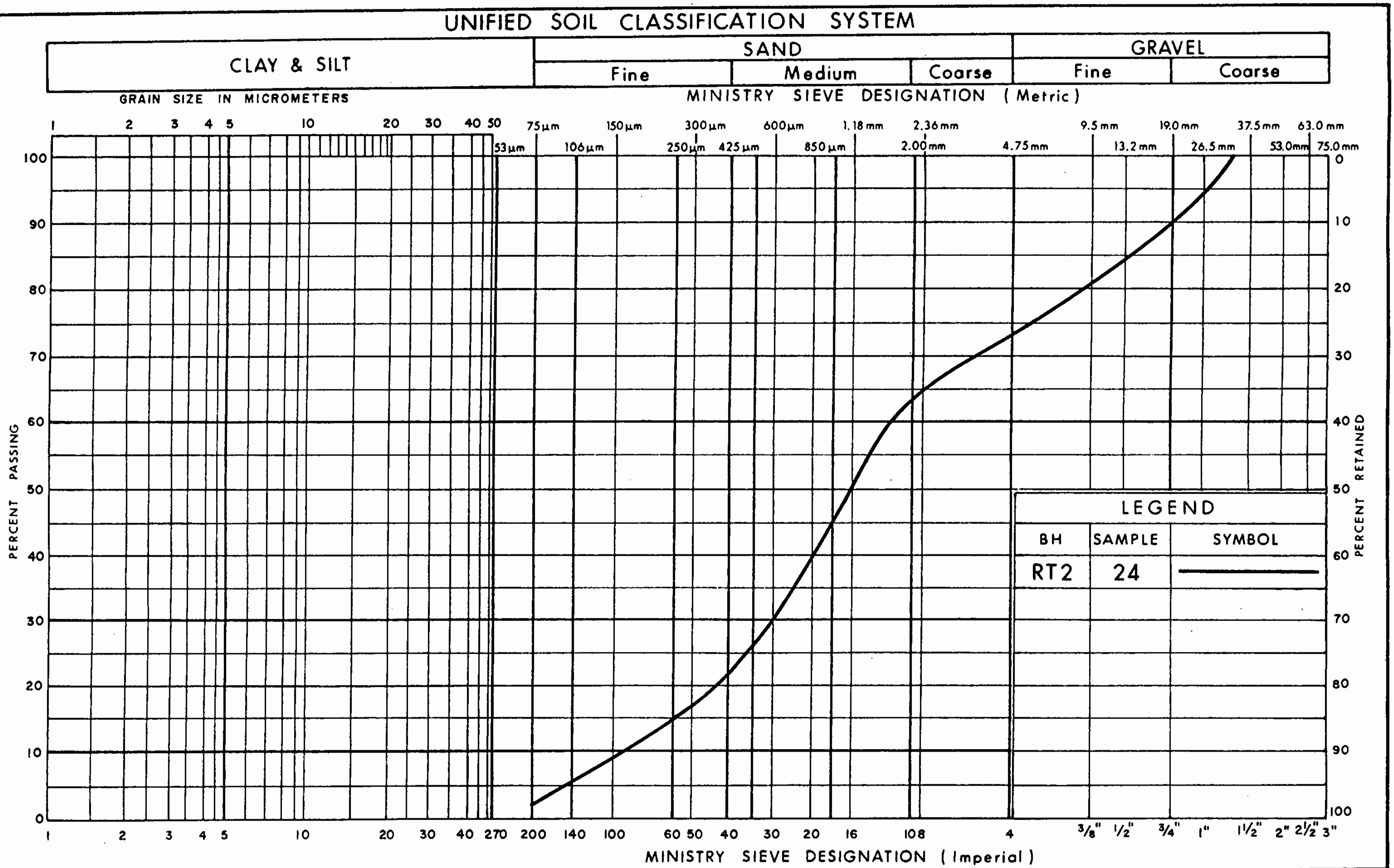
SILT, SOME FINE SAND

FIG No 4

W P 314-99-00

SPT 1010A

78 12 M



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GRAIN SIZE DISTRIBUTION
GRAVELLY SAND

FIG No 5

W P 314-99-00

SPT 1010A

Appendix D

Foundation Comparison

COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

Driven Piles	Footing on Native Soil	Footing on Engineered Fill	Caisson
Advantages: i. Piles will develop high geotechnical resistance if driven to refusal in the very dense soil. ii. Allows choice of conventional, integral or semi-integral abutment design. iii. Readily installed. ***Disadvantages:*** i. Higher unit costs than footings. ii. Construction concerns related to the possibility of pile being obstructed by a boulder during driving.	***Advantages:*** i. Ease of construction. ii. Allows choice of conventional or semi-integral abutment. iii. Lower cost than deep foundations. ***Disadvantages:*** i. Low geotechnical resistance available in upper soil deposits at this site. ii. Potential for unacceptable magnitude of settlement. **NOT RECOMMENDED**	***Advantages:*** i. Would permit use of higher geotechnical resistance than is available on the native soil. ii. Allows choice of conventional or semi-integral abutment. iii. Allows use of perched abutments. iv. Lower cost than deep foundations. ***Disadvantages:*** iii. Cost of constructing engineered fill. iv. Low geotechnical resistance available at this site. v. Potential for unacceptable magnitude of settlement. **NOT RECOMMENDED**	***Advantages:*** i. High resistance is available for caissons founded on very dense soil. ii. Construction of caissons could continue in freezing weather. iii. Choice of conventional or semi-integral abutment design. ***Disadvantages:*** i. Soil conditions encountered at this site are considered to be unsuitable. **NOT RECOMMENDED**

Appendix E

Special Provisions

The following Special Provisions are referenced in this report:

- Amendment to OPSS 206, December 1993
- Special Provision No. 902S01
- Special Provision No. 903S01

Suggested text for a NSSP on Pile Installation should contain the following:

" The soil at this site contains cobbles and boulders. The presence of cobbles and boulders will potentially have an impact on the installation of piles. Some possible impacts that must be taken into consideration include, but are not necessarily limited to:

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

Appendix F

Selected Slope Stability Output

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Rock Fill	20	0	42	1
Sand and Silt	20	0	30	1
Firm Silty Clay	19	0	27	1
Stiff Silty Clay	20	0	28	1
Sand and Silt	20	0	30	1
Sand & Gravel	21	0	35	1

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South Approach Effective Stress

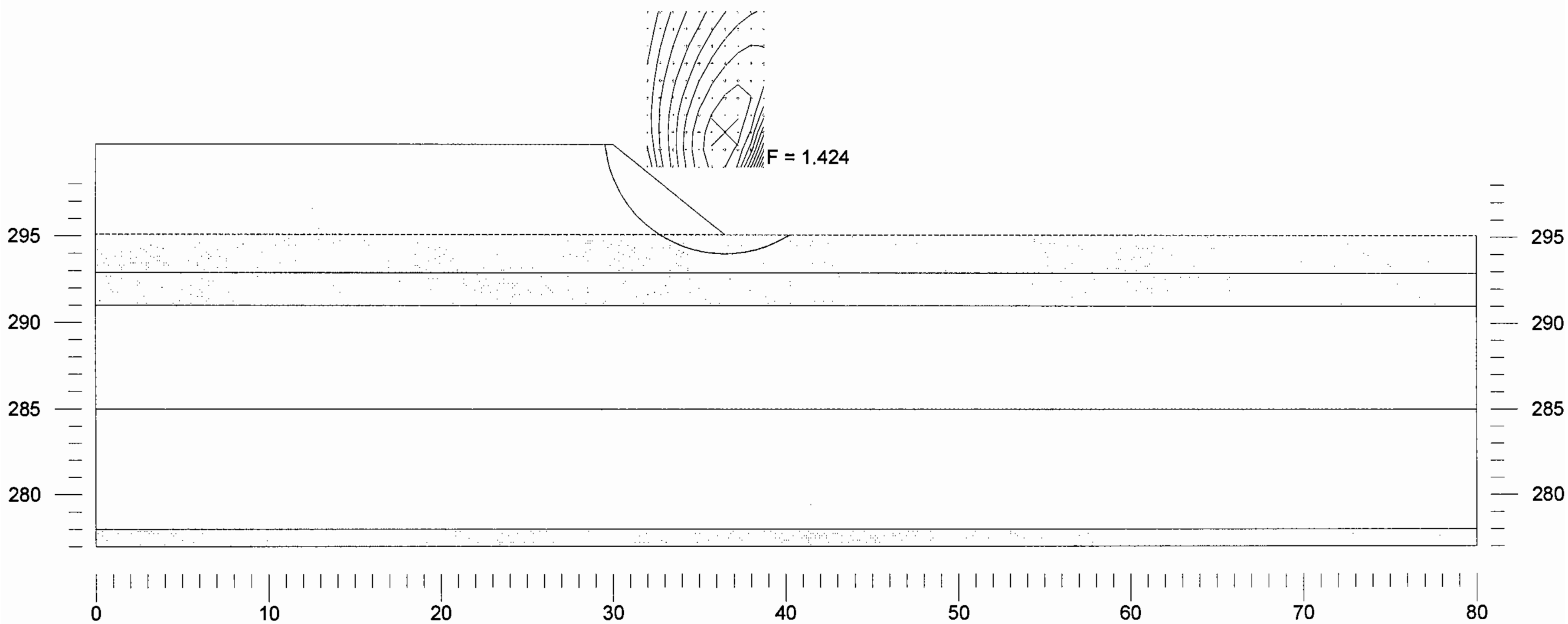

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Figure 1a

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Rock Fill	20	0	42	1
Sand and Silt	20	0	30	1
Firm Silty Clay	19	40	0	1
Stiff Silty Clay	20	80	0	1
Sand and Silt	20	0	30	1
Sand & Gravel	21	0	35	1

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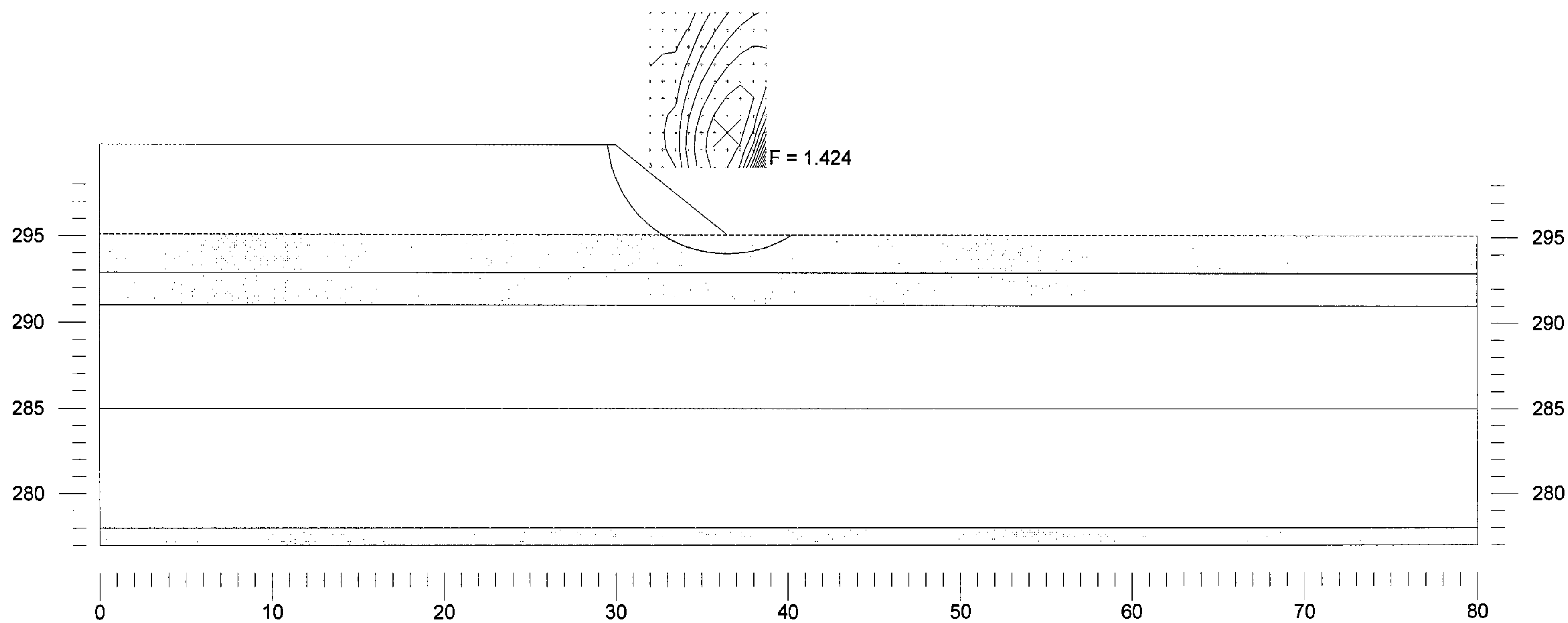

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Figure 1b

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Rock Fill	20	0	42	1
Sand and Silt	20	0	30	1
Firm Silty Clay	19	0	27	1
Stiff Silty Clay	20	0	29	1
Sand and Silt	20	0	30	1
Sand & Gravel	21	0	35	1

Seismic coefficient = 0.08

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South Approach Effective Flood Seismic

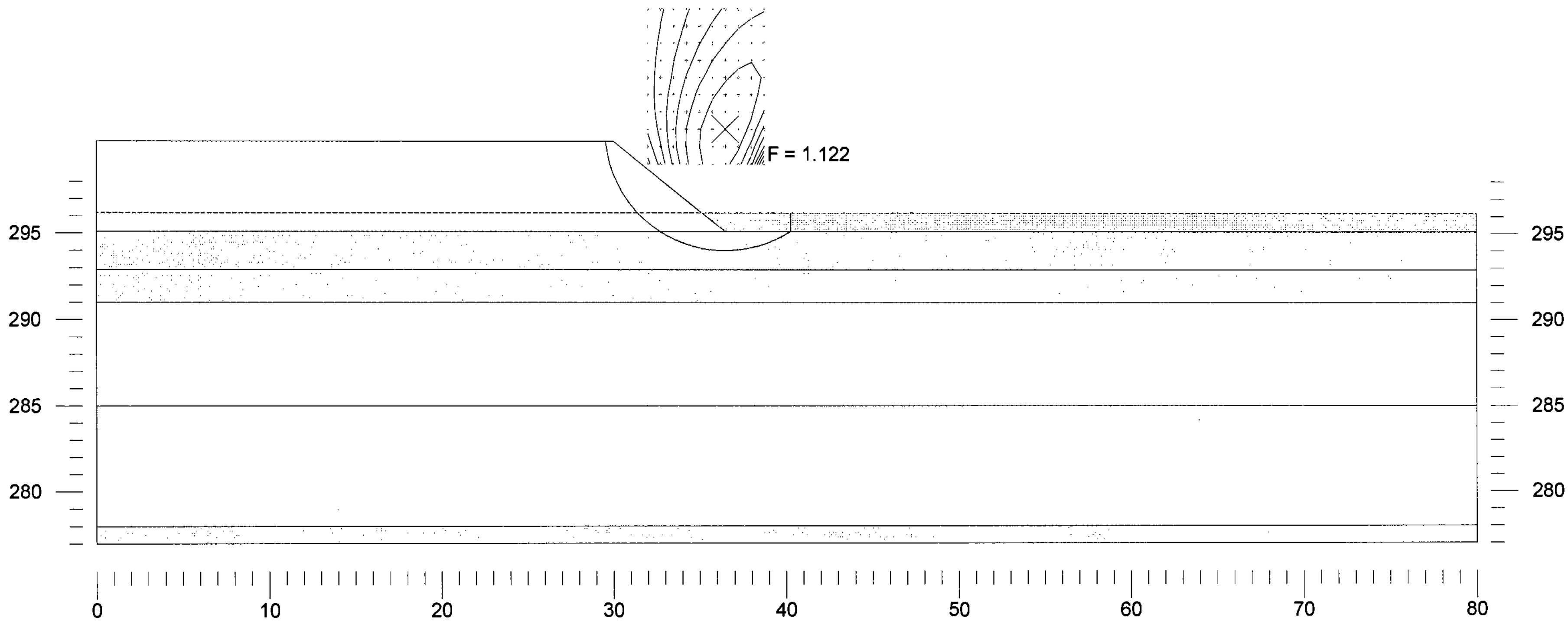

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Figure F2a

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Rock Fill	20	0	42	1
Sand and Silt	20	0	30	1
Firm Silty Clay	19	40	0	1
Stiff Silty Clay	20	80	0	1
Sand and Silt	20	0	30	1
Sand & Gravel	21	0	35	1

Seismic coefficient = 0.08

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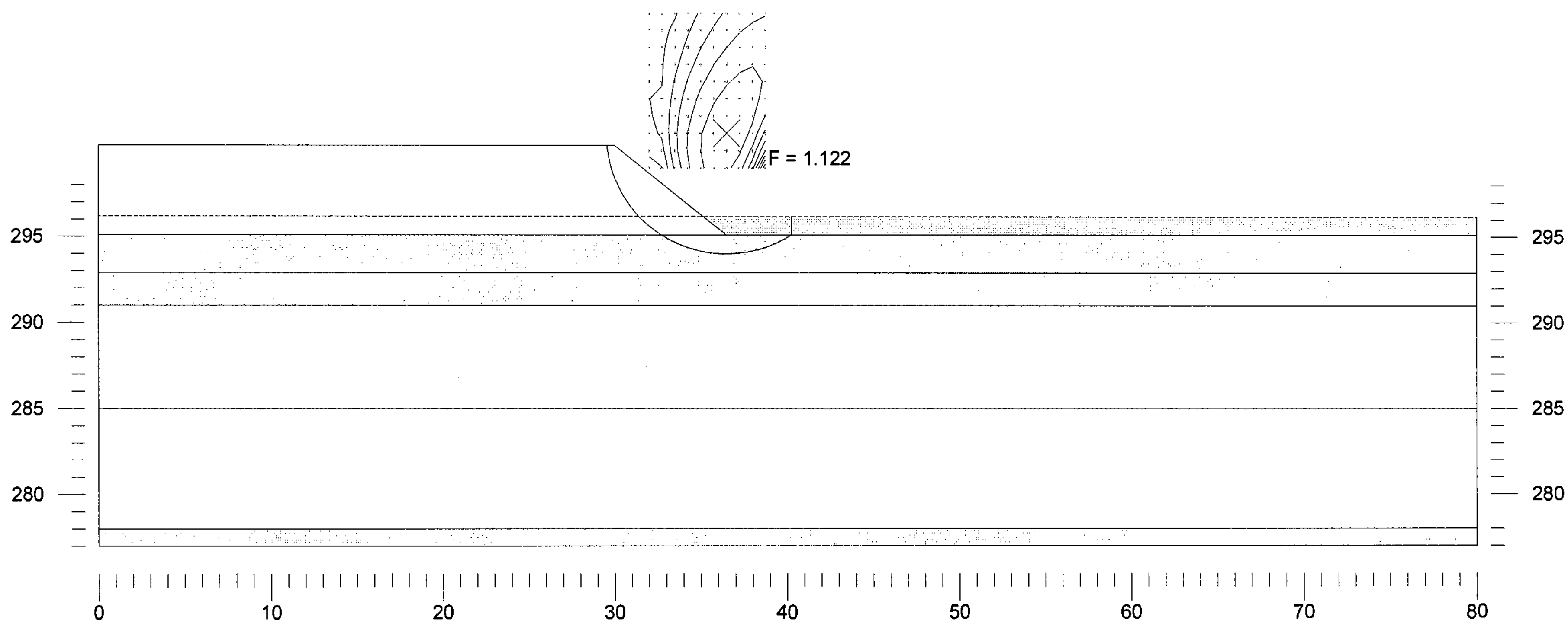

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Figure F2b

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Earth Fill	21	0	30	1
Sand and Silt	20	0	30	1
Firm Clay	19	0	27	1
Stiff Clay	20	0	28	1
Sand and Silt	20	0	30	1
Sand & Gravel	21	0	35	1

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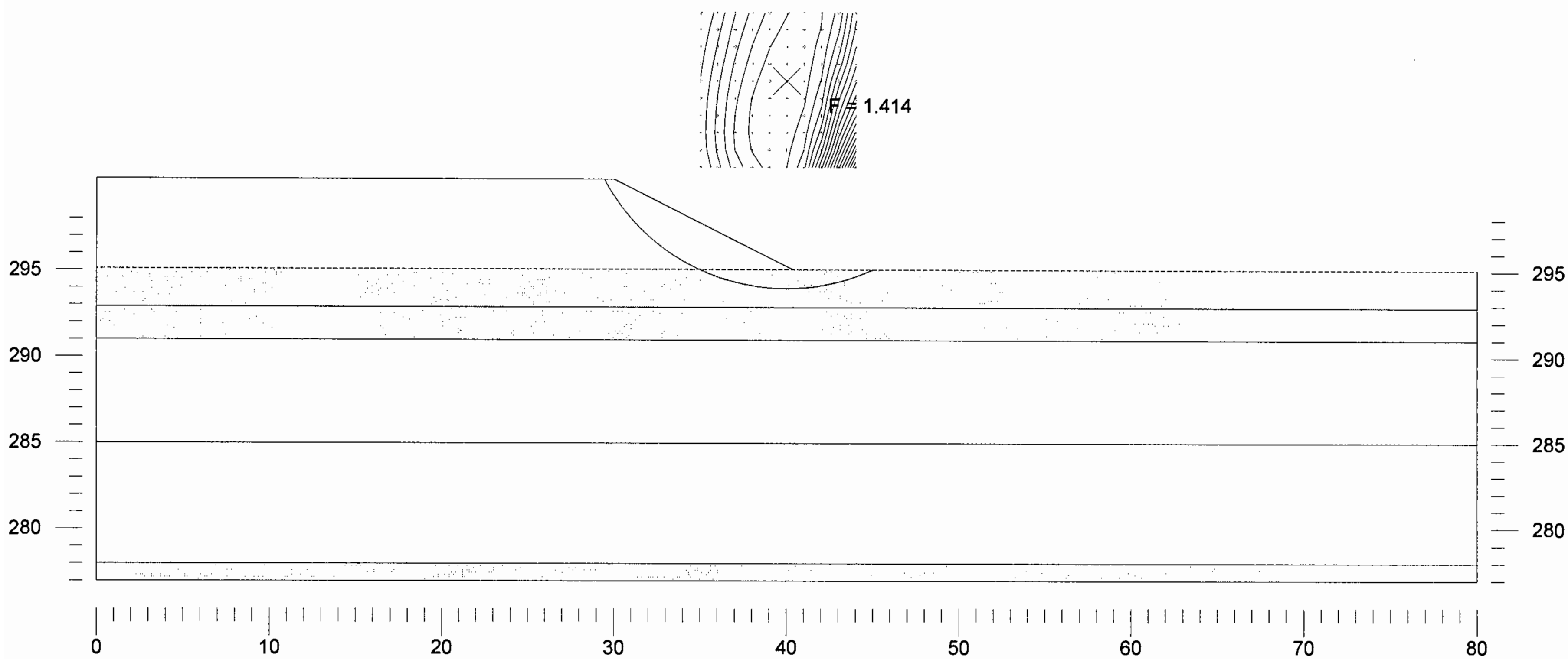

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Figure F3a

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Earth Fill	21	0	30	1
Sand and Silt	20	0	30	1
Firm Clay	19	40	0	1
Stiff Clay	20	80	0	1
Sand and Silt	20	0	30	1
Sand & Gravel	21	0	35	1

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South Approach Total

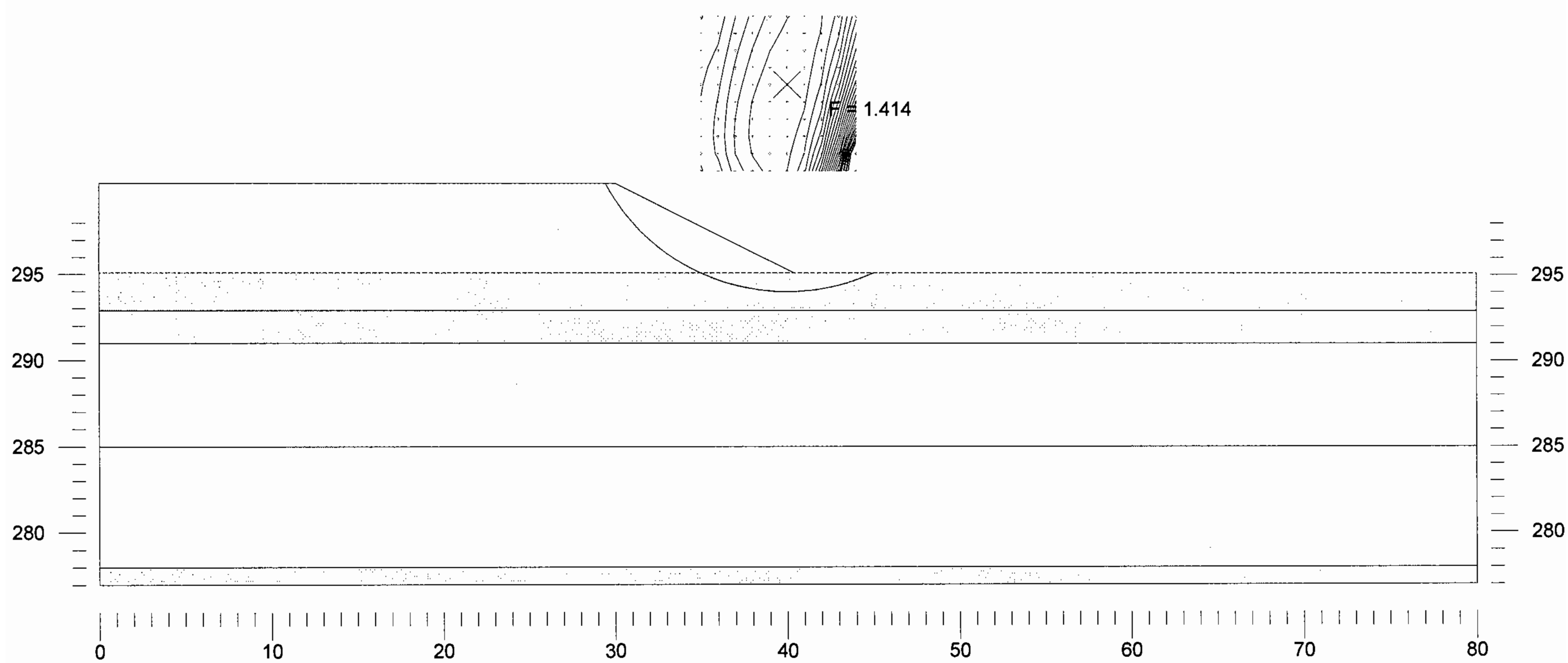

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Figure F3b

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Earth Fill	21	0	30	1
Sand and Silt	20	0	30	1
Firm Clay	19	0	27	1
Stiff Clay	20	0	28	1
Sand and Silt	20	0	30	1
Sand & Gravel	21	0	35	1

Seismic coefficient = 0.08

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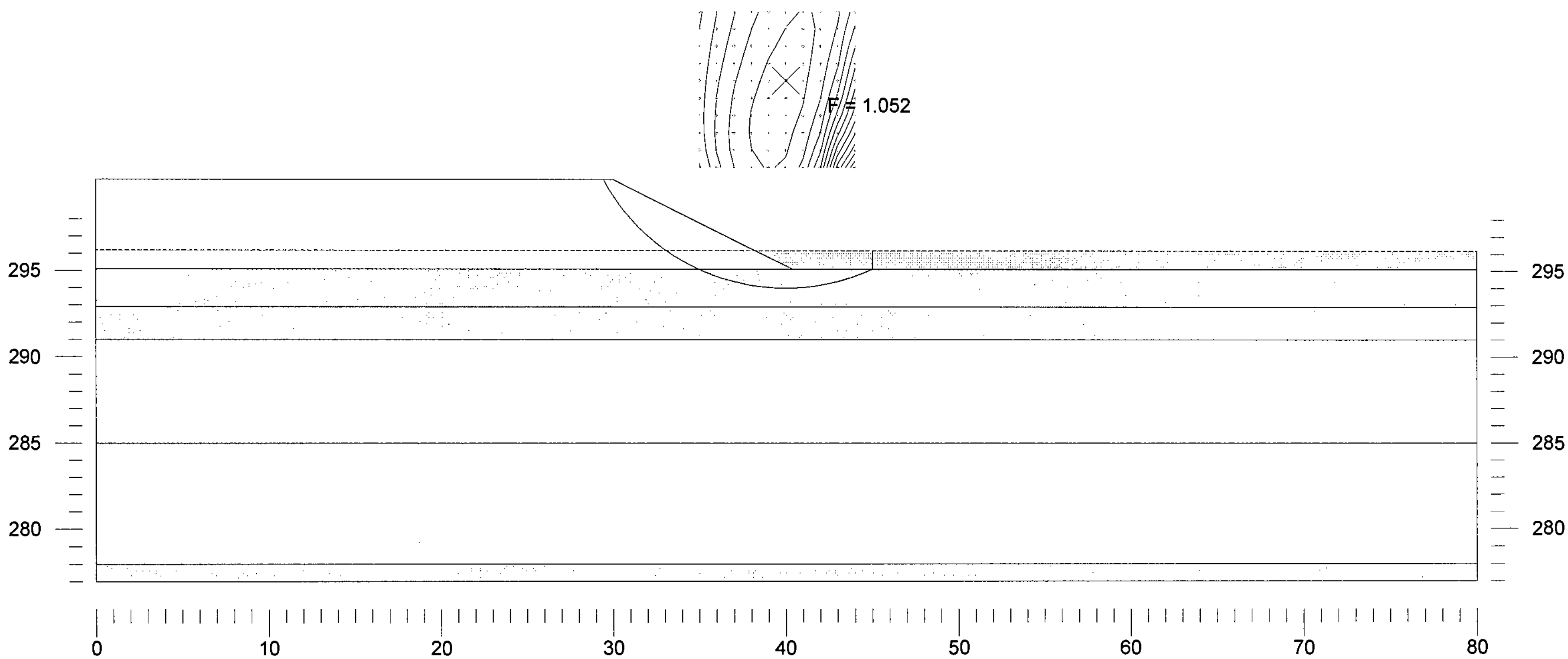

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Figure F4a

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Earth Fill	21	0	30	1
Sand and Silt	20	0	30	1
Firm Clay	19	40	0	1
Stiff Clay	20	80	0	1
Sand and Silt	20	0	30	1
Sand & Gravel	21	0	35	1

Seismic coefficient = 0.08

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South Approach Total Flood Seismic

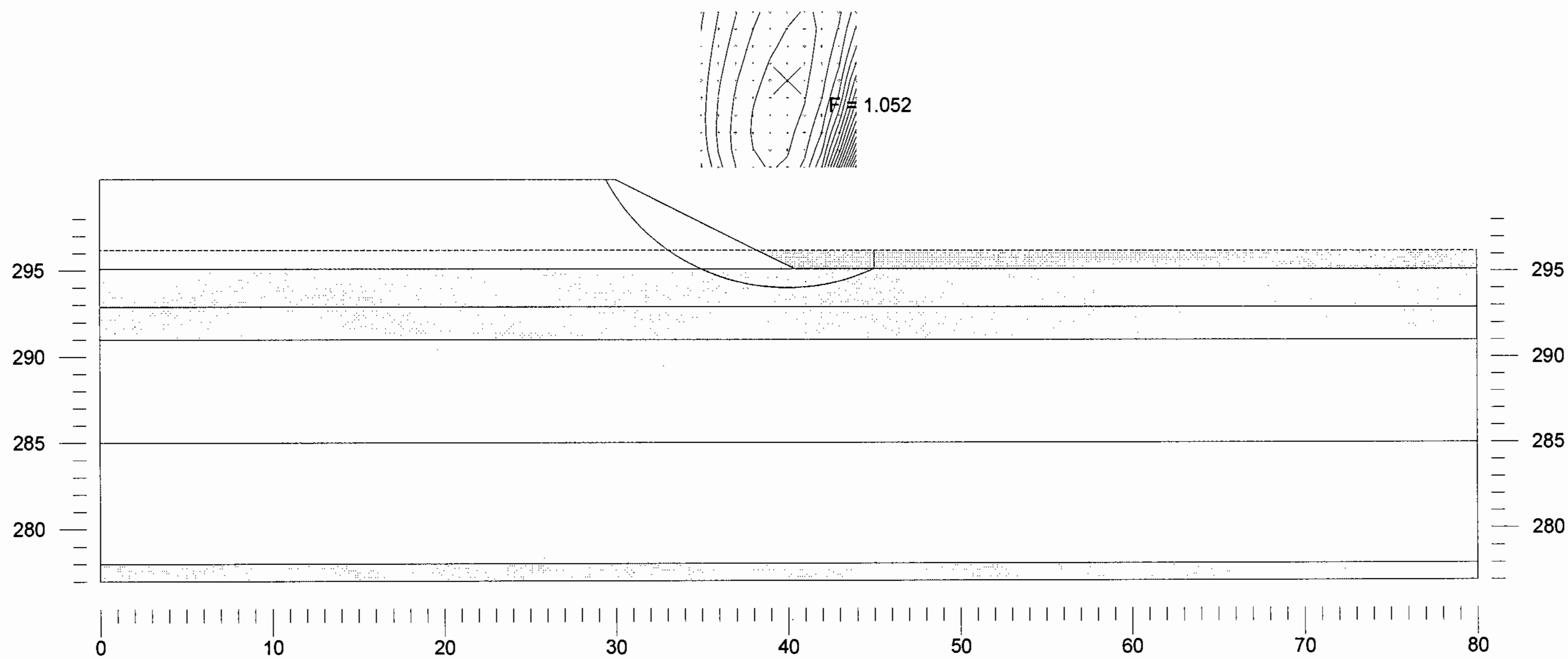

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Figure F4b

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Rock Fill	20	0	42	1
Sand and Silt	20	0	29	1
Sand & Gravel	21	0	35	1

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North Approach

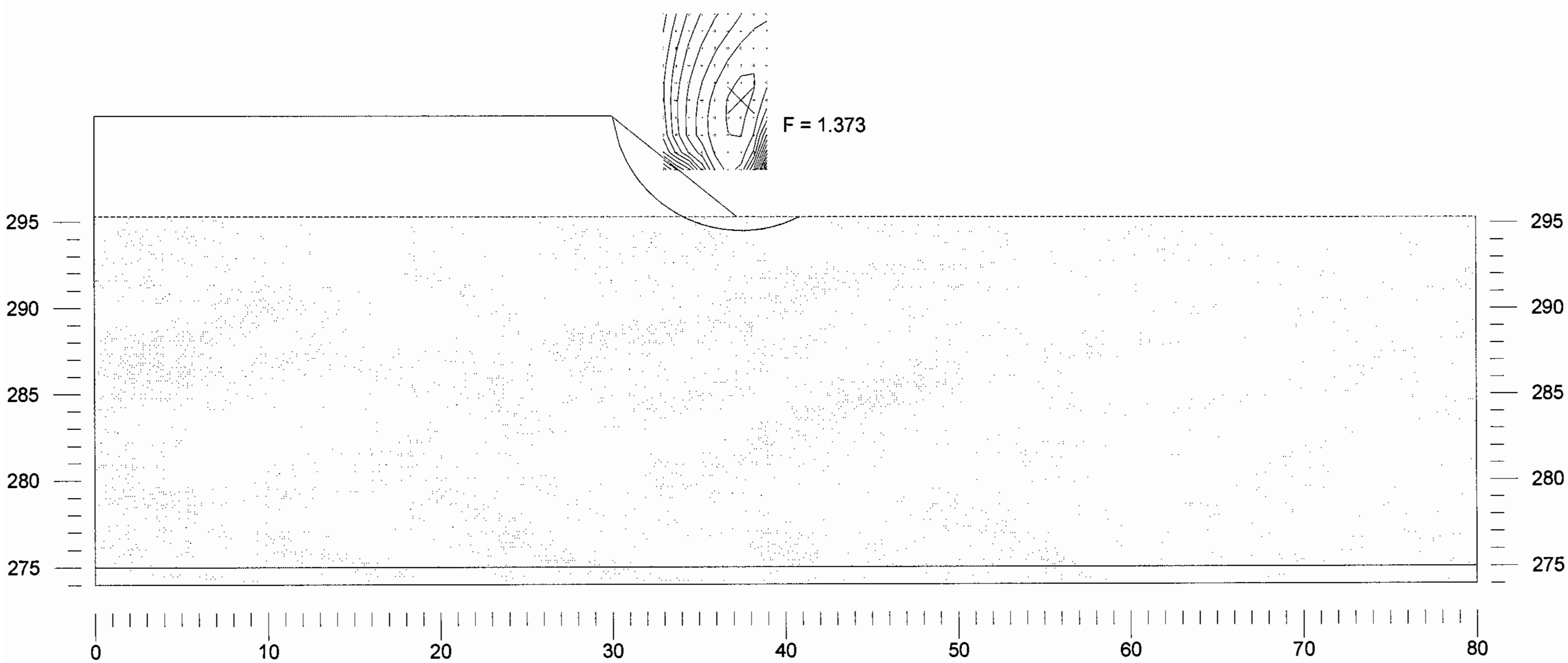

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Figure F5

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Rock Fill	20	0	42	1
Sand and Silt	20	0	29	1
Sand & Gravel	21	0	35	1

Seismic coefficient = 0.08

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North Approach 100 Yr Flood Seismic

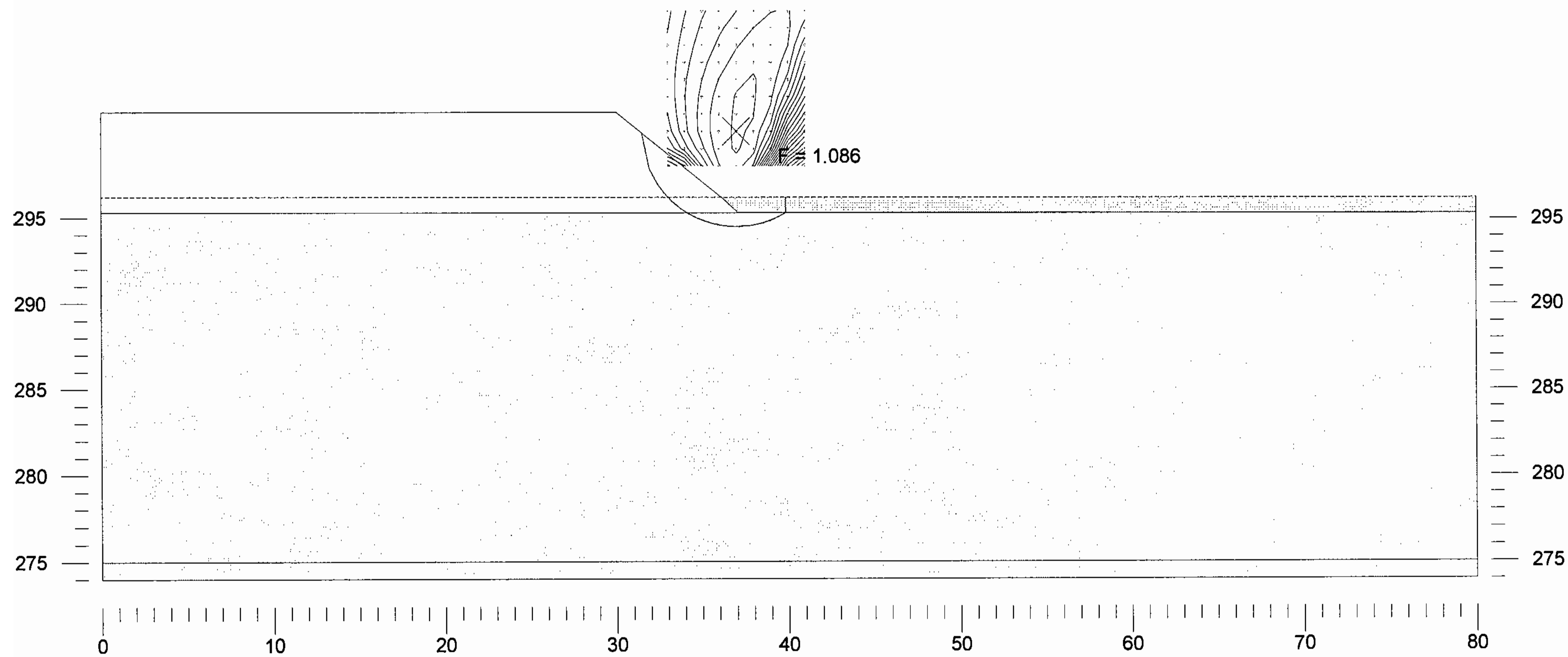

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Figure F6

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Earth Fill	21	0	30	1
Sand and Silt	20	0	29	1
Sand & Gravel	21	0	35	1

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North Approach

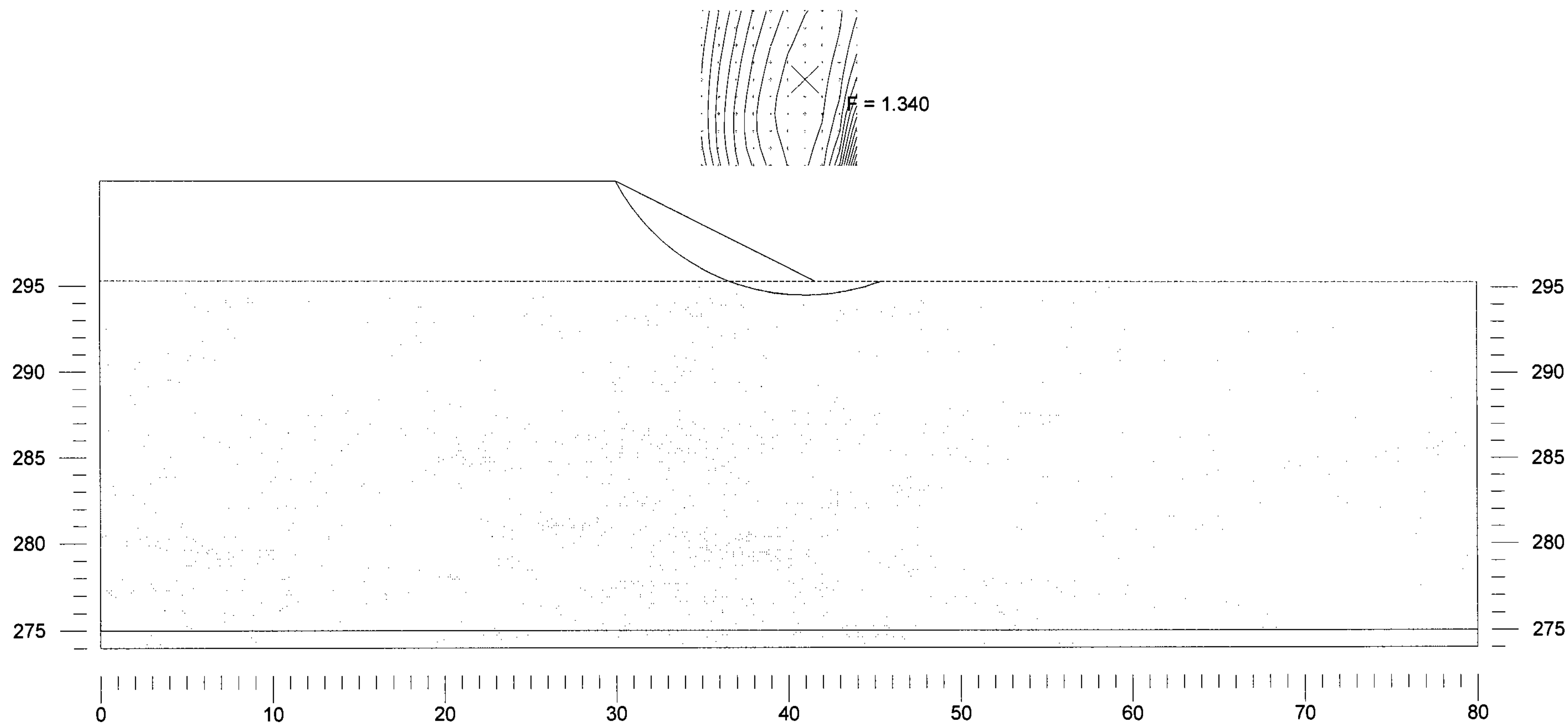

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Figure F7

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.
Water	10	0	0	1
Earth Fill	21	0	30	1
Sand and Silt	20	0	29	1
Sand & Gravel	21	0	35	1

Seismic coefficient = 0.08

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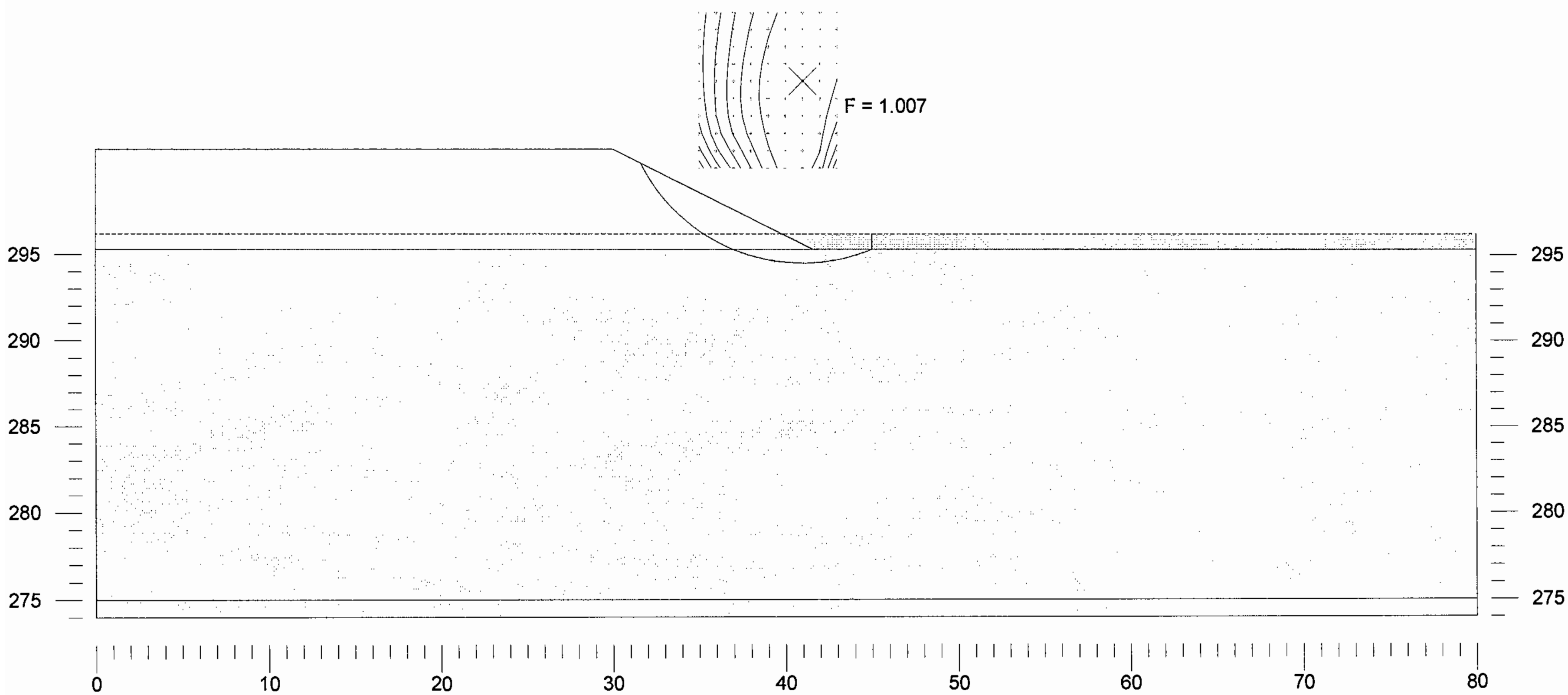

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Figure F8

Appendix G

Drawings